

# Composition and Diversity of Areas Under Restoration Process From the Brazilian Atlantic Forest

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## Abstract

The evaluation of the forest restoration scenario is of great importance, with floristic composition and diversity being among the most used ecological variables as indicators. This research aimed to identify the current situation, in terms of species composition and diversity, of two riparian forests under restoration based on a reference ecosystem, the Brazilian Atlantic Forest. Twenty permanent plots (250 m<sup>2</sup>) were located in areas under restoration process (AR1 and AR2) and in a forest fragment of the region which served as a reference ecosystem (ER). We sampled, identified and classified all tree individuals with CBH  $\geq$  15.0 cm in each plot. Aiming to understand species richness and diversity, besides the traditional indexes (Shannon and Simpson), we also estimated the effective numbers of Hill's diversity ( $qD = 0, 1$  and  $2$ ) considering rarefaction ( $P \leq 0.05$ ); and to detect floristic similarities among the study areas we performed a Principal Coordinate Analysis (PCoA). We found dissimilarity among ARs and ER, and the presence of exotic species, indicating that, as recommended, such reference should have been taken into account during the planning of the restoration action. Considering the effective numbers of species ( $qD$ ) we found differences between the areas, species richness and diversity was higher in  $ER > AR2 > AR1$ . We also show that among the restoration areas, with the same age and submitted to the same conditions, AR2 has features that allow us to conclude that this area has a bigger chance of success in the restoration process. However, aiming environmental sustainability, we suggest that some corrective actions should be taken in order to favour the reestablishment of ecological processes in these areas.

**Keywords:** corrective actions, ecological indicators, floristic similarity, monitoring, recovery

## 1. Introduction

Tropical forests globally account for about two-thirds of the species, being irreplaceable for maintaining biodiversity, providing ecosystem services, and mitigating climate change (Gardner et al., 2010). However, the gradual decline of these forests has been observed due to the loss, fragmentation and degradation of ecosystems resulting from land-use change for the deployment of agriculture and urban expansion (Gibbs et al., 2010), directing the efforts each for restoring degraded ecosystems (Aronson et al., 2007; Chazdon, 2008; Holl & Aide, 2011).

Riparian forests are among the most threatened ecosystems and play an important role in maintaining the ecological balance of water bodies, since they act as filters, ecological corridors and protect the soil against erosive processes (Ávila et al., 2011; Martins, 2014). For Brazilian Atlantic Forest, mainly in the riparian areas, restoration by planting seedlings has increased in the last decades, due to legal laws requirements, providing a growing opportunity for the study of successional trajectories (Rodrigues et al., 2009; Castro et al., 2012). According to Suganuma and Durigan (2014), forest restoration by planting trees usually accelerates the succession process, however, trajectories towards reference ecosystems are rarely evaluated.

By taken restoration actions, it is expected that such forests formed will be self-sustaining and resilient to disturbances (Ruiz-Jaen & Aide, 2005; Morimoto et al., 2006), however, it is still unknown whether such restorations will actually produce mature native forests (Oldfield et al., 2013). Therefore, it is important to carry out studies that evaluate the actions made and to identify whether such environments are becoming

self-sustaining or whether they need corrective actions to support this process (Benayas et al., 2009; Dey & Schweitzer, 2014). In the evaluation of restoration, besides using ecological indicators, the Society for Ecological Restoration (2004) recommends the use of a reference ecosystem as a starting point for evaluation. According to Brancalion et al. (2015), reference ecosystems represent the desired state of the restoration object, considered as the final goal to be achieved.

The floristic composition and diversity are among the most used ecological variables as indicators of the restoration process (Gatica-Saavedra et al., 2017). For decades, studies on diversity in tree species communities were based only on the absolute number of species and the values of indexes with statistical properties were not very accurate (Chao & Jost, 2012; Chao et al., 2014; Hsieh et al., 2016), which reduced and underestimated the real shape of plant diversity—due to traditional biased methodologies (Colwell et al., 2012). Recently, reformulations have been proposed in the indices and allow for a better understanding of species diversity, giving less importance to rare species (Chao et al., 2014; Gotelli & Chao, 2013). Although, these indexes were not yet explored in studies focused on restoration areas, they are considered promising for bringing a real idea of the diversity on the environments.

