

Original Research Article

Floristic composition in chronosequence in Atlantic Rainforest fragments

ABSTRACT

Secondary forests play an important role in tropical landscapes and have important ecological functions such as the ability to accumulate biomass. Although the literature points to the convergence between primary and secondary forests, however there are few studies in Atlantic Rainforest in a chronosequence to show it. This study aimed to characterize the changes of floristic composition in a chronosequence (5, 16, 24, 30 years of regeneration and mature forest) in the Atlantic Rainforest. He sought to answer the following questions: Young forests tend to converge resembling floristically with mature forest? In case of this floristic convergence from what age these young forests present rate of growth closer forms of mature forest? The fact that about 35% of the tree species are present in young and mature forests suggests that the floristic composition of young forests tends to resemble the mature forest. The results suggest that from 16 young forests tended to converge with the mature forest in terms of the proportion of growth forms.

Keywords: Floristic convergence, Young forests, Growth forms, Secondary rainforest.

1. INTRODUCTION

Secondary forests play an important role in tropical landscapes. These ecosystems are sources of timber and non-timber products and generally perform important ecological functions, such as the ability to accumulate biomass and nutrients at high rates, maintain biogeochemical cycles and water conservation at levels comparable to primary forests [1,2]. Current research on succession in secondary forests in the tropical regions occurs especially in studies in chronosequences [3].

Regarding succession [4] proposed that it is a highly ordered and predictable process, emphasizing the sequential substitution of herbaceous species by shrubs and finally arboreal species. Differently, [5] suggested that the sequence does not have this fixed and regular sequence, being influenced by the composition of the community, which is determined by stochastic factors.

In relation to floristic composition throughout the succession, [6] described two alternative scenarios. The floristic rotation, with a broadly clementsian view, in which each group of species colonizes the place at certain stage of development, thus making conditions unsuitable for itself and more appropriate for colonization of the next group, at the final stage of succession convergence with the region's mature vegetation. Other scenario is the hypothesis of initial floristic composition, which proposes that after the abandonment of a site, development unfolds from the initial flora; [6] concluded that the secondary succession

Comment [AL1]: Who?
The statement should be reported without the use of pronouns

36 is determined more by the initial floristic composition of an area than by the floristic rotation
37 proposed by [4].

38 At present, it is known that natural landscapes, in general, have a historical complex of land
39 use disturbances [7]. These authors argued that succession represents a series of
40 unpredictable events that results from interactions between individuals and the abiotic
41 environment, involving different patterns (convergence or divergence), mechanisms and
42 causes that lead to complex paths that will determine the processes of recovery of the local
43 vegetation. The trajectory followed by the sequence depends on the initial conditions and
44 stochastic events. The results of chronosequences found in tropical forests by several
45 authors [2,8] have reported floristic convergence with mature vegetation.

46 Although the literature cites some papers that point to convergence, it is known that there
47 are studies reporting the floristic divergence along the chronosequence [9,10]. The authors
48 argued that this may be due to less similarity of habitats and/or landscape effects [11]. On
49 the landscape effect, [12] found that in landscapes with less than 10-30% of vegetation
50 covering, there are negative effects on the persistence of the species due to the combined
51 effect of landscape area and geometry, which may lead to convergent or divergent
52 trajectories, according to the degree of vegetative cover.

53 From the perspective of the current literature, there is still a great deal of research to be
54 done. The present research aims to characterize the changes in floristic composition in a
55 chronosequence (5, 16, 24, 30 years of regeneration and mature forest). Thus, we sought to
56 answer the following questions: From what age do young forests present a proportion of
57 growth forms closer to the mature forest? Do young forests tend to diverge or converge
58 floristically with mature forest?
59

60 **2. MATERIAL AND METHODS**

61

62 **2.1. Local study and selection of areas**

63 The fragments of mature and young forest studied are located at the São José Plant (USJ)
64 (07° 54' 17" - 07° 54' 41"S, 34° 54' 17" - 35° 05' 07"), located in the Zona da Mata Norte de
65 Pernambuco, in the domain of the Dense Ombrophylous Forest [13]. The property occupies
66 270 km², where it has forest remnants that cover 24% of the landscape, being the average
67 size of the fragments of 61 ha, occupying the less useful areas for planting [14].

68 The local climate is As' (hot and humid), with an annual average temperature of 24.9 °C,
69 average rainfall of 1687 mm (Laboratory of Meteorology of Pernambuco - LAMEPE/ITEP).

70 Young forests with 5, 16, 24 and 30 years of regeneration were selected from aerial
71 photographs of the 1960s, 1970s, 1980s, 2005 satellite images and interviews with former
72 residents. As a comparison, an area of mature forest (over 60 years old) studied by [15] was
73 selected. It is important to point out that mature forest is the one in which we can guarantee,
74 based on cartographic material and interviews, that there was no intervention in the last 60
75 years.

76 **2.2. Data collect**

77 Thirty plots of 10 × 10 m were sampled in each forest of the chronosequence, as well as the
78 floristic survey near the plots. The collection was carried out by the walking method [16],
79 according to the usual collection techniques for plants [17]. The studied habits were: 1)
80 arboreal; 2) shrub; 3) grass; 4) bindweed (woody) and 5) epiphyte.

