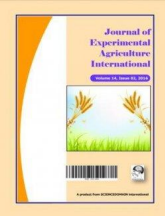

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Dynamics of Natural Regeneration in a Fragment of Dense Ombrophilous Forest in Urban Area

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Authors' contributions

This work was carried out in collaboration between all authors. Authors ABA, DSCJ, YSL and PCGC designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors DSCJ and LFCC managed the analyses of the study. Authors ABA, DSCJ, YSL and PCGC managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The objective of this study was to evaluate the dynamics of natural regeneration in an urban forest fragment in Recife - PE. Ten plots of 5 m x 5 m were installed, the individuals with height (H) ≥ 1 m and the circumference at breast height (CBH) ≤ 15 cm were measured in 2010 and 2017. The floristic composition, diversity, phytosociological parameters and natural regeneration by height and total classes were evaluated. The individuals were distributed in height classes, where: C1 = H ≥ 1.0 up to 2.0 m; C2 = H> 2.1 to 3.0 m; C3 = H> 3.0 m and CAP <15 cm. The families with the highest number of individuals in both years were: Moraceae, Burseraceae, Euphorbiaceae and Fabaceae. Together, these families accounted for 74.57% of the total number of individuals in 2010 and 73.40% in 2017. The predominance of individuals in the first class was observed, followed by the second and third. The species with the highest Total Natural Regeneration (TNR) were: *Artocarpus heterophyllus*, *Helicostylis tomentosa*, *Protium giganteum*, *Protium heptaphyllum*, *Brosimum guianense* and *Mabea occidentalis*, which together corresponded to a TNR of 60.09% in 2010 and

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59.03 % in 2017. The species with the highest number of recruitments were *Brosimum guianense*, *Artocarpus heterophyllus*, *Helicostylis tomentosa*, *Siparuna guianensis* and *Cymbopetalum brasiliense*. It was concluded that there were no significant differences in the fragment within the time interval studied.

Keywords: Ecology; diversity; phytosociology; structure.

1. INTRODUCTION

The Atlantic forest is one of the biomes with the greatest heterogeneity of the Brazilian territory [1]. Therefore, studies are necessary to know the diversity of these environments, since they are increasingly submitted to progressive anthropic interventions, regardless of their protection and conservation.

According to Brasileiro Institute of Geography and Statistics (IBGE) [2] among phytophysiognomies of the Atlantic forest is the dense ombrophilous forest, characterised by the presence of woody lianas and epiphytes in abundance, which differentiate them from other classes of vegetal formations. Its main ecological feature resides in ombrophilous environments. This feature, allied to tropical climatic factors such as well distributed high temperatures and high precipitation determine environments with practically no dry periods.

Understanding the complexity of ecosystems of the Atlantic Forest is essential to subsidise actions that aim at the development of conservation strategies and management of these environments. In this context, knowing the development of natural regeneration of a forest is crucial for its maintenance, in addition to understanding the behaviour of vegetation under adverse conditions [3].

According to Silveira and Silva [4], natural regeneration of a forest can be defined as the recovery process in which it passes after a natural or anthropic disturbance. It is a slow succession process that can be influenced by a number of factors such as environmental conditions, seed sources, and the duration and intensity of the disturbance. In environments with favourable environmental conditions, the process of natural regeneration occurs spontaneously, occurring in an orderly and predictable manner through dynamics of succession of species involved. In anthropogenic environments, natural regeneration process may occur slowly and be conditioned by some factors such as environmental conditions (climate and slope), type and intensity of disturbance and distance and source of propagules [4,5].

The evaluation of natural regeneration as a process of succession makes it possible to establish relationships between patterns of diversity and composition of observed species and mechanisms that accelerate or delay this process [6].

Phytosociological surveys are widely used for monitoring natural regeneration, consisting in obtaining qualitative and quantitative information of the species in the area and of plant stratification to provide subsidies for studies related to preservation and recovery of areas [7,8]. Natural regeneration represents one of the parameters of phytosociology studies in which it is allowed to calculate other parameters that express, for example, density, spatial distribution and stratification of the regenerating plant community, through the arithmetic mean as described by Finol [9]. Therefore, an effective way of estimating the state of conservation and maintenance of a forest is through the characterisation of structural parameters to represent the whole forest [10].

Studies about the dynamics of tropical forests are important to assist in decision-making processes, allowing selection of the best strategies to regenerate forest environments [11]. In addition, in order to understand the natural regeneration of a forest, it is necessary to know the dynamics of plant populations to establish mechanisms for recovery and forest conservation.

The objective of this study was to evaluate the composition and structure of the natural regeneration of shrub and tree species in permanent sample units, located in an urban forest fragment located in the city of Recife – PE, aiming to obtain technical information that subsidizes future studies to assist in decision making for the preservation and maintenance of urban forest ecosystems.

2. MATERIALS AND METHODS

The present study on the dynamics of natural regeneration was carried out at the Botanical

Garden of Recife (JBR) at coordinates 08º 04' 34.57 " S and 34º 58' 00.03" W. The Botanical Garden covers a total area of 10.72 ha, in which 8.53 ha are covered by vegetation, characterized as dense ombrophylous forest [2], and 2.19 ha of area destined to the infrastructure of the Botanical Garden, in an area of average altitude of 35.55 m. The soil is predominant of the dystrophic red-yellow argisol type [12], with tropical As' climate according to Köppen-Geiger climatic classification, with rainfall from May to July averaging 1,651 mm, and average annual temperature of 25°C [13].

The sampling method was the Fully Random Sampling, where 10 permanent plots with dimensions of 5 m x 5 m were installed in 2010, when individuals were identified and measured. For the study of the dynamics of natural regeneration, individuals were remeasured in 2017, counting the dead and the appearance of new individuals.

According to methodology proposed by Marangon et al. [14], individuals with height equal to or greater than 1.0 m (H ≥ 1 m) and with a circumference at breast height (CBH) less than or equal to 15 cm (CAP ≤ 15 cm) were included in the sample, receiving numerated platelets, and were distributed in height classes, where: C1 = H ≥ 1.0 up to 2.0 m; C2 = H> 2.1 to 3.0 m; C3 = H> 3.0 m and CAP <15 cm, and were subsequently identified. Individuals who met inclusion criteria had their circumference at the ground level and total height measured. Measurement of the circumference was made using a measuring tape graduated in centimetres. The height of individuals up to 3.0 m was measured with a measuring tape and a graduated ruler, while for individuals over 3.0 m, estimation was made through natural ocular observation, with a ruler.