Considering that the evaluation the forest restoration actions is of great importance, the goal of this study was to identify the current situation, in terms of species composition and diversity, of two riparian forests under restoration based on a reference ecosystem, at the Brazilian Atlantic Forest. To do so, we evaluated the floristic composition, taxonomic diversity and floristic similarities among restoration areas and the reference ecosystem. We sought to answer the following questions: (i) Are the vegetation of the areas under restoration part of the natural ecosystem of the region? ii) Do the attributes of diversity and composition indicate the progress of the restoration process in areas with eight years post-planting? With this study we hope to provide important information to encourage workers and researchers to evaluate and disseminate results about forest restoration actions, mainly regarding their ecological benefits.

## 2. Method

This study was developed in three areas located between the towns of Lagoa de Itaenga and Paudalho, at Zona da Mata Norte in the state of Pernambuco, Brazil. The climate classification of the region is type As, according to Köppen-Geiger; the mean annual temperature is 24.2 °C and the mean annual rainfall is 989 mm (Alvares et al., 2013). The predominant vegetation in the region is classified as tropical rainforest - seasonal semideciduous forest typology (IBGE, 2012).

In 2008, the planting of seedlings in riparian areas started with the goal of changing these degraded areas into Permanent Preservation Areas (APP). The restoration technique adopted was total plantation of tree species in the total area, at a spacing of 3 × 3 m, restoring, on average, 6 hectares (ha) of the Engenho Conceição forest (AR1) and 5 ha in the area known as Petribu I (AR2). In the past, AR1 has been used as pasture for animals from neighbouring communities, whereas AR2 has been used as sugar cane plantation.

The Reference Ecosystem (ER) we chose was based on the recommendations of the Society for Ecological Restoration (2004), a forest fragment inserted in the same local context of the areas under restoration, with similar environmental conditions and anthropic pressures. The ER is located between the two ARs, 2.7 km from the start of AR1 and 1.5 km from AR2. Important information about these areas are presented in Table 1.

Table 1. Information of the areas under restoration process (AR1 and AR2) and of the reference ecosystem (ER) of the Brazilian Atlantic Forest, in Pernambuco-Brazil

Features	AR1	AR2	ER
Geographical coordinates	7°53'23" S 35°13'16.3" W	7°53'16.7" S 35°15'9" W	7°53'40.8" S 35°14.2'35" W
Total area (ha)	6.15	5.11	26.55
Restoration technique	Total planting	Total planting	Natural secondary succession
Age (years)	8	8	> 30 years
Sampling area (m <sup>2</sup> )	5000	5000	5000

We carried out an evaluation of the restoration areas (AR1 and AR2) and the reference ecosystem using ecological indicators, making it possible to analyse the composition, diversity and similarity among the

environments. These indicators were applied in all areas using the same methodology, as suggested by Brancalion et al. (2015).

In the three areas (AR1, AR2 and ER), 20 permanent plots of 10 × 25 meters (250 m<sup>2</sup>) were placed systemically to collect the variables. In 2016, we performed a floristic and phytosociological assay, in which we labelled and identified all tree individuals with circumference at breast height (CBH) ≥ 15.0 cm. We also measured the circumferences of the trees and estimated their height.

We collected plant material of the individuals and sent it to the Herbarium Sérgio Tavares of the Forest Science Department from the Federal Rural University of Pernambuco for taxonomic identification. The individuals sampled in the floristic assay were related in a floristic list and the species were named and distributed in families according to the Angiosperm Phylogeny Group IV classification system (APG, 2016). Aiming to verify plant scientific names and authors we consulted the List of Species of the Brazilian Flora (Flora do Brasil, 2019) and the database of Botanical Garden of Missouri (<http://www.tropicos.org>). Following identification, the species were classified according to their origin (native or exotic), we considered as exotic those species that do not occur naturally in the native vegetation of the region (Atlantic Forest).

Aiming to understand species richness and diversity, we estimated the effective numbers of Hill's diversity (Hill, 1973) based on the proposal of Chao et al. (2014). This estimator includes the three measurements of species diversity that are widely used: species richness ( $q = 0$ ), the exponential of the Shannon diversity ( $q = 1$ ) and the Simpson diversity ( $q = 2$ ) which is also called as number of common species (Chao et al., 2014). This procedure was performed with the aid of the functions of the "iNEXT" package of the R environment (iNterpolation/EXTrapolation) which provides functions for plotting species diversity curves by interpolation and extrapolation (Hsieh et al., 2016).

