

Forest restoration in an indigenous land considering a forest remnant influence (Avaí, São Paulo State, Brazil)

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Abstract

The expansion of agricultural and pasture areas over native forest areas has been broadly documented and represents the main cause of deforestation that has occurred for the last decades. Such reality is not different in indigenous lands, and has been considered as an important obstacle for individuals who directly depend upon the appropriate management of natural resources to maintain their traditions. We investigated the seed rain, seed bank and natural regeneration of native woody species within a degraded pasture land in different distances from an adjacent seasonal semideciduous forest fragment to define methodological procedures based on ecological processes that might subsidize forest restoration in an indigenous land. Most seeds and seedlings picked from the seed rain and seed bank belonged to anemochoric and autochoric dispersing shrubby and herbaceous species originated in the pasture land. The woody species regeneration, on the other hand, reached higher levels, in terms of abundance and richness, as the forest fragment became closer. Zoochoric dispersal was predominant among such species and was mainly detected closer to the forest fragment. Several woody species picked in the forest fragment were also found in the pasture land, thus reinforcing their important role in supplying propagules and easing the successional process.

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1. Introduction

Despite the fact that tropical forests are recognized as one of the biggest biodiversity containers in the world, they have been destroyed in a very alarming way (Holl, 1999). Most of such degradation has taken place in tropical regions in America, Africa and Asia, where the cutting down of native vegetation along with its burning up is a common practice applied in 30% of plowing soils (Bandy et al., 1994).

The destruction of areas with native vegetation has led to greater distances among remnant fragments, besides the drastic reduction on biodiversity, thus making it difficult to keep the contact with nearby populations and their sustainability. Continuous disturbance events generated from plowing, soil cultivation and deployment of agrochemicals in agricultural and pastoral areas are added to the above; that set of activities eventually changes the chemical-structural soil composition

significantly, as well as favors the increase of invader species populations that compete with native pioneer species, which can hardly settle down (Bormann and Likens, 1979; Quintana-Ascencio et al., 1996; Mortimer et al., 1998; Rivera et al., 2000). Moreover, the effects of such activities on ecosystem diversity and balance are known and many deforested areas for cultivation have been left behind after few years of usage because of either productivity dropdown or changes on rules to economic support programs (Uhl et al., 1988; Singleton et al., 2001).

As an attempt to reverse such scenario, many initiatives have been held in the last years to study and restore forests in those areas or implement less impacting production systems (Sanchez and Bandy, 1992; Lugo, 1995; Salick et al., 1995; Ruiz-Jaen and Aide, 2005).

Successional dynamics, through the elimination of disturbance factors and adoption of management techniques, has proved to be a very viable alternative on economic bases and recommendable in areas that have not been exposed to intense degradation (Rodrigues and Gandolfi, 1996). Under such conditions, the soil seed bank, the seed rain and the budding from stems and roots represent the main natural regeneration

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sources (Young et al., 1987), and quite often only need a stimulus to make the successional process start (Uhl et al., 1982; Willems and Bik, 1998). The simple protection of underground structures that may have remained in soil and are still able to bud might be enough to favor regeneration, mainly in areas that are affected with fire and subject to cutting (Nyerges, 1989; Kammesheidt, 1998).

In those areas where disturbance events destroyed their vegetation and seed bank, the proximity to forest fragments has proved to be an important facilitator to regenerate neighbour areas as these act as allochthonous propagule sources that are able to stimulate the successional dynamics (Cubiña and Aide, 2001; Martínez-Garza and González-Montagut, 2002).

The current research aimed to previously investigate the natural regeneration potential of a pasture land nearby a forest remnant and define the restoration methodology for the area by knowing its ecological processes, so that a future forest restoration project can be developed within the indigenous land.

The main questions that motivated the research were: (1) are there propagule sources that might be able to start the reconstruction process of a forest inside properly managed pasture lands in the Araribá indigenous land? and (2) can the presence of forest remnants grant or speed such process up, even in very fragmented pasture lands?

