

Diversity and structure of adult and regenerating arbor component in forest 'submontana', Paraíba-Brazil

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 m² was sampled in a remaining rainforest (Open Ombrophylous Forest), in which woody species of adult stratum and regenerating were measured. In this survey was considered all woody individuals among adult strata with CFG $\geq$ 10 cm in circumference (circumference of the trunk at 30 cm from the ground). Regenerating were measured in the same plot (CFG < 10 cm), to justify richness and diversity comparisons in the same scale of 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 are intensified as more important in the diversity measures, it was proved that the tree component began to maintain greater diversity, respectively, by Shannon and Simpson's entropy. 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 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 are considered crucial for its understanding [1, 2]. For decades, studies on diversity in tree species community had as base only the absolute numbers of species and the index values with so insufficient mathematical properties [3, 4, 5]. Under this approach, the true profiles that make up the plants diversity are lowered and underused, since the traditional methodologies are inadequate and tendentious [6]. In the last years, more elaborate indexes with more robust mathematical properties emerge as an important 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 Brazilian Northeast is comprised of 'submontana' forest areas, known in Brazil as "brejo de altitude", which are inserted in phytogeographic domain of 'Caatinga' [7, 8]. These areas are located predominantly in 'Agreste' region between Paraíba and Pernambuco states, Brazil, and have intermediate weather, hot and dry climate that are specifically from 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 data from first records [7, 11], the swamp forest areas of original vegetation, which corresponded to semideciduous and open ombrophilous forests, was 18,500.00 km², but there are only 2,626.68 km². 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 consider 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

38 maintenance and conservation of these forest mosaics that remain in Brazilian Northeast.
39 Nevertheless, empirical studies describing diversity processes are very scarce, and when they exist,
40 they are directed only at floristic-descriptive aspects, requiring a better exploitation of this information
41 occupied area. Second, the latest official dos órgãos de pesquisa espacial ambiental estimates do not

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

53 The objective of research was to study modulations of woody species diversity from adult and
54 regenerating stratum, from the point of view of the same sample area for both strata in forest area
55 'submontana', evaluating floristic similarity and possible alterations of the diversity profiles among
56 strata. In order to do so, we tried to test the following hypotheses: i) the pattern of diversity changes
57 among strata, especially due to differences about how the distribution of relative abundances are
58 organized among species in both strata; ii) the floristic similarity is little changed among the strata
59 and that the conjecture of the natural regeneration in the present moderate scenario of disturbances
60 allows a reasonable prognosis.

61 62 2. MATERIAL AND METHODS / EXPERIMENTAL DETAILS / METHODOLOGY (ARIAL, 63 BOLD, 11 FONT, LEFT ALIGNED, CAPS) 64

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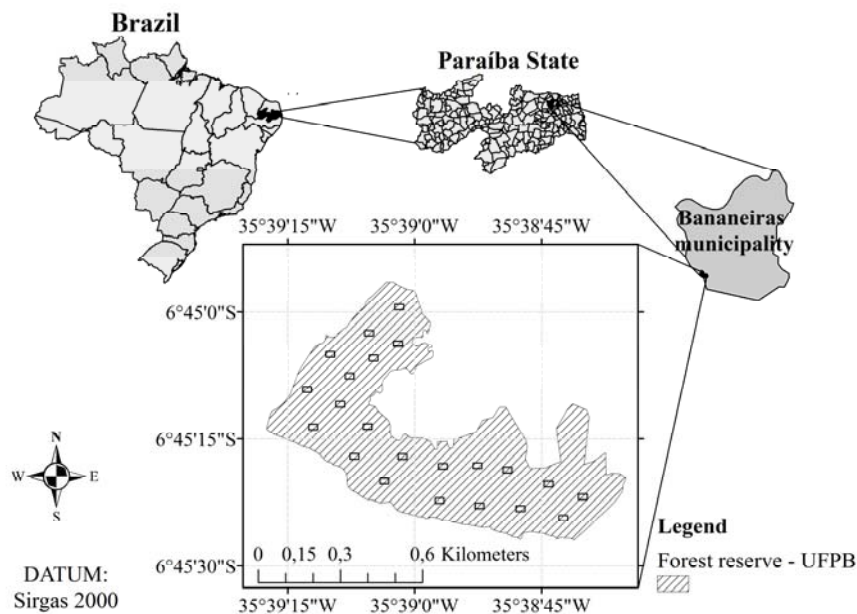


Figure 1. Geographic location of forest garden in UFPB area, municipality of Bananeiras - PB, Brazil. Details with rectangles (□) denote the distribution of experimental units.

