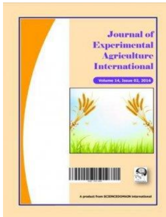


Journal of Experimental Agriculture International

25(5): 1-14, 2018; Article no.JEAI.42854
ISSN: 2457-0591
(Past name: American Journal of Experimental Agriculture, Past ISSN: 2231-0606)

Diversity and Structure of Adult and Regenerating Arbor Component in Forest 'Submontana', Paraíba-Brazil

José Nailson Barros Santos[1*], Robson Luis Silva de Medeiros[2*], Tales Emanuel Duarte Santos[3], Adamastor Pereira Barros[4], Ezequias Junior Borges Lopes de Oliveira[5], Fernando Antônio da Silva Fernande[5], Maria José Araújo Wanderley[6] and Alex da Silva Barbosa[6]

[1]Postgraduate Program in Forestry Science, Department of Forestry Science, Federal Rural University of Pernambuco, Recife, Brazil.
[2]Postgraduate Program in Agronomy (Crop Production), CNPq Scholarship, São Paulo State University (UNESP), School of Agricultural and Veterinary Sciences, Jaboticabal, Brazil.
[3]Department of Agronomy, Federal University of Paraíba, Areia, Brazil.
[4]Postgraduate Program in Agronomy, Federal Rural University of Rio de Janeiro, Brazil.
[5]Department of Agricultural Sciences, Federal University of Paraíba, Bananeiras, Brazil.
[6]Department of Agriculture, Federal University of Paraíba, Bananeiras, Brazil.

Authors' contributions

All authors had particular collaboration on this work's confection. The main author participated on elaborating the research project, collecting data and writing the article. Author JNBS performed calculations, interpreted the results, drafted the first draft of the manuscript and finalized the paper, considering all authors' suggestions. Authors RLSM, TEDS, APB, EJBLO and FASF were responsible for collecting, tabulating and analyzing the data and they supervised the development of the research since its implantation up to data collection. Authors MJAW and ASB planned and administered the study. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEAI/2018/42854
Editor(s):
(1) Suleyman Korkut, Professor, Duzce University, Department of Forest Industrial Engineeering, Division of Wood Mechanic and Technology, Turkey.
Reviewers:
(1) Daniel Jaleta, Ethiopian Environment and Forest Research Institute, Ethiopia.
(2) Zar Chi Hlaing, United Nations University Institute for the Advanced Study of Sustainability (UNU-IAS), Japan.
Complete Peer review History: http://www.sciencedomain.org/review-history/26040

Original Research Article

Received 08 June 2018
Accepted 10 August 2018
Published 30 August 2018

**Corresponding author: E-mail: nailson.gba@hotmail.com, robsonluissm@gmail.com;*

ABSTRACT

The objective of this research was to study the diversity and similarity profiles of vegetal species from adult and regenerating arboreal component in 'submontana' forest area, evaluating the modulation of the effective numbers of vegetal species on the different strata. An area of 4400 m^2 was sampled in a remaining rainforest (Open Ombrophylous Forest), in which woody species of adult stratum and regenerating were measured. All woody individuals were considered among the adult strata with CFG ≥ 10 cm in circumference (circumference of the trunk at 30 cm from the ground). Regenerating components were measured in the same plot (CFG < 10 cm), to justify richness and diversity comparisons in the same scale of the area. The numbers of effective Hill diversity (qD) to Shannon entropy, Simpson and species Richness was estimated by rarefaction (*P* = .05). The effective plant species numbers (qD) were estimated at 71.00; 37.48 and 25.31 species in relation to adult stratum, and 69.0; 25.36 and 16.87 species for the regenerant. No significant differences were found for richness of species among the strata. On the other hand, when plant species abundances were intensified as more important in the diversity measures, it was proved that the tree component began to maintain greater diversity, by Shannon and Simpson's entropy. The pattern of proportionality in species abundance changed systematically as the community directed its development to the adult stratum. The hypothesis on floristic similarity was confirmed, indicating reasonable perspectives on the regeneration power of these forests, front of the great scenario of moderate local disturbances.

Keywords: "Brejo de altitude"; plant diversity profiles; floristic composition.

1. INTRODUCTION

Plants diversity is a complex concept, multifaceted, that includes not only the richness of species but also the abundance and factors that have some effect on the community structure, which is considered crucial for its understanding [1,2]. For decades, studies on diversity in the tree species community had only the absolute numbers of species as a base and the index values with such insufficient mathematical properties [3,4,5]. Under this approach, the actual profiles that make up the plants diversity are lowered and underused, since the traditional methodologies are inadequate and tendentious [6]. In the last few years, more elaborate indexes with more robust mathematical properties emerge as an essential tool to overcome problems of applications in conservationist actions and on the underutilization of information about the knowledge of the communities in different groups of plants [2,5].

Part of the Atlantic Forest in the Northeastern Brazil is comprised of 'submontana' forest areas, known in Brazil as "brejo de altitude", which are inserted in the phytogeographic domain of 'Caatinga' [7,8]. These areas are located predominantly in 'Agreste' region between Paraíba and Pernambuco states, Brazil, and enjoys an intermediate weather, having hot and dry climate that are specifically found in semi-arid and subhumid areas in Atlantic Forest [9]. These particularities compose part of abiotic factors that increase diversity of these vegetation refuges, considered important for the distribution and conservation of many endemic species [10]. Despite this complexity, according to the data from first records [7,11], the swamp forest areas of original vegetation, which corresponded to semideciduous and open ombrophilous forests, was reported to be 18,500.00 km², but only 2,626.68 km² of land is actually present. The remaining vegetation from this sector is one of the most threatened in Brazilian Atlantic Forest. First, because it is not possible to establish how much this value represents, in terms of considering these refuges in the last surveys [12]. In addition, many existing floristic and diversity information in Northeast, Brazil are directed mainly to the coastal Atlantic Forest, and may not apply to interior forest zones' reality. Therefore, one of the worrying issues is that the lack of ecological information may put in risk the maintenance and conservation of these forest mosaics that remain in the Northeastern Brazil. Nevertheless, empirical studies describing diversity processes are very scarce, and when they exist, they are directed only at floristic-descriptive aspects, requiring a better exploitation of this information occupied area.