2. Material and methods

2.1. Study area

This research was carried out within the Araribá indigenous land (22°10', 22°20'S and 49°19', 49°23'W), 1930.39 ha total area, in Avaí, Sao Paulo State. The local climate is CB'cw, sub-humid, mesothermal, with low-humidity winters according to Thornthwaite System (Figueiredo and Sugahara, 1997). As the current research was developed, the annual mean temperature and precipitation rates were, respectively 22.3 °C and 1455 mm. The alternation of hot and cold months causes a strong seasonality, being December to February the hottest months and June to August the coldest ones. Rhodic Hapludox is the predominant low-fertility soil type in the region (Soil Survey Staff, 2003) resulting from very low-nutrient reserves; moreover, it

presents high phosphorus retention held by oxide minerals, low cation exchange capacity, sandy texture, high susceptibility to erosion and occurs in soft topographic sites.

The area was formerly covered with seasonal semideciduous forests, but from the beginning of the 20th century both lumber exploitation and coffee culture started to deforest it. Except a 9.42 ha forest fragment, only shrubs and scattered trees remained from the original forest. The most extensive deforestation took place 12 years before the current research was carried out, at the time when the area was rendered to intensive cassava cultivation, which is a very soil impacting activity. Nowadays these areas have been used as pasture lands and only some secondary forest fragments have remained. Even if no species had been planted in the area since that, the deforested area was completely covered by the African grasses *Urochloa brizantha* and *Rhyncheiyrum repens*, probably introduced by the excrement of cattle coming from neighbouring pastures. Two rivers cross the indigenous land and, despite their importance to the community activities and agriculture, their volume and flow capacity have been gradually smaller as a consequence of gallery forest deforestation and marginal sand filling.

Problems generated from the deforestation at the Araribá indigenous land, together with subsistence difficulties, have worried local inhabitants for many years and people thus started to think of the need of a forest restoration that could represent not only a way to expand the ongoing subsistence sources, but also to grant the perpetuation of their cultural identity, values and traditions that are strongly linked to the forest.

In order to subsidize the future forest restoration in the indigenous land, two areas (A and B) next to the least disturbed forest fragment were chosen for regeneration evaluation and subsequently fenced to avoid cattle influence in the experiment. In each area, eighteen 15 m × 20 m plots were established, making up 36 plots (10,800 m²). Plots were located at three distances (50, 120 and 230 m) from the forest fragment, to test their influence (Fig. 1). For statistical purposes, the three distances were randomly defined among the intervals 0–100 m, 100–200 m and 200–300 m from the forest fragment. These intervals were arbitrarily determined. From time to time, herbaceous species that could be abundantly found inside the plots were mowed. Seed bank, seed rain and regeneration were investigated within all plots.

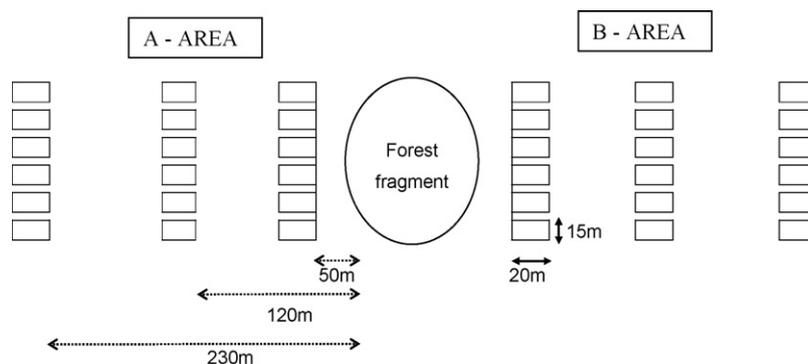


Fig. 1. Schematic representation of the plot distribution grid inside the Araribá indigenous land.

2.2. Seed rain

A 1.0 m × 1.0 m × 0.1 m box was placed in the center of each plot (18 m² each area). Boxes had 10 cm-high support bases, with wooden sides and nylon screened bottoms. Seeds were collected every 2 months in each area, for 18 months. The Student *t*-test and analysis of variance (ANOVA) (Zar, 1999) were used to check both the seasonality and collection area effect over the richness and abundance rates of the propagules.

2.3. Seed bank

The seed bank was studied by applying the seedling emergence method (Graham and Hopkins, 1990; Roizman, 1993). Twice a year, by the end of the rainy and dry seasons, 5 soil samples were randomly collected in each of the 36 plots with a spade and a metal shape (0.15 m × 0.15 m width × 3.0 cm depth). In 2 years, 720 soil samples (16.2 m² total) were collected. Soil samples were laid into disposable aluminum trays in a transparent plastic-cover greenhouse with frequent irrigation. Seedlings from the seed bank were observed in the greenhouse for 6 months, identified and then cast off trays. The analysis of variance (Zar, 1999) was applied to check both the seasonality and collect area effect over the richness and abundance rates of the propagules.