In addition, we also estimated the Shannon diversity index ( $H'$ ) and Simpson index of dominance ( $C'$ ), following the same methodology proposed by Brower and Zar (1984), which were calculated in a traditional way. The values obtained from the Shannon and Simpson indices were compared for their significance using Hutcheson t-test (1970) with 95% probability level. This test provides the difference between the diversity index of two samples in order to detect significant differences between them (Magurran, 1988), making comparisons between two sets of data obtained in the study areas.

For the analysis of species composition, in order to detect the floristic similarity among the areas, we did an exploratory data analysis using the Principal Coordinate Analysis (PCoA), through the Bray-Curtis distance. We measured the significance among groups by Permutational analysis of variance (PERMANOVA) from 999 permutations ( $\alpha = 0.01$ ). The distances of Bray-Curtis and the dissimilarity matrix were calculated using the "vegdist" and "metaMDS" functions, respectively, from the "vegan" package of the R statistical software (Oksanen et al., 2017). All statistical analysis and graphics were performed in the R environment - version 3.4.0 (R Development Core Team, 2017).

### 3. Results

We sampled 164 individuals in the AR1, which were distributed in 23 species: 20 were identified at species level, one at genus level and two at family level (Table 2). The most representative families were Fabaceae, with approximately 34.8% of the species, Malvaceae and Bignoniaceae (13%) and Anacardiaceae (8.7%). The other families (Euphorbiaceae, Meliaceae, Moraceae, Myrtaceae, Rubiaceae, Sapindaceae and Urticaceae) had only one species (4.3%).

We sampled 325 three individuals in the AR2, which were distributed in 31 species: 30 were identified at species level and one at genus level (Table 2). These species were distributed in 15 families: Fabaceae, with the highest amount of species (35.5%), followed by Anacardiaceae and Bignoniaceae (9.7%), Annonaceae and Malvaceae (6.5%) and others (Chrysobalanaceae, Euphorbiaceae, Lamiaceae, Malpighiaceae, Meliaceae, Myrtaceae, Rhamnaceae, Rubiaceae, Sapindaceae and Urticaceae) that had only one species (3.2%).

We sampled 675 individuals in the ER, which were distributed in 43 species: 40 were identified at specific level, one at genus level and two at family level. The species were distributed in 23 families: Fabaceae (14% of species), followed by Bignoniaceae, Erythroxylaceae, Moraceae, Myrtaceae, Rubiaceae and Sapindaceae (7%), Nyctaginaceae, Rutaceae and Salicaceae (4.7%). These results showed that in the three areas, the Fabaceae family was the most representative (Table 2).

Table 2. Tree species found in two restoration areas (AR1 and AR2) and in the reference ecosystem (ER) of the Brazilian Atlantic Forest, in Pernambuco-Brazil