Parallel, it is known that the natural regeneration processes can provide a higher level of understanding about the survival and future consequences of the community since the forest dynamics maintenance depends strictly on this process for its functioning [13]. Thus, this diagnosis becomes a fundamental component to direct the current conservation and food status prognoses about its possible responses to natural or anthropic disturbances [14,15]. On the other hand, the absence of on-site information is highly necessary and is difficult to get due to the high costs for implementation of long-term researches. Therefore, a first approximation of the responses to the associations of the components of species diversity, as well as their regenerant contribution, is shown as a valuable source of information for local conservation. Besides, the conjecture of diversity processes in particular environments assumes a fundamental role in other generalist botanical works, which can be integrated into studies with biogeography [16].

The objective of this research was to study the modulations of woody species diversity from adult and regenerating stratum, for the same sample area for both strata in the 'submontana' forest area. The aim was to evaluate the floristic similarity and possible alterations of the diversity profiles among strata. In order to do so, the following hypotheses were tested: i) the pattern of diversity changes among strata, especially due to the differences about how the distribution of relative abundances are organized among the species in both strata; ii) the floristic similarity is little changed among the strata and that the conjecture of the natural regeneration in the present moderate scenario of disturbances allows a reasonable prognosis.

2. MATERIALS AND METHODS

The research was carried out at a forest fragment of the Paraíba Federal University (UFPB) in Bananeiras, Paraíba state, Brazil (Fig. 1). The area has approximately 49.5 ha, and is a part of an important vegetation refuge complex (located under the coordinates: 6°45'15'' S and 35°39'0'' W). It has altitude variations around 510 and 617 m, classified as the Open Ombrophylous Forest [8]. The climate of the region is As' (tropical rainy), warm and humid (Köppen Classification), presenting maximum temperature of 38°C and minimum of 18°C, with rainfall from autumn to winter (concentrated in May to August). The soil is dystrophic yellow latosol with texture varying from light sand consistency to clayish soil. Geomorphologically, this under-evergreen tropical forestis characterized by mild and slightly undular relief [17]. Although the area belongs to the institution, the reserve passes through small levels of natural and man-made disturbances, e.g., falling trees in sloping areas, cattle treading, and sporadic tree cuttings.

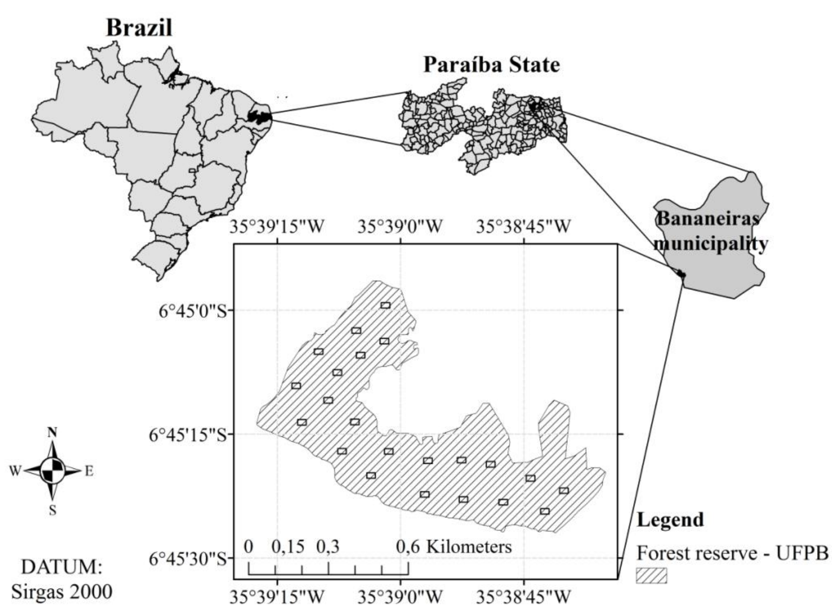


Fig. 1. Geographic location of forest garden in UFPB area, municipality of Bananeiras - PB, Brazil. Details with rectangles (□) denote the distribution of experimental units

2.1 Data Collection

Twenty-two plots of 10 x 20 m (200 m²) were distributed randomly which covered a total area of 4400 m² (8.88% of the total area).The outermost areas of the fragment were excluded from sampling to avoid the "edge effect" (Fig. 1). In this survey all the woody individuals of the adult extract were considered, CFG ≥ 10 cm in circumference (circumference the trunk at 30 cm from the ground). Regenerating were measured in the same plot (CFG < 10 cm), to justify the richness and diversity comparisons in the same scale of area [18]. The individuals were divided into three height classes (H), where class 1 with H ≥ 1.0 m and H ≤ 2.0 m, class 2 with H> 2.0 m and H ≤ 3.0 m and class 3 with H> 3.0 m [19]. All individuals represented from both the strata were identified and CFG was measured (at 30 cm from the ground), using a dendrometric caliper,and the total height was estimated upto the apex of the treetop.

The community structure parameters were calculated using the following main phytosociological parameters: absolute density (AD), absolute frequency (AF), absolute dominance (ADo) expressed by the basal area, abundance and/or relative density (RD), relative frequency (RF), relative dominance (RDo) and importance value (IV) [20]. For natural regeneration, Total Natural Regeneration (TNR) was considered, obtained it from the relative frequencies of individuals per species in each size class (i.e., class 1, 2 and 3). All the structural parameters were estimated with Mata Nativa® software version 4.0 [21]. The botanical material of the taxa was collected and sent to "Herbarium Jaime Coelho de Morais" at Agricultural Sciences Center (CCA) in UFPB, Areia-PB. Species were identified by comparisons and expert assistance according to the Angiosperm Phylogeny Group - APG III [22]. The current nomenclature of any species was conferred by means of consulting to Missouri Botanical Garden database.