2.4. Regeneration

Twice a year, by the end of the rainy and dry seasons, all the woody plants present in the 36 20 m × 15 m-plots were quantified and had their total height measured, for 2 years. The Student *t*-test and the analysis of variance were used for double and multiple comparisons. When data dispersion was too high, the non-parametric Friedman test (Zar, 1999) was used.

The diversity rate was calculated by applying Shannon (*H'*) and Simpson (*D*) indexes (Magurran, 1996). Taxonomic identification followed rules set by the Angiosperm Phylogeny Group II (2003). Species were classified according to habits (Mori et al., 1989) and dispersion syndromes (van der Pijl, 1982). The similarity Jaccard index was applied to compare data from the seed rain, seed bank and regeneration composition. Some fertile specimens of each species were treated and donated to UEC, ESA, UNBA and BAUR herbaria. The absolute density was calculated using the formula: total seed number of each species/18 m² (seed rain); total seedling number of each species/16.2 m² (seed bank); and total individual number of each species/1.08 ha (regeneration). Results from areas A and B were considered together in graphs.

3. Results and discussion

3.1. Seed rain

A total of 241,802 seeds belonging to 39 species were surveyed in the pasture land for 18 months. That figure represented 13,433.45 seeds/m². The African exotic grasses *R. repens* and *U. brizantha* (Poaceae) were the most abundant

species, followed by *Vernonia polyanthes* (Asteraceae) and *Sida* sp. (Malvaceae). These species represented 95% of the seed rain altogether. *R. repens* propagates by seeds and its abundance in the studied area can be associated with its preference for nutritionally poor soil. *U. brizantha* can be used as forage but becomes an aggressive invader when present in cultivated soil (Kissmann, 1997; Lorenzi, 2000). Invader species, represented by herbs, subshrubs, shrubs and non-woody lianas (climbers), held the highest richness (60%) and abundance (97.6%) rates. Only seven species and 0.05% of the propagules, all of these belonging to the first successional stages (Table 1), showed arboreal habits. All of these arboreal species were found in the neighbouring forest fragment, except *Ricinus communis* and *Syagrus romanzoffiana*, only found in the pastures around the forest.

Propagules were dispersed mainly through anemochory (55.4%) and autochory (44.5%) (Table 1). From the amount of identified species, 41.2% were anemochoric, 32.3% were autochoric and 26.5% were zoochoric. Despite other researches carried out within forest areas, at the indigenous land most anemochoric species were lianas and only 5% of the species were arboreal.

The total seed density rate (241,802 seeds/18 m²/18 months = 746.30 seeds/m²/month) was quite superior to that found in other Brazilian forests (Penhalber and Mantovani, 1997; Grombone-Guaratini and Rodrigues, 2002; Sorreano, 2002), where densities reached 150.35, 36.81 and 97.12 to 146.53 seeds/m²/month, respectively. This reinforces the idea that at disturbed areas the seed rain is more abundant than in forest areas, probably due to the prevalence of pioneer or invader species, characterized by the intense seed production. Although the number of propagules and species had gone up along time, diversity did not show any proportional growth and in some cases its rate went down as a consequence of the growing dominance of some species after the area was protected (Table 2).

We did not find a significant difference between the seed rain occurring in areas “A” and “B”. The significance level was $p = 0.23$, although propagules were almost twice as many in area “A” than in area “B” at 230 m. At 50 and 120 m, the mean number of collected propagules was pretty close in both areas, respectively $p = 0.47$ and 0.36 .