Data collection

Twenty-two plots of 10 x 20 m (200 m²) were distributed randomly which totaled an 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" (Figure 1). In this survey was considered all woody individuals of the adult extract, 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 richness and diversity comparisons in the same scale of area [18]. The individuals were divided into three height classes (H), where class 1: H ≥ 1.0 m H ≤ 2.0 m, class 2 H > 2.0 m and H ≤ 3.0 m and class 3 with H > 3.0 m [19]. All individuals represented from both strata were identified and measured the CFG (at 30 cm from the ground), using a dendrometric caliper, and estimated the total height at the apex of the treetop.

The community structure parameters were calculated using 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 Moraes" at Agricultural Sciences Center (CCA) in UFPB, Areia - PB. Species were identified by comparisons and expert assistance according to Angiosperm Phylogeny Group - APG III [22]. The species current nomenclature was conferred by means of consulting to Missouri Botanical Garden database.

Diversity profiles analysis

It was used a sample coverage estimator equation 1 [3] with the aim of quantifying the sampling intensity from 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 approximate variances for each diversity component ($q = 1, 2$ and 3), and later to construct the associated confidence limits ($\alpha = 0.05$).

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

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 [23] effective diversity numbers for both strata was calculated. 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 = is 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]. All data statistical manipulation and chart construction were performed using ambient R version 3.4.0 [27].

Results

Floristics and structures

It were sampled 2308 individuals, distributed into 36 families, 54 genera and 80 species, with predominance of tree species (56.25%), 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 presented 800 individuals, 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 presented 1508 individuals, distributed into 69 species and 32 families. Plant families with highest richness were the same ones recorded to adult stratum, except: Malvaceae (anyone specie), Anacardiaceae, Fabaceae (three species each one), Myrtaceae (four species). The number registered for regenerating individuals was higher than adult stratum, due to the plot size, 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. caesalpiniiifolia*, *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.

Plant species in alphabetical order of family, genus and species.			
Family/species	Common name	In	
		A	R
Anacardiaceae			
<i>Anacardium occidentale</i> L.	"Cajueiro"	5	1
<i>Anacardium</i> sp.	"Cajú-do-mato"	2	–
<i>Tapirira guianensis</i> Aubl.	"Cupiúba"	21	20

<i>Thyrsoedium spruceanum</i> Benth.	"Caboatã-de-leite"	39	28
Annonaceae			
<i>Xylopia frutescens</i> Aubl.	"Embira"	–	2
Apocynaceae			
<i>Tabernaemontana</i> sp.	"Leiteira"	3	1
Araliaceae			
<i>Schefflera morototoni</i> (Aubl.) Maguire et al.	"Sambaquim"	1	–
Bignoniaceae			
<i>Handroanthus</i> sp. 1	"Ipê"	5	7
<i>Handroanthus</i> sp. 2	"Ipê-amarelo"	1	7
Boraginaceae			
<i>Cordia taguahyensis</i> Vell.	"Frei-jorge"	10	101
Burseraceae			
<i>Protium heptaphyllum</i> (Aubl.) Marchand	"Amescla-de-cheiro"	36	171
Cannabaceae			
<i>Celtis iguanaea</i> (Jacq.) Sarg.	"Cabrinha"	–	3
Capparaceae			
<i>Cynophalla flexuosa</i> (L.) J.Presl	"Feijão-bravo"	2	1
Clusiaceae			
<i>Clusia</i> sp.	"Clusia"	2	20
Connaraceae			
<i>Connarus</i> sp.		20	20
Erythroxylaceae			
<i>Erythroxylum</i> sp.		8	1
<i>Erythroxylum paufferense</i> Plowman	"Guarda-orvalho"	85	274
<i>Erythroxylum simonis</i> Plowman	"Quebra-foice"	28	37
Euphorbiaceae			
<i>Croton</i> sp.	"Marmeleiro"	–	3
Fabaceae			
<i>Albizia polycephala</i> (Benth.) Killip ex Record	"Vassourinha"	8	5
<i>Anadenanthera colubrina</i> (Vell.) Brenan	"Angico-de-carço"	21	–
<i>Bowdichia virgilioides</i> Kunth	"Sucupira-preta"	9	5
<i>Enterolobium contortisiliquum</i> (Vell.) Morong	"Timbaúva"	5	–
Fabaceae 1		7	32
Fabaceae 2		–	7
<i>Hymenaeae courbaril</i> L.	"Jatobá"	10	2
<i>Inga</i> sp. 1		2	6
<i>Inga</i> sp. 2		4	8
<i>Inga</i> sp. 3	"Inga-feijão"	11	24
<i>Mimosa caesalpiniiifolia</i> Benth.	"Sabiá"	56	15
<i>Piptadenia stipulacea</i> (Benth.) Ducke	"Jurema-branca"	2	2
<i>Pterogyne nitens</i> Tul.	"Madeira-nova"	9	3
<i>Senegalia tenuifolia</i> (L.) Britton & Rose	"Jequiri"	1	6
Hypericaceae			
<i>Vismia guianensis</i> (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			
<i>Vitex rufescens</i> A.Juss.	"Mama-cachorro"	1	–