Comment [AL2]: Describe your sampling method

81 2.3. Analysis and processing of data

82 The species sampled were identified with the help of experts and comparisons with
83 collections deposited at the Herbarium Sergio Tavares (HST) and Dárdano de Andrade Lima
84 (IPA). The exsiccates were placed in the Herbarium Professor Vasconcelos Sobrinho
85 (PEUFR). The classification of angiosperm families followed the recommendations of [18].

86 To test the possible convergence or divergence of habits between the different dropout ages
87 and the proportion between the different habits during the chronosequence, one-way
88 ANOVA was applied, followed by the post-hoc Tukey test through the PAST 2.01 software
89 [19].

90 In order to verify if there is floristic convergence between the young forests and the mature
91 forest the degree of floristic similarity between the tree species in the chronosequence was
92 evaluated. To do this, we performed: 1) a clustering analysis using the Jaccard similarity
93 index and the mean linkage method per group (UPGMA) [20]; 2) Principal component
94 analysis (PCA), Multidimensional linear analysis technique [21], and 3) non-metric
95 multidimensional scaling (NMDS) [22]. Based on the tree species present in the five ages, a
96 presence/absence matrix was elaborated to analyze if there would be indicator species for
97 each age, using TWINSPLAN (Two Way Indicator Species Analysis) analysis [23] using PC-
98 ORD version 4.0 [24]. The option to analyze only trees occurred because it is the best
99 registered habit in the five areas.

100

101 3. RESULTS AND DISCUSSION

102

103 In the five fragments sampled, 198 taxa were recorded, distributed by 131 genera and 59
104 families (Table 1). In the area of 5 years, 66 species and 42 families occurred, being
105 Myrtaceae and Melastomataceae the most representative. In the forest of 16 years of
106 abandonment, we found 75 species and 44 families, with greater representation of
107 Fabaceae, especially the subfamilies Papilionoideae and Mimosoideae. In the area of 24
108 years, 88 species and 51 families occurred, Myrtaceae being the one with the greatest
109 number of species. In the 30 years, with 75 species and 41 families, with highlight to
110 Myrtaceae and Fabaceae (Mimosoideae) families, due to the greater species richness. In
111 the mature forest, there were 95 species and 52 families, with Myrtaceae, Sapindaceae and
112 Rubiaceae with the largest number of species (Table 1).

113 The trends observed during the chronosequence in the fragments at the São José Plant
114 reveal that in the youngest forest (5 years) there were several herbs with a short life cycle
115 and an increase in the number of tree species and decrease of the herbs in the more
116 advanced stages (16, 24, 30 and mature), what was pattern observed in other
117 chronosequence studies [25,26,27].

118 Tree habit showed the highest number of families (43) and species (124), from these 124
119 species, 51 occurred in the young forests and 72 in the mature forest, and the two groups
120 shared 43 species. The families that presented the greatest wealth of trees were Myrtaceae
121 and Fabaceae (Mimosoideae), with 15 and 10 species, respectively. There was an increase
122 in the number of species in the families Sapindaceae, Annonaceae, Myrtaceae and
123 Fabaceae throughout the chronosequence; from these 124 tree species recorded in young
124 forests and mature forest, 15 species (12.9%) were common at all ages (Table 1).

125 The shrub habitat presented 13 families and 39 species. In the herbs group, 12 families and
126 19 species were recorded (Table 1). Among the bindweed, nine families and 16 species

127 were recorded (Table 1). The epiphyte of the hemiparasite type *Psittacanthus dichrous*
 128 (Loranthaceae) was found only in the young forest of 5 years.

129 It can be noticed an advance to a more typical pattern of mature forests from 16 years after
 130 the abandonment, due to the increase of the trees and decrease of the herbaceous ones,
 131 showing the directional substitution of forms of growth.

132 The small trees that occurred in all the young forests are typical species of edges and
 133 clearings of forests [28,29], being present in the young forests in sunny areas [30].
 134

135 **Table 1. Species recorded in four fragments of young forests (5, 16, 24 and 30) and**
 136 **a mature forest. ARO - Arboreal, TRE - Bindweed, ARB - Bush, ERV - Herb, EPI -**
 137 **Epiphyte. Young forests (FJ5 = 5 years = 16 years FJ16, FJ24 = 24, FJ30 = 30 years)**
 138 **and mature forest (FM). * arborescent plant with similar size to tree. Through the**
 139 **analysis of indicator species TWINSPAN: ♦ mature forest; • young forests.**

Specie	Habit	FJ5	FJ16	FS24	FS30	FM
Anacardiaceae						
<i>Anacardium occidentale</i> L.	ARO				X	
<i>Mangifera indica</i> L.	ARO		X			
<i>Tapirira guianensis</i> Aubl.	ARO	X	X	X	X	X
<i>Thyrsodium spruceanum</i> Benth.	ARO		X	X	X	X
Annonaceae						
<i>Anaxagorea dolichocarpa</i> Sprague & Sandwith	ARO		X			
<i>Annona salzmannii</i> A.DC.	ARO					X
<i>Guatteria cf. australis</i> A. St.-Hil.	ARO					X
<i>Guatteria pogonopus</i> Mart.	ARO					X
<i>Guatteria schomburgkiana</i> Mart. ♦	ARO	X	X			X
<i>Xylopia frutescens</i> Aubl. •	ARO	X	X	X	X	
Apocynaceae						
<i>Condylocarpon</i> sp.	TRE		X			
<i>Himathanthus phagedaenicus</i> (Mart.) Woodson	ARO	X	X	X	X	X
<i>Rauvolfia grandiflora</i> Mart. ex A.DC.	ARB		X	X		
<i>Tabernaemontana flavicans</i> Willd. ex Roem. & Schult.	ARO					X
Araliaceae						
<i>Schefflera morototoni</i> (Aubl.) Maguire, Steyerl. & Frodin	ARO	X	X	X	X	X
Areceaceae						
<i>Acrocomia sclerocarpa</i> Mart. *•	ARO	X	X	X	X	
<i>Bactris ferruginea</i> Burret *	ARO					X
<i>Desmoncus</i> sp.	TRE					X
<i>Elaeais guineensis</i> Jaquim *	ARO	X		X	X	