As most surveyed propagules originated from herbaceous species, there was not a significant influence of the distance from the forest fragment over the density or propagules from the seed rain, both in area “A” ($F = 0.42$; $gl = 2$; $p = 0.66$) and area “B” ($F = 1.23$; $gl = 2$, $p = 0.32$). Considering that primary and secondary dispersal and predation processes involve great spatial and temporal heterogeneity, the number and distribution of collectors might not have been enough to grasp incoming propagules. Seed density becomes perceptibly lower as the distance from the matrix tree gets higher (Alvarez-Buylla and Martínez-Ramos, 1990; Dalling et al., 1998; Barot et al., 1999) and that possibly hampered dispersal to the pasture spot where collecting boxes had been placed, at 50, 120 and 230 m off fragment. Although wind and vertebrates may disperse some seeds to long distances (Willson and Crome, 1989), in Holl’s

Table 1
Density of seeds, seedlings and regenerating individuals in pasture areas at the Araribá indigenous land

Species	DS	Seed rain (seeds/m ²)	Seed bank (seedlings/m ²)	Regeneration		
				Density (plants/ha)	Initial height (m)	Last** height (m)
Trees, palms						
<i>Acacia polyphylla</i> DC.	ANEMO	0.06	–	34.26	1.70 ± 0.00	3.35 ± 2.05
<i>Acrocomia aculeata</i> (Jacq.) Lodd. ex Mart.	ZOO	–	–	1.85	0.38 ± 0.17	–
<i>Actinostemon conceptionis</i> (Chodat and Hassl.) Hochr.	AUTO	0.06	–	0.93	0.30 ± 0.00	–
<i>Aloysia virgata</i> (Ruiz and Pav.) Juss.	ANEMO	–	–	19.45	2.45 ± 1.62	3.75 ± 0.78
<i>Casearia gossypiosperma</i> Briq.	ANEMO	–	–	2.78	0.90 ± 0.00	0.85 ± 0.00
<i>Casearia sylvestris</i> Sw.	ZOO	–	–	1.85	–	0.70 ± 0.00
<i>Cedrela fissilis</i> Vell.	ANEMO	0.28	–	–	–	–
<i>Centrolobium tomentosum</i> Guillemain ex Benth.	ANEMO	–	–	3.70	0.40 ± 0.00	0.70 ± 0.00
<i>Cordia ecalyculata</i> Vell.	ZOO	–	–	14.81	1.18 ± 0.04	2.20 ± 0.71
<i>Croton floribundus</i> Spreng.	AUTO	–	0.12	–	–	–
<i>Dalbergia frutescens</i> (Vell.) Britton	ANEMO	–	–	0.93	1.60 ± 0.00	–
<i>Gochmatia polymorpha</i> (Less.) Cabrera	ANEMO	–	–	3.70	1.50 ± 0.00	2.30 ± 0.00
<i>Luehea candicans</i> Mart.	ANEMO	–	–	0.93	–	0.40 ± 0.00
<i>Machaerium brasiliense</i> Vogel	ANEMO	–	–	0.93	–	1.60 ± 0.00
<i>Machaerium hirtum</i> (Vell.) Stellfeld	ANEMO	–	–	18.52	0.70 ± 0.42	1.63 ± 0.58
<i>Machaerium stipitatum</i> (DC.) Vogel	ANEMO	–	–	0.93	–	1.60 ± 0.00
<i>Psidium guajava</i> L.	ZOO	0.22	–	–	–	–