2.2 Diversity Profiles Analysis

A sample coverage estimator equation 1 [3] was used with the aim of quantifying the sampling intensity from the strata, which can be calculated by the iNEXT package (iNterpolation / EXTrapolation) developed by Hsieh and Chao [5]. This package provides functions for calculating and plotting sampling curves by interpolation and extrapolation, based on the intensity of sampling coverage along confidence intervals at 95% probability. *Bootstrap* randomization method was applied to obtain the approximate variances for each diversity component (q = 1, 2 and 3), and later to construct the associated confidence limits (α = 0.05).

$$\hat{C}_n = 1 - \frac{f_1}{n}\left[\frac{(n-1)f_1}{(n-1)f_1+2f_2}\right] \quad (1)$$

Where: $\hat{C}_n$ = sampling coverage intensity; f_1 = species represented by exactly one individual in the reference sample and f_2 = number of duplicated species in the reference sample. The entropy based on the effective diversity numbers for both strata was calculated [23]. This estimator includes the three most widely used species diversity profiles: species richness (q=0), Shannon diversity (q = 1, Shannon entropy exponential) and Simpson diversity (q=2; inverse of Simpson's dominance) [cf, 10], and can be calculated by equation 2:

$$\left(\sum_{i=1}^{S} p_i^q\right)^{1/(1-q)} \quad (2)$$

Where: S = number of species; p_i = relative abundance and q = the parameter that determines the sensitivity to relative abundance on the diversity profiles.

Shannon-Weaver (H'), Simpson's dominance (-ln (D') and Pielou's Equation’s (J) traditional indices were calculated from the 'vegan' (ecological diversity) software package R [24]. The similarity between the strata of the community: "adult" and "regenerating" was calculated by the Chao-Sørensen index (ChaoS ') with the aid of the “fossil” package [25], according to a methodology proposed by [26]. The statistical analysis of all data and chart construction were performed using ambient R version 3.4.0 [27].

3. RESULTS

3.1 Floristics and Structures

A total of 2308 individuals, distributed into 36 families, 54 genera and 80 species, with predominance of tree species (56.25%), were sampled followed by shrubs and subshrubs, including two species of lianas (43.75%). The families with greatest richness were Fabaceae (14 species), Anacardiaceae and Myrtaceae (four species each), Erythroxylaceae, Malvaceae, Sapotaceae and Sapindaceae (three species each). Seventeen were identified at genus level, four at family level, and 12 were not identified due to the absence of fertile botanical samples and were described as indeterminate.

Adult tree stratum was presented by 800 individuals and distributed into 32 families and 71 species. The most abundant botanical families were Anacardiaceae (four species), Fabaceae (13 species), Erythroxylaceae, Malvaceae, Myrtaceae, Sapindaceae and Sapotaceae (three species each one). Regenerating stratum was presented by 1508 individuals and distributed into 69 species and 32 families. Plant families with highest richness were the same ones recorded to adult stratum, except: Malvaceae (one species), Anacardiaceae, Fabaceae (three species from each family), Myrtaceae (four species). Due to the plot size, the number registered for regenerating individuals was higher than adult stratum, , since in this study the same plot was considered for both strata (200 m²). Floristic composition did not show significant differences among the strata, which shared 60 species (~ 84% species). This result was confirmed by ChaoS' similarity test, which revealed high similarity between the strata (0.9854).

It should be pointed out that *E. pauferrense, H. courbaril, M. caesalpiniifolia, P. nitens* species are included in threatened flora official list [28], confirming the importance of preserving biodiversity in the area. In addition, the presence of an exotic species (*Artocarpus heterophyllus* Lam.) and many regenerating individuals outside the experimental units were recorded, especially in places more anthropized. Other species of plants were also recorded outside the experimental units, in fragment edge, areas close to trail and roads, for example: *Cassia ferruginea* (Schrad.) Schrad. ex DC. (Fabaceae), *Eriotheca macrophylla* (K.Schum.) *A. robyns* (Malvaceae) and *Maclura tinctoria* (L.) D.Don ex Steud. (Moraceae).

Table 1. Woody component, adult and regenerating strata floristic sampled in area ‘submontana’ forest - "brejo de altitude", municipality of Bananeiras – Paraíba state, Brazil. Species in alphabetical order of family, genus and species

Family/species	Common name	In	
		A	R
Anacardiaceae			
Anacardium occidentale L.	“Cajueiro”	5	1
Anacardium sp.	“Cajú-do-mato”	2	−
Tapirira guianensis Aubl.	“Cupiúba”	21	20
Thyrsodium spruceanum Benth.	“Caboatã-de-leite”	39	28
Annonaceae			
Xylopia frutescens Aubl.	“Embira”	−	2
Apocynaceae			
Tabernaemontana sp.	“Leiteira”	3	1
Araliaceae			
Schefflera morototoni (Aubl.) Maguire et al.	“Sambaquim”	1	−
Bignoniaceae			
Handroanthus sp. 1	“Ipê”	5	7
Handroanthus sp. 2	“Ipê-amarelo”	1	7
Boraginaceae			
Cordia taguahyensis Vell.	“Frei-jorge”	10	101
Burseraceae			
Protium heptaphyllum (Aubl.) Marchand	“Amescla-de-cheiro”	36	171
Cannabaceae			
Celtis iguanaea (Jacq.) Sarg.	“Cabrinha”	−	3
Capparaceae			
Cynophalla flexuosa (L.) J.Presl	“Feijão-bravo”	2	1
Clusiaceae			
Clusia sp.	“Clusia”	2	20
Connaraceae			
Connarus sp.		20	20

