Journal of Experimental Agriculture International

40(5): 1-16, 2019; Article no.JEAI.51348
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Structure and Successional Classification of the Shrub-Arboreal Component in a Remnant of Atlantic Forest, Northeastern Brazil

Nelio Domingos da Silva[1*], Luiz Carlos Marangon[1], Ana Lícia Patriota Feliciano Marangon[1] and José Antônio Aleixo da Silva[1]

[1]*Department of Forestry Sciences, Rural Federal University of Pernambuco, 52171-900, Brazil.*

Authors' contributions

This work was carried out in collaboration with all authors. All authors developed the study proposal. Author NDS implemented and collected the data and participated in the writing of the article together with authors LCM, ALPFM and JAAS. The species identification and the phytosociological data were calculated by author NDS. Authors NDS and JAAS performed all the statistical calculations. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2019/v40i530375
Editor(s):
(1) Dr. Rusu Teodor, Agrotechnics, Experimental Techniques and Rural Development Department of Technical and Soil Sciences, Faculty of Agriculture, University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca, 3-5 Manastur, 400372, RO, Romania.
Reviewers:
(1) Junir Antonio Lutinski, Universidade Comunitária da Regão de Chapecó, Brazil.
(2) Rahim Foroughbakhch, University of Nuevo León, Mexico.
Complete Peer review History: http://www.sdiarticle3.com/review-history/51348

Original Research Article

Received 01 July 2019
Accepted 05 September 2019
Published 14 September 2019

ABSTRACT

Aims: We aimed to evaluate the structure and successional classification of component shrub-arboreal in the edge and interior environments in a remnant of Tropical Forest in Pernambuco, Brazil.

Place and Duration of Study: The study was conducted in a remnant of the Lowland Ombrophilous Dense Forest categorized as Urban Forest Reserve named Mata of Manassu, with an area approximately 264.24 ha and located in Jaboatao dos Guararapes, Pernambuco. The data were registered between March 2017 and September 2017.

Methodology: The data were collected in 40 100 m^2 plots, 20 plots in each environment: edge and forest interior. The ''edge'' was considered to comprise a 100-m strip at the border of the forest and the ''interior'' at least 300 m in from this strip. In all plots, were cataloged, identified and measured

**Corresponding author: E-mail: nelio.domingos@gmail.com;*

the circumferences at height of the base at 30 cm from the soil of all shrub-arboreal individuals whose height were equal or greater than 1.0 meter and circumference at breast height at 1.30 m of soil, less than 15.0 cm. For the communities on the edge and forest interior were estimated: total density (TD), absolute density (AD), relative density (RD), total frequency (TF), absolute frequency (AF), relative frequency (RF), total dominance (TDo), absolute dominance (ADo), relative dominance (RDo), relative natural regeneration by height class (RNRij), total natural regeneration by height class (TNR), importance value index (IVI) and was performed the distribution analysis of individuals in three height classes using the Chi-square test with 95% significance. The sampled individuals were classified into family, genus, and species, and the species classified for the successional group (pioneers, initial secondary, late secondary or uncharacterized).

Results: The environment of the edge showed the highest absolute density (10.240 ind.ha^{-1}) to the forest interior (9.805 ind.ha^{-1}). In both environments, it was found the high representativity of initial and late secondary species. The structural distributions of individuals by height class at the edge and interior environments showed curves shaped as inverted "J" indicating "dynamic balance" of the forest.

Conclusion: The higher representativity of initial and late secondary species probably is due to the forest being in an advanced successional stage, having a structure with well-defined stratum. Among the shrub-arboreal species sampled which presented higher total natural regeneration per height class to both in the edge and forest interior and that can be used for the enrichment of areas in the recovery process of Atlantic Forest are *Miconia prasina* e *Eschweilera ovata*.

Keywords: Natural regeneration; density; Dense Ombrophylous forest; structure; successional classification.

1. INTRODUCTION

The forest fragmentation transforms contiguous natural habitats in small remnants of a forest through the expansion of the areas of contact between natural and anthropic environments. This forest replacement, increasingly frequent, causes significant changes in composition and vegetation structure [1].

From the 16th century, this process intensified in Pernambuco with successive cycles of logging, expansion of urban areas and agroindustrial exploitation, especially sugarcane, reducing the continuous natural vegetation of the Atlantic Forest of State to some remnants, many isolated from them [2,3].

These constant interferences anthropogenic increase the edge area in relation to the original fragment, favoring the proximity and the level of interaction with the areas coming from the matrix and can lead to changes significant in the biotic and abiotic conditions of the remnant, with consequences about the vegetable species existing [4,5,6,7].

Consequences of this forest fragmentation have compromise of ecosystem services, promoving isolation, invasion of exotic species and interference in evolutionary processes through which diversity originates [8].

Among the main abiotic alterations, we can mention the increase: in sunlight intensity, litter leaf rate, temperature and wind speed, and reduction: in soil and air humidity; direct biotic: species abundance, composition and structure; and indirect biotics: in interactions between species, such as predation, competition, herbivory, pollination and dispersal, that in the short, medium or long term, may endanger the maintenance of plant populations on the edge and forest interior [9,10].

Phytosociological studies represent adequate methods to describe initial responses of the vegetation because is possible to characterize the floristic composition and structure of the species in a given forest fragment. Besides it allows the comparison of results obtained in areas and at different times [11].

By observing phytosociological parameters is possible to characterize the horizontal and vertical structures of fragments forest. These parameters can indicate specific groupings and it supplies information about the development stages of vegetable community, as well as the distribution of environmental resources among the populations, possibilities of using plant resources, among other [12].

Another analysis that assists in the definition of strategies for recovery and conservation of forest fragments is the identification of ecological groups in the process of natural regeneration. For each ecological group that presents different biological characteristics and requirements, the proportion of the number of seedlings per species chosen in management and recovery projects of degraded areas are defined in the function of these [13].

Under full light availability, pioneer species tend to produce a high number of seeds with rapid growth and establish communities with high population density and low species diversity. Late secondary species, in the most part, have antagonistic characteristics, that is, with lower seed production, slower growth, developing preferentially in the shadow, with communities of greater species diversity and lower population density. The initial secondary species have intermediate characteristics to those previously described [13,14].

Thus, this study aims to evaluate the structure and successional classification of the shrub-arboreal component in the edge and interior environments of a remnant of Atlantic Forest, located in Jaboatão dos Guararapes, Pernambuco.

2. MATERIALS AND METHODS

2.1 Area of Study

The study was conducted in a remnant of Lowland Ombrophilous Dense Forest of 264.24 ha, located under the coordinates 8º04'44.5"S latitude and 35º01'23.0"W longitude, north area of Jaboatao dos Guararapes city in Pernambuco, Brazil. According to State Law n° 14,324/11 the area is a Conservation Unit categorized as Urban Forest Reserve Mata of Manassu, being considered important for the protection of numerous species of plants, wild animals and hydrographic system of the region. It has soils classified as Yellow Latosols, Red-Yellow Podzolic, Gleysols with relief wavy to strong wavy. It presents the shape of irregular polygon and a diversified matrix of urban and rural land use [15,16]. Was issued Technical Opinion SAUC n° 07/2017 of authorization to carry out the research by the State Environment Agency (CPRH).

The areas of forest edge surveyed have rugged topography with the presence of ravines and altitude quota above 100 m, reaching up to 125 m, higher incidence of sunlight and exposure to winds, in contrast to lower litter leaf input due to the soil leaching process. In interior, there is the presence of a uniform canopy, a lower incidence of light and winds, a larger litter leaf fall and the formation of small hills that, in most cases, did not exceed 70 meters and flat areas near the Manassu River.

The predominant climate of the region is tropical type Am, according to the classification [17], climate tropical of monsoon with early rainy season at autumn. The accumulated annual precipitation of approximately 1.487 mm and the average temperature around 24ºC [18].