<i>Platygodium elegans</i> Vogel	ANEMO	–	–	39.81	1.20 ± 0.99	1.58 ± 0.59
<i>Pterogyne nitens</i> Tul.	ANEMO	–	–	0.93	0.60 ± 0.00	–
<i>Rhamnidium elaeocarpum</i> Reissek	ZOO	–	–	0.93	–	1.60 ± 0.00
<i>Ricinus communis</i> L.	AUTO	3.28	0.06	114.81	0.63 ± 0.11	2.05 ± 0.01
<i>Strychnos brasiliensis</i> (Spreng.) Mart.	ZOO	–	–	5.56	0.60 ± 0.28	0.65 ± 0.21
<i>Syagrus romanzoffiana</i> (Cham.) Glassman	ZOO	0.06	–	–	–	–
<i>Tabebuia chrysotricha</i> (Mart. ex A. DC.) Standl.	ANEMO	–	–	2.78	0.90 ± 0.00	–
<i>Tabernaemontana catharinensis</i> A. DC.	ZOO	–	–	162.96	1.14 ± 0.24	2.20 ± 0.66
<i>Trema micrantha</i> (L.) Blume	ZOO	2.22	–	–	–	–
Shrubs and subshrubs						
<i>Ambrosia polystachya</i> DC.	ANEMO	–	–	129.63	1.30 ± 0.00	1.70 ± 0.00
<i>Baccharis dracunculifolia</i> DC.	ANEMO	–	–	65.74	1.02 ± 0.34	2.07 ± 0.15
<i>Cestrum strigilatum</i> Ruiz and Pav.	ZOO	–	–	1.85	0.70 ± 0.00	1.40 ± 0.00
<i>Cestrum</i> sp.	ZOO	0.06	–	–	–	–
<i>Eupatorium cf. squalidum</i> DC.	ANEMO	–	–	13.89	1.07 ± 0.38	1.63 ± 0.45
<i>Heliotropium transalpinum</i> Vell.	ZOO	–	–	11.11	0.40 ± 0.00	–
<i>Indigofera suffruticosa</i> Mill.	AUTO	–	–	6.48	0.50 ± 0.00	1.70 ± 1.13
<i>Lantana camara</i> L.	ZOO	–	–	14.81	0.75 ± 0.35	1.93 ± 0.55
<i>Marsypianthes</i> sp.	AUTO	18.67	–	105.56	1.95 ± 0.07	1.79 ± 0.18
<i>Solanum paniculatum</i> L.	ZOO	2.26	–	1007.41	1.49 ± 0.09	1.84 ± 0.17
<i>Solanum</i> sp.	ZOO	0.17	–	–	–	–
<i>Stylosanthes guyanensis</i> (Aubl.) Sw.	ZOO	25.06	5.37	–	–	–
<i>Tournefortia rubicunda</i> Salzmann ex DC.	ZOO	–	–	34.26	1.50 ± 0.54	2.40 ± 0.00
<i>Triumfetta bartramia</i> L.	ZOO	8.39	0.18	129.63	1.47 ± 0.67	1.35 ± 0.35
<i>Vernonia chamissonis</i> Less.	ANEMO	–	–	93.52	0.45 ± 0.07	1.86 ± 0.05
<i>Vernonia polyanthes</i> Less.	ANEMO	706.06	–	106.48	1.20 ± 0.00	1.97 ± 0.18
<i>Vernonia</i> sp.	INDET	–	–	368.52	0.85 ± 0.78	1.02 ± 0.33
<i>Wissadula subpeltata</i> (Kuntze) R.E.Fr.	AUTO	1.83	–	31.48	1.93 ± 0.75	0.9 ± 0.00
sp. 1	AUTO	–	0.31	–	–	–
sp. 2	ANEMO	–	3.34	–	–	–
Climbers						
<i>Temnadenia</i> sp.	ANEMO	0.17	–	*	*	*
sp. 1	ANEMO	14.72	–	*	*	*
sp. 2	ANEMO	0.89	–	*	*	*
sp. 3	ANEMO	0.11	–	*	*	*
Herbs and subshrubs						
<i>Axonopus aff. capillaris</i> (Lam.) Chase	ANEMO	–	0.62	*	*	*
<i>Bidens pilosa</i> L.	ZOO	0.67	0.49	*	*	*
<i>Commelina benghalensis</i> L.	AUTO	–	4.45	*	*	*
<i>Croton glandulosus</i> L.	AUTO	–	0.06	*	*	*
<i>Cynodon cf. dactylon</i> (L.) Pers.	ANEMO	–	1.05	*	*	*
<i>Cyperus cayennensis</i> Willd. ex Link	AUTO	–	87.78	*	*	*