Family/species	Common name	In	
		A	R
Erythroxylaceae			
Erythroxylum sp.		8	1
Erythroxylum pauferrense Plowman	"Guarda-orvalho"	85	274
Erythroxylum simonis Plowman	"Quebra-foice"	28	37
Euphorbiaceae			
Croton sp.	"Marmeleiro"	−	3
Fabaceae			
Albizia polycephala (Benth.) Killip ex Record	"Vassourinha"	8	5
Anadenanthera colubrina (Vell.) Brenan	"Angico-de-caroço"	21	−
Bowdichia virgilioides Kunth	"Sucupira-preta"	9	5
Enterolobium contortisiliquum (Vell.) Morong	"Timbaúva"	5	−
Fabaceae 1		7	32
Fabaceae 2		−	7
Hymenaeae courbaril L.	"Jatobá"	10	2
Inga sp. 1		2	6
Inga sp. 2		4	8
Inga sp. 3	"Inga-feijão"	11	24
Mimosa caesalpiniifolia Benth.	"Sabiá"	56	15
Piptadenia stipulacea (Benth.) Ducke	"Jurema-branca"	2	2
Pterogyne nitens Tul.	"Madeira-nova"	9	3
Senegalia tenuifolia (L.) Britton & Rose	"Jequirí"	1	6
Hypericaceae			
Vismia guianensis (Aubl.) Choisy	"Lacre"	5	6
Indeterminadas			
undetermined 1		2	−
undetermined 2		1	2
undetermined 3		2	2
undetermined 4		2	23
undetermined 5		1	135
undetermined 6		1	7
undetermined 7		1	7
undetermined 8		1	8
undetermined 9		1	2
undetermined 10		−	1
undetermined 11		−	1
undetermined 12		−	1
Lamiaceae			
Vitex rufescens A.Juss.	"Mama-cachorro"	1	−
Lauraceae			
Ocotea glomerata (Nees) Mez	"Louro-preto"	13	20
Lecythidaceae			
Eschweilera ovata (Cambess.) Mart. ex Miers	"Imbiriba"	45	23
Lecythis pisonis Cambess.	"Sapucaia"	22	9
Malpighiaceae			
Byrsonima sericea DC.	"Murici"	11	3
Malvaceae			
Ceiba glaziovii (Kuntze) K.Schum.	"Barriguda"	1	−
Guazuma ulmifolia Lam.	"Mutamba"	1	−
Luehea paniculata Mart. & Zucc.	"Açoita-cavalo"	6	−

Family/species	Common name	In	
		A	R
Melastomataceae			
Miconia albicans (Sw.) Triana	"Quaresmeira"	1	3
Miconia minutiflora (Bonpl.) DC.	"Tinteiro"	4	7
Moraceae			
Brosimum guianense (Aubl.) Huber	"Quiri"	15	18
Sorocea sp.	"Folha-de-serra"	3	23
Myrtaceae			
Myrcia sp.	"Araçá-bravo"	2	11
Myrcia splendens (Sw.) DC.	"Araçazinho"	7	108
Myrtaceae 1		6	5
Psidium sp.	"Araçá"	1	5
Nyctaginaceae			
Guapira laxa (Netto) Furlan	"Guapira"	16	−
Guapira opposita (Vell.) Reitz	"João-mole"	34	12
Peraceae			
Pera distichophylla (Mart.) Baill.	"Rabo-de-galo"	−	5
Piperaceae			
Piper mollicomum Kunth.	"Pimenteira-do-mato"	30	51
Polygonaceae			
Coccoloba sp.	"Cravaçú"	9	6
Rubiaceae			
Guettarda viburnoides Cham. & Schltdl.	"Veludo-branco"	−	4
Randia sp.	"Baga-preta"	5	10
Rutaceae			
Zanthoxylum rhoifolium Lam.	"Limãozinho"	1	2
Salicaceae			
Casearia sylvestris Sw.	"Café-bravo"	15	16
Sapindaceae			
Allophylus edulis (A.St.-Hil. et al.) Hieron. ex Niederl.	"Baga-se-morcego"	10	30
Cupania impressinervia Acev.-Rodr.	"Caboatã"	51	80
Talisia esculenta (Cambess.) Radlk.	"Pitomba"	19	22
Sapotaceae			
Pouteria sp. 1		8	5
Pouteria sp. 2		8	6
Sapotaceae 1		12	11
Simaroubaceae			
Simarouba amara Aubl.	"Pau-paraíba"	3	2
Solanaceae			
Brunfelsia uniflora (Pohl) D.Don	"Manacá-de-cheiro"	5	4
Urticaceae			
Cecropia pachystachya Trécul	"Embaúba"	5	−
Total		**800**	**1508**

***A** = adult; **R** = regenerant and **In** = individuals number, details with dash (−)represent absence of species.*

In adult stratum 800 individuals (4132 ind/ha) and in regenerating stratum 1508 individuals (7789 ind./ha) were sampled and,. Basal areas were estimated at 33.4429 and 0.7322 m²/ha, concerned to adult and regenerating strata, respectively. Genera *Erythroxylum* (121 individuals from three species), *Mimosa* (56 individuals from one species), *Cupania* (51 individuals from one species) and *Eschweilera* (45 species from one species) represented by higher number of individulas (In). In the regenerating extract genera with high number of representatives were: *Erythroxylum* (three species with 312 individuals), *Protium* (one species with 171 individuals), indeterminate genera 5 (one species with 135 individuals) and *Myrcia* (three species with 124 individuals). Although there were no differences in floristic composition, species relative abundance pattern showed clear divergences on its distribution. In other words the regenerating stratum concentrated most of the relative values of density individuals in 11 morphospecies (RD = 69.43%); a contrast with the adult stratum, since the relative contribution of individuals density was more distributed among the species, about 18 morphospecies (RD = 70.75%).