Lauraceae			
<i>Ocotea glomerata</i> (Nees) Mez	"Louro-preto"	13	20
Lecythydaceae			
<i>Eschweilera ovata</i> (Cambess.) Mart. ex Miers	"Imbiriba"	45	23
<i>Lecythis pisonis</i> Cambess.	"Sapucaia"	22	9
Malpighiaceae			
<i>Byrsonima sericea</i> DC.	"Murici"	11	3
Malvaceae			
<i>Ceiba glaziovii</i> (Kuntze) K.Schum.	"Barriguda"	1	-
<i>Guazuma ulmifolia</i> Lam.	"Mutamba"	1	-
<i>Luehea paniculata</i> Mart. & Zucc.	"Açoita-cavalo"	6	-
Melastomataceae			
<i>Miconia albicans</i> (Sw.) Triana	"Quaresmeira"	1	3
<i>Miconia minutiflora</i> (Bonpl.) DC.	"Tinteiro"	4	7
Moraceae			
<i>Brosimum guianense</i> (Aubl.) Huber	"Quiri"	15	18
<i>Sorocea</i> sp.	"Folha-de-serra"	3	23
Myrtaceae			
<i>Myrcia</i> sp.	"Araçá-bravo"	2	11
<i>Myrcia splendens</i> (Sw.) DC.	"Araçazinho"	7	108
Myrtaceae 1		6	5
<i>Psidium</i> sp.	"Araçá"	1	5
Nyctaginaceae			
<i>Guapira laxa</i> (Netto) Furlan	"Guapira"	16	-
<i>Guapira opposita</i> (Vell.) Reitz	"João-mole"	34	12
Peraceae			
<i>Pera distichophylla</i> (Mart.) Baill.	"Rabo-de-galo"	-	5
Piperaceae			
<i>Piper mollicomum</i> Kunth.	"Pimenteira-do-mato"	30	51
Polygonaceae			
<i>Coccoloba</i> sp.	"Cravaçu"	9	6
Rubiaceae			
<i>Guettarda viburnoides</i> Cham. & Schltdl.	"Veludo-branco"	-	4
<i>Randia</i> sp.	"Baga-preta"	5	10
Rutaceae			
<i>Zanthoxylum rhoifolium</i> Lam.	"Limãozinho"	1	2
Salicaceae			
<i>Casearia sylvestris</i> Sw.	"Café-bravo"	15	16
Sapindaceae			
<i>Allophylus edulis</i> (A.St.-Hil. et al.) Hieron. ex Niederl.	"Baga-se-morcego"	10	30
<i>Cupania impressinervia</i> Acev.-Rodr.	"Caboatã"	51	80
<i>Talisia esculenta</i> (Cambess.) Radlk.	"Pitomba"	19	22
Sapotaceae			
<i>Pouteria</i> sp. 1		8	5
<i>Pouteria</i> sp. 2		8	6
Sapotaceae 1		12	11
Simaroubaceae			
<i>Simarouba amara</i> Aubl.	"Pau-paraíba"	3	2
Solanaceae			
<i>Brunfelsia uniflora</i> (Pohl) D.Don	"Manacá-de-cheiro"	5	4
Urticaceae			
<i>Cecropia pachystachya</i> Trécul	"Embaúba"	5	-
Total		800	1508

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

It were sampled 800 individuals (4132 ind/ha) and 1508 individuals (7789 ind./ha) in adult stratum and in regenerating stratum, respectively. Basal areas were estimated at 33.4429 and 0.7322 m²/ha, concerned to adult and regenerating strata. Genera *Erythroxylum* (three species - 121

individuals), *Mimosa* (one species - 56 individuals), *Cupania* (one species - 51 individuals) and *Eschweilera* (one species - 45 species) represent that with more individuals (In). In the regenerating extract genera with more representants were: *Erythroxylum* (three species - 312 individuals), *Protium* (one species - 171 individuals), indeterminate genera 5 (one species - 135 individuals) and *Myrcia* (three species - 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%).