Table 1 (Continued)

Species	DS	Seed rain (seeds/m ²)	Seed bank (seedlings/m ²)	Regeneration		
				Density (plants/ha)	Initial height (m)	Last ^{**} height (m)
<i>Cyperus sesquiflorus</i> (Torr.) Mattf. and Kük.	AUTO	–	5.93	*	*	*
<i>Digitaria insularis</i> (L.) Fedde	ANEMO	221.22	0.43	*	*	*
<i>Emilia sonchifolia</i> (L.) DC.	ANEMO	–	0.18	*	*	*
<i>Eragrostis ciliaris</i> (L.) R. Br.	ANEMO	–	23.89	*	*	*
<i>Eustachys distichophylla</i> (Lag.) Nees	ANEMO	21.28	–	*	*	*
<i>Gnaphalium purpureum</i> L.	ANEMO	–	42.04	*	*	*
<i>Hyptis</i> sp.	AUTO	13.17	–	*	*	*
<i>Mimosa</i> sp.	INDET	–	0.06	*	*	*
<i>Panicum maximum</i> Jacq.	AUTO	15.83	–	*	*	*
<i>Porophyllum ruderale</i> (Jacq.) Cass.	ANEMO	–	0.86	*	*	*
<i>Portulaca fluviatilis</i> D. Legrand.	AUTO	–	92.41	*	*	*
<i>Portulaca halimoides</i> L.	AUTO	–	8.21	*	*	*
<i>Portulaca oleracea</i> L.	AUTO	–	1.91	*	*	*
<i>Portulaca</i> sp.	AUTO	0.28	–	*	*	*
<i>Richardia brasiliensis</i> Gomes	AUTO	–	0.06	*	*	*
<i>Rhynchelytrum repens</i> (Willd.) C. E. Hubb.	ANEMO	6167.44	22.78	*	*	*
<i>Sida</i> sp.	AUTO	670.67	82.90	*	*	*
<i>Urochloa brizantha</i> (Hochst. ex A. Rich.) R. D. Webster	AUTO	5224.44	49.07	*	*	*
<i>Waltheria indica</i> L.	AUTO	0.22	–	*	*	*
sp. 1	INDET	–	0.06	*	*	*
sp. 2	ANEMO	1.39	–	*	*	*
sp. 3	ANEMO	–	0.18	*	*	*
Indeterminate						
Asteraceae	INDET	304.44	–	*	*	*
sp. 1	INDET	0.22	–	*	*	*
sp. 2	INDET	0.22	–	*	*	*
sp. 3	INDET	0.06	–	*	*	*
sp. 4	INDET	3.89	–	*	*	*
sp. 5	INDET	0.94	–	*	*	*
sp. 6	INDET	1.89	–	*	*	*
sp. 7	INDET	0.39	–	*	*	*
sp. 8	INDET	0.22	–	*	*	*
sp. 9	INDET	–	2.72	*	*	*
sp. 10	INDET	–	–	1.85	0.40 ± 0.31	–
Total		13,433.45	437.52	2555.57		

Species included in the survey but not found were marked with (–). Species not included in the regeneration survey were marked with (*). The last height was measured 2 years after the initial survey (**). The mean height was only calculated for regenerating individuals. DS, dispersion syndrome; ANEMO, anemochory; ZOO, zoochory; AUTO, autochory; INDET, indeterminate.

Table 2
Seed rain, seed bank and regeneration diversity according to time

Months (seasons)	Seed rain (3, 8, 15 and 20 months after)					Seed bank (0, 6, 18 and 24 months after)					Regeneration ^a (0, 6, 12, 18 and 24 months after)				
	Spp.	Seeds	H'	J	1 – D	Spp.	Seedl	H'	J	1 – D	Spp.	Plants	H'	J	1 – D
0–03 (ERS)	6	239	1.24	0.69	0.67	23	1,909	2.04	0.65	0.85	18	89	2.02	0.75	0.81
06–08 (EDS)	8	1,981	0.75	0.36	0.37	17	1,786	1.70	0.60	0.76	25	222	1.80	0.61	0.69
12–15 (ERS)	10	32,117	1.15	0.50	0.67	–	–	–	–	–	37	578	2.08	0.64	0.77
18–20 (EDS)	12	3,409	0.28	0.11	0.10	19	1,466	1.68	0.56	0.75	41	804	2.20	0.66	0.79
24 (ERS)	–	–	–	–	–	21	1,927	2.22	0.73	0.87	45	1,067	2.30	0.67	0.83

Spp., species number; Seedl, seedling number; H', Shannon diversity; J, Jaccard equitability; D, Simpson diversity; ERS, end of rainy season; EDS, end of dry season.

^a Only woody species were considered.

work (1999) berry-like fruit species had been rarely found in pasture lands farther than 10 m from the forest remnant margin.

The influence of forest fragments in the regeneration of nearby pasture lands is commonly more important when some remaining arboreal individuals exist in the pasture land

(Robinson and Handel, 1993) and can offer landing and nidifying spots, protection and food to disperser animals. Forest dwelling animals are important dispersing vectors throughout pasture lands, but they do not always risk their lives in open areas (Cardoso da Silva et al., 1996). In the studied area, this

influence was not so strong because the majority of woody plants present in the pasture only reached an arboreal size at the end of the experiment.