Family/Species	Individuals number		
	AR1	AR2	ER
<b>Anacardiaceae</b>			
<i>Anacardium occidentale</i> L.		3	
<i>Astronium fraxinifolium</i> Schott			5
<i>Mangifera indica</i> L.		1	
<i>Schinus terebinthifolius</i> Raddi	32		
<i>Spondias mombin</i> L.		2	
<i>Tapirira guianensis</i> Aubl.	1		
<b>Annonaceae</b>			
<i>Annona montana</i> Macfad.		2	
<i>Annona salzmannii</i> A.DC.		1	
<b>Apocynaceae</b>			
<i>Tabernaemontana flavicans</i> Willd. ex Roem. & Schult.			11
<b>Bignoniaceae</b>			
Bignoniaceae 1			20
Bignoniaceae 2			6
<i>Handroanthus impetiginosus</i> (Mart. ex DC.) Mattos	3		
<i>Handroanthus serratifolius</i> (Vahl) S.Grose			6
<i>Handroanthus</i> sp.	1		
<i>Tabebuia aurea</i> (Silva Manso) Benth. & Hook.f. ex S.Moore	1	1	
<i>Tabebuia rosea</i> (Bertol.) Bertero ex A.DC.		11	
<i>Tecoma stans</i> (L.) Juss. ex Kunth		1	
<b>Boraginaceae</b>			
<i>Cordia sellowiana</i> Cham.			21
<b>Capparaceae</b>			
<i>Cynophalla flexuosa</i> (L.) J.Presl			10
<b>Chrysobalanaceae</b>			
<i>Licania tomentosa</i> (Benth.) Fritsch		3	
<b>Erythroxylaceae</b>			
<i>Erythroxylum passerinum</i> Mart.			3
<i>Erythroxylum simonis</i> Plowman			24
<i>Erythroxylum</i> sp.			25
<b>Euphorbiaceae</b>			
<i>Euphorbia tirucalli</i> L.			1
<i>Jatropha curcas</i> L.		2	
<i>Ricinus communis</i> L.	1		
<b>Fabaceae</b>			
<i>Albizia polycephala</i> (Benth.) Killip ex Record			48
<i>Anadenanthera colubrina</i> (Vell.) Brenan			7
<i>Adenanthera pavonina</i> L.	7	3	
<i>Bowdichia virgilioides</i> Kunth			3
<i>Clitoria fairchildiana</i> R.A.Howard	4		
<i>Enterolobium contortisiliquum</i> (Vell.) Morong		7	
Fabaceae 1	1		
Fabaceae 2	1		
<i>Geoffroea spinosa</i> Jacq.	1	33	
<i>Inga cf. capitata</i> Desv.		7	
<i>Inga edulis</i> Mart.	15		
<i>Inga ingoides</i> (Rich.) Willd.		3	
<i>Inga striata</i> Benth.	24		
<i>Leucaena leucocephala</i> (Lam.) de Wit	1	14	
<i>Libidibia ferrea</i> (Mart. ex Tul.) L.P.Queiroz		6	
<i>Machaerium hirtum</i> (Vell.) Stellfeld			9
<i>Mimosa caesalpiniiifolia</i> Benth.		9	

<i>Mimosa</i> sp.		2	
<i>Paubrasilia echinata</i> (Lam.) E.Gagnon, H.C.Lima & G.P.Lewis			18
<i>Pithecellobium dulce</i> (Roxb.) Benth.		15	
<i>Senna siamea</i> (Lam.) H.S.Irwin & Barneby		1	
<i>Swartzia pickelii</i> Killip ex Ducke			1
<b>Hypericaceae</b>			
<i>Vismia guianensis</i> (Aubl.) Choisy			2
<b>Lamiaceae</b>			
<i>Tectona grandis</i> L.f.		4	
<i>Vitex rufescens</i> A.Juss.			7
<b>Malpighiaceae</b>			
<i>Malpighia emarginata</i> DC.		2	
<b>Malvaceae</b>			
<i>Ceiba speciosa</i> (A.St.-Hil.) Ravenna	3	81	
<i>Guazuma ulmifolia</i> Lam.	1		1
<i>Sterculia foetida</i> L.	3	4	
<b>Meliaceae</b>			
<i>Azadirachta indica</i> A.Juss.	3	55	
<i>Trichilia hirta</i> L.			9
<b>Moraceae</b>			
<i>Artocarpus heterophyllus</i> Lam.			1
<i>Brosimum guianense</i> (Aubl.) Huber			1
<i>Maclura tinctoria</i> (L.) D.Don ex Steud.			3
<i>Morus nigra</i> L.	1		
<b>Myrtaceae</b>			
<i>Campomanesia dichotoma</i> (O.Berg) Mattos			2
<i>Campomanesia eugenoides</i> (Cambess.) D.Legrand ex Landrum			7
<i>Syzygium cumini</i> (L.) Skeels	57	40	1
<b>Nyctaginaceae</b>			
<i>Guapira laxa</i> (Netto) Furlan			7
<i>Guapira opposita</i> (Vell.) Reitz			63
<b>Phyllanthaceae</b>			
<i>Margaritaria nobilis</i> L.f.			3
<b>Polygonaceae</b>			
<i>Coccoloba mollis</i> Casar.			13
<b>Rhamnaceae</b>			
<i>Ziziphus joazeiro</i> Mart.		1	5
<b>Rubiaceae</b>			
<i>Coutarea hexandra</i> (Jacq.) K.Schum.			10
<i>Genipa americana</i> L.	1	4	2
<i>Tocoyena brasiliensis</i> Mart.			1
<b>Rutaceae</b>			
<i>Zanthoxylum monogynum</i> A.St.-Hil.			2
<i>Zanthoxylum rhoifolium</i> Lam.			1
<b>Salicaceae</b>			
<i>Casearia hirsuta</i> Sw.			15
<i>Casearia sylvestris</i> Sw.			92
<b>Sapindaceae</b>			
<i>Allophylus edulis</i> (A.St.-Hil. et al.) Hieron. ex Niederl.			108
<i>Cupania impressinervia</i> Acev.-Rodr.			63
<i>Talisia esculenta</i> (Cambess.) Radlk.	1	1	37
<b>Urticaceae</b>			
<i>Cecropia pachystachya</i> Trécul	1	6	1
<b>Total</b>	<b>164</b>	<b>325</b>	<b>675</b>