2.2 Collection of Data

Sampling units were implanted in environments of the edge and forest interior. The ‘‘edge’’ was considered to comprise a 100-m strip at the border of the forest and the ‘‘interior’’ at least 300 m in from this strip (Fig. 1).

The data were collected in 40 plots of 10 m × 10 m (100 m^2 each), being 20 in each environment (edge and forest interior), totaling 4.000 m^2 of the sample area (Fig. 1). Edge plots were allocated along parallel transects in the border of the fragment and equidistant each other in 25 m, with 10 plots each. In the forest interior, 20 plots were distributed systematically in mesh format, being interspersed in 25 m each other (Fig. 1).

In all plots, we cataloged, identified, and measured the circumferences at 30 cm of the soil surface. All shrub-arboreal individuals whose height were equal or greater than 1.0 meter and circumference at breast height at 1.30 m of soil, less than 15.0 cm, as well as were estimated the respective heights using high pruning shears, with modules of 2.0 meters.

All sample units were georeferenced with GPS receiver (Global Positioning System) Garmin model 76map CSx and demarcated with a tape measure, PVC pipe pickets, and nylon cord. All individuals registered received a numbered field card in ascending order.

During fieldwork, were recorded the following data on the field card: identification number of the individual; the height, in meters; their botanical identification, the date of sampling and the collection of fertile material, when possible.

The botanical material collected was duly herborized according to techniques of preparation, drying, and assembly of exsiccata. The species were identified according to

Angiosperm Phylogeny Group IV [19], by comparison with exsiccates deposited in the Herbarium Professor Vasconcelos Sobrinho and Herbarium Sérgio Tavares, both of the Federal Rural University of Pernambuco (UFRPE).

2.3 Data Analysis

The species were classified into successional groups: pioneers, initial secondary, late secondary or uncharacterized [14,20], by observations in the field and literature.

The main phytosociological parameters were estimated for the communities in edge and forest interior, being them: total density (TD), absolute density (AD), relative density (RD), total frequency (TF), absolute frequency (AF), relative frequency (RF), total dominance (TDo), absolute dominance (ADo), relative dominance (RDo), relative natural regeneration by height class (RNRij), total natural regeneration by height class (TNR) and importance value index (IVI) with the aid of software Microsoft Excel for Windows ™ 2010 and Mata Nativa 4 [20,21].

We analyzed the diametric structure by interpreting frequency histogram of the number of individuals per diameter class at intervals of 1.0 cm.

For analysis of vertical structure in each forest environment, we generated distribution histograms by size classes of shrub-arboreal individuals whose height were equal to or greater than 1.0 meter and circumference at breast height at 1.30 m of soil, less than 15.0 cm. Three size classes of natural regeneration were considered, being individuals of class 1 (C1) with 1.0 m ≤ H ≤ 2.0 m, class 2 (C2) with 2.0 m < H ≤ 3.0 m and class 3 (C3) with (H) > 3.0 m [20].

The distribution analysis of individuals in height classes was performed using the Chi-square test with 95% significance with the aid of software Microsoft Excel for Windows ™ 2010.

To infer if there are significant differences between mean basal area and mean height in edge and forest interior environments were calculated the confidence limits by size class.

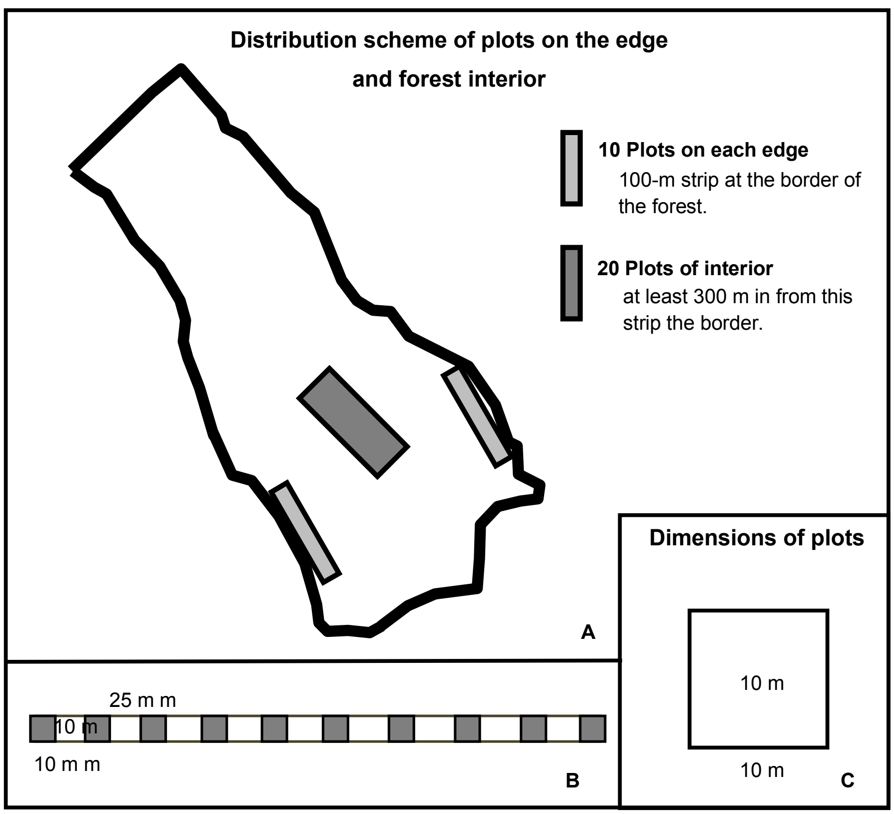

Fig. 1. Distribution scheme of plots on the edge and forest interior (A); Spacings between plots (B); Dimensions of plots (C)

3. RESULTS AND DISCUSSION

3.1 Structure

In the environments of the edge and forest interior, we recorded 4009 shrub-arboreal individuals, corresponding the estimated total density (TD) of 10022.5 ind.ha^{-1} (Appendix 1). However, we cataloged 2048 individuals in 20 plots in edge environment (2,000 m²), corresponding to the total density of 10240 ind.ha^{-1}. And in the forest interior environment we found 1961 individuals, indicating a total density of 9805 ind.ha^{-1}. It indicates that the edge area presented density higher than the forest interior about 4.44%.

This higher representativeness of arboreal individuals in edge forest may be related the fact that higher areas tend to present greater intensity of sunlight [22], which could benefit the recruitment of new individuals, providing higher density. Also, these individuals are located in areas with limited accessibility to the site, with altitude above 100 m of sea level, so density, as well as diversity increases as degradation factors, are less intensified and older [23].

In the edge environment, the species that stood out in number of individuals (in descending order) and consequently in absolute density (AD) were: *Erythroxylum mucronatum* with 201 individuals and 1005 ind.ha^{-1} of absolute density, followed by *Eschweilera ovata* 160 and 800 ind.ha^{-1}), *Hirtella racemosa* (132 and 660 ind.ha^{-1}), *Erythroxylum squamatum* (127 and 635 ind.ha^{-1}) and *Brosimum guianense* (123 and 615 ind.ha^{-1}). They describe 36.28% of total sampled individuals in this environment.

In forest interior, the most representative species were *Eschweilera ovata* with 280 individuals and 1400 ind.ha^{-1}, *Psychotria carthagenensis* (175 and 875 ind.ha^{-1}), *Paypayrola blanchet*iana (145 and 725 ind.$^{-1}$), *Artocarpus heterophyllus* (133 and 665 ind.ha^{-1}) and *Siparuna guianensis* (118 and 590 ind.ha^{-1}). They correspond 43.40% of the total individuals in this environment.

Among the species that presented greater abundance both in the edge and fragment interior, *E. ovata* according to Lorenzi [24] is an initial secondary species, perennial and heliophyte, with occasional frequency and dispersion more or less contiguous along its distribution area and for being considered ornamental tree, it has its use indicated in landscaping and composition of mixed reforestation destined for the recovery of vegetation of degraded areas, besides having its seed is very appreciated by frugivorous bats.