Measured plants had their samples collected for herbalism and were later identified by comparison with exsiccates deposited at the Herbarium Sérgio Tavares, at Federal Rural University of Pernambuco, at the time of implementation of the permanent plots in 2010. The same procedure was adopted when new species appeared during the evaluation of the dynamics of their natural regeneration.

For confirmation of the scientific name of the species, the website of the Botanical Garden of Rio de Janeiro was used, based on the Angiosperm Phylogeny Group (APG IV) [15].

Floristic composition was evaluated by the distribution of individuals in their respective species and families, as well as by Shannon-Wiener diversity index (H ') [16].

The phytosociological parameters analysed were density, frequency, dominance (absolute and relative values) and importance value (VI), as proposed by Mueller-Dumbois and Ellenberg [17].

For analysis of natural regeneration, a method developed by Volpato [18] which involves calculation of the Natural Regeneration Index, the Absolute and Relative Density and Frequency estimation of each species in each size class was used. From these parameters, natural regeneration by height class and Total Natural Regeneration (TNR) were estimated.

Data were tabulated, processed and analysed using Microsoft Excel and MATA NATIVA® software, version 4.

3. RESULTS AND DISCUSSION

In the survey carried out in 2010, 291 individuals belonging to 22 families and 41 species were registered, in which seven were identified only at the gender level (Table 1).

In 2017, 312 individuals belonging to 20 families and 40 species were counted, in which seven were identified only at the gender level (Table 2).

The families that presented the greatest richness of species in 2010 were Moraceae (41.92%), Fabaceae (5.16%) and Rubiaceae (1.72%), each family represented by four species, representing 48.80% of the registered individuals. The families that showed the greatest species richness in 2017 were Moraceae (42.95%), Fabaceae (5.45%) and Rubiaceae (1.60%), each family represented by four species, with the addition of one species in the Fabaceae family and the addition of the Sapindaceae family (4.49%), which together represented 54.49% of the individuals. In a study carried out in a tropical rainforest in Pernambuco, Lopes et al. [3] also recorded, among other families, Moraceae, Fabaceae and Sapindaceae as families with the highest species richness. The Fabaceae family was also reported as having higher species richness by Cruz et al. [19], studying the structure and floristic of tree community in different areas of Dense Ombrophylous Forest.

Table 1. Horizontal structure of a Dense Ombrophylous Forest area in the Botanical Garden of Recife, PE, in the year 2010

Scientific name	Family	N	DA	DR	FA	FR	DoA	DoR	VI	CS
Artocarpus heterophyllus Lam.	Moraceae	50	2000	17.18	70	6.36	0.56	17.49	41.03	ES
Helicostylis tomentosa (Poepp. & Endl.) Rusby	Moraceae	34	1360	11.68	90	8.18	0.47	14.7	34.56	PI
Protium giganteum Engl.	Burseraceae	30	1200	10.31	80	7.27	0.29	9.11	26.69	NP
Protium heptaphyllum (Aubl.) Marchand	Burseraceae	30	1200	10.31	90	8.18	0.24	7.55	26.04	ES
Brosimum guianense (Aubl.) Huber	Moraceae	29	1160	9.97	90	8.18	0.15	4.6	22.74	NP
Mabea occidentalis Benth.	Euphorbiaceae	13	520	4.47	50	4.55	0.17	5.31	14.32	NP
Eschweilera ovata (Cambess.) Mart. ex Miers	Lecythidaceae	9	360	3.09	40	3.64	0.16	5.04	11.77	LS
Sorocea hilarii Gaudich.	Moraceae	9	360	3.09	40	3.64	0.14	4.43	11.16	LS
Dialium guianense (Aubl.) Sandwith	Fabaceae	9	360	3.09	50	4.55	0.05	1.45	9.08	LS
Siparuna guianensis Aubl.	Siparunaceae	12	480	4.12	40	3.64	0.04	1.27	9.0	ES
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	Euphorbiaceae	5	200	1.72	30	2.73	0.10	3.09	7.53	LS
Cymbopetalum brasiliense (Vell.) Benth. ex Baill.	Annonacea	5	200	1.72	30	2.73	0.10	3.03	7.47	NC
Cordia nodosa Lam.	Boraginaceae	3	120	1.03	20	1.82	0.11	3.53	6.38	ES
Cupania racemosa (Vell.) Radlk.	Sapindaceae	7	280	2.41	20	1.82	0.07	2.08	6.30	ES
Cupania revoluta Radlk.	Sapindaceae	2	80	0.69	20	1.82	0.08	2.43	4.94	PI
Albizia pedicellaris (DC.) L.Rico	Fabaceae	1	40	0.34	10	0.91	0.12	3.66	4.90	PI
Licania tomentosa (Benth.) Fritsch	Chrysobalanaceae	3	120	1.03	30	2.73	0.03	0.82	4.58	ST
Zornia sp.	Fabaceae	3	120	1.03	20	1.82	0.04	1.22	4.06	NC
Piper sp.	Piperaceae	3	120	1.03	20	1.82	0.03	0.9	3.75	SB
Miconia sp.	Melastomataceae	4	160	1.37	10	0.91	0.04	1.35	3.63	PI
Paypayrola blanchetiana Tul.	Violaceae	2	80	0.69	20	1.82	0.01	0.43	2.93	NC
Myrciaria ferruginea O. Berg	Myrtaceae	2	80	0.69	20	1.82	0.01	0.42	2.92	NC
Pera ferruginea (Schott) Müll. Arg.	Euphorbiaceae	2	80	0.69	20	1.82	0.01	0.29	2.79	LS
Eugenia uvalha Cambess.	Myrtaceae	2	80	0.69	20	1.82	0.01	0.25	2.75	NC
Andira nitida Mart. ex Benth	Fabaceae	1	40	0.34	10	0.91	0.05	1.43	2.68	ES
Guapira opposita (Vell.) Reitz	Nyctaginaceae	4	160	1.37	10	0.91	0.01	0.4	2.68	ES
Allophylus edulis (A. St.-Hil. et al.) Hieron. ex Niederl.	Sapindaceae	2	80	0.69	10	0.91	0.03	0.82	2.41	NP
Morfo-espécie 2	Rubiaceae	2	80	0.69	10	0.91	0.03	0.81	2.40	NC
Morfo-espécie 1	Rubiaceae	1	40	0.34	10	0.91	0.01	0.42	1.67	NC
Ouratea crassa Tiegh.	Ochnaceae	1	40	0.34	10	0.91	0.01	0.36	1.61	NC
Psychotria carthagenensis Jacq.	Rubiaceae	1	40	0.34	10	0.91	0.01	0.29	1.54	NP
Eriotheca crenulaticalyx A. Robyns	Malvaceae	1	40	0.34	10	0.91	0.01	0.2	1.45	ES