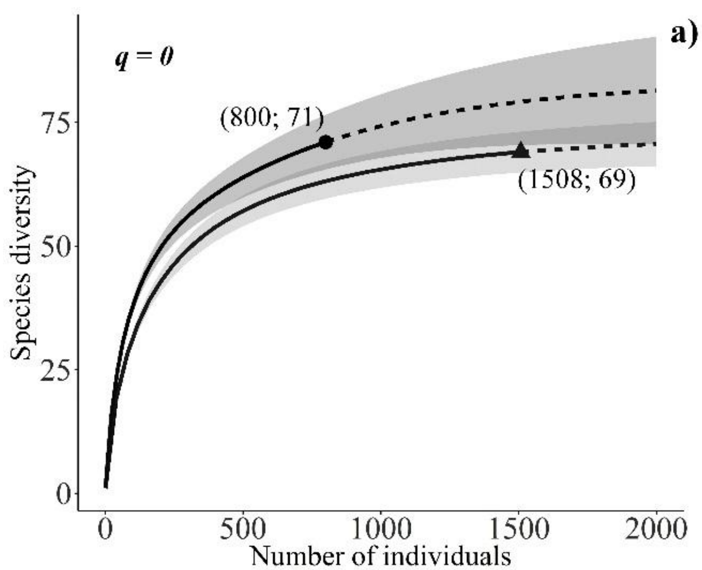
Species with the highest importance value (IV) in the adult stratum were: *G. opposita* (26.46), *M. caesalpiniifolia* (19.31), *A. colubrina* (18.18), E. pauferrense (16), *T. guianensis* (15.64), *C. impresinervia* (14.89). Among these species, morphospecies with the highest structural representativity (Relative Dominance - RDo) of this component were: *G. opposita* (17.39%), *A.colubrina* (13.15%), *T. guianensis* (10.61%) and *M. caesalpiniifolia* (9.50%). In relation to regenerating stratum, the species with the highest Total Natural Regeneration were: *E. pauferrense* (10.96%), with higher expressiveness in the first class (1 ≤ H ≤ 2 m), *P. heptaphyllum* (10.76%), *M. splendens* (10.20%) and Indeterminate 5 (8.07%), with expressiveness in all classes, and *P. mollicomum* (7.18%) with higher distribution in the last class (H> 3 m) (data not shown).

3.2 Vegetal Species Profile Diversity

Shannon's index value (S ') ranged from 3.62 to 3.23 nats. ind^{-1}, while Simpson's dominance index (D ') ranged from 3.21 to 2.63, for arboreal and regenerating strata, respectively. According to these values, the vegetal species profile diversity from adult woody component was higher in both facets, i.e, considering the rare species or most common species. The dominance equability (J) was also higher for adult stratum (0.85) than for the regenerant (0.76), which confirms the presumption of a major relative abundance distribution for the most adult component of the forest.

The effective plant species numbers (qD) were estimated at 71.00; 37.48 and 25.31 species in relation to adult stratum, and 69.0; 25.36 and 16.87 species for the regenerant, q = 0, 1 and 2, respectively. Regardless of the sample size (by interpolation or extrapolation), in both strata, confidence limits at 95% of probability overlap, suggests similarity for species richness (q = 0) among adult and regenerant strata (Fig. 2a). On the other hand, when plant species abundances were intensified as more important in the diversity measures (order q> 0), it was proved that the tree component began to maintain greater diversity, respectively, by Shannon and Simpson's entropy (Fig. 2b and c).

The differences in the diversity profiles for q> 0 are more visible because the increase in the parameter 'q' determines greater sensitivity to the abundance of individuals (Fig. 2b and c). This pattern especially occurs because the abundance is more distributed in a larger number of species in the tree stratum. In contrast, the regenerating stratum of plant community, showed high values for abundance in a smaller effective number of species (qD = 16.87).



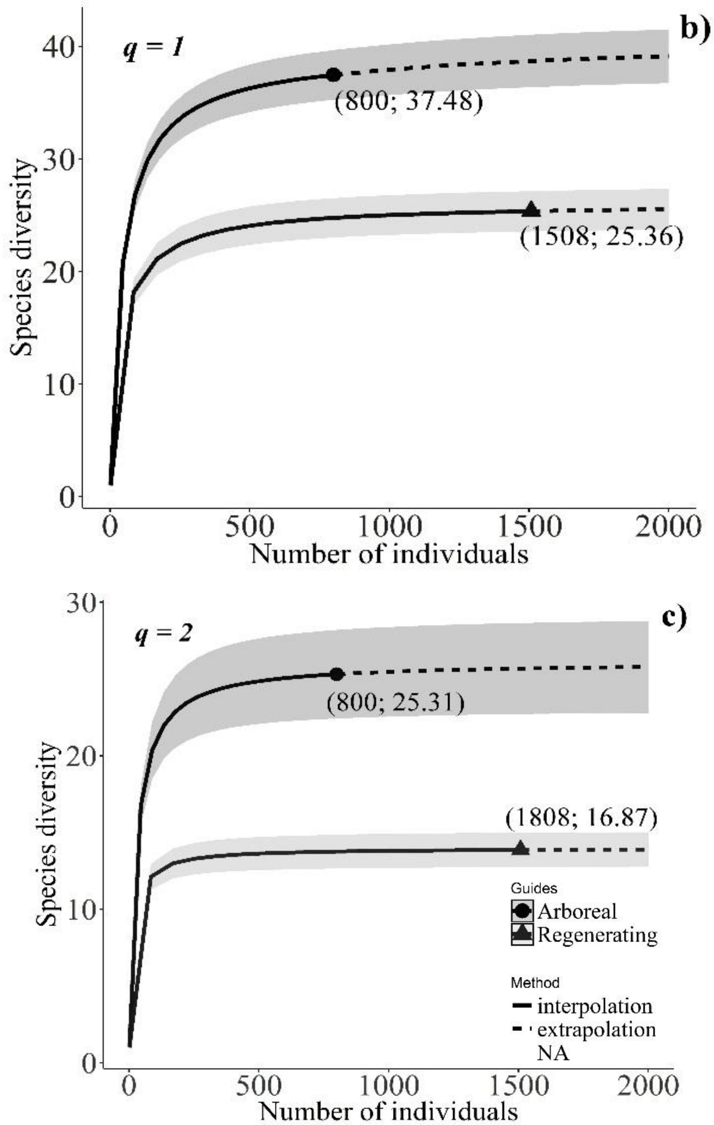


Fig. 2. Sampling curves by interpolation (-) and extrapolation (--), both with 95% confidence intervals (shaded areas). Data from adult and regenerant strata are shown separately by diversity profiles. Points and solid triangles represent the limits from reference samples; numbers in parentheses represent the number of individuals and the effective number of species (qD = Hill numbers in q order)

In all diversity components (i.e., Hill's numbers in the order of q = 0; 1 and 2), the sample size was extrapolated to 2000 individuals to avoid possible effects of sample size on the diversity components, due the fact that the arboreal stratum sample was almost twice smaller. The theoretical expectations of Shannon and Simpson's entropy for before reference sample confirming the sampling efficiency for both strata (Fig. 3a, b and c).