Although the group of species highest density in the fragment interior, mostly, is not same those records in the edges studied, except for *Eschweilera ovata*, *Miconia prasina*, and *Siparuna guianensis*. In general, it can be observed that among 123 registered species, 91 are from the border, 90 from forest interior and 58 from these are common in both areas. Of that species common the two environments and that were cataloged in the forest interior, described to 77.15% of the total of individuals in this area. And the edge groups indicated 91.85%, thus, is verified that the group of shrub-arboreal species in natural regeneration in the edge environment, mostly are similar to the forest interior.

Were observed 19 species with only 1 individual (each), indicating 0.93% of the total shrub-arboreal in edge environment, this result is lower than that found in the interior forest, in which 24 species expressed 1.22% of the total in the area (Appendix 1).

The species that occurred with only 1 individual (in each environment) both in edge and forest interior were: *Abarema cochliacarpos*, Annonaceae 1 and *Sloanea garckeana* (Appendix 1). Exclusively, in edge enviroments were: *Aspidosperma spruceanum*, *Bowdichia virgilioides*, *Cordia sellowiana*, *Couepia rufa*, *Eugenia umbrosa*, *Hyeronima oblonga*, uncharacterized 2, *Inga capitata*, *Miconia albicans*, Myrtaceae 1, *Ouratea polygyna*, *Pouteria gardneri*, *Sarcaulus brasiliensis*, *Tabernaemontana flavicans*, *Talisia coriacea* and *Xylopia frutescens* (Appendix 1). And in the forest interior were: *Adenanthera pavonina*, *Campomanesia dichotoma*, *Cupania racemosa*, *Dialium guianense*, *Eriotheca macrophylla*, Fabaceae 1, *Guapira* sp.1, *Guatteria schomburgkiana*, uncharacterized 3, uncharacterized 4, *Inga ingoides*, Lauraceae 1, *Leptobalanus octandrus*, *Licania kunthiana*, *Miconia holosericea*, *Myrcia splendens*, *Plathymenia reticulata*, *Pouteria durlandii*, *Sloanea guianensis*, *Talisia esculenta* and *Virola gardneri* (Appendix 1).

The occurrence of only one individual of some species both fragment edge and interior may not be sufficient to guarantee its conservation. For the different biotic and abiotic conditions in edge and interior of fragment, such as shading, nutrient cycling, water availability, as well as chemical and physical characteristics of the soil may not favor certain species due to their morphophysiology, characteristics and the degrees of phenotypic plasticity of each organism support each environmental condition [25].

The shrub-arboreal species whose occurrence were equal or greater than 50% sampled plots in the forest edges were: *Cordia nodosa* present in all sample units (100% absolute frequency), followed by *Erythroxylum mucronatum* (80%), *Eschweilera ovata*, *Miconia prasina* and *Siparuna guianensis* (70% each), *Brosimum guianense*, *Guatteria pogonopus*, *Inga thibaudiana*, *Myrcia guianensis*, *Thyrsodium spruceanum* (60% each), *Brosimum rubescens* and *Casearia javitensis* (55% each), and *Hirtella racemosa*, *Lacistema robustum*, *Parkia pendula* and *Tapirira guianensis* (50% each). In the forest interior the species *Siparuna guianensis* occurred in 95% of plots, followed by *Eschweilera ovata* (90%), *Miconia prasina* and *Psychotria carthagenensis* (85% each), *Symphonia globulifera* (80%), Myrtaceae 2 (75%), *Cordia nodosa*, *Myrcia spectabilis* and *Thyrsodium spruceanum* (70% each), *Protium heptaphyllum Erythroxylum citrifolium* and *Guapira opposita* (60% each), and, *Inga thibaudiana* and *Hyeronima oblonga* (50% each). The higher representativeness of species with high frequency in the edge compared to forest interior demonstrates a greater range of distribution and repartition of resources in forest edge environment.

The total dominance (TDo) in forest edge provided 3.91 $m^2.ha^{-1}$, while that in the interior it was 3.87 $m^2.ha^{-1}$, that is, the edge environment showed higher dominance of species sampled, per hectare, about the interior in 1.03%. However, both analyzed environments presented higher results than the one recorded (3.28 $m^2.ha^{-1}$) by Lima et al. [26] when analyzing the regenerative potential of tree species in a fragment of Atlantic Forest in Sirinhaém, Pernambuco.

The species with highest absolute and relative dominance in edge environment were, in decreasing order: *Miconia prasina* with 0.39969 $m^2.ha^{-1}$ of ADo and 10.21% of RDo, followed by *Erythroxylum mucronatum* (0.26487 $m^2.ha^{-1}$, 6,77%), *Eschweilera ovata* (0.25825 $m^2.ha^{-1}$, 6.60%), *Brosimum rubescens* (0.19667 $m^2.ha^{-1}$, 5.02%) and *Erythroxylum squamatum* (0.19389 $m^2.ha^{-1}$, 4.95%). In the forest interior were: *Psychotria carthagenensis* with 0.50932 $m^2.ha^{-1}$ and 13.16%, followed by *Eschweilera ovata* (0.33047 $m^2.ha^{-1}$, 8.54%), *Artocarpus heterophyllus* (0.25992 $m^2.ha^{-1}$, 6.71%), *Miconia prasina* (0.24555 $m^2.ha^{-1}$, 6.34%) and *Siparuna guianensis* (0.21975 $m^2.ha^{-1}$, 5.68%).

The highest concentration of individuals was found between 1.0 m and 2.0 m height with 999 individuals in the edge and 1043 in the forest interior (Fig. 2). However, the result of Chi-square test (0.0074466) with (p) = <0.05, contingency table 3 x 2 and 2 degrees of freedom, indicated that the distribution of regenerating individuals by height classes do not differ significantly between edge and interior of the fragment.

Some species may be responding favorably to the environmental conditions of forest edge and interior, which could to possibly explain the high abundance of species in the early stages of regeneration in these environments.

In both environments, the largest number of individuals are concentrated in the first class of diameter with 868 in the edge and 941 in interior and the lowest representativeness of individuals in the largest classes, respectively (Fig. 3). It's verified that the number of shrub-arboreal individuals decreased with the increase of the diametric class, similar to those recorded in other studies carried out on fragments of the Atlantic Forest in Pernambuco, as already reported in Sirinhaém by Lima et al. [27] and in Nazaré da Mata by Holanda et al. [28].

The distribution of shrub-arboreal individuals by diameter classes both in the edge and fragment interior tend to form inverted "J" curves (Fig. 3), that is, progressively decreasing its distribution until reaching a lower number of individuals in the larger height classes, indicating the dynamic balance of the forest. This behavior enables that dynamic processes to be perpetuated in the forest, since the sudden absence of dominant individuals will give originate to so-called "replacement trees" [29].

These data indicate to possible variations in the vertical structure of shrub-arboreal communities between the environments studied. In that case, it's proposed to perform a dynamic study of this component to better understand how these species behave in face of the natural and anthropic disturbances occurring in the area.