Scientific name	Family	N	DA	DR	FA	FR	DoA	DoR	VI	CS
Chrysophyllum splendens Spreng.	Sapotaceae	1	40	0.34	10	0.91	0.01	0.16	1.41	CL
Schefflera morototoni (Aubl.) Maguire et al.	Araliaceae	1	40	0.34	10	0.91	0.01	0.14	1.39	PI
Paubrasilia echinata Lam.	Fabaceae	1	40	0.34	10	0.91	0.00	0.14	1.38	LS
Casearia javitensis Kunth	Salicaceae	1	40	0.34	10	0.91	0.00	0.12	1.37	ES
Cupania oblongifolia Mart.	Sapindaceae	1	40	0.34	10	0.91	0.00	0.08	1.33	ES
Eugenia sp.	Myrtaceae	1	40	0.34	10	0.91	0.00	0.07	1.32	NC
Coffea sp.	Rubiaceae	1	40	0.34	10	0.91	0.00	0.05	1.30	NC
Erythroxylum citrifolium A. St.-Hil.	Erythroxylaceae	1	40	0.34	10	0.91	0.00	0.05	1.30	LS
Lecythis pisonis Cambess.	Lecythidaceae	1	40	0.34	10	0.91	0.00	0.04	1.29	ES
Total		291	11640	100	1100	100	3.21	100	300	

N = Individuals number; DA = Absolute Density (Individuals /ha); DR = Relative density (%); FA = Absolute Frequency (%); FR = Relative Frequency (%); DoA = Absolute Dominance (%); DoR = Relative Dominance; VI = Value of Importance; PI = Pioneer, ES = Early Secondary; LS = Late Secondary; CL = Clímax; SB = Tolerant of sub-forest; NP = Not pioneering; NC = unclassified

Table 2. Horizontal structure of a Dense Ombrophylous Forest area in the Botanical Garden of Recife, PE, in the year 2017

Scientific name	Family	N	DA	DR	FA	FR	DoA	DoR	VI	CS
Artocarpus heterophyllus Lam.	Moraceae	56	2240	17.95	70	6.09	1.16	23.13	47.17	ES
Helicostylis tomentosa (Poepp. & Endl.) Rusby	Moraceae	33	1320	10.58	100	8.7	0.5	11.79	31.07	PI
Protium giganteum Engl.	Burseraceae	26	1040	8.33	80	6.96	0.49	9.68	24.97	NP
Brosimum guianense (Aubl.) Huber	Moraceae	35	1400	11.22	90	7.83	0.28	5.63	24.68	NP
Protium heptaphyllum (Aubl.) Marchand	Burseraceae	30	1200	9.62	90	7.83	0.34	6.75	24.19	ES
Mabea occidentalis Benth.	Euphorbiaceae	14	560	4.49	40	3.48	0.28	5.46	13.42	NP
Siparuna guianensis Aubl.	Siparunaceae	17	680	5.45	70	6.09	0.08	1.66	13.20	NC
Eschweilera ovata (Cambess.) Mart. ex Miers	Lecythidaceae	10	400	3.21	40	3.48	0.20	3.87	10.55	LS
Sorocea hilarii Gaudich.	Moraceae	10	400	3.21	40	3.48	0.19	3.67	10.36	LS
Dialium guianense (Aubl.) Sandwith	Fabaceae	10	400	3.21	60	5.22	0.06	1.1	9.52	LS
Cymbopetalum brasiliense (Vell.) Benth. ex Baill.	Annonacea	9	360	2.88	40	3.48	0.15	3.04	9.40	NC
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	Euphorbiaceae	6	240	1.92	30	2.61	0.20	3.92	8.45	LS
Cupania racemosa (Vell.) Radlk.	Sapindaceae	8	320	2.56	30	2.61	0.13	2.54	7.71	ES
Cordia nodosa Lam.	Boraginaceae	3	120	0.96	20	1.74	0.16	3.12	5.82	ES
Cupania revoluta Radlk.	Sapindaceae	2	80	0.64	20	1.74	0.11	2.14	4.51	PI
Licania tomentosa (Benth.) Fritsch	Chrysobalanaceae	3	120	0.96	30	2.61	0.04	0.75	4.32	LS
Zornia sp.	Fabaceae	3	120	0.96	20	1.74	0.08	1.48	4.19	NC