4. DISCUSSION

4.1 Floristics and Structures

The floristic and physiognomic profile of the area contains conspicuous elements, which characterize a closer approximation to Atlantic Forest of the coast (e.g., *Tapirira guianenses, Protium heptaphyllum, Eschweilera ovata*) than the Northeast Caatinga (e.g., *Piptadenia stipulacea, Croton* sp., *Senegalia tenuifolia*). In

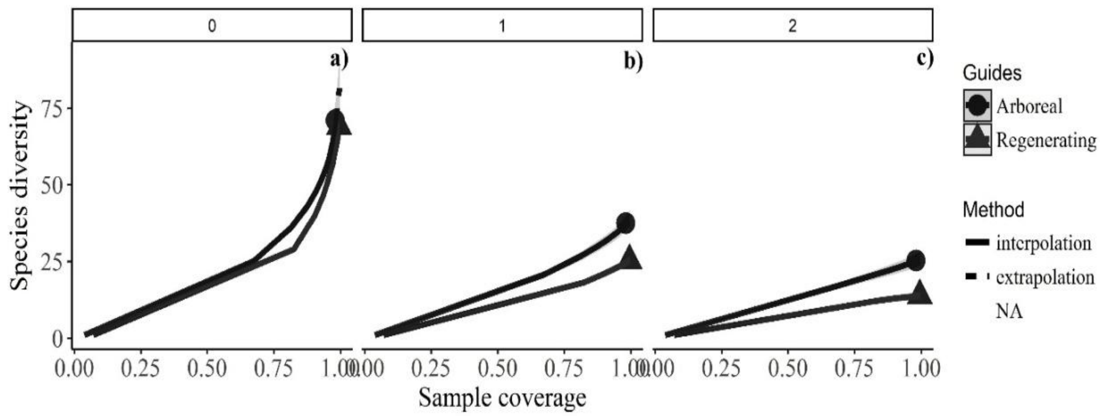


Fig. 3. Sample intensity curve by interpolation (-) and extrapolation (--), both with 95% confidence intervals (shaded areas). Arboreal community data: arboreal and regenerating are shown separately by diversity profiles (order: q = 0, 1 and 2). Points and solid triangles represent the sample limits of the reference sample, the numbers in parenthesis represent sample sufficiency (%) and the effective number of species (qD = Hill numbers in q order)

the broad sense, it is known that other floristic and physiognomic changes can also be evidenced as it is far from the coast and close to “sertão” areas, and those changes are also found in the western part of Northeast [7,9]. According to Alcoforado-Filho et al. [29] there is a greater floristic overlap of these areas with thorny deciduous vegetation from the region, probably due to more similar proximity and conditions between these fitofisionomies.

In terms of diversity, for adult stratum, there is a considerable similarity to the regional surveys of the Atlantic Forest in the Zona da Mata in Pernambuco state, Brazil, for example, Alves-Júnior et al., Costa-Júnior et al. and Guimarães et al. [30,31,32] who found: 3.09; 3.20; 3.83 and 3.43 nats. ind. -1 for H ', based on similar inclusion criteria that have been adopted by this study (CFG ≥ 15cm). For regenerating stratum, values of 3.20; 3.32 and 3.45 nats. $ind.^{-1}$ were found in the papers of Lima et al., Aparício et al. and Oliveira et al. [33,34,35], respectively, considering the same inclusion criterion in regenerant classes. These generalizations, while showing little implication in conservation, confirm a slight idea of the similarity of the diversity of the woody component between the coastal Atlantic Forest and the innermost areas (i.e., when they move away from the coast towards the West).

In a study carried out in "Mata do Pau-Ferro" State Ecological Reserve, where the inclusion limit was adopted over of 15 ≥ CFG [36]. 67 species from 35 plant families were sampled. In this area H' ranged from 3.04 to 2.99 nats. ind.-1, for different ciliary forest environments and this did not differ from the present research findings. On the other hand, in terms of forest structure, there was higher individuals’ density in the area where the present study was conducted, as the basal area. Although the two areas are quite close, considering a regional scale, differences in forest structure can be attributed in part to the history of use and occupation and differences in successional stages of the areas. The forest area of the present study is easily associated with a successional stage that is more 'young' than 'Mata do Pau-Ferro'.

As demonstrated in other studies, the first regenerating plant class was responsible for most of the TNR (92.75%), followed by classes 2 (5.03%) and 3 (2.22%). This result generalizes as an expected consensus in tropical forests, due to high proportion of regenerating individuals in early ontogenetic classes. As plants recruit to larger classes, mortality rates increase because of the risks associated with herbivory, competition and other biotic and abiotic stresses, so that only the most adapted individuals continue developing [14,15,37]. In the present study, *G. opposita* species, which is predominant in the phytogeographic domain of the Atlantic Forest, presented high values for adult component, but, low values for TNR (0.80%). These results seem to point to difficulties, which species face in recruiting new individuals into length classes and consequently reaching higher forest stratum.

From 71 morphospecies sampled in the adult woody component, only 11 were not recorded in the regenerating stratum (Table 1). Among these, most are considered uncommon species of spatial distribution. If we portray the biological risks these species presents, the knowledge cannot be scaled and compared, since the sample area is much smaller than the scope of distribution of these biological entities. On the other hand, some species such as *G. opposita, B. sericea* and *E. contortisiliquum* seem to have problems in regeneration, suggesting that the reduction of propagule availability may be limiting, making these species more susceptible to future changes in the forest.

Among the threatened species, *E. pauferrense* has recently been discovered in the botanical field [38]. It has endemism restricted to the forest areas of swamp in Paraíba state and is threatened with extinction. One of the concerns is due to habitat deforestation and the isolation of subpopulations, as well as the decline of individuals [39]. However, the species does not go through problems, due to its high abundance as listed in other works in this typology [36,40]. The fact that the species shows high values for TNF is associated with the habit of shrub growth and the ecological preference for the lower forest stratum (sub-forest), a fact observed *in-situ* in the fragment studied.