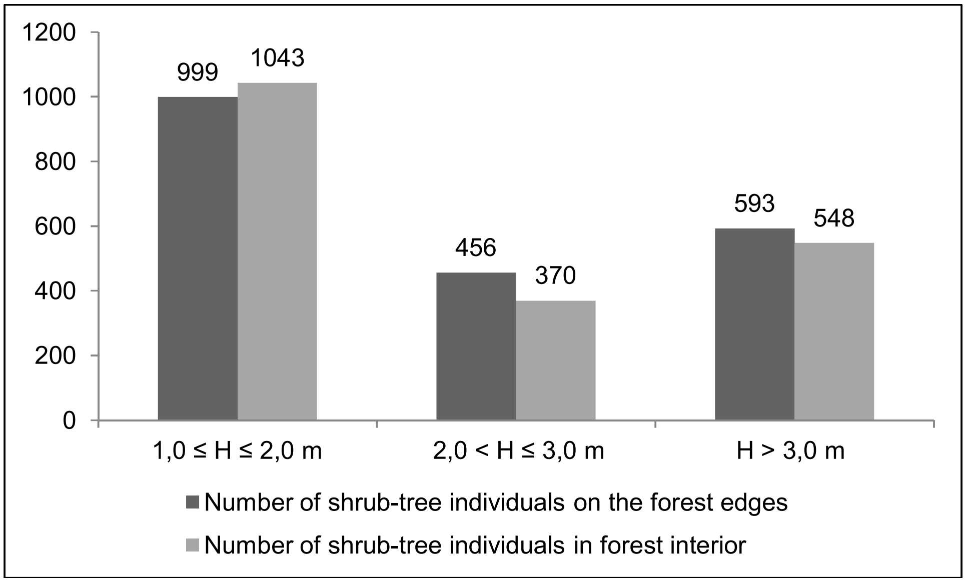

Fig. 2. Distribution of the number of shrub-arboreal individuals by height classes (1.0 m ≤ H ≤ 2.0 m, 2.0 m < H ≤ 3.0 m, H > 3.0 m) in the edge and forest interior

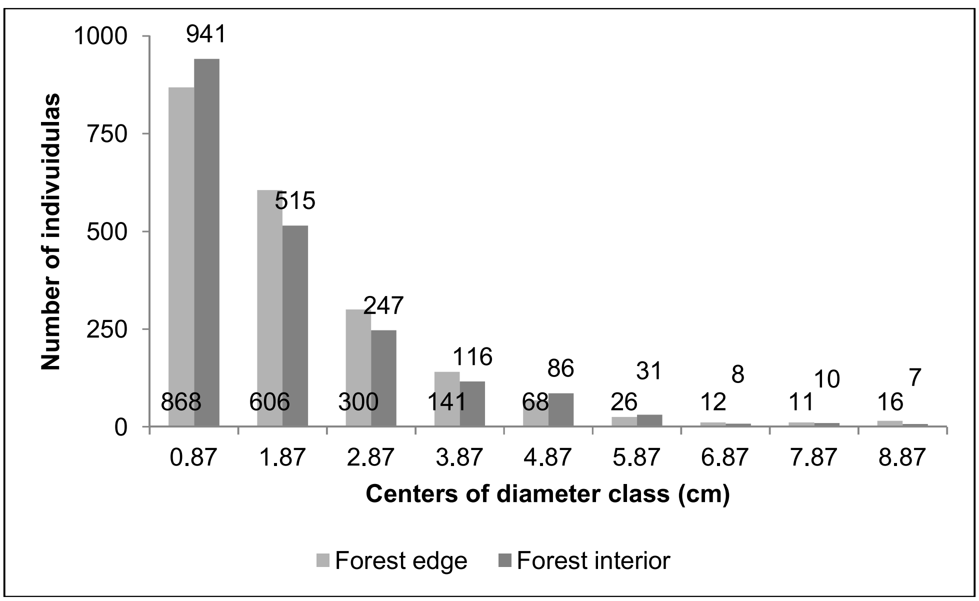

Fig. 3. Distribution of shrub-arboreal individuals by diameter class centers (cm) in the edge and forest interior

The highest percentages of total natural regeneration per height class (TNR) registred in the forest edge were represented by *Erythroxylum mucronatum* with 8.82%, followed by *Eschweilera ovata* (7.21%) and *Cordia nodosa* (5.12%) that grouped 21.15% of total TNR in this environment (Fig. 4). And in the interior the spceies were: *Eschweilera ovata* with 11.87% of TNR, *Psychotria carthagenensis* (8.33%) and *Siparuna guianensis* (6.12%) which together congregate 26.32% of total TNR per height class in this area (Fig. 5).

The species *Erythroxylum mucronatum* and *Eschweilera ovata* were also recorded with high percentages of TNR in other studies carried out on fragments of the Atlantic Forest in Pernambuco, as already presented in Sirinhaém by Lima et al. [26] and in Abreu e Lima by Estigarribia et al. [30].

In the forest edge environment, the most representative species in percentages of relative natural regeneration in the FSC (1.0 m ≤ H ≤ 2.0 m) were: *Cordia nodosa*, *Erythroxylum mucronatum*, and *Hirtella racemosa*. In SSC (2.0 m < H ≤ 3.0 m) were *Erythroxylum mucronatum*, *Eschweilera ovata* and *Cordia nodosa*, and in TSC (H > 3.0 m) were *Erythroxylum mucronatum*, *Eschweilera ovata* and *Miconia prasina*. In the interior were *Eschweilera ovata*, *Psychotria carthagenensis*, and *Symphonia globulifera* in the FSC (1.0 m ≤ H ≤ 2.0 m). In the SSC (2.0 m < H ≤ 3.0 m), *Eschweilera ovata*, *Psychotria carthagenensis*, and *Paypayrola blanchetiana*, and in TSC (H > 3.0 m) were *Eschweilera ovata*, *Psychotria carthagenensis*, and *Siparuna guianensis*. Regarding TNR, it was observed that except for the species *Paypayrola blanchetiana* and *Artocarpus heterophyllus* exclusive to the forest interior, the others were recorded in both analyzed environments.

The results corroborate those reported by Torres [31], who indicated *Eschweilera ovata* and *Miconia prasina* among the most representative in the relative percentages of FSC (1.0 m ≤ H ≤ 2.0 m), SSC (2.0 m <H ≤ 3.0 m) and TSC (H > 3.0 m) in the edge and interior environments of an Atlantic Forest fragment, in São Lourenço da Mata, Pernambuco.

The high representativeness of the species *Eschweilera ovata* and *Miconia prasina*, among the ten species with highest percentages of total natural regeneration per height class (TNR), both in the edge and fragment interior, indicate to the trend of different occupation strategies in the environments studied. Because initial secondary species, they present dependence intermediate of sunlight to complete their life cycles and may develop in the edges, under clearings or forest interior [14].

The main species that stood out with the highest importance value index (IVI) at the edge of the fragment were: *Myrcia spectabilis*, *Pouteria nordestinensis*, *Thyrsodium spruceanum*, *Himatanthus bracteatus* and *Miconia* sp. which together make up more than 28% of the IVI percentage of this environment (Fig. 6). And interior were: *Eschweilera ovata*, *Psychotria carthagenensis*, *Siparuna guianensis*, *Artocarpus heterophyllus* and *Paypayrola blanchetiana* which together account for more than 33% of the IVI percentage of this area (Fig. 7).

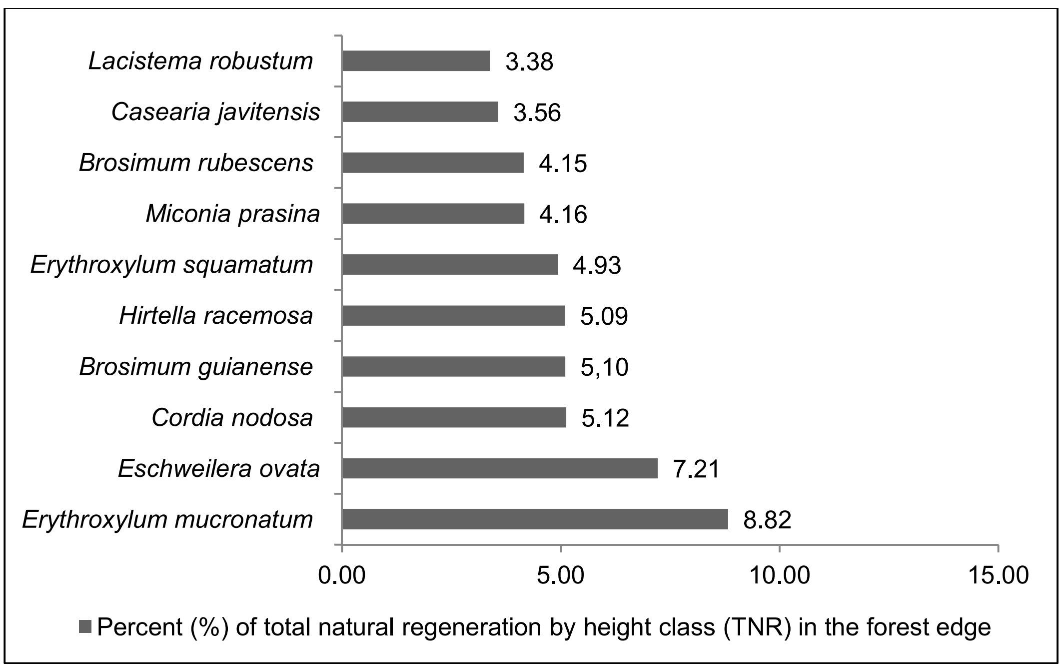

Fig. 4. Highest percentages of total natural regeneration per height class (TNR) in the forest edge