Scientific name	Family	N	DA	DR	FA	FR	DoA	DoR	VI	CS
Myrciaria ferruginea O. Berg	Myrtaceae	3	120	0.96	30	2.61	0.03	0.52	4.09	NC
Albizia pedicellaris (DC.) L.Rico	Fabaceae	1	40	0.32	10	0.87	0.12	2.35	3.54	PI
Piper sp.	Piperaceae	3	120	0.96	20	1.74	0.03	0.64	3.34	SB
Miconia sp.	Melastomataceae	3	120	0.96	10	0.87	0.06	1.09	2.92	PI
Eugenia uvalha Cambess.	Myrtaceae	3	120	0.96	20	1.74	0.01	0.19	2.89	NC
Pera ferruginea (Schott) Müll. Arg.	Euphorbiaceae	2	80	0.64	20	1.74	0.02	0.35	2.73	ES
Guapira opposita (Vell.) Reitz	Nyctaginaceae	3	120	0.96	10	0.87	0.02	0.44	2.27	ES
Andira nitida Mart. ex Benth	Fabaceae	1	40	0.32	10	0.87	0.05	0.93	2.12	ES
Allophylus edulis (A. St.-Hil. et al.) Hieron. ex Niederl.	Sapindaceae	2	80	0.64	10	0.87	0.03	0.6	2.11	NP
Morfo-espécie 2	Rubiaceae	2	80	0.64	10	0.87	0.02	0.47	1.98	NC
Morfo-espécie 1	Rubiaceae	1	40	0.32	10	0.87	0.02	0.46	1.65	NC
Cupania oblongifolia Mart.	Sapindaceae	2	80	0.64	10	0.87	0.01	0.11	1.62	ES
Eriotheca crenulaticalyx A. Robyns	Malvaceae	1	40	0.32	10	0.87	0.02	0.41	1.60	ES
Ouratea crassa Tiegh.	Ochnaceae	1	40	0.32	10	0.87	0.02	0.31	1.50	NC
Eugenia sp.	Myrtaceae	1	40	0.32	10	0.87	0.01	0.27	1.46	NC
Paypayrola blanchetiana Tul.	Violaceae	1	40	0.32	10	0.87	0.01	0.26	1.45	LS
Psychotria carthagenensis Jacq.	Rubiaceae	1	40	0.32	10	0.87	0.01	0.23	1.42	NP
Casearia javitensis Kunth	Salicaceae	1	40	0.32	10	0.87	0.01	0.16	1.35	ES
Coffea sp.	Rubiaceae	1	40	0.32	10	0.87	0.01	0.15	1.34	NC
Erythroxylum citrifolium A. St.-Hil.	Erythroxylaceae	1	40	0.32	10	0.87	0.01	0.1	1.29	LS
Inga capitata Desv.	Fabaceae	1	40	0.32	10	0.87	0.01	0.1	1.29	ES
Paubrasilia echinata Lam.	Fabaceae	1	40	0.32	10	0.87	0.00	0.09	1.28	LS
Lecythis pisonis Cambess.	Lecythidaceae	1	40	0.32	10	0.87	0.00	0.04	1.23	ES
Total		312	12480	100	1150	100	5.03	100	300	

N = Individuals number; DA= Absolute Density (Individuals /ha); DR= Relative density (%); FA= Absolute Frequency (%); FR= Relative Frequency (%); DoA= Absolute Dominance (%); DoR = Relative Dominance; VI = Value of Importance; PI = pioneer, ES = Early Secondary; LS = Late Secondary; CL = Clímax; SB = Tolerant of sub-forest; NP = Not pioneering; NC = unclassified

The families with the highest number of individuals in 2010 were: Moraceae, Burseraceae, Euphorbiaceae and Fabaceae. Together, these families accounted for 74.57% of the total number of individuals. Moraceae family alone contributed with 41.92% of the individuals that year. Families with the highest number of individuals in 2017 were: Moraceae, Burseraceae, Euphorbiaceae and Fabaceae. That is, the same ones found previously. Together, these families accounted for 73.40% of the total number of individuals. Moraceae family alone contributed 42.95% of the number of individuals that year.

Similar results were found in a study in the municipality of São Lourenço da Mata-PE, where the species with the largest number of individuals were *Helicostylis tomentosa*, *Eschweilera ovata*, *Protium heptaphyllum*, *Protium giganteum* and *Brosimum guianense*. However, the species *Artocarpus heterophyllus*, whose number of individuals was higher than the others found in the present study, was not observed by those authors [20].

In 2010, *Artocarpus heterophyllus* had the highest number of individuals, highest Absolute and Relative Density, highest Absolute and Relative Dominance and highest Importance Value. A study about the ecological aspects and influence of *Artocarpus heterophyllus* on the structure of the arboreal component of the Botanical Garden of Recife stated that the population of this species is in an expansion phase, being well adapted to the environment [21]. According to Manufacturer et al. [22], this species has invasive potential in dense ombrophylous forests, causing changes in richness and diversity of species. This fact was also reported by Silva [23] while studying the natural regeneration in the presence and absence of this species in the Botanical Garden of Recife, where the author noticed an influence on the decrease of regenerating individuals, as well as lower species richness in areas with presence of *Artocarpus heterophyllus*.

The species *Helicostylis tomentosa*, *Protium heptaphyllum* and *Brosimum guianense* presented higher Relative and Absolute Frequencies, being present in 90% of the plots. Oliveira et al. [24] also reported *Protium heptaphyllum* as a species of high Absolute Frequency in a dense ombrophilous forest study, being present in 80% of the plots.

The late secondary species occurred in greater abundance, and those of climax occurred in smaller abundance in the area inventoried in the year 2010.

In 2017, *Artocarpus heterophyllus* had the highest number of individuals, highest Absolute and Relative Density, highest Absolute and Relative Dominance and highest Importance Value. *Helicostylis tomentosa* obtained higher values of Absolute and Relative Frequency. The Moraceae family continued to represent the largest number of individuals in the inventory area. According to Lima et al. [20], the Moraceae family is commonly found in studies on natural regeneration developed in the Atlantic Forest in the State of Pernambuco.

The absence of the Araliaceae and Sapotaceae families in the second survey may have occurred due to the fact that they were represented by only one species with one individual each, which, probably suffered competition with the other species, environmental disturbances or anthropogenic pressure, leading to death [3].

In a research carried out in the municipality of Moreno-PE by Oliveira et al. [24], found an estimated Density of 1,386.67 ind.ha-1 for the species *Protium heptaphyllum*, similar to what was found in the present study, where the species presented a Density of 1.200 ind.ha^{-1} in both years.

Total Density and Absolute Dominance estimated were 11.640 ind.ha^{-1} and 3.21 m².ha^{-1} in 2010, and 12,480 ind.ha^{-1} and 5.03 m².ha^{-1} in 2017, respectively. Similar results to the ones found in 2010, were found by Oliveira et al. [24] in a dense ombrophylous forest, where the authors found a Density of 10,853 ind.ha^{-1} and 3.72 m².ha^{-1} of Absolute Dominance. Different values were found by Lima et al. [20], in dense ombrophylous forest, where the authors reported a Total Density of 8,160 ind.ha^{-1} and Absolute Dominance of 18.88 m².ha^{-1}.

The species *Chrysophyllum splendens* and *Schefflera morototoni* disappeared from the inventoried area in 2017, and the species *Inga capitata*, which had not occurred in the area of the 2010 inventory, appeared in the inventory of 2017. Comparing the surveys conducted in 2010 and 2017, in this interval of seven years, there was an increase of only 21 individuals and increment of only one new species in the inventory area.