Comment [AL3]: All of these are expected to be at the footnote of the table

Asteraceae

Conocliniopsis prassifolia (DC.) R.M. King & H. Rob. ARB X

Conyzas umatrensis (Retz.) E. Walker. ARB X

Pterocaulonalo pecuroides (Lam.) DC. ERV X

Sphagnetico latrilobata (L.) Pruski ERV X

Tilesiabaccata (L.) Pruski ARB X X

Boraginaceae ARB X

Tournefortia candidula (Miers) I.M. Johnst.

Burseraceae

Protium heptaphyllum (Aubl.) Marchand ARO X X X X X

Cecropiaceae

Cecropia pachystachya Trécul. ARO X X X X X

Celastraceae

Maytenus distichophylla Mart. Ex Reissek ♦ ARO X X X X

Maytenus obtusifolia Mart. ARO X X X X

Chrysobalanaceae

Hirtella racemosa Lam. ARB X X X X

Licania tomentosa (Benth.) Fritsch ARO X

Clusiaceae

Clusia nemorosa G.Mey ARO X X X

Rheedia gardneriana Blanch. & Triana ARO X X X

Symphonia globulifera L. f. ARO X X X X

Vismia guianensis (Aubl.) Pers. • ARO X X X X

Cochlospermaceae

Cochlospermum vitifolium (Willd.) Spreng. ARO X X

Combretaceae

Buchenavia tetraphylla (Aubl.) R.A. Howard ARO X X

Convolvulaceae

Jacquemontia glaucescens Choisy. TRE X

Dilleniaceae

Davilla aspera (Aubl.) Benoist TRE X X X

Davilla sp. TRE X X X

Tetracera breyniana Schltld. TRE X X X

Tetracera sp. TRE X

Ehretiaceae

Cordia multispicata Cham. ARB X X

Cordia nodosa Lam. ARB X X X

Cordia sellowiana Cham. ARO X X

<i>Cordia superba</i> Cham.	ARO					X
Erythroxylaceae						
<i>Erythroxylum citrifolium</i> A. St.-Hil.	ARB	X	X	X	X	X
<i>Erythroxylum mucronatum</i> Sw.	ARB		X			
Euphorbiaceae						
<i>Croton floribundus</i> Spreng.	ARO		X			
<i>Croton</i> sp.	ARO				X	
<i>Euphorbia hyssopifolia</i> L.	ERV	X				
<i>Microstachys corniculata</i> (Vahl) Griseb.	ERV	X				
Fabaceae – Caesalpinoideae						
<i>Apuleia leiocarpa</i> (Vogel) J.F. Macbr.	ARO	X	X		X	
<i>Bauhinia</i> sp.	ARO				X	
<i>Dialium guianense</i> (Aubl.) Sandwith ♦	ARO					X
<i>Senna georgica</i> H.S. Irwin & Barneby	ARB		X		X	
<i>Senna quinquangulata</i> (L.C. Rich.) H.S. Irwin & Barneby	ERV		X			
<i>Swartzia pickelii</i> Killip ex Ducke	ARO	X	X		X	
Fabaceae – Mimosoideae						
<i>Abarema cochliacarpus</i> (Gomez) Barneby & Grimes	ARO	X				X
<i>Albizia polycephala</i> (Benth.) Killip. •	ARO		X	X	X	
<i>Albizia saman</i> (Jacq.) F. Muell.	ARO			X	X	
<i>Inga cayennensis</i> Sagotex Benth.	ARO	X	X			X
<i>Inga flagelliformes</i> (Vell.) Mart.	ARO		X			
<i>Inga ingoides</i> (Rich.) Willd.	ARO			X	X	
<i>Inga thibaudiana</i> DC.	ARO		X	X	X	X
<i>Inga</i> sp.	ARO					X
<i>Plathymenia foliolosa</i> Benth.	ARO		X		X	X
<i>Stryphnodendron pulcherrimum</i> (Willd.) Hochr.	ARO				X	
Fabaceae – Papilionoideae						
<i>Andira fraxinifolia</i> Benth.	ARO		X			
<i>Andira nitida</i> Mart. Ex Benth.	ARO					X
<i>Bowdichia virgilioides</i> Kunth	ARO	X	X	X	X	X
<i>Desmodium axillare</i> (Sw.) DC.	ERV			X		
<i>Desmodium barbatum</i> (L.) Benth.	ERV	X				
<i>Dioclea virgata</i> (L.C. Rich.) Amshoff	TRE	X				
<i>Machaerium hirtum</i> (Vell.) Stellfeld	ARO			X	X	X
<i>Machaerium salzmannii</i> Benth.	ARO		X			
<i>Stylosanthes scabra</i> J. Vogel	ARB	X				