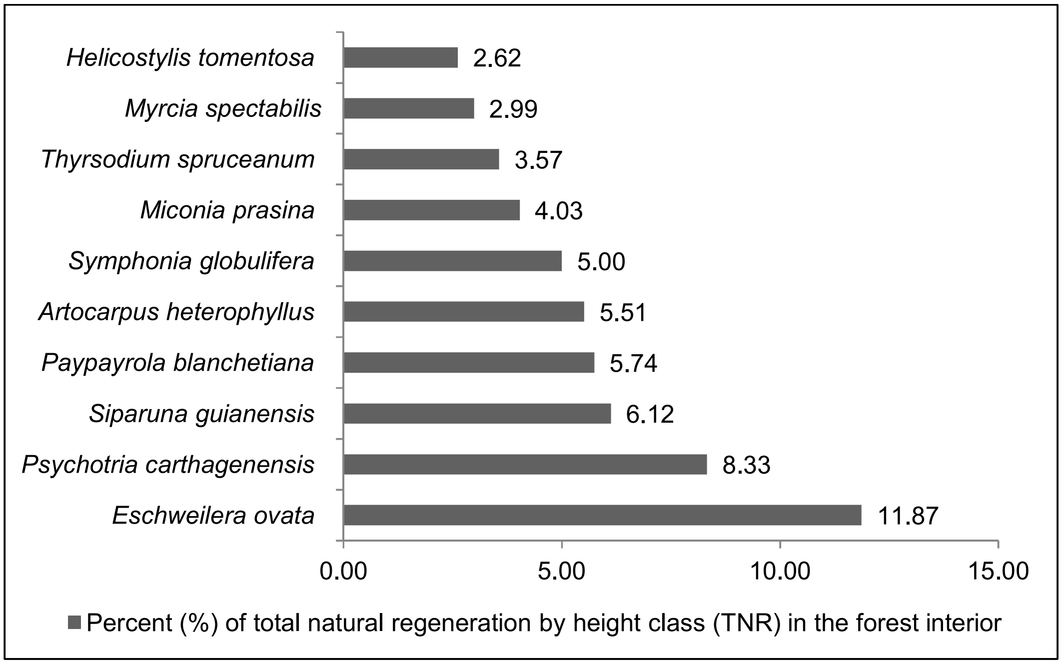

Fig. 5. Highest percentages of total natural regeneration per height class (TNR) in the forest interior

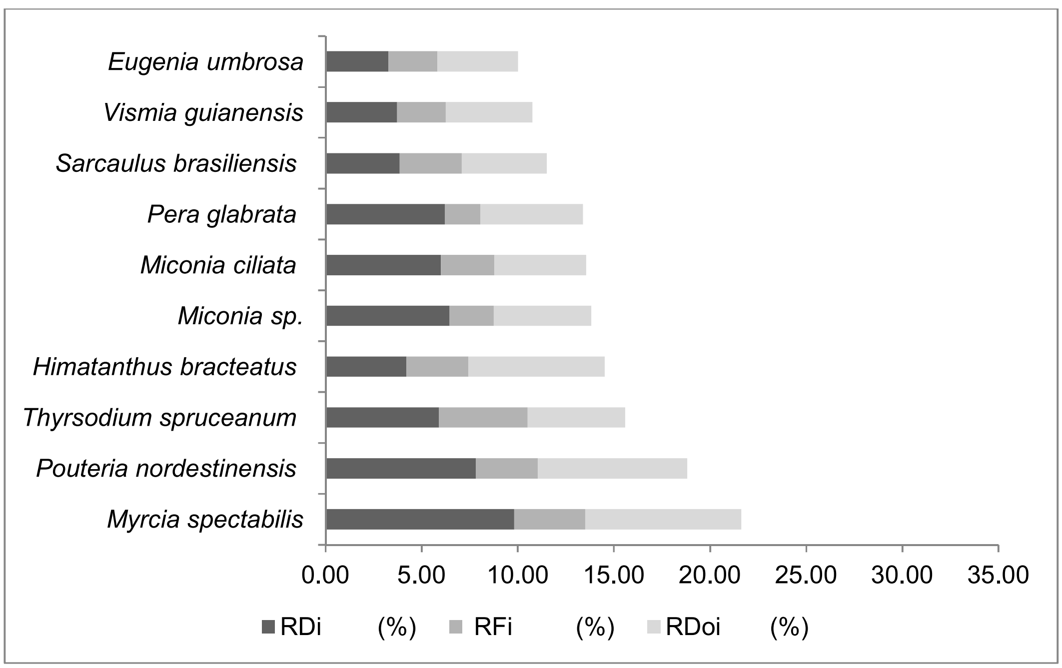

Fig. 6. The main species with highest importance value index (IVI) in the forest edge

Torres [31] also recorded *Cordia nodosa*, *Miconia prasina*, *Siparuna guianensis* and *Eschweilera ovata* among the main species with the highest importance value index (IVI) when evaluating natural regeneration n a fragment of the Lowland Dense Ombrophilous Forest in São Lourenço da Mata, State of Pernambuco. And Lima et al. [26] pointed out *Thyrsodium spruceanum*, *Eschweilera ovata* and *Symphonia globulifera* among the main species with the

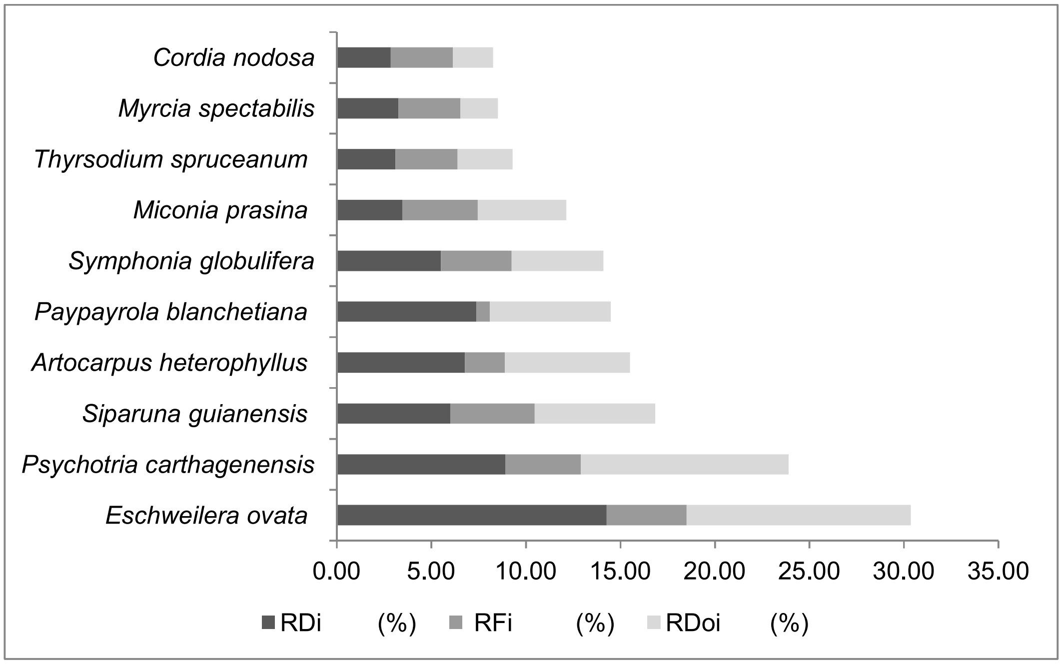

Fig. 7. The main species with highest importance value index (IVI) in the forest interior

highest IVI by analyzing the natural regeneration of tree species in a fragment of the Forest Lowland Dense Ombrophilous in Sirinhaém, Pernambuco.