Regarding natural regeneration, species that obtained the highest percentage of regeneration in class 1 of height in 2010 were *Brosimum guianense*, *Artocarpus heterophyllus* and *Protium heptaphyllum*. In 2017, *Brosimum Guianense*, *Artocarpus heterophyllus* also stood out, followed by *Protium giganteum*. In relation to class 2, in 2010 the species that obtained the highest percentage of regeneration were *Helicostylis tomentosa* and *Artocarpus heterophyllus*, and in 2017 *Artocarpus heterophyllus* and *Protium heptaphyllum*. For class 3, the species that stood out were *Helicostylis tomentosa* and *Artocarpus heterophyllus* in both 2010 and 2017 inventories. The five species with the highest values of importance in the three classes analysed in the seven-year period (2010 to 2017) can be observed in Figs. 1 and 2. In both years, *Artocarpus heterophyllus* presented the highest values of importance. Also reported that *Artocarpus heterophyllus* presented the highest Values of Importance, being also among species with the highest Absolute and Relative Dominance [19].

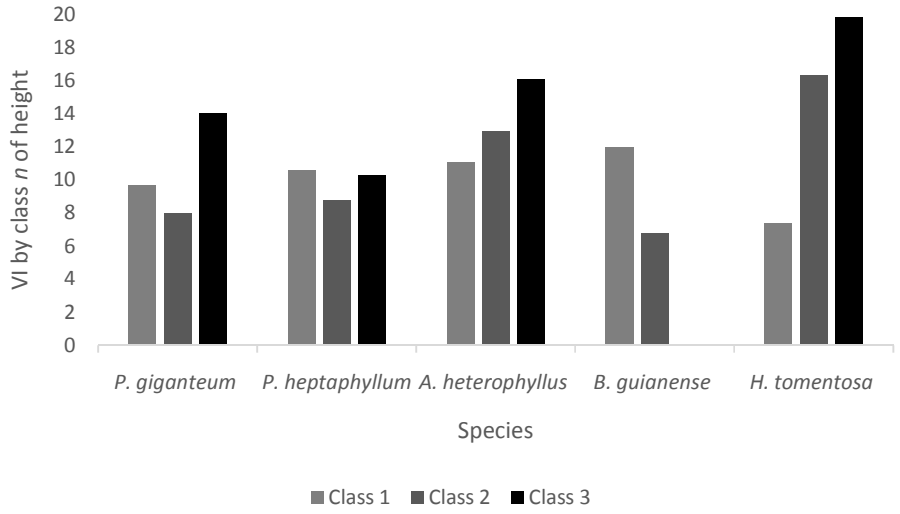

Fig. 1. Distribution of the species with the highest values of importance by height classes of the natural regeneration in 2010 in the Botanical Garden of Recife, PE

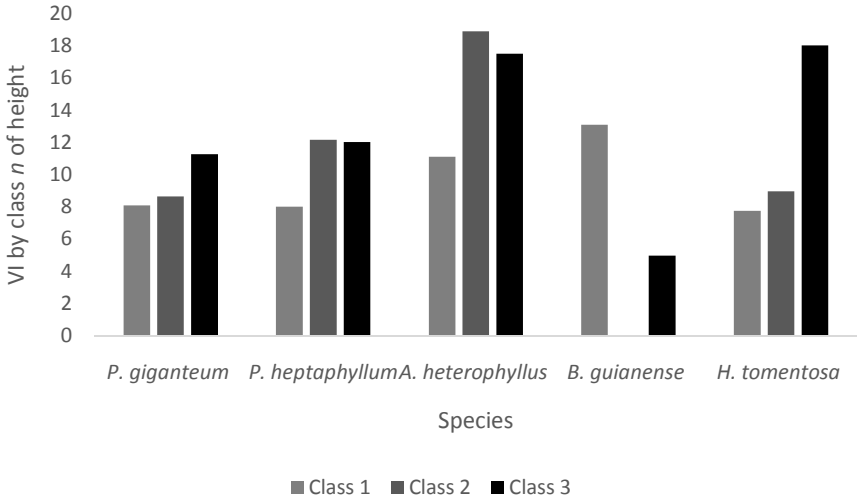

Fig. 2. Distribution of the species with the highest values of importance by height classes of the natural regeneration in 2017 in the Botanical Garden of Recife, PE

Species with the highest Total Natural Regeneration (TNR) were *Artocarpus heterophyllus* (13.36% in 2010 and 15.85% in 2017), *Helicostylis tomentosa* (14.52% in 2010 and 11.5% in 2017), *Protium giganteum* (10.58% in 2010 and 9.34% in 2017), *Protium heptaphyllum* (9.88% in 2010 and 10.75% in 2017), *Brosimum guianense* (6.26% in 2010 and 6.03% % in 2017) and *Mabea occidentalis* (5.49% in 2010 and 5.46% in 2017), which together corresponded to an TNR of 60.09% in 2010 and 59.03% in 2017 (Figs. 1 and 2). Similar results were observed by [20] studying the natural regeneration in a forest fragment in Pernambuco. Oliveira et al. [24] found similar results for the species *Protium heptaphyllum*, which obtained a Total Natural Regeneration of 12.61%.

According to Oliveira et al. [24], species that stand out for presenting higher estimates of natural regeneration can be considered well adapted in the studied community, showing good efficiency in the establishment and development of new individuals.

The species that showed the highest Values of Importance in 2010 were *Artocarpus heterophyllus*, *Helicostylis tomentosa*, *Protium giganteum*, *Protium heptaphyllum*, *Brosimum guianense*, *Mabea occidentalis*, *Eschweilera ovata*, *Sorocea hilarii*, *Dialium guianense* and *Siparuna guianensis*. In 2017, the species with the highest Values of Importance were *Artocarpus heterophyllus*, *Helicostylis tomentosa*, *Protium giganteum*, *Brosimum guianense*, *Protium heptaphyllum*, *Mabea occidentalis*, *Siparuna guianensis*, *Eschweilera ovata*, *Sorocea hilarii*, *Dialium guianense*. Oliveira et al. [24] found similar results, where the species among significant Values of Importance were *Eschweilera ovata*, *Protium heptaphyllum* and *Siparuna guianensis*.