Regarding the occurrence of exotic species, we found in the AR1 eight species (35% of the total), in the AR2 13 species (42%) and in the ER only four species (9%). Analyzing the exotic in relation to the number of

individuals, the percentage values increased. In AR1, 46.85% of individuals were exotic ones (77 of 164 ind.), in AR2 46.77% (152 of 325 ind.) and in ER only 1.19% of individuals were exotic of this region (8 of 675 ind.).

Differences in floristic composition among the restoration areas and the reference ecosystem were enough to group the pairs of plots at each level using the Principal Coordinate Analysis (PCoA) (Figure 1). The graph shows: communities close to each other in the graph have similar species composition and abundance; communities distant to each other have distinct species composition and abundance. Moreover, PERMANOVA corroborated these data, because it showed a significant difference between the environments studied (P-value = 0.001) which is also shown by the graphical analysis—taking into account the centroid points and distances, it can be argued that there is no floristic similarity between the restoration areas and the reference ecosystem.

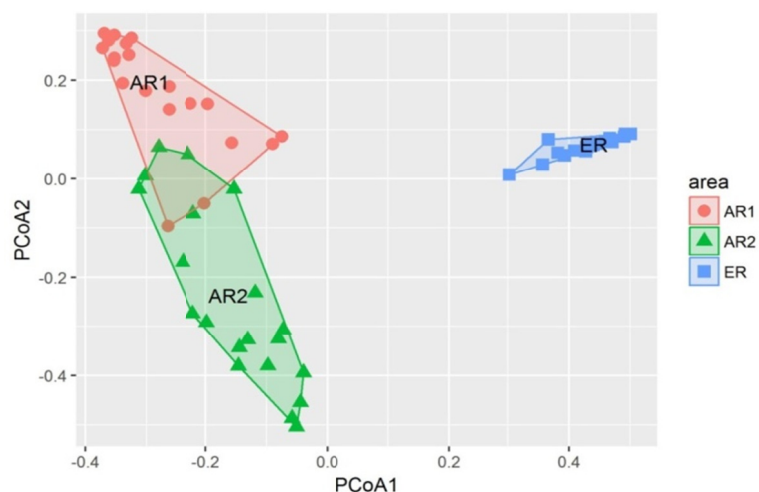


Figure 1. PCoA of tree species sampled in the restoration areas (AR1 and AR2) and in the reference ecosystem (ER) of the Atlantic Forest, Pernambuco-Brazil

*Note.* The circles, triangles and squares denote the distance estimates (“method” = Bray-Curtis) among the number of individuals of each species within the sample plots in the different areas (AR1, AR2 and ER).

Considering the traditional diversity indexes (Table 3), the Shannon diversity index ( $H'$ ) was higher in the reference ecosystem than in the restoration areas. The Simpson index of dominance ( $D'$ ) followed this same pattern, *i.e.*, it was higher in the ER than in the AR2 and AR1.

Table 3. Diversity indexes estimated for the restoration areas (AR1 and AR2) and the reference ecosystem (ER) of the Atlantic Forest, in Pernambuco-Brazil

Indexes	AR1	AR2	ER
Shannon diversity index ( $H'$ ) (nats/ind)	2.11 b	2.56 b	2.97 a
Simpson index of dominance ( $D'$ )	0.81 c	0.88 b	0.92 a

*Note.* \* Different letters indicate significant differences ( $\alpha < 0.05$ ); Hutcheson t-test.

The effective numbers of species ( $qD$ ) or true components of diversity, were for AR1: 23, 8.24 and 5.18 species; for AR2: 31, 12.91 and 8.02 species and for the ER: 43, 19.50 and 12.89 species (orders  $q = 0, 1$  and  $2$ , respectively). The sampling curve was used for reliable comparisons, starting from any size of an observed sample (interpolation) to twice as many individuals (extrapolated) (Figure 2). The analyses of species richness confirmed that the reference ecosystem was the environment with the largest number of individuals, followed by AR2. The same pattern was observed when diversity components that prioritize species abundance were incorporated ( $q = 1$  and  $2$ ), showing higher diversity in the ER > AR2 > AR1.