It was observed that *Myrcia spectabilis* and *Thyrsodium spruceanum* registered among the main species with the highest importance value index (IVI), both on the edge and fragment interior, presented high relative density and dominance rates. Possibly, these species are better adapted to the environmental conditions of the fragment, which could explain the expressive establishment in the community.

3.2 Successional Classification

The highest percentage of species (47.15%) and the number of individuals (65.88%) were classified as initial secondary, followed by late secondary with 30.08% of species and 25.17% of the individuals. The uncharacterized group corresponded to 15.45% of species and 3.17% of individuals. Pioneers represented 7.32% of species and 5.69% of individuals (Appendix 1).

When grouped the initial and late secondary species they covered 77.23% of the total species and 91.05% of the total number of individuals cataloged in the fragment. These are results superior the 72% of initial and late secondary species recorded by Brandão et al. [20] in the fragment of Ombrophilous Dense Forest in Igarassu, Pernambuco.

According to Callegaro et al. [32], the low representativity of pioneer species, possibly is due to the advanced successional stage of the forest, in this sense it is proposed to evaluate the adult arboreal component to better understand the mechanisms of renewal of these species in the fragment.

4. CONCLUSION

The higher representativity of initial and late secondary species probably is due to the forest being in an advanced successional stage, having a structure with well-defined stratum.

Estimates of abundance and dominance in this study are similar to those recorded in research with the regeneration of shrub-arboreal species in Atlantic Forest of Pernambuco State and indicate that fragment studied the present good state of conservation. However, the environmental conditions of each habitat (edge and forest interior) may be contributing to a pattern of increase of density in the edge community and differences in population abundances of species of the greater density of each environment.

It is recommended to evaluate the dynamics of the regenerating shrub-arboreal community and the adult component, to better understand the mechanisms of survival and renewal of these species in the area.

Probably, some species are having a good regeneration strategy, as *Miconia prasina* and *Eschweilera ovata* with high total natural regeneration per height class both in the edge and forest interior. These species can be focal in future actions of recovery of degraded areas in the fragment studied.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Figueiredo LTM, Soares CPB, Souza AL, Martins SB. Floristic changes in a semideciduous seasonal forest in the municipality of Viçosa, MG, between 1994 and 2008. Forest. 2013;43(2):169-180. Portuguese
(Accessed 22 February 2019)
Available:http://dx.doi.org/10.5380/rf.v43i2.28869
2. Kimmel T, Piechowski D, Gottsberger G. The history of fragmentation of the lowland Atlantic Forest of Pernambuco, Brazil. In: Rodal MJN, Lins e Silva ACB, Gottsberge G, (Eds.). The Fragments Project. Bioremediation, Biodiversity and Bioavailability. 2008:2(1);1-4.
(Accessed 02 September 2019)
Available:http://www.globalsciencebooks.info/Online/GSBOnline/images/0812/BBB_2(SI1)/BBB_2(SI1)1-4o.pdf
3. Joly C, Metzger JP, Tabarelli M. Experiences from the Brazilian Atlantic Forest: Ecological findings and conservation initiatives. New Phytol. 2014;204(3):459-473.
(Accessed 01 September 2019)
Available:http://dx.https://doi.org/10.1111/nph.12989
4. Kennel E, Hubbart JA, Ikem A. A comparison of forest and agricultural shallow groundwater chemical status a century after land use change. Sci. Total Environ. 2015:529;82-90.
(Accessed 02 September 2019)
Available:https://doi.org/10.1016/j.scitotenv.2015.05.052
5. Popradit A, Srisatit T, Kiratiprayoon S, Yoshimura J, Ishida A, Shiyomi M, Murayama T, Chantaranothai P, Outtaranakorn S, Phromma I. Anthropogenic effects on a tropical forest according to the distance from human settlements. Sci. Rep. 2015;5(14689):1-10.
(Accessed: 03 September 2019)
Available:https://doi.org/10.1038/srep14689
6. Magura T, Lövei GL, Tóthmérész B. Edge responses are different in edges under natural versus anthropogenic influence: A meta-analysis using ground beetles. Ecol. Evol. 2017;7(3):1009-1017.
(Accessed 02 September 2019)
Available:http://dx.doi.org/10.1002/ece3.2722
7. Fahrig L. Ecological responses to habitat fragmentation per se. Annu. Rev. Ecol. Evol. Syst. 2017:48(1);1-23.
(Accessed 01 September 2019)
Available:http://dx.doi.org/10.1146/annurev-ecolsys-110316-022612
8. Haddad NM, Brudvig LA, Clobert J, Davies KF, Gonzalez A, Holt RD, Lovejoy TE, Sexton JO, Austin MP, Collins CD, Cook WM, Damschen EI, Ewers RM, Foster BL, Jenkins CN, King AJ, Laurance WF, Levey DJ, Margules CR, Melbourne BA, Nicholls AO, Orrock JL, Song Dan-Xia, Townshend JR. Habitat fragmentation and its lasting impact on Earth’s ecosystems. Sci. Adv. 2015;1(2):1-9.
(Accessed 01 September 2019)
Available:http://dx.doi.org/10.1126/sciadv.1500052
9. Schmidt M, Jochheim H, Kersebaum Kurt-Christian, Lischeid G, Nendel C. Gradients of microclimate, carbon and nitrogen in transition zones of fragmented landscapes – a review. Agricultural and Forest Meteorology. 2017:232;659-671.
(Accessed 01 September 2019)
Available:https://doi.org/10.1016/j.agrformet.2016.10.022
10. Endres Júnior D, Sasamori MH, Schmitt JL, Droste A. Survival and development of reintroduced *Cattleya intermedia* plants related to abiotic factors and herbivory at the edge and in the interior of a forest fragment in South Brazil. Acta Bot. Bras. 2018:32(4);555-566.
(Accessed 02 September 2019)
Available:http://dx.doi.org/10.1590/0102-33062018abb0009