The Shannon diversity index (H') was 2.91 nats. ind^{-1} in the first evaluation (2010), and 2.90 $nats.ind.^{-1}$ in the following evaluation (2017). Differently from what was obtained in the present research, [24], studying natural regeneration in a dense ombrophylous forest, found a Shannon-Wiener diversity index of 3.45 $nats.ind.^{-1}$ for the regenerating component of the Mata da Onça, PE. Also in Pernambuco, a Shannon-Wiener diversity index of 3.20 $nats.ind.^{-1}$ was found by Lima et al. [20]. According to Felfili and Rezende [25], the occurrence of a relative variation in the values of diversity of Shannon in the natural regeneration in areas of Tropical Forest is common, varying from 1.3 to 3.5 $nats.ind.^{-1}$, while values superior to 4.5 $nats.ind.^{-1}$ are rare.

Regarding the Shannon diversity index (H '), it can be observed that there were no significant differences in diversity between the evaluated periods. However, Alves et al. [26] found H' values of 2.56 $nats.ind^{-1}$ in a scientific study carried out in the same fragment, evaluating different sizes of sample units in rectangular plots of 1 m x 25 m. For the square plots (5 m x 5 m), the authors found an H' value of 2.62 $nats.ind^{-1}$. The difference between these values and those found in the present research may have been influenced by the number of species listed in the assembly since they are different allocations of plots within the fragment. Late secondary species occurred in greater abundance, whereas the pioneer species occurred in smaller abundance, and no climax species were found in the inventoried area in 2017.

In 2010, of the 291 individuals inventoried in the study area, 177 individuals belonging to 34 species, at least 31 genus and 21 families were present in the first height class of Total Natural Regeneration (CI); 64 individuals belonging to 22 species, 20 genus and 15 families in the second class (CII); and 50 individuals belonging to 14 species, 12 genus and 7 families in the third class (CIII). In 2017, of the 312 individuals inventoried in the study area, 193 individuals belonging to 32 species, at least 28 genus and 18 families were present in the first height category of total natural regeneration (CI); 52 individuals belonging to 18 species, at least 15 genus and 12 families in the second class (CII); and 67 individuals belonging to 20 species, 18 genus and 11 families in the third class (CIII). Thus, it is possible to observe the predominance of individuals in the first class of natural regeneration, that is, individuals with a lower height, followed by the second and third classes (CI> CII> CIII), which can be attributed to an initial phase of succession. The same behaviour was observed by Lima et al. [20] studying a fragment in the Mata de Quizanga, PE, in which the authors observed a predominance of individuals in the first classes of natural regeneration.

In the period evaluated (2010-2017), it was possible to observe an increase in the number of individuals in CI, but there was a reduction in the

Table 3. Natural regeneration in a Dense Ombrophylous Forest area in the Botanical Garden of Recife, PE, in the years 2010 and 2017

Family/ Species	2010										2017									
	RD_1	RF_1	NR_1	RD_2	RF_2	NR_2	RD_3	RD_3	NR_3	TNR	RD_1	RF_1	NR_1	RD_2	RF_2	NR_2	RD_3	RF_3	NR_3	TNR
Annonaceae																				
Cymbopetalum brasiliense	1.13	2.47	1.80	3.13	4.88	4.00	2.04	3.45	2.74	2.85	3.11	3.61	3.36	3.85	5.13	4.49	1.56	2.63	2.10	3.32
Araliaceae																				
Schefflera morototoni	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Boraginaceae																				
Cordia nodosa	0.56	1.23	0.90	3.13	2.44	2.78	0.00	0.00	0.00	1.23	0.52	1.20	0.86	0.00	0.00	0.00	3.13	2.63	2.88	1.25
Burseraceae																				
Protium giganteum	10.73	8.64	9.69	6.25	9.76	8.00	14.29	13.79	14.04	10.58	7.77	8.43	8.10	9.62	7.69	8.65	9.38	13.16	11.27	9.34
Protium heptaphyllum	11.30	9.88	10.59	7.81	9.76	8.78	10.20	10.34	10.27	9.88	8.81	7.23	8.02	11.54	12.82	12.18	10.94	13.16	12.05	10.75
Chrysobalanaceae																				
Licania tomentosa	1.13	2.47	1.80	1.56	2.44	2.00	0.00	0.00	0.00	1.27	1.04	2.41	1.72	0.00	0.00	0.00	1.56	2.63	2.10	1.27
Erythroxylaceae																				
Erythroxylum citrifolium	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Euphorbiaceae																				
Hevea brasiliensis	0.56	1.23	0.90	1.56	2.44	2.00	6.12	10.34	8.23	3.71	0.52	1.20	0.86	3.85	5.13	4.49	4.69	5.26	4.98	3.44
Mabea occidentalis	2.82	2.47	2.65	9.38	7.32	8.35	4.08	6.90	5.49	5.49	3.11	2.41	2.76	9.62	7.69	8.65	4.69	5.26	4.98	5.46
Pera ferruginea	1.13	2.47	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.52	1.20	0.86	0.00	0.00	0.00	1.56	2.63	2.10	0.99
Fabaceae																				
Albizia pedicellaris	0.00	0.00	0.00	0.00	0.00	0.00	2.04	3.45	2.74	0.91	0.00	0.00	0.00	0.00	0.00	0.00	1.56	2.63	2.10	0.70
Andira nitida	0.00	0.00	0.00	1.56	2.44	2.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	1.92	2.56	2.24	0.00	0.00	0.00	0.75
Paubrasilia echinata	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Dialium guianense	5.08	6.17	5.63	0.00	0.00	0.00	0.00	0.00	0.00	1.88	4.15	6.02	5.08	3.85	5.13	4.49	0.00	0.00	0.00	3.19
Inga capitata	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Zornia sp.	1.13	2.47	1.80	0.00	0.00	0.00	2.04	3.45	2.74	1.51	1.04	2.41	1.72	0.00	0.00	0.00	1.56	2.63	2.10	1.27
Lecythidaceae																				
Eschweilera ovata	1.69	2.47	2.08	3.13	4.88	4.00	8.16	3.45	5.81	3.96	2.07	2.41	2.24	3.85	5.13	4.49	6.25	2.63	4.44	3.72
Lecythis pisonis	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Malvaceae																				
Eriotheca crenulaticalyx	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Melastomataceae																				
Miconia sp.	1.69	1.23	1.46	1.56	2.44	2.00	0.00	0.00	0.00	1.16	0.52	1.20	0.86	1.92	2.56	2.24	1.56	2.63	2.10	1.73
Moraceae																				
Artocarpus heterophyllus	14.69	7.41	11.05	23.44	2.44	12.94	18.37	13.79	16.08	13.36	15.03	7.23	11.13	25.00	12.82	18.91	21.88	13.16	17.52	15.85