Heliconiaceae						
<i>Heliconia psittacorum</i> L.	ERV				X	
<i>Heliconia</i> sp.	ERV		X			
Hernandiaceae						
<i>Sparattanthelium botocudorum</i> Mart.	ARB		X	X	X	
Humiriaceae						
<i>Sacoglottis mattogrossensis</i> Benth.	ARO					X
Lamiaceae						
<i>Marsippanthes chamaedrys</i> (Vahl) Kuntze	ERV	X				
Lauraceae						
<i>Ocotea gardneri</i> (Meissn.) Mez	ARO					X
<i>Ocotea glomerata</i> (Nees) Mez	ARO		X	X	X	
<i>Ocotea indecora</i> (Schott) Mez	ARO					X
<i>Ocotea limae</i> Vattimo	ARO					X
Lecythydaceae						
<i>Eschweilera ovata</i> (Cambess.) Miers.	ARO	X	X	X	X	X
<i>Gustavia augusta</i> L.	ARO			X	X	
<i>Lecythis pisonis</i> (Cambess.) Miers. ♦	ARO					X
Loganiaceae						
<i>Strychnos bahiensis</i> Krukoff & Barneby	ARB		X			
<i>Strychnos</i> sp.	ARB				X	X
Loranthaceae						
<i>Psittacanthus dichrous</i> (Mart.) Mart.	EPI	X				
Malpighiaceae						
<i>Byrsonima sericea</i> A.DC.	ARO	X	X	X	X	X
<i>Stigmaphyllon blanchetii</i> C.E. Anderson	ERV				X	
Malvaceae						
<i>Apeiba tibourbou</i> Aubl. •	ARO		X	X	X	
<i>Guazuma ulmifolia</i> Pers.	ARO			X		
<i>Luehea paniculata</i> Mart.	ARO			X		X
<i>Sida rhombifolia</i> L.	ERV	X				
Melastomataceae						
<i>Clidemia capitellata</i> (Bonpl.) D. Don.	ARB	X	X	X	X	
<i>Clidemia hirta</i> Cong.	ARB	X				
<i>Henriettea succosa</i> (Aubl.) DC.	ARO	X	X			X
<i>Miconia albicans</i> (Benth.) Triana	ARB	X	X	X	X	X
<i>Miconia ciliata</i> (Rich.) DC.	ARB	X	X	X		X
<i>Miconia multiniflora</i> (Bonpl.) DC.	ARO	X	X	X	X	
<i>Miconia prasina</i> (Sw.) DC.	ARO			X	X	

<i>Miconia</i> sp.	ARB		X	X		
Meliaceae						
<i>Guarea guidonia</i> (L.) Sleumer	ARO		X			
<i>Trichilia lepidota</i> Mart.	ARO					X
Menispermaceae						
<i>Cissampelos</i> sp.	ERV					X
Monimiaceae						
<i>Siparuna guianensis</i> Aubl.	ARO		X	X	X	
Moraceae						
<i>Artocarpus heterophyllus</i> Lam. •	ARO		X	X	X	
<i>Brosimum guianense</i> (Aubl.) Huber	ARO	X	X	X	X	X
<i>Sorocea hilarii</i> Gaudich.	ARO		X	X	X	X
Myristicaceae						
<i>Virola gardneri</i> (A. DC.) Warb.	ARO		X			
Myrsinaceae						
<i>Rapanea guianensis</i> Aubl.	ARO		X	X	X	X
Myrtaceae						
<i>Calyptanthes brasiliensis</i> Spreng.	ARO			X		X
<i>Campomanesia dichotoma</i> (O.Berg) Mattos	ARO	X	X	X	X	X
<i>Eugenia florida</i> DC.	ARO			X		
<i>Eugenia puniceifolia</i> (Kunth) DC.	ARO	X			X	X
<i>Eugenia umbrosa</i> O. Berg	ARO					X
<i>Eugenia</i> sp.	ARO	X		X		X
<i>Myrcia fallax</i> (Rich.) DC.	ARO		X			X
<i>Myrcia guianensis</i> (Aubl.) DC.	ARO	X	X	X	X	X
<i>Myrcia racemosa</i> Barb. Rodr.	ARO	X	X	X	X	X
<i>Myrcia sylvatica</i> (G. Mey.) DC.	ARO	X	X	X		X
<i>Myrcia tomentosa</i> (Aubl.) DC.	ARO		X	X	X	
<i>Myrcia</i> sp.	ARO	X			X	
<i>Myrciaria ferruginea</i> O.Berg	ARO					X
<i>Psidium guajava</i> L.	ARO			X		
<i>Psidium guineense</i> Sw.	ARO	X	X	X	X	
Nyctaginaceae						
<i>Guapira laxa</i> (Netto) Furlan	ARO		X			
<i>Guapira nítida</i> (Schmidt) Lundell	ARO				X	X
<i>Guapira opposita</i> (Vell.) Reitz	ARO					X
<i>Neea</i> sp.	ARO					X
Ochnaceae						
<i>Ouratea castaneifolia</i> (DC.) Engl.	ARO					X