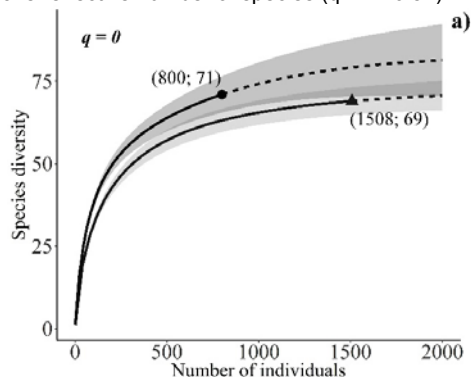
Species with the highest importance value (IV) in the adult stratum were: *G. opposita* (26.46), *M. caesalpiniiifolia* (19.31), *A. colubrina* (18.18), *E. paufferense* (16), *T. guianensis* (15.64), *C. impresinervia* (14.89). Among these species, morphospecies with the highest structural representativity (Relative Dominance - RDo) of this component were: *G. opposita* (17.39%), *A. colubrina* (13.15%), *T. guianensis* (10.61%) and *M. caesalpiniiifolia* (9.50%). In relation to regenerating stratum, the species with the highest Total Natural Regeneration were: *E. paufferense* (10.96%), with higher expressiveness in the first class ($1 \leq H \leq 2$ 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).

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, arboreal and regenerating strata, respectively. According to these values, the vegetal species profile diversity from adult woody component was higher in both facets, that is, 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, suggesting similarity for species richness ($q = 0$) among adult and regenerant strata (Figure 2a). On the other hand, when plant species abundances are 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 (Figure 2b and c).

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



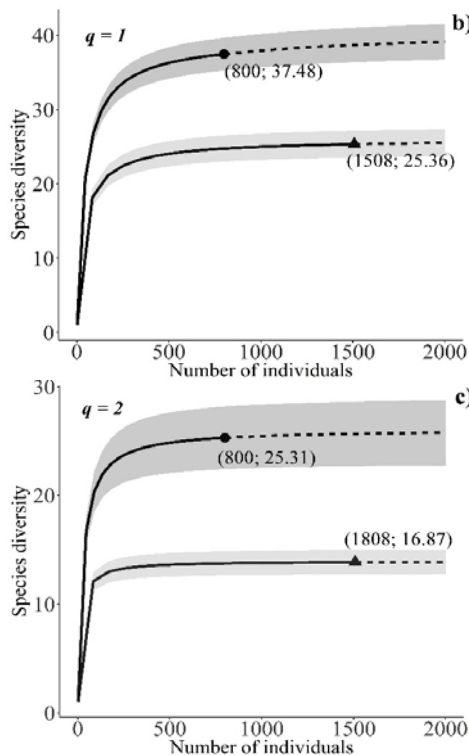


Figure 2. Sampling curves by interpolation (-) and extrapolation (--), both with 95% confidence intervals (shaded areas). Data from adult and regenerating strata are shown separately by diversity profiles. Points and solid triangles represent the limits from reference samples; numbers in parentheses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

In all diversity components (ie, 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 (Figure 3a, b and c).

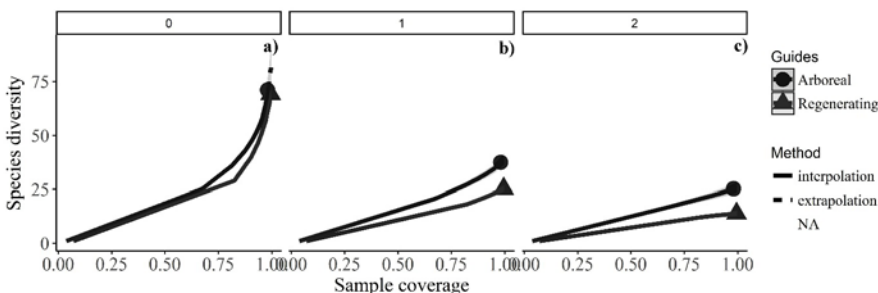


Figure 3. Sample intensity curve by interpolation (-) and extrapolation (--), both with 95% confidence intervals (shaded areas). Arboreal community data: arboreal and regenerating are shown separately by diversity profiles (order: $q = 0, 1$ and 2). Points and solid triangles represent the sample limits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