Family/ Species	2010										2017									
	RD_1	RF_1	NR_1	RD_2	RF_2	NR_2	RD_3	RD_3	NR_3	TNR	RD_1	RF_1	NR_1	RD_2	RF_2	NR_2	RD_3	RF_3	NR_3	TNR
Brosimum guianense	14.12	9.88	12.00	6.25	7.32	6.78	0.00	0.00	0.00	6.26	16.58	9.64	13.11	0.00	0.00	0.00	4.69	5.26	4.98	6.03
Helicostylis tomentosa	7.34	7.41	7.38	15.63	17.07	16.35	22.45	17.24	19.85	14.52	8.29	7.23	7.76	7.69	10.26	8.97	20.31	15.79	18.05	11.59
Sorocea hilarii	3.39	3.70	3.55	3.13	4.88	4.00	2.04	3.45	2.74	3.43	3.11	3.61	3.36	5.77	7.69	6.73	1.56	2.63	2.10	4.06
Myrtaceae																				
Eugenia sp.	0.00	0.00	0.00	1.56	2.44	2.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	0.00	0.00	0.00	1.56	2.63	2.10	0.70
Eugenia uvalha	0.56	1.23	0.90	1.56	2.44	2.00	0.00	0.00	0.00	0.97	1.55	2.41	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.66
Myrciaria ferruginea	1.13	2.47	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.04	2.41	1.72	1.92	2.56	2.24	0.00	0.00	0.00	1.32
Nyctaginaceae																				
Guapira opposita	2.26	1.23	1.75	0.00	0.00	0.00	0.00	0.00	0.00	0.58	1.55	1.20	1.38	0.00	0.00	0.00	0.00	0.00	0.00	0.46
Ochnaceae																				
Ouratea crassa	0.00	0.00	0.00	1.56	2.44	2.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	1.92	2.56	2.24	0.00	0.00	0.00	0.75
Piperaceae																				
Piper sp.	1.69	2.47	2.08	0.00	0.00	0.00	0.00	0.00	0.00	0.69	1.55	2.41	1.98	0.00	0.00	0.00	0.00	0.00	0.00	0.66
Rubiaceae																				
Coffea sp.	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Psychotria carthagenensis	0.00	0.00	0.00	1.56	2.44	2.00	0.00	0.00	0.00	0.67	0.00	0.00	0.00	1.92	2.56	2.24	0.00	0.00	0.00	0.75
Rubiaceae 1	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29
Rubiaceae 2	1.13	1.23	1.18	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.52	1.20	0.86	1.92	2.56	2.24	0.00	0.00	0.00	1.04
Salicaceae																				
Casearia javitensis Kunth	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	1.92	2.56	2.24	0.00	0.00	0.00	0.75
Sapindaceae																				
Allophylus edulis	0.00	0.00	0.00	1.56	2.44	2.00	2.04	3.45	2.74	1.58	0.00	0.00	0.00	1.92	2.56	2.24	1.56	2.63	2.10	1.45
Cupania oblongifolia	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	1.04	1.20	1.12	0.00	0.00	0.00	0.00	0.00	0.00	0.37
Cupania racemosa	2.26	1.23	1.75	1.56	2.44	2.00	4.08	3.45	3.76	2.50	3.63	3.61	3.62	0.00	0.00	0.00	1.56	2.63	2.10	1.91
Cupania revoluta	0.00	0.00	0.00	0.00	0.00	0.00	4.08	6.90	5.49	1.83	0.00	0.00	0.00	0.00	0.00	0.00	3.13	5.26	4.19	1.40
Sapotaceae																				
Chrysophyllum splendens	0.56	1.23	0.90	0.00	0.00	0.00	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Siparunaceae																				
Siparuna guianensis	6.21	4.94	5.58	1.56	2.44	2.00	0.00	0.00	0.00	2.53	8.81	8.43	8.62	0.00	0.00	0.00	0.00	0.00	0.00	2.87
Violaceae																				
Paypayrola blanchetiana	0.56	1.23	0.90	1.56	2.44	2.00	0.00	0.00	0.00	0.97	0.52	1.20	0.86	0.00	0.00	0.00	0.00	0.00	0.00	0.29

RD_n = Relative Dominance (%); RF_n = Relative Frequency (%); NR_n = Natural Regeneration (%); TNR = Total Natural Regenaration (%)

Table 4. Dynamics of natural regeneration between the years 2010 and 2017 in an area of Ombrophylous Dense Forest in the Botanical Garden of Recife, PE