3.2. Seed bank

A total of 29 species and 7088 seedlings (437.5 seedlings/m²) (Table 1) found in the seed bank next to the forest fragment were surveyed in 2 years. The most abundant species were *Portulaca fluvialis* (Portulacaceae), *Cyperus cayennensis* (Cyperaceae), *Sida* spp. (Malvaceae), and *U. brizantha* (Poaceae), all of these invader, herbaceous or subshrubby species typically found in pasture lands (Lorenzi, 2000). The most abundant families were Poaceae (121.91 seedlings/m²), Cyperaceae (117.59 seedlings/m²), Portulacaceae (95.12 seedlings/m²) and Malvaceae (82.90 seedlings/m²), whereas Poaceae (seven species) and Asteraceae (five species) presented the highest specific richness. Most species (81.5%) and individuals (99.5%) were herbaceous and subshrubby and only three species and 0.5% of the individuals were shrubs and trees.

Soil seed density is commonly much higher in disturbed areas than in tropical forests (Whitmore, 1983; Garwood, 1989; Jerry, 1992). In 90% out of 64 seed bank surveys carried out in tropical forests, Garwood (1989) found a density rate of 2–1000 seeds/m², whereas around 60% of the surveys carried out in disturbed or cultivation areas presented rates above 1000 seeds/m². However, the conversion of forests into pasture lands and the constant use of fire for their maintenance can bring out a drastic reduction on the seed bank density and richness, leading to the dominance of invader species (Uhl et al., 1982; Rico-Gray and Garcia-Franco, 1992; Miller, 1999), like the ones being found abundant in the present study.

Breeding animals also propitiates the development of such species, mainly because the root system of the species that were formerly in that place is destroyed. In such cases when both the seed bank and bud-making vegetative structures are destroyed, regeneration starts to exclusively depend upon either immigrant species (Janzen and Vásquez-Yanes, 1988) or the introduction of species that may help a forest to recover (Jerry, 1992).

The Araribá indigenous land presents a disturbance history that features the cutting-down of its original forest vegetation and its subsequent replacement for impacting agricultural and pastoral systems, which represented the main seed bank-modifying and soil fertility/structure-modifying factor (Bertoncini, 2003). The subsequent use of the area as a pasture land and common burning practices favoured the establishment of invader species and jeopardized the seed bank diversity and richness. In comparison with other works carried out in native tropical forests (Baider et al., 1999; Grombone-Guaratini and Rodrigues, 2002; Sorreano, 2002) and cultivated forests (Moura, 1998), the current research has shown the lowest species richness rate, despite sampling time, collect abundance and sampling area were one of the biggest.

Shannon's diversity index was higher during the rainy season and went up to 2.04–2.22, whereas it varied from 1.68 to 1.70 during the dry season (Table 2).

Autochory (50%) and anemochory (38%) were the main dispersal syndromes that have been found among emerging seedlings, from which 76.7% showed autochory, 21.9% anemochory and only 1.4% zoochory (Table 1). That was a predictable result when we consider that, within disturbed environments, the low number of disperser animals may hamper the area regeneration if species were zoochoric. Under disturbance situations, zoochoric species tend to go down in number whilst anemochoric species become more abundant (Janzen and Vásquez-Yanes, 1991).

Croton floribundus and *R. communis* were the only arboreal species of the seed bank. The first one probably came from the nearest forest fragment where it is one of the most abundant species and the second from the pastures nearby (Bertoncini, 2003). There was not a significant influence of the distance from the forest fragment on the seed bank in areas "A" ($F = 1.74$; $gl = 2$; $p = 0.25$) and "B" ($F = 1.96$; $gl = 2$; $p = 0.22$). The scarcity of arboreal representatives in the sampling may have occurred because samples were collected only at distances further than 50 m from the forest remnant. At such distance, detecting very heterogeneous processes in time and space, i.e., dispersal and establishment of arboreal species, becomes a more difficult task. Moreover, seed banks are usually dominated by herbaceous species in tropical areas, independently of its vegetal formation. Seeds of late secondary arboreal species are usually big and do not present any dormancy mechanism, whereas seeds of both ruderal and climber species may remain in soil and build a relatively rich flora during disturbance periods (Janzen and Vásquez-Yanes, 1988). When arboreal species are represented in the bank, these are usually pioneer species and occur in numbers that are very often not enough to let the forest reestablish its structure (Janzen and Vásquez-Yanes, 1991).