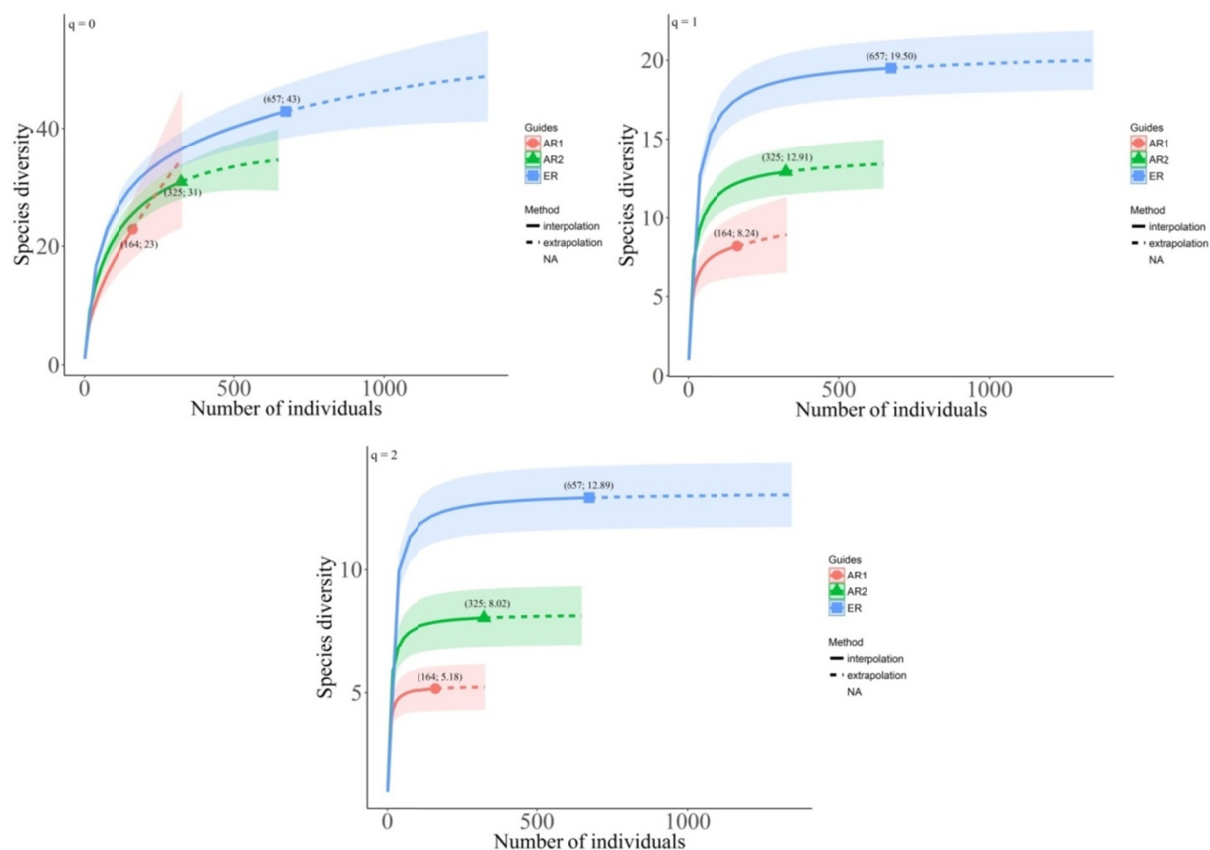


Figure 2. Sample curves by interpolation and extrapolation with 95% confidence intervals (shaded areas), obtained by the bootstrap method. Data from the tree community: AR1, AR2 and ER are shown separately by diversity profiles with  $q = 0$  (species richness, A),  $q = 1$  (Shannon diversity, B) and  $q = 2$  (Simpson diversity, C)

Note. The solid points, triangles and squares are the mark for the reference samples, and the numbers in brackets are the number of individuals and the effective number of species in each profile ( $qD =$  Hill numbers in  $q$ -order).