Species	Gi	M	R	L	G
Albizia pedicellaris (DC.) L. Rico	0	0	0	0	0.14
Allophylus edulis (A. St.-Hil. et al.) Hieron. ex Niederl.	0	0	0	0	1.94
Andira nitida Mart. ex Benth	0	0	0	0	0.22
Artocarpus heterophyllus Lam.	0.09	22.86	57.14	0.55	10.39
Brosimum guianense (Aubl.) Huber	0.02	28.57	62.86	1.3	10.1
Paubrasilia echinata Lam.	0	0	0	0	0
Casearia javitensis Kunth	0	0	0	0	9.76
Coffea sp.	0	0	0	0	19.5
Cordia nodosa Lam.	0.01	0	0	0	4.56
Cupania oblongifolia Mart.	0	0	5.71	0	11.1
Cupania racemosa (Vell.) Radlk.	0.01	5.71	11.43	2.37	11.05
Cupania revoluta Radlk.	0	0	0	0	4.46
Cymbopetalum brasiliense (Vell.) Benth. ex Baill.	0.01	0	22.86	0	6.3
Dialium guianense (Aubl.) Sandwith	0	11.4	17.14	4.78	7.12
Eriotheca crenulaticalyx A. Robyns	0	0	0	0	15.23
Erythroxylum citrifolium A. St.-Hil.	0	0	0	0	15.65
Eschweilera ovata (Cambess.) Mart. ex Miers	0	0	5.71	0	2.61
Eugenia sp.	0	0	0	0	22.19
Eugenia uvalha Cambess.	0	0	5.71	0	2.81
Guapira opposita (Vell.) Reitz	0	5.71	0	3.06	10.51
Helicostylis tomentosa (Poepp. & Endl.) Rusby	0.02	51.43	45.71	2.05	5.21
Hevea brasiliensis (Willd. ex A. Juss.) Müll. Arg.	0.01	0	5.71	0	9.36
Inga capitata Desv.	0	0	5.71	0	100
Lecythis pisonis Cambess.	0	0	0	0	6.18
Licania tomentosa (Benth.) Fritsch	0	0	0	0	4.95
Mabea occidentalis Benth.	0.01	5.71	11.43	0.55	7.11
Miconia sp.	0	5.71	0	1.25	4.48
Myrciaria ferruginea O. Berg	0	0	5.71	0	9.02
Ouratea crassa Tiegh.	0	0	0	0	4,33
Paypayrola blanchetiana Tul.	0	5.71	0	7.63	6.87
Pera ferruginea (Schott) Müll. Arg.	0	0	0	0	8.82
Piper sp.	0	0	0	0	1.43
Protium giganteum Engl.	0.03	34.29	11.43	1.72	8.63
Protium heptaphyllum (Aubl.) Marchand	0.01	22.86	22.86	0.88	5.54
Psychotria carthagenensis Jacq.	0	0	0	0	2.95
Morfo-espécie 1	0	0	0	0	7.41
Morfo-espécie 2	0	0	0	0	1.46
Siparuna guianensis Aubl.	0.01	17.1	45.71	5.56	14.76
Sorocea hilarii Gaudich.	0.01	0	5.71	0	3.68
Zornia sp.	0.01	0	0	0	8.87
Total	0.25	217	354.25	131.7	383.8

Gi = Basal Area ($m^2.ha^{-1}$); M = mortality or egress ($ind.ha^{-1}$); R = recruit or ingress ($ind.ha^{-1}$); L = Loss in basal area (%); G = Gain in basal area (%)

number of species with the exit of *Chrysophyllum splendens*, *Schefflera morototoni* and *Casearia javitensis*, and the entry of *Inga capitata*, besides reduction in the number of families, with the exit of Sapotaceae, Araliaceae and Salicaceae. In CII, a reduction was observed in both number of individuals, species and families. The species *Brosimum guianense*, *Siparuna guianensis*, *Cordia nodosa*, *Cupania racemosa*, *Licania tomentosa*, *Paypayrola blanchetiana*, *Eugenia uvalha* and *Eugenia* sp. were no longer present. The entry of *Dialium guianense*, *Myrciaria ferruginea*, *morphospecies* 2 and *Casearia javitensis* were observed. Regarding families, the exit of Siparunaceae, Boraginaceae, Chrysobalanaceae and Violacea families and entry of Salicaceae family were observed. In relation to CIII, increases were observed in both

number of individuals, species and families. The species that entered this height class were *Brosimum guianense*, *Cordia nodosa*, *Licania tomentosa*, *Miconia* sp., *Pera ferruginea* and *Eugenia* sp., and families that entered this class were Boraginaceae, Chrysobalanaceae, Melastomataceae and Myrtaceae.

Table 3 shows the natural regeneration by height class, as well as the percentage of total regeneration, both assembled by species of occurrence in the plots sampled in the period between 2010 and 2017.

The species that presented the highest basal area per hectare was *Artocarpus heterophyllus* with 0.09 $m^2.ha^{-1}$, followed by *Protium giganteum* with 0.03 $m^2.ha^{-1}$, and *Brosimum guianense* and *Helicostylis tomentosa* with 0.02 $m^2.ha^{-1}$ each (Table 4).

In the process of natural dynamics, the species with the highest egress values were *Helicostylis tomentosa*, with 51.43 $ind.ha^{-1}$. Other species with a high number of deaths per hectare were *Protium giganteum* with 34.29 $ind.ha^{-1}$, *Brosimum guianense* with 28.57 $ind.ha^{-1}$, *Artocarpus heterophyllus* and *Protium heptaphyllum* with 22.86 $ind.ha^{-1}$ each. The species with the highest recruitment numbers were *Brosimum guianense*, with 62.86 $ind.ha^{-1}$, *Artocarpus heterophyllus*, with 57.14 $ind.ha^{-1}$, *Helicostylis tomentosa* and *Siparuna guianensis*, with 45.71 $ind.ha^{-1}$ each, *Cymbopetalum brasiliense* and *Protium heptaphyllum*, with 22.86 $ind.ha^{-1}$ each.

According to Oliveira et al. [24], species that stand out for presenting higher estimates of natural regeneration can be considered well adapted in the studied community, showing good efficiency in the establishment and development of new individuals.

The species that presented the highest losses in the basal area were *Paypayrola blanchetiana* with 7.63%, *Siparuna guianensis* with 5.56% and *Dialium guianense*, with 4.78%.

Regarding basal area gains, the species with the highest gain was *Eugenia* sp. with 22.19% (Table 4), followed by *Coffea* sp. with 19.5%, *Erythroxylum citrifolium* with 15.65%, *Eriotheca crenulaticalyx* with 15.23%, and *Siparuna guianensis* with 14.76 $m^2.ha^{-1}$, disregarding the species *Inga capitata* due to the fact that it did not occur in the previous period.

The entry of species in the second survey may be explained by the potential for dispersion and germination of seedlings and propagules. The egress may have occurred due to competition for light and nutrients in the environment, as well as environmental disturbances and the low representativeness of some species in the previous study.

4. CONCLUSION

With the results obtained in the present study, it can be concluded that there were no significant changes in the composition and structure of the forest species of the area between 2010 and 2017. Therefore, it can be inferred that the environment is not exposed to any severe biotic or abiotic changes that compromise its natural regeneration process. Thus, future studies are needed to contribute even more to the understanding of the forest dynamics of the area, aiming the development of adequate management and the establishment of conservation strategies and methods.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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