11. Estevan DA, Vieira AOS, Gorenstein MR. Structure and floristic relationships of a fragment of remnant forest, Londrina, Paraná State, Brazil. Scienc. Forest. 2016;26(3):713-725. Portuguese
(Accessed 20 February 2019)
Available:http://dx.doi.org/10.5902/1980509824195
12. Eisenlohr PV, Felfili JM, Melo MMRF, Andrade LA, Meira Neto JAA. (Org.). Phytosociology in Brazil: Methods and case studies. 2nd Vol. 1st Ed. Viçosa - MG: Publishing Company UFV; 2015. Portuguese
13. Rodrigues RR, Brancalion PHS, Isernhagen I. Pact for the restoration of Atlantic forest: reference of the concepts and actions of forest restoration. São Paulo: LERF/ESALQ - Institute Bio Atlantic; 2009. Portuguese
(Accessed 02 March 2019)
Available:http://www.lerf.esalq.usp.br/divulgacao/produzidos/livros/pacto2009.pdf
14. Almeida DS. Environmental recovery of the Atlantic Forest [online].3rd. Ed. rev. and ext. - Ilhéus, BA: Editus; 2016.
(Accessed 02 March 2019)
Available:http://www.uesc.br/editora/livrosdigitais2016/recuperacao_ambiental_da_mata_atlantica_nova.pdf
15. State Agency for the Environment (CPRH). Caburé - Geoenvironmental Information System of Pernambuco. Conservation Units: FURB Mata of Manassu; n.d.
(Accessed 02 March 2019)
Available:http://200.17.134.119/arcgis/rest/services/MyMapServiceuso/FeatureServer/2/24/attachments/4005
16. Silva FBR, Santos JCP, Silva AB, Cavalcanti AC, Silva FHBB, Burgos N, et al. Agroecological zoning of the State of Pernambuco. Recife: Embrapa Soils - UEP Recife; 2001.
17. Alvares CA, Stape JL, Sentelhas PC, Gonçalves JLM. Modeling monthly mean air temperature for Brazil. Theor. Appl. Climatol. 2013;113(3-4):407-427.
(Accessed 16 March 2019)
Available:http://dx.doi.org/10.1007/s00704-012-0796-6
18. Pernambuco Agency for Waters and Climate (APAC). Services. Meteorology. Pluviometric Monitoring. Monthly view: Initial date: July 1, 2016 - Final date: June 30, 2017. Meso-region: Metropolitan of Recife. Post: Jaboatão dos Guararapes (Two Unas Dam - 268). Government of the State of Pernambuco. Recife; 2017.
(Accessed 21 March 2019)
Available:http://www.apac.pe.gov.br/meteorologia/monitoramento-pluvio.php
19. Angiosperm Phylogeny Group IV (APG IV). An update of the Angiosperm Phylogeny Group classification for the orders and families of flowering plants: APG IV. Bot. J. Linn. Soc. 2016;181(1):1-20.
(Accessed 24 January 2019)
Available:https://doi.org/10.1111/boj.12385
20. Brandão CFS, Marangon LC, Ferreira RLC, Lins e Silva ACB. Phytosociological structure and sucessional classification of arboreus component in a fragment of a Dense Ombrophylous Forest, Igarassu - Pernambuco. Brazil J Agric Scienc. 2009;4(1):55-61. Portuguese
(Accessed 13 February 2019)
Available:http://dx.doi.org/10.5039/agraria.v4i1a9
21. Consulting and Development Systems Lted. (CIENTEC). Software Mata Nativa 4: System for phytosociological analysis, Elaboration of inventories and management plans of native forest. Viçosa - MG: Cientec; 2016.
22. Ediriweera S, Singhakumara BMP, Ashton MS. Variation in canopy structure, light and soil nutrition across elevation of a Sri Lankan tropical rain forest. For. Ecol. Manage. 2008;256(6):1339-1349.
(Accessed 12 February 2019)
Available:https://doi.org/10.1016/j.foreco.2008.06.035
23. Cadotte MW, Franck R, Reza L, Lovett-Doust J. Tree and shrub diversity and abundance in fragmented littoral forest of southeastern Madagascar. Biodivers. Conserv. 2002;11(8):1417-1436.
(Accessed 27 February 2019)
Available:https://doi.org/10.1023/A:1016282023542
24. Lorenzi H. Brazilian trees: Identification and cultivation of tree plants in Brazil. 3rd Ed, 2nd Vol. Nova Odessa: Plantarum; 2009.
25. Paradizo IC, Macieira BPB, Gama VN, Zanetti LV, Cuzzuol GRF. Plasticidade fenotípica como indicador de arbóreas não pioneiras mais tolerantes à elevada luminosidade. Pesqui Florest Bras. 2015;35(84):359-369. Portuguese
(Accessed 30 January 2019)
Available:https://doi.org/10.4336/2015.pfb.35.84.927

26. Lima RBA, Marangon LC, Freire FJ, Feliciano ALP, Silva RKS. Regenerative potential of arboreal species in a fragment of the Atlantic Forest, Pernambuco, Brazil. Rev. Green. 2017;12(4):666-673. Portuguese
(Accessed 13 February 2019)
Available:http://dx.doi.org/10.18378/rvads.v12i4.5002
27. Silva RKS, Feliciano ALP, Marangon LC, Lima RBA. Floristics and ecological succession of the arboreal vegetation in the spring area of an Atlantic forest fragment, Pernambuco, Brazil. Brazil J Agric Scienc. 2010;5(4):550-559. Portuguese
(Accessed 01 March 2019)
Available:http://dx.doi.org/10.5039/agraria.v5i4a829
28. Holanda AC, Feliciano ALP, Marangon LC, Santos MS, Melo CLSMS, Pessoa MML. Edge effect on the structure of tree species in a Seasonal Forest fragment in Pernambuco. Rev. Tree. 2010;34(1):103-114. Portuguese
(Accessed 05 February 2019)
Available:http://dx.doi.org/10.1590/S0100-67622010000100012
29. Watzlawick LF, Albuquerque JM, Redin CG, Longhi RV, Longhi SJ. Structure, diversity and spatial distribution of trees in the Araucaria Forest in faxinal system, Rebouças (PR). Ambiência. 2011;7(3):415-427. Portuguese
(Accessed 23 February 2019)
Available:http://dx.doi.org/10.5777/ambiencia.2011.03.01
30. Estigarribia F, Silva JP, Cândido PF, Silva ND, Silva JA, Chaves LF. Natural regeneration in tropical rainforest, Northeastern Brazil. JEAI. 2019;31(2):1-11.
Available:https://doi.org/10.9734/jeai/2019/v31i230070
31. Torres JEL. Regenerating tree species on the edge and interior of an Atlantic Forest fragment in Pernambuco. Dissertation (MSC in Forestry Sciences). Rural Federal University of Pernambuco. Recife; 2014.
(Accessed 03 September 2019)
Available:http://www.ppgcf.ufrpe.br/sites/www.ppgcf.ufrpe.br/files/documentos/jose_edson_de_lima_torres_0.pdf
32. Callegaro RM, Andrzejewski A, Longhi SJ, Longhi RV, Biali LJ. Composition of successional categories in the horizontal, vertical and diametric structures of a Montane Mixed Ombrophilous Forest. Brazil J Agric Scienc. 2016;11(4):350-358. Portuguese
(Accessed 19 February 2019)
Available:https://dx.doi.org/10.5039/agraria.v11i4a5406

APPENDIX

Appendix 1. Relation of the shrub-arboreal species sampled in the edge (E) and interior (I) environments of Urban Forest Reserve Mata of Manassu in Jaboatão dos Guararapes, Pernambuco, Brazil