Olacaceae						
<i>Schoepfia brasiliensis</i> A. DC.	ARB		X			X
<i>Ximenia americana</i> L.	ARO	X				
Passifloraceae						
<i>Turnera ulmifolia</i> L.	ERV	X				
Peraceae						
<i>Pera ferruginea</i> (Schott) Müll. Arg.	ARO	X	X	X	X	X
<i>Pogonophora schomburgkiana</i> Miersex Benth.♦	ARO		X			X
Piperaceae						
<i>Piper arboreum</i> Aublet	ARB			X		X
<i>Piper marginatum</i> Jacq.	ARB			X		
Poaceae						
<i>Urochloa fusca</i> (Sw.) B.F. Hansen & Wunderlin	ERV			X		
Polygonaceae						
<i>Coccoloba mollis</i> Casar.	ARO			X	X	X
Ranunculaceae						
<i>Clematis dioica</i> L.	TRE			X		X
Rhamnaceae						
<i>Colubrina glandulosa</i> Perkins.	ARO			X		
<i>Gouania</i> sp.	TRE					X
Rubiaceae						
<i>Alseis pickelii</i> Pilg. & Schmale	ARO					X
<i>Borreria verticillata</i> (L.) G. Mey	ERV	X				
<i>Diodia apiculata</i> (Roem. & Schult.) K. Schum.	ERV			X		
<i>Diodia</i> sp.	ERV					X
<i>Genipa americana</i> L.	ARO	X				
<i>Palicourea crocea</i> (Sw.) Roem. & Schult.	ARB		X		X	X
<i>Posoqueria longiflora</i> Aubl.	ARO					X
<i>Posoqueria</i> sp.	ARO	X				
<i>Psychotria barbiflora</i> DC.	ARB		X	X	X	X
<i>Psychotria bracteocardia</i> (DC.) Müll. Arg.	ARB		X		X	
<i>Psychotria capitata</i> Ruiz & Pav.	ARB			X		
<i>Psychotria carthagenensis</i> Jacq.	ARO			X		X
<i>Psychotria cf. deflexa</i> DC.	ARB					X
<i>Psychotria hoffmannseggiana</i> (Willd. ex Roem. & Schult.)	ARB		X			
<i>Psychotria</i> sp.	ARB				X	
<i>Richardia grandiflora</i> (Cham. & Schtdl.)	ERV	X				

Steud						
<i>Sabicea grisea</i> Cham. & Schtdl.	TRE	X		X	X	
<i>Salzmannia nitida</i> DC.	ARB					X
Rubiaceae	ARB		X			
Rutaceae						
<i>Ertela trifolia</i> (L.) Kuntze	ERV	X				
<i>Zanthoxylum rhoifolium</i> Lam.	ARO			X		
Salicaceae						
<i>Banara brasiliensis</i> (Schott) Benth.	ARO			X		
<i>Banara guianensis</i> Aubl.	ARO			X		
<i>Casearia javitensis</i> Humb., Bonpl. & Kunth	ARO			X	X	X
<i>Casearia sylvestris</i> Sw.	ARO	X		X	X	X
<i>Casearia</i> sp.	ARO				X	
Sapindaceae						
<i>Allophylus edulis</i> (A.St.-Hil., Cambess. & A. Juss.) Radlk.	ARO	X	X	X	X	X
<i>Cupania oblongifolia</i> Mart.	ARO			X	X	X
<i>Cupania paniculata</i> Cambess.	ARO			X		
<i>Cupania racemosa</i> (Vell.) Radlk.	ARO	X	X	X	X	X
<i>Cupania revoluta</i> Radlk.	ARO			X	X	
<i>Cupania</i> sp.	ARO					X
<i>Paullinia pinnata</i> L.	TRE			X		X
<i>Paullinia trigona</i> Vell.	TRE		X		X	
<i>Serjania salzmanniana</i> Seem.	TRE			X		X
<i>Talisia esculenta</i> (A. St.-Hil) Radlk.	ARO	X		X	X	
<i>Talisia</i> sp.	ARO					X
Sapindaceae	TRE		X	X		
Sapotaceae						
<i>Pouteria grandiflora</i> (A.DC.) Baehni	ARO					X
<i>Pouteria peduncularis</i> (Mart. & Eichlerex Miq.) Baehni	ARO					X
<i>Pouteria</i> sp.	ARO					X
Sapotaceae	ARO			X		
Simaroubaceae						
<i>Simarouba amara</i> Aubl. ♦	ARO		X	X		X
Solanaceae						
<i>Solanum perum</i> Rich.	ARB			X		
<i>Solanum paludosum</i> Moric.	ARB	X			X	X
<i>Solanum</i> sp.	ARB	X				

Verbenaceae

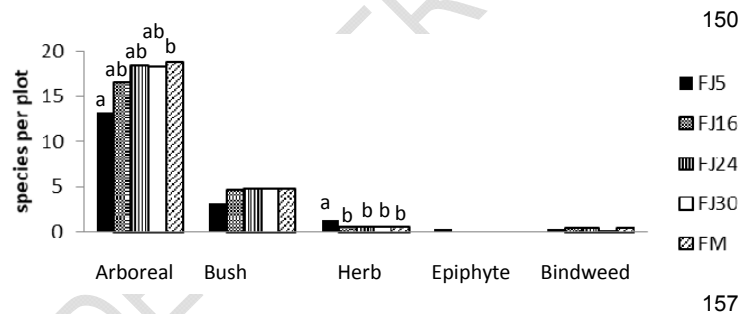
<i>Aegiphila pernambucensis</i> Moldenke.	ARB		X	
<i>Aegiphila vitelliniflora</i> Walpers.	ARB		X	
<i>Aegiphila</i> sp.	ARB	X		
<i>Lantana radula</i> Sw.	ARB	X		X
Violaceae				
<i>Amphirrhox longifolia</i> (A.St.-Hil.) Spreng.	ARO		X	
<i>Paypayrola blanchetiana</i> Tul.	ARO		X	X
Unknown 1	ERV		X	
Unknown 2	ERV		X	