Aiming to improve the understanding of the results, we show in Figure 3 the abundance of species in each area. Note that in AR1 only four species are responsible for the majority of the individuals of the community (about 80%) which is quite distant from the ER that has a more subtle distribution, with more abundant species. Although the ARs have been implanted at the same time, the individuals in AR2 are more distributed among species than in AR1, showing, a higher potential for sustainability and success.

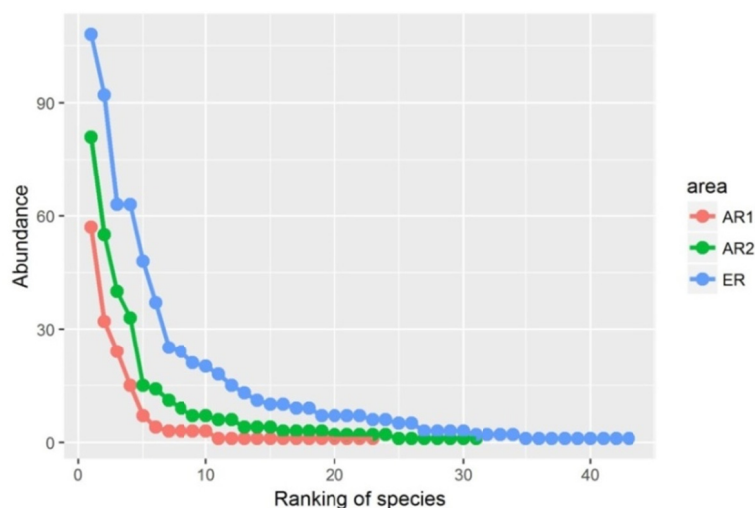


Figure 3. Abundance of species in two restoration areas (AR1 and AR2) and in the reference ecosystem (ER) of the Atlantic Forest, in Pernambuco-Brazil

#### 4. Discussion

Regarding the botanical families, Fabaceae is the most predominant family in the three study areas. This family has been found in forest restoration plantations which it is usually the most abundant (Klippel et al., 2015; Silva et al., 2016; Pimentel et al., 2018); favouring plant diversity of the tropical forests, especially in areas of the Atlantic Forest (Zimmermann et al., 2012). Pereira et al. (2013) emphasize the importance of the Fabaceae family in restoration projects, because plants from this family contribute to atmospheric nitrogen fixation, helping in the reestablishment of the soil with increased biological activity and increasing the probability of other trees species, which are less tolerant to stressful conditions, to be found in these areas.

Although the number of exotic species we found in ARs are larger than in the native ecosystem (ER) it is still higher than those observed by Marcuzzo et al. (2014), which studied seven years old restoration areas and found a percentage of exotic species ranging from 17 to 26%. Considering the criteria established by SER (2004), one criteria that deserves attention is the exclusion of exotic species in ecological restoration actions. According to Podadera and Engel (2013), the ecological role of these species in restoration environments as facilitating species seems to decrease over time and in some years, such exotic species can compete with native species delaying and hindering the successional process in the restoration environment. Some studies have shown that when exotic species invade natural environments they can alter plant diversity, nutrient cycling, and to decrease ecosystem services (Powell et al., 2011; Vila et al., 2011; Katsanevakis et al., 2014).

Considering that restoration areas should mirror natural ecosystems (SER, 2004; Rodrigues et al., 2009; Fengler et al., 2017) we can argue that the results found in ARs are not acceptable due to the presence of such exotic species. It is important to identify, eliminate and prevent sowing exotic species because they occupy the niches of native species which can disturb important biotic relationships (Coelho et al., 2014). Thus, it is known that the use of exotic individuals may lead to modifications in the natural systems.

Among the species found in the two restoration environments (AR1 and AR2): *Adenantha pavonina*, *Azadirachta indica*, *Cecropia pachystachya*, *Ceiba speciosa*, *Genipa americana*, *Geoffroea spinosa*, *Leucaena leucocephala*, *Sterculia foetida*, *Syzygium cumini*, *Tabebuia aurea* and *Talisia esculenta*, only four (*Cecropia pachystachya*, *Genipa americana*, *Syzygium cumini* and *Talisia esculenta*) were present in the three areas evaluated. These results indicate that it is possible that more time is needed to determine the influence of ER in the recovery of the floristic composition of the areas under restoration evaluated in our study. This pattern was also observed by Trujillo-Miranda et al. (2018), which compared a reference ecosystem with areas under different restoration strategies.