Family	Species	Number of individuals	SC	E	I
Anacardiaceae	*Mangifera indica* L. (**)	2	IS		X
	Tapirira guianensis Aubl.	65	IS	X	X
	Thyrsodium spruceanum Benth.	120	IS	X	X
Annonaceae	*Anaxagorea dolichocarpa* Sprague & Sandwith	63	LS		X
	Annonaceae 1	2	UN	X	X
	Annonaceae 2	11	UN	X	
	Cymbopetalum brasiliense (Vell.) Benth. ex Baill.	7	LS		X
	Guatteria pogonopus Mart.	49	LS	X	X
	Guatteria schomburgkiana Mart.	1	LS		X
	Xylopia frutescens Aubl.	6	IS	X	X
Apocynaceae	*Aspidosperma discolor* A. DC.	8	IS	X	
	Aspidosperma spruceanum Benth. ex Müll.Arg.	1	IS	X	
	Himatanthus bracteatus (A. DC.) Woodson	22	IS	X	X
	Tabernaemontana flavicans Willd. ex Roem. & Schult.	6	IS	X	X
Araliaceae	*Schefflera morototoni* (Aubl.) Maguire et al.	11	IS	X	X
Boraginaceae	*Cordia nodosa* Lam.	177	IS	X	X
	Cordia sellowiana Cham.	1	IS	X	
Burseraceae	*Protium aracouchini* (Aubl.) March.	15	LS	X	X
	Protium giganteum Engl.	16	LS	X	X
	Protium heptaphyllum (Aubl.) Marchand	77	IS	X	X
Celastraceae	*Maytenus distichophylla* Mart. ex Reissek	18	LS	X	X
Chrysobalanaceae	*Couepia rufa* Ducke	1	LS	X	
	Hirtella racemosa Lam.	136	IS	X	X
	Leptobalanus octandrus (Hoffmanns. ex Roem. & Schult.) Sothers & Prance	10	IS	X	X
	Licania kunthiana Hook. f.	1	LS		X
Clusiaceae	*Clusia nemorosa* G. Mey.	3	LS	X	
	Symphonia globulifera L.f.	114	IS	X	X
	Tovomita brevistaminea Engl.	7	LS	X	X
Elaeocarpaceae	*Sloanea garckeana* K.Schum.	2	LS	X	X
	Sloanea guianensis (Aubl.) Benth.	1	LS		X
Erythroxylaceae	*Erythroxylum citrifolium* A.St.-Hil.	94	LS	X	X
	Erythroxylum mucronatum Benth.	217	LS	X	X
	Erythroxylum squamatum Sw.	137	LS	X	X
Euphorbiaceae	*Mabea piriri* Aubl.	48	IS	X	X
Fabaceae	*Abarema cochliacarpos* (Gomes) Barneby & J.W. Grimes (***)	2	IS	X	X
	Abarema sp.	5	UN	X	
	Adenanthera pavonina L. (**)	1	IS		X
	Albizia pedicellaris (DC.) L.Rico	23	PI	X	X
	Andira fraxinifolia Benth. (***)	11	LS	X	X
	Bowdichia virgilioides Kunth	1	LS		X
	Chamaecrista ensiformis (Vell.) H. S. Irwin & Barneby (***)	4	IS	X	
	Dialium guianense (Aubl.) Sandwith	8	LS	X	X
	Fabaceae 1	1	UN		X
	Fabaceae 2	6	UN	X	
	Inga capitata Desv.	4	IS	X	X

Family	Species	Number of individuals	SC	E	I
	Inga ingoides (Rich.) Willd.	1	LS		X
	Inga thibaudiana DC.	57	IS	X	X
	Parkia pendula (Willd.) Benth. ex Walp.	40	LS	X	X
	Plathymenia reticulata Benth. (***)	7	IS	X	X
	Swartzia pickelii Ducke	2	LS		X
	Tachigali densiflora (Benth.) L.G.Silva & H.C.Lima (***)	20	PI	X	X
Hypericaceae	*Vismia guianensis* (Aubl.) Choisy	4	PI	X	
Uncharacterized	Uncharacterized 1	6	UN	X	
	Uncharacterized 2	1	UN	X	
	Uncharacterized 3	1	UN		X
	Uncharacterized 4	1	UN		X
Lacistamataceae	*Lacistema robustum* Schnizl. (***)	79	IS	X	X
Lauraceae	Lauraceae 1	1	UN		X
	Lauraceae 2	8	UN		X
	Nectandra cuspidata Nees	5	LS		X
	Ocotea glomerata (Nees) Mez	32	IS	X	
	Ocotea longifolia Kunth	3	IS	X	
Lecythidaceae	*Eschweilera apiculata* (Miers) A.C.Sm.	3	LS	X	
	Eschweilera ovata (Cambess.) Mart. ex Miers	440	IS	X	X
	Lecythis pisonis Cambess.	3	LS	X	
Malphigiceae	*Byrsonima sericea* DC.	7	IS	X	
Malvaceae	*Eriotheca macrophylla* (K.Schum.) A.Robyns	1	IS		X
Melastomataceae	*Henriettea succosa* (Aubl.) DC.	19	IS	X	X
	Miconia albicans (Sw.) Steud.	1	PI	X	X
	Miconia affinis DC.	8	PI	X	
	Miconia ciliata (Rich.) DC.	9	PI	X	
	Miconia holosericea (L.) DC.	7	PI	X	X
	Miconia minutiflora (Bonpl.) DC.	5	IS	X	
	Miconia prasina (Sw.) DC.	154	PI	X	X
	Miconia sp.	24	UN	X	
	Miconia tomentosa (Rich.) D.Don (***)	6	IS		X
Meliaceae	*Guarea guidonia* (L.) Sleumer	2	LS		X
Moraceae	*Artocarpus heterophyllus* Lam. (**)	133	IS		X
	Brosimum guianense (Aubl.) Huber	141	IS	X	X
	Brosimum rubescens Taub.	84	LS	X	X
	Helicostylis tomentosa (Poepp. & Endl.) Rusby (***)	62	IS	X	X
	Sorocea hilarii Gaudich.	7	IS	X	
Myristicaceae	*Virola gardneri* (A. DC.) Warb.	1	LS		X
Myrtaceae	*Campomanesia dichotoma* (O.Berg) Mattos	1	IS		X
	Eugenia candolleana DC.	8	LS	X	X
	Eugenia tumescens B.S.Amorim & M.Alves	8	IS	X	
	Eugenia umbrosa O. Berg	7	IS	X	X
	Myrcia guianensis (Aubl.) DC.	48	IS	X	X
	Myrcia sp.	2	UN	X	
	Myrcia spectabilis DC.	86	IS	X	X
	Myrcia splendens (Sw.) DC.	8	IS	X	X
	Myrcia sylvatica (G.Mey.) DC.	10	IS	X	X
	Myrcia tomentosa (Aubl.) DC.	16	IS	X	
	Myrtaceae 1	1	UN	X	
	Myrtaceae 2	45	UN	X	X
Nyctaginaceae	*Guapira nitida* (Mart. ex J.A.Schmidt) Lundell	4	IS		X
	Guapira opposita (Vell.) Reitz	33	IS		X
	Guapira sp.	1	UN		X

Family	Species	Number of individuals	SC	E	I
Ochnaceae	*Ouratea polygyna* Engl.	1	IS	X	
	Ouratea sp.	3	UN		X
Peraceae	*Pera glabrata* (Schott) Poepp. ex Baill.	20	IS	X	X
	Pogonophora schomburgkiana Miers ex Benth.	10	LS	X	X
Phyllanthaceae	*Hyeronima oblonga* (Tul.) Müll.Arg.	47	IS	X	X
	Phyllanthus sp.	10	UN	X	
Primulaceae	Primulaceae 1	2	UN	X	
Rubiaceae	*Posoqueria latifolia* (Rudge) Schult.	8	IS		X
	Psychotria carthagenensis Jacq.	189	IS	X	X
Salicaceae	*Casearia javitensis* Kunth	76	IS	X	X
	Casearia sylvestris Sw.	2	IS		X
Sapindaceae	*Cupania racemosa* (Vell.) Radlk.	40	IS	X	X
	Talisia coriacea Radlk.	3	LS		X
	Talisia esculenta (A. St.-Hil.) Radlk.	1	IS	X	X
Sapotaceae	*Pouteria bangii* (Rusby) T. D. Penn.	41	LS	X	
	Pouteria durlandii (Standl.) Baehni	1	LS	X	X
	Pouteria gardneri (Mart. & Miq.) Baehni	1	LS	X	
	Pouteria nordestinensis Alves-Araújo & M. Alves	6	LS	X	X
	Sarcaulus brasiliensis (A.DC.) Eyma (***)	1	LS		X
Schoepfiaceae	*Schoepfia brasiliensis* A. DC.	5	IS	X	
Simaroubaceae	*Simarouba amara* Aubl.	7	IS	X	X
Siparunaceae	*Siparuna guianensis* Aubl.	197	IS	X	X
Urticaceae	*Cecropia pachystachya* Trécul	2	PI		X
Violaceae	*Paypayrola blanchetiana* Tul.	145	LS		X
	Rinorea guianensis Aubl.	13	IS	X	X
	Total number of individuals	4009			

In that: SC = successional classification; PI = pioneer; IS = initial secondary, LS = late secondary or UN = uncharacterized; (**) Exotic species; (***) Threatened species of extinction according to obtained data from the IUCN Red List of Threatened Species TM 2017-2 (The World Conservation Union) (see http://www.iucnredlist.org/search)

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle3.com/review-history/51348