Comment [AL4]: Does the empty cells in this table represent? And what does the X stand for? Please add it to the footnote

140
141
142
143
144
145
146
147
148
149

Significant differences were observed in terms of number of species in tree and herbaceous habits among the different ages studied (Fig. 1). There was a trend of increasing tree species and decreasing of herbs along the chronosequence, where mature forest had the highest number of species ($p < .02$) in relation to the young (5 years). In the chronosequence, another trend was observed, in which the richness of the herbaceous growth form decreased towards the mature forest, where the forest of the initial stage (5 years) presented the highest proportion, differing from the other forests studied ($p < .01$) (Fig. 1). In this way, it was observed that from 16 years after the abandonment the proportion of the growth forms were closer to the mature forest.

Comment [AL5]: This could be attributed to the canopy gaps in the 5 years forest as compared to the mature forest where the canopy is highly densed without allowing enough penetratration of sunlight to the forest floor.



158
159
160
161
162
163
164

Fig. 1. Average number of species per plot with different growth habits in four young forests (5, 16 and 24 and 30) and a mature forest. Letters indicate that the average within each habit do not differ by Tukey test ($P < 0.05$) and the same letter are not statistically different from each other. Young forests (FJ5 = 5 years = 16 years FJ16, FJ24 = 24, FJ30 = 30 years) and mature forest (FM).

Comment [AL6]: Footnote should be separated from the figure heading, foot note should give the interpretation of "a", "ab", "b"

Comment [AL7]: Write it properly

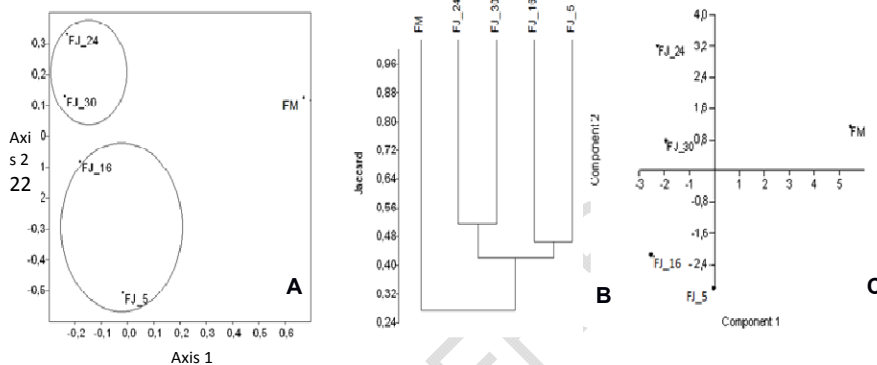
Comment [AL8]: Why does it not have an age? It could be 100 years or 200 years?

165
166
167
168
169
170
171
172

However, the analysis of TWINSpan (Table 1) identified in division 1 (eigenvalue 0.911) the mature forest area of the young forests. *Albizia polycephala*, *Artocarpus heterophyllus*, *Xylopia frutescens*, *Apeiba tibourbou* and *Vismia guianensis* were arboreal species indicative of young forests, as well as the *Acrocomia sclerocarpa* palm, which was also common in young forests. In the mature forest, only species with more advanced stages were found, such as *Pogonophora schomburgkiana*, *Simarouba amara*, *Guatteria schomburgkiana*, *Maytenus distichophylla*, *Dialium guianense* and *Lecythis pisonis* (Table 1). The species considered as indicators of mature forest are in agreement with several authors

173 [28,29], since they are species with similar habitat characteristics, being common in the inner
174 of forests and shaded areas.

175 NMDS analysis applied to the tree species in the chronosequence revealed the formation of
176 two groups, isolating the mature forest (FM) (Fig. 2A). The grouping analysis individualized
177 the mature forest (FM) and two groups, one formed by the young forests of 5 (FJ 5) and 16
178 years (FJ 16) of regeneration, with 46% similarity and a second formed by the young forests
179 of 24 (FJ 24) and 30 years (FJ 30), with 50% similarity (Fig. 2B). The two groups composed
180 of young forests (FJ 5 - FJ 16 and FJ 24 - FJ 30) differed from mature forest in floristic
181 composition with 28% similarity. This same pattern was also evident in the principal



182 component analyzes (PCA) (Fig. 2C).