3.3. Regeneration

Protection against cattle grazing and trampling provided an expressive increment in the number of species and individuals, mainly that of invader species that are frequently found in disturbed areas. A total of 37 species and 2760 woody regenerating plants (2555.56 individuals/ha) were surveyed in the pasture land in 2 years. There were no significant differences between areas "A" and "B".

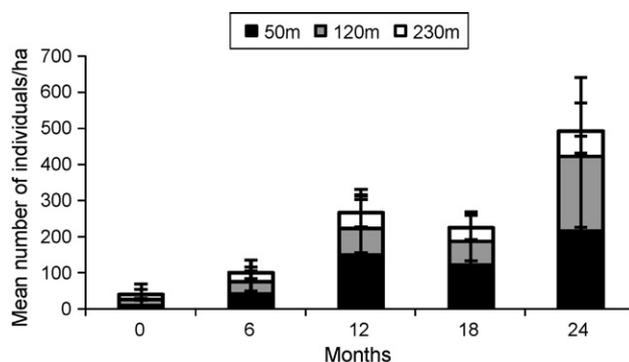


Fig. 2. Mean number of woody individuals according to the forest fragment distance and the time.

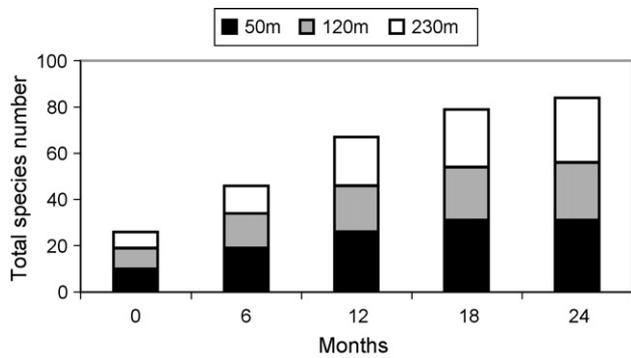


Fig. 3. Species richness according to the time and the forest fragment distance.

The abundance rate increased significantly in time (Fig. 2) in both areas “A” ($F = 18.72$, $gl = 4$, $p = 0.0004$) and “B” ($F = 5.48$, $gl = 4$, $p = 0.02$) after cattle was isolated. Most species showed an increase in total height in the course of time. Pioneer and invader species presented the greatest height increase (Table 1). The number of species increased progressively (Table 2) and was greater in the nearest areas to the forest fragment (Fig. 3).

Woody invader species presented the greatest abundance and richness rates, the shrub *Solanum paniculatum* L. (Solanaceae) (Table 1), being a true highlight. Dispersed by bats, frequently found in opened areas, this species can also be propagated by rhizomes sprouting, mainly after cutting, which explains its great abundance in the studied area (Kissmann, 1997). Other abundant species were *Tabernaemontana catharinensis* A. DC. (Apocynaceae) and the exotic *R. communis* L. (Euphorbiaceae), both invaders and considered as tree-like species. The *T. catharinensis* abundance can be associated with its tolerance of nutritionally poor soil and its capacity of propagation by underground structures sprouting, as well as by seed dispersal (ornithochory). The dispersion of seeds by fruit explosion is the main responsible for the *R. communis* abundance in warm and luminous areas (Kissmann, 1997). Less abundant but not less important were *Platypodium elegans* Vogel, *Acacia polyphylla* DC., *Aloysia virgata* (Ruiz and Pav.) Juss., *Machaerium hirtum* (Vell.) Stellfeld and *Cordia ecalyculata* Vell., species probably originated from the nearest forest fragment, where they were equally found (Bertoncini, 2003).

The abundance of pioneer and invader species decreased with the forest fragment distance in areas “A” ($F = 8.59$, $gl = 2$, $p = 0.01$) and “B” ($F = 4.87$, $gl = 2$, $p = 0.04$). To the last successional species, it was only true in area “B” ($F = 28.90$, $gl = 2$, $p = 0.0002$).

Various studies, mainly those ones related to seed rain (Gorchov et al., 1993; Cubiña and Aide, 2001; Martínez-Garza and González-Montagut, 2002), have reported the influence of distance from forest fragments on the