230 Discussion

231 Floristics and structures

232 The floristic and physiognomic profile of the area contains conspicuous elements, which
233 characterize a closer approximation to Atlantic Forest of the coast (eg, *Tapirira guianenses*, *Protium*
234 *heptaphyllum*, *Eschweilera ovata*) than the Northeast Caatinga (eg, *Piptadenia stipulacea*, *Croton* sp.,
235 *Senegalia tenuifolia*). In the broad sense, it is known that other floristic and physiognomic changes
236 can also be evidenced as it is far from the coast and close to "sertão" areas, and those changes are
237 also found in western part of Northeast [7, 9]. According to [29] there is a greater floristic overlap of
238 these areas with thorny deciduous vegetation from the region, probably due to proximity and
239 conditions more similar between these fitofisionomies.

240 In terms of diversity, for adult stratum, there is a considerable similarity to the regional surveys
241 of the Atlantic Forest in the Zona da Mata in Pernambuco state, Brazil, for example, [30, 31, 32] who
242 found: 3.09; 3.20; 3.83 and 3.43 nats. ind. ⁻¹ for H', based on inclusion criteria similar to that adopted
243 by this study (CFG ≥ 15 cm). For regenerating stratum, were found 3.20; 3.32 and 3.45 nats. ind. ⁻¹ in
244 papers of [33, 34, 35], respectively, considering the same inclusion criterion in regenerating classes.
245 These generalizations, while showing little implication in conservation, confirm a slight idea of the
246 similarity of the diversity of the woody component between the coastal Atlantic Forest and the
247 innermost areas (i.e., when they move away from the coast towards the West).

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

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

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

274 Among threatened species, *E. pauferrense* has recently been discovered in the botanical field
275 [39], it has endemism restricted to the forest areas of swamp in Paraíba state and is threatened with
276 extinction. One of concerns is due to habitat deforestation and the isolation of subpopulations, as well
277 as the decline of individuals [39]. However, the species does not go through problems, due to its high
278 abundance listed also in other works in this typology [36, 40]. The fact that the species shows high
279 values for TNF is associated with the habit of shrub growth and the ecological preference for the lower
280 forest stratum (sub-forest), a fact observed *in-situ* in the fragment studied.

281 Vegetal species profile diversity

282 Yield curve of rarefaction is the expected increasing if an individual is added to the sample. In
283 other words it is the probability of the next individual sampled be a new species not previously
284 sampled [3]. In this sense, considering the sample standardized in 98 and 99% for the sample
285 intensity curve ($\hat{C}_n$), arboreal and regenerating stratum, respectively, it is observed that sample
286 coverage estimates slightly increase qD values (q=1 and 2), confirming satisfactory sample levels
287 (Figure 3b and c). This property becomes more visible in the diversity components, whose Hill number

$q > 0$ (Figure 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].

In this work, it was proved that there are no significant differences for richness and floristic composition, considering adult and regenerating stratum in the same area. However, this pattern has 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 ($P = .05$) (Figure 2). In other words, it is defended the hypothesis that, when properly protected, these areas have the capacity to 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 is 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 twice greater than the density of individuals in the adult stratum. In this conception, the tree community had greater distribution on 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 increase significantly the complexity levels of wealth and structure's components (ie, density, biomass, richness and equitability) after few years of disturbance [40]. These authors, who studied the natural regeneration of shrub-arboreal component, in disturbed areas with different years old, proved that clear advances in the forest with 20 years old much approached to what was expected concerned to older forests.

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 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, this indicates reasonable perspectives on the regeneration power and natural resilience these forest, although the great scenario of disturbances and disappearance that these ecosystems currently suffer.

These findings provide informations for studies in diversity of phytophysiognomic sectors that are still little known and, also, value the importance of small forest fragments for woody flora conservation and their role in maintaining the Atlantic Forest biodiversity. Additionally, we hope that these findings will be later incorporated in actions for conservation and which can be integrated into biogeographical and macroecological studies.

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 assemblages. *Journal of plant ecology*, 2012; 5(1): 3-21.