183
184 **Fig. 2. Multivariate analysis based on the presence and absence of tree species**
185 **sampled in young and mature forest forests. Ordination by the not metric**
186 **multidimensional scaling method (NMDS) (A), cluster analysis generated by the**
187 **Jaccard similarity indices and average link method group (B) and principal**
188 **component analysis (C). Young forests (FJ_5 = 5 years FJ_16 = 16, FJ_24 = 24, FJ_30**
189 **= 30 years) and mature forest (FM).**

190

191 The results of all multivariate analyzes indicate the formation of two groups of young forests
192 (5 and 16 years old and another 24 and 30 years old), individualizing the mature forests. The
193 literature also points out that the recovery of floristic young forests occurs slowly [31,2].
194 Regarding this slowness, the fact that young forests and mature forest share 43 tree
195 species, 15 in all forests, suggests that the floristic composition of young forests tends to
196 converge with mature forest, as well as recorded in several researches in tropical forests
197 [2,32,33,34,30].

198 It can be hypothesized that the floristic convergence and the strong influence of the initial
199 floristic composition on the chronosequence flora in the fragments may be related to the fact
200 that this area presents more than 24% vegetation cover, since, according to [12], landscapes
201 above the threshold of 10-30% of covering tend to have positive effects on the persistence of
202 species, leading to different trajectories according to the size and connectivity of the
203 patches.

204

205 **4. CONCLUSIONS**

206

207

208

209

210

211

212

213

214

215

216

217

218

219

In the chronosequence studied at the São José Plant, it can be seen that from 16 years, young forests tended to converge with mature forest in proportion of tree and herbaceous species. The distribution of 43 tree species among young and mature forests suggests that the floristic composition of young forests tends to resemble that of mature forest, confirming the hypotheses of floristic convergence.

Floristic convergence may have been influenced by the São José Plant landscape, which has a 24% vegetation cover, facilitating the persistence of the species in the studied fragments. In addition to sharing 43 species, there were 15 species that were present at all ages, supporting the hypothesis of initial floristic composition, in which the species that participate in the succession over time are established from the beginning in the abandoned area.

220

COMPETING INTERESTS

221

222

Authors have declared that no competing interests exist.

223

224

REFERENCES

225

226

227

228

229

1. Denich M. Estudo da importância de uma vegetação secundária nova para o incremento da produtividade do sistema de produção na Amazônia Oriental Brasileira. Belém: Embrapa - CPATU/ GTZ; 1991.

230

231

232

233

2. Chazdon RL, Peres CA, Dent D, Sheil D, Lugo AE, Lamb D et al. The potential for species conservation in tropical secondary forests. *Conservation Biology*. 2009;23(6): 1406-1417. Doi: <https://doi.org/10.1111/j.1523-1739.2009.01338.x>

234

235

236

3. Chazdon, RL. Regeneração de florestas tropicais. *Boletim do Museu Paraense Emílio Goeldi. Ciências Naturais*. 2012;7(3): 195-218.

237

238

239

4. Clements FE. *Plant succession: analysis of the development of vegetation*. Washington, D.C.: Carnegie Institute of Washington Publication; 1916.

240

241

242

5. Gleason HA. The individualistic concept of the plant association. *Bulletin of the Torrey Botanical Club*. 1926;53(1): 7-26.

243

244

245

6. Egler FE. Vegetation science concepts I. Initial floristic composition, a factor in old-field vegetation development. *Plant Ecology*. 1954;4(10): 412-417.

246

247

248

7. Pickett STA, Collins SL, Armeto JJ. A hierarchical consideration of causes and mechanisms of succession. *Vegetatio*. 1987;69(1): 109-114.

249

250

251

252

8. Piotto D, Montagnini F, Thomas W, Ashton M, Oliver C. Forest recovery after swidden cultivation across a 40-year chronosequence in the Atlantic forest of southern Bahia, Brazil. *Plant Ecology*. 2009;205(2): 261-272. Doi: [doi: 10.1007/s11258-009-9615-2](https://doi.org/10.1007/s11258-009-9615-2).

253

254

255

256

9. Toledo M, Poorter L, Pena-Claros M, Alarcon A, Balcazar J, Chuvina J et al. Patterns and determinants of floristic variation across lowland forests of Bolivia. *Biotropica*. 2011;43(4): 405-413. Doi: [10.1111/j.1744-7429.2010.00711.x](https://doi.org/10.1111/j.1744-7429.2010.00711.x).