4.2 Vegetal Species Profile Diversity

Yield curve of rarefaction is expected to be increasing if an individual is added to the sample. In other words, it is the probability of the next individual sampled being a new species [3]. In this sense, considering the sample standardized in 98 and 99% for the sample intensity curve ($\hat{C}_n$), arboreal and regenerating stratum, respectively, it is observed that sample coverage estimates slightly increase qD values (q=1 and 2), confirming satisfactory sample levels (Fig. 3b and c). This property becomes more visible in the diversity components, whose Hill number is q> 0 (Fig. 3c). It occurs because the effect on the sample intensity curve ($\hat{C}_n$) is more dominated by common species, presenting less pronounced curves for effective species numbers [4].

This work proved that there were no significant differences in richness and floristic composition, considering adult and regenerating stratum in the same area. However, this pattern changed when diversity components that prioritize species abundance were incorporated. In this sense, the community of the adult stratum modulated the diversity, so that the adult arboreal stratum obtained a greater diversity (*P* = .05) (Fig. 2). In other words, it defended the hypothesis that, when adequately protected, these areas can regenerate themselves easily, and this process assumes a fundamental role in the natural reconstruction and conservation of this forest typology.

It is important to note that the similarity in species richness between adult and regenerating arboreal strata does not mean that the identities of the species are the same [18]. It was observed that there was a floristic similarity between two strata cited above independent of the patterns of richness described. As diversity does not depend exclusively on total density, it would be easy to point out greater diversity for the regenerating stratum, which has similar species richness, as long as that the individuals' abundance is almost two times greater than the density of individuals in the adult stratum. In this conception, the tree community had greater distribution of individuals/species' abundance becoming a more tolerant environment, presenting natural ecological levels of ecological stability.

The perspective of natural regeneration in these environments, after moderate disturbance levels (e.g., trampling of animals and eventual cutting of trees), tends to significantly increase the complexity levels of wealth and structure's components (i.e., density, biomass, richness and equitability) after few years of disturbance [40]. Other authors, who studied the natural regeneration of shrub-arboreal component, in disturbed areas with different age, proved clear advances in the forest with 20 years old much approached to what was expected concerned to older forests.

5. CONCLUSIONS

The present study confirmed the hypotheses of natural changes in diversity between adult and regenerating strata in the 'submontana' forest area. Species richness remains unchanged among the strata. However, the pattern of proportionality in species abundance changes systematically as the community directs its development to the adult stratum. The hypothesis on floristic similarity was confirmed, indicating reasonable perspectives on the regeneration power and natural resilience of these forests, even with the current scenario of disturbances and disappearance faced by these ecosystems.

These findings provide information for studies of the diversity of phytophysiognomic sectors that are still less known and, also, consider the importance of small forest fragments for woody flora conservation and their role in maintaining the Atlantic Forest biodiversity. Additionally, it can be assumed that these findings can be utilized for conservation in future and be integrated into biogeographical and macroecological studies.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pavoine S, Bonsall MB. Measuring biodiversity to explain community assembly: A unified approach. Biological Reviews. 2011;86(4):792-812.
2. Chao A, Jost L. Estimating diversity and entropy profiles via discovery rates of new species. Methods in Ecology and Evolution. 2015;6(8):873–882.
3. Chao A, Jost L. Coverage-based rarefaction and extrapolation: Standardizing samples by completeness rather than size. Ecology. 2012;93(12): 2533-2547.
4. Chao A, Gotelli NJ, Hsieh TC, Sander EL, Ma KH, Colwell RK, Ellison AM. Rarefaction and extrapolation with Hill numbers: a framework for sampling and estimation in species diversity studies. Ecological Monographs. 2014; 84(1):45-67.
5. Hsieh TC, Ma KH, Chao A. iNEXT: An R package for rarefaction and extrapolation of species diversity (Hill numbers). Methods in Ecology and Evolution. 2016; 7(12):1451-1456.
6. Colwell RK, Chao A, Gotelli NJ, Lin SY, Mao CX, Chazdon RL, et al. Models and estimators linking individual-based and sample-based rarefaction, extrapolation and comparison of assemb-lages. Journal of Plant Ecology. 2012;5(1):3-21.
7. Barbosa MRV, Agra MF, Sampaio EV. S. B, Cunha JP, Andrade LA. Diversidade florística da Mata do Pau-Ferro, Areia, Paraíba. In: Pôrto KC, Cabral JJP, Tabarelli M. Brejos de altitude em Pernambuco e Paraíba: História natural, ecologia e conservação. Brasília: MMA; 2004.
8. IBGE. Manuais técnicos em geociências: Manual técnico da vegetação brasileira. Rio de Janeiro; 2012.
9. Moro MF, Lughadha EN, Araújo FS, Martins FR. A phytogeographical metaanalysis of the semiarid caatinga domain in Brazil. The Botanical Review. 2016;82(2):91–148.
10. Tabarelli M, Santos AMM. Uma breve descrição sobre a história natural dos Brejos Nordestinos. In: Pôrto KC, Cabral JJP, Tabarelli M. Brejos de altitude em Pernambuco e Paraíba: História natural, ecologia e conservação. Brasília: MMA; 2004.
11. Instituto Brasileiro de Geografia e Estatística. Atlas nacional do Brasil: Região Nordeste: Rio de Janeiro; 1985.
12. Fundação Sos Mata Atlântica. Atlas dos remanescentes florestais da Mata Atlântica período 2015 – 2016. Relatório Parcial. São Paulo: Instituto Nacional de Pesquisas Espaciais; 2017.
13. Finol, UH. Nuevos parámetros a considerarse en el análisis estructural de las selvas vírgenes tropicales. Revista Forestal Venezolana. 1971;21:29-42.
14. Oliveira MC, Felfili JM, Silva-Júnior, MC. Comparação florístico-estrutural dos estratos adulto e de regeneração em mata de galeria perturbada no Distrito Federal, Brasil. Revista Brasileira de Biociências. 2015;13(3):142-154.
15. Aguiar MD, Silva AC, Higuchi P, Negrini M, Schollemberg AL. Similaridade entre adultos e regenerantes do componente arbóreo em floresta com araucária. Floresta e Ambiente. 2017;24 (e00083214):1-10.
16. Moro MF, Lughadha EN, Filer DL, Araújo FS, Martins FR. A catalogue of the vascular plants of the Caatinga Phytogeographical Domain: A synthesis of floristic and phyto-sociological surveys. Phytotaxa. 2014; 160(1):001-118.
17. EMBRAPA. Centro Nacional de pesquisa de solos. Sistema brasileiro de classificação dos solos. Brasília: Embrapa-SPI; 1999.
18. Kindt R, Coe, R. Tree diversity analysis. A manual and software for common statistical methods for ecological and