It is clear that the floristic composition in AR1 and AR2 areas are different from ER. The differences observed between these areas might be due to several factors, especially because regional species were not selected in the planning of the restoration nor in the planting act. When selecting species for forest restoration is very important



to consider the composition of the local flora and regional native species, since these species are already adapted to local conditions (Brancalion et al., 2015), increasing the chances of success (Ivanauskas et al., 2007).

Taking into account Shannon and Simpson indices, we can argue that the diversity is higher in ER, followed by AR2 and AR1. When compared to other studies, we showed that the estimated  $H'$  values for the study areas are lower than those found for riparian fragments at the same region, which were 3.29 nats / ind. and 3.08 nats / ind. (Hollanda et al., 2010; Oliveira et al., 2009). Regarding the estimated values for Simpson (C), the diversity of plant species in ER was higher than in ARs. Our results are in agreement with aspects previously observed, i.e. showed that difference exists in the floristic composition of the restoration environments and reference ecosystem, which affected the ecological diversity.

When analysing the curve for richness ( $q = 0$ ), it can be observed that in AR1 there was no stabilization (Figure 2a), suggesting that the sampling we used was not enough to stabilize the number of species in the area. However, considering that the sampling was the same for all areas and that AR1 and AR2 are areas with similar ages and conditions, we can conclude that suppression or death of the individuals planted must have had occurred, contributing for loss of diversity, and, consequently, curve destabilization. With the analysis of the other components of diversity ( $q = 1$  and  $2$ ), we can observe that there is in fact a greater diversity in the ER > AR2 > AR1, corroborating our previous results. Importantly, diversity does not depend exclusively on total density, as highlighted by Santos et al. (2018), when compared two areas in a single environment. In other words, although we found the higher species richness in ER, it does not necessarily mean that ER has the higher diversity. It happened because the reference ecosystem showed a higher distribution of individuals/abundance of species, categorizing ER as an environment with ecological stability, i.e. more tolerant.

The diversity of species in restoration plantations is widely discussed among researchers (Aronson et al., 2010; Salomão et al., 2013; Brancalion et al., 2015; Amazonas et al., 2018). According to Martins (2014), the use of few species in restoration projects, in a scenario with low resilience, can lead to the failure of the process, since pest attacks or repeated degrading actions can eliminate several tree individuals. Brancalion et al. (2010) argue that restoration with a high number of tree species can create different micro-habitats and niches, which will contribute to produce a self-sustaining forest. However, Durigan et al. (2010) argue that searching for a high number of species without planning it can contribute to misidentification of species, genetic contamination and even the extinction of locally rare populations due to failures in the collection of seeds. In fact, the use of more species does not guarantee the success in the restoration process, however, if the goal is to restore the biodiversity of native species in the area, to make use of more species can contribute greatly.

Considering the composition and diversity data evaluated from the indicators presented above, we showed that there is no similarity between the restoration areas and the landscape reference ecosystem, as suggested by SER (2004) and researchers working in this field. With respect to the success of the restoration, we showed that AR2 shows better results of species richness and diversity than AR1, indicating an evolution in the process of forest restoration that has been implemented eight years ago. However, it is important to highlight that other monitoring should be done in order to analyse the reestablishment of ecological functions in long-term environments, as well as the need to embrace corrective actions. As Hotta et al. (2015) suggested, these corrective actions also called as adaptive management are important for the integration of restoration sites with the surrounding vegetation, favouring the process.

## 5. Conclusions

The study of the composition, diversity and floristic similarity of the areas under restoration and the comparison with a reference ecosystem was fundamental to evaluate the effectiveness of the restoration process. The present study showed that the floristic composition of the areas under restoration (AR1 and AR2) were not reflect what was observed in the natural ecosystem (ER), indicating absence of floristic similarity and differences in both species richness and diversity patterns.

Taken into account the areas in restoration, which are of the same age, AR2 was considered the area with higher potential to reach the ER level and, consequently, it has higher chances of success. However, we suggest the continuity of monitoring in the future aiming to investigate the restoration process and that corrective actions be applied, mainly associated with the control of exotic species. These findings infer about the importance of planning restoration actions based on a reference ecosystem, in order to minimize errors. Additionally, it can be assumed that these findings can be utilized used to base future restoration actions in environments similar to the present study.

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