- 257 10. Harvey BJ, Holzman BA. Divergent successional pathways of stand development
258 following fire in a California closed-cone pine forest. *Journal of Vegetation Science*. 2014;25
259 (1): 88-99. Doi: <https://doi.org/10.1111/jvs.12073>.
260
- 261 11. Del Moral R, Saura JM, Emenegger JN. Primary succession trajectories on a barren
262 plain, Mount St. Helens, Washington. *Journal of Vegetation Science*. 2010;21(5): 857-867.
263 Doi: <https://doi.org/10.1111/j.1654-1103.2010.01189.x>.
264
- 265 12. Andr n H. Effects of habitat fragmentation on birds and mammals in landscapes with
266 different proportions of suitable habitat: a review. *Oikos*. 1994
267
- 268 13. IBGE – (Instituto Brasileiro de Geografia e Estatística). Manual t cnico da vegeta o
269 brasileira. Manuais t cnicos em Geoci ncias, 1. Rio de Janeiro: IBGE; 2012.
270
- 271 14. Trindade MB, Lins-e-Silva ACB, Silva HP, Filgueira, SB, Schessl M. Fragmentation of
272 the Atlantic Rainforest in the northern coastal region of Pernambuco, Brazil: recent changes
273 and implications for conservation. *Bioremediation, Biodiversity and Bioavailability*. 2008;2(1):
274 5-13.
275
- 276 15. Silva MAM. Efeito de borda na estrutura e na din mica espa o-temporal de um
277 fragmento de Mata Atl ntica no nordeste do Brasil. Recife: Universidade Federal Rural de
278 Pernambuco; 2010.
279
- 280 16. Filgueiras TS, Brochado AL, Nogueira PE, Guala II GF. Caminhamento: um m todo
281 expedito para levantamentos flor sticos qualitativos. *Cadernos de Geoci ncias*. 1994;12(1):
282 39-43.
283
- 284 17. Mori AS, Silva LAM, Lisboa G, Coradin L. Manual de manejo do herb rio fanerog mico.
285 Ilh us: Centro de Pesquisas do Cacau; 1989.
286
- 287 18. APG III. An update of the Angiosperm Phylogeny Group classification for the orders and
288 families of flowering plants: APG III. *Botanical Journal of the Linnean Society*. 2009;161(2):
289 105-121. Doi: <https://doi.org/10.1111/j.1095-8339.2009.00996.x>.
290
- 291 19. Hammer  , Harper DAT, Ryan PD. PAST: Paleontological statistics software package
292 for education and data analysis. *Paleont Electronica* 4: 9p.
293 http://www.paleoelectronica.org/2001_1/past/issue1_01.htm.
294
- 295 20. Brower JE, Zar JH. Field and laboratory methods for general ecology. 2 ed. Iowa, W.C.
296 Brown Company Publishes; 1984.
297
- 298 21. Jongman RHG, Ter Braak CJF, Van Tongeren OFR. editors. Data analysis in community
299 and landscape ecology, 2nd Edition. New York: Cambridge University Press. 1995; 71(3):
300 355-366.
301
- 302 22. Clarke KR, Warwick RM. Change in marine communities: an approach to statistical
303 analysis and interpretation. Plymouth: Plymouth Marine Laboratory; 1994.
304
- 305 23. Valentim JA. Ecologia num rica: uma introdu o a an lise multivariada de dados
306 ecol gicos. Rio de Janeiro: Interc ncia; 2000.
307
- 308 24. Mccune B, Mefford MJ. PC-ORD version 4.0: Multivariate analysis of ecological data –
309 users guide. MjM Software Design. Glaneden Beach; 1999.

- 311 25. Gómez-Pompa A, Vázquez-Yanes C. Successional studies of a rain forest in México. In:
312 West DC, Shugart HH, Botkin DB. (Eds.), Forest succession: concepts and application. New
313 York: Springer-Verlag; 1981.
314
- 315 26. Finegan B. Pattern and process in Neotropical secondary rain forests: the first 100 years
316 of succession. *Trends in Ecology and Evolution*. 1996;11(3): 119-124.
317
- 318 27. Spyreas G, Meiners SJ, Matthews JW, Molano-Flores B. Successional trends in floristic
319 quality. *Journal of Applied Ecology*. 2012;49(2): 339-348. Doi: doi: 10.1111/j.1365-
320 2664.2011.02100.x.
321
- 322 28. Alves Júnior FT, Brandão CFL, Rocha KD, Marangon LC, Ferreira RLC. Efeito de borda
323 na estrutura de espécies arbóreas em um fragmento de Floresta Ombrófila Densa, Recife,
324 PE. *Revista Brasileira de Ciências Agrárias*. 2006;1(1): 49-56.
325
- 326 29. Gomes JS, Lins-e-Silva ACB, Rodal MJN, Silva HCH. Estrutura do sub-bosque lenhoso
327 em ambientes de borda e interior de dois fragmentos de floresta atlântica em Igarassu,
328 Pernambuco, Brasil. *Rodriguésia*. 2009;60(2): 295-310.
329
- 330 30. Nascimento LM, Sampaio EVSB, Rodal MJN, Lins-e-Silva ACB. Natural forest
331 regeneration in abandoned sugarcane fields in northeastern Brazil: floristic changes. *Biota*
332 *Neotropica*. 2012;(12): 1-14. Doi: <http://dx.doi.org/10.1590/S1676-06032012000400009>.
333
- 334 31. Guariguata MR, Ostertag R. Neotropical secondary forest succession: changes in
335 structural and functional characteristics. *Forest Ecology and Management*. 2001;148(9):
336 185-206.
337
- 338 32. Letcher SG, Chazdon RL. Rapid recovery of biomass, species richness, and species
339 composition in a forest chronosequence in Northeastern Costa Rica. *Biotropica*. 2009;41(5):
340 608-617. Doi: <https://doi.org/10.1111/j.1744-7429.2009.00517.x>.
341
- 342 33. Norden N, Chazdon RL, Chao A, Jiang YH, Vilchez-Alvarado B. Resilience of tropical
343 rain forests: tree community reassembly in secondary forests. *Ecology Letters*. 2009;12(4):
344 385-394. Doi: <https://doi.org/10.1111/j.1461-0248.2009.01292.x>.
345
- 346 34. Nascimento LM, Sampaio EVSB, Rodal MJN, Lins-e-Silva ACB. Secondary succession
347 in a fragmented Atlantic Forest landscape: evidence of structural and diversity convergence
348 along a chronosequence. *Journal of Forest Research*. 2014;19(6):1-13. Doi:
349 <https://doi.org/10.1007/s10310-014-0441-6>.
350
351
352
353
354
355