biodiversity studies. Nairobi: World Agroforestry Centre; 2005.

19. Marangon, LC, Soares JJ, Feliciano ALP, Brandão CFLS. Regeneração natural em um fragmento de floresta estacional semidecidual em Viçosa, Minas Gerais. Revista Árvore. 2008;32(1):183-191.
20. Mueller-Dumbois D, Ellenberg H. Aims and methods of vegetation ecology. New York: JonhWilly; 1974.
21. CIENTEC. Mata Nativa 4. Manual do usuário. Viçosa: CIENTEC; 2016.
22. APG III. An update of the angiosperm phylogeny group classification for the orders and families of flowering plants: APG III. Botanical Journal of the Linnean Society. 2009;161:105-121.
23. Hill M. Diversity and evenness: A unifying notation and its consequences. Ecology. 1973;54:427-432.
24. Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB et al. Vegan: Community Ecology Package; 2014.
25. Vavrek, Matthew J. Fossil: Palaeo-ecological and palaeogeographical analysis tools. Palaeontologia Electronica; 2011.
26. Chao A, Chazdon RL, Colwell RK, Shen TJ. A new statistical approach for assessing compositional similarity based on incidence and abundance data. Ecology Letters. 2005;8:148-159.
27. R development core team: A language and environment for statistical computing. R foundation for statistical computing. Vienna; 2017.
28. The IUCN Red List of Threatened Species™ (IUCN). Available:http://www.iucnredlist.org/ (Accessed on: 28 ago. 2017. The Plant List). Available: http://www. theplantlist.org (Accessed on: 29 jun. 2017).
29. Alcoforado-Filho FG, Sampaio EVSB; Rodal, MJN. Florística e fitossociologia de um remanescente de vegetação caducifólia espinhosa arbórea em Caruaru, Pernambuco. Acta Botanica Brasilica. 2003;17(2):287-303.
30. Alves-Júnior FT, Brandão CFLS, Rocha KD, Marangon LC, Ferreira RLC. Efeito de borda na estrutura de espécies arbóreas em um fragmento de Floresta Ombrófila Densa, Recife, PE. Revista Brasileira de Ciências Agrárias. 2006;1(1):49-56.
31. Costa-Júnior RF, Ferreira RLC, Rodal MJN, Feliciano ALP, Marangon LC, Silva WC. Estrutura fitossociológica do componente arbóreo de um fragmento de Floresta Ombrófila Densa na mata sul de Pernambuco, Nordeste do Brasil. Ciência Florestal. 2008;18(2):173-183.
32. Guimarães FJP, Ferreira RLC, Marangon LC, Silva JAA, Aparício PS, Alves-Júnior FTA. Estrutura de um fragmento florestal no Engenho Humaitá, Catende, Pernambuco, Brasil. Revista Brasileira de Engenharia Agrícola e Ambiental, Campina Grande. 2009;13(1):940-947.
33. Lima AS, Feliciano ALP, Marangon LC, Oliveira LSB, Pessoa MML. Regeneração natural de um fragmento de Floresta Ombrófila Densa na bacia hidrográfica do rio Capibaribe, PE. Revista Brasileira de Ciências Agrárias. 2013;8(2):273-278.
34. Aparício WCS, Marangon LC, Ferreira RLC, Feliciano ALP, Aparicio OS, Costa-Junior RF. Estrutura da regeneração natural de espécies arbóreas em um fragmento de Mata Atlântica, Pernambuco. Revista Brasileira de Ciências Agrárias. 2011;6(3):483-488.
35. Oliveira LSB, Marangon LC, Feliciano ALP, Cardoso MO, Lima AS, Albuquerque MJB. Fitossociologia da regeneração natural de uma Floresta Ombrófila Densa em Moreno, Pernambuco, Brasil. Revista Brasileira de Ciências Agrárias. 2013;8(1): 119-124.
36. Andrade, LA, Oliveira FX, Nascimento IS, Fabricante JR, Sampaio EVSB, Barbosa MRV. Análise florística e estrutural de matas ciliares ocorrentes em brejo de altitude no município de Areia, Paraíba. Revista Brasileira de Ciências Agrárias. 2006;1:31-40.
37. Amaral CS, Amaral WG, Pereira IM, Oliveira PA, Machado VM. Comparação florístico-estrutural dos estratos adultos e regenerantes em área minerada de campo rupestre, Diamantina, Mg. Cerne. 2015; 21(2):183-190.
38. Loiola MIB, Agra MF, Baracho GS, Queiroz RT. Flora da Paraíba, Brasil: Erythroxylaceae Kunth. Acta Botânica Brasilica. 2007;21(2):473-487.

39. CNCFLORA. Centro Nacional de Conservação da Flora. Lista vermelha da flora brasileira versão 2012.2
Available:http://cncflora.jbrj.gov.br/portal/ptbr/profile/Erythroxylum pauferrense
(Accessed on: 01 September 2017).

40. Oliveira FX, Andrade LA, Félix LP. Comparações florísticas e estruturais entre comunidades de Floresta Ombrófila Aberta com diferentes idades, no município de Areia, PB, Brasil. Acta Botanica Brasilica. 2006;20(4):861-873.

Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sciencedomain.org/review-history/26040