344 7. Barbosa MRV, Agra MF, Sampaio EV. S. B, Cunha JP, Andrade LA. Diversidade
345 florística da Mata do Pau-Ferro, Areia, Paraíba. In: Pôrto KC, Cabral JJP, Tabarelli M. Brejos
346 de altitude em Pernambuco e Paraíba: história natural, ecologia e conservação. Brasília:
347 MMA; 2004.

348 8. IBGE. Manuais técnicos em geociências: Manual técnico da vegetação brasileira. Rio de
349 Janeiro; 2012.

350 9. Moro MF, Lughadha EN, Araújo FS, Martins FR. A phytogeographical metaanalysis of the
351 semiarid caatinga domain in Brazil. *The Botanical Review*, 2016; 82(2): 91–148.

352 10. Tabarelli M, Santos AMM. Uma breve descrição sobre a história natural dos Brejos
353 Nordestinos. In: Pôrto KC, Cabral JJP, Tabarelli M. Brejos de altitude em Pernambuco e
354 Paraíba: história natural, ecologia e conservação. Brasília: MMA; 2004.

355 11. Instituto Brasileiro de Geografia e Estatística. Atlas nacional do Brasil: região Nordeste:
356 Rio de Janeiro; 1985.

357 12. Fundação Sos Mata Atlântica. Atlas dos remanescentes florestais da Mata Atlântica
358 período 2015 – 2016. Relatório Parcial. São Paulo: Instituto Nacional de Pesquisas Espaciais;
359 2017.

360 13. Finol,
361 UH. Nuevos parámetros a considerarse en el análisis estructural de las selvas vírgenes tropica
362 les. *Revista Forestal Venezolana*, 1971; 21: 29-42.

363 14. Oliveira MC, Felfili JM, Silva-Júnior, MC. Comparação florístico-estrutural dos estratos
364 adulto e de regeneração em mata de galeria perturbada no Distrito Federal, Brasil. *Revista*
365 *Brasileira de Biociências*, 2015; 13(3): 142-154.

366 15. Aguiar MD, Silva AC, Higuchi P, Negrini M, Schollemberg AL. Similaridade entre
367 adultos e regenerantes do componente arbóreo em floresta com araucária. *Floresta e*
368 *Ambiente*, 2017; 24(e00083214): 1-10.

369 16. Moro MF, Lughadha EN, Filer DL, Araújo FS, Martins FR. A catalogue of the vascular
370 plants of the Caatinga Phytogeographical Domain: a synthesis of floristic and
371 phytosociological surveys. *Phytotaxa*, 2014; 160(1): 001-118.

372 17. EMBRAPA. Centro Nacional de Pesquisa de Solos. Sistema brasileiro de classificação
373 dos solos. Brasília: Embrapa-SPI, 1999.

374 18. Kindt, R, Coe, R. Tree diversity analysis. A manual and software for common statistical
375 methods for ecological and biodiversity studies. Nairobi: World Agroforestry Centre; 2005.

376 19. Marangon, LC, Soares JJ, Feliciano ALP, Brandão CFLS. Regeneração natural em um
377 fragmento de Floresta Estacional Semidecidual em Viçosa, Minas Gerais. *Revista Árvore*,
378 2008; 32(1): 183-191.

379 20. Mueller-Dumbois D, Ellenberg H. Aims and methods of vegetation ecology. New
380 York: JonhWilly; 1974.

381 21. CIENTEC. Mata Nativa 4. Manual do usuário. Viçosa: CIENTEC; 2016.

382

383 22. APG III. An update of the Angiosperm Phylogeny Group classification for the orders and
384 families of flowering plants: APG III. *Botanical Journal of the Linnean Society*, 2009; 161:
385 105-121.

386 23. Hill M. Diversity and evenness: a unifying notation and its consequences. *Ecology*, 1973;
387 54: 427-432.

388 24. Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB et al. *Vegan:*
389 *Community Ecology Package*; 2014.

390 25. Vavrek,
391 J. Fossil: palaeoecological and palaeogeographical analysis tools. *Palaeontologia Electronica*,
392 2011.

Matthew

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). Disponível em: <<http://www.iucnredlist.org/>> Acesso em: 28 ago. 2017. The Plant List. Disponível em: <<http://www.theplantlist.org>>. Acesso em: 29 jun. 2017.
29. Alcoforado-Filho FG, Sampaio EVSB; Rodal, MJN. Florística e fitossociologia de um remanescente de vegetação caducifolia 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, Aparício 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 Disponível em <<http://cncflora.jbrj.gov.br/portal/ptbr/profile/Erythroxylum pauferrense>>. Acesso em 01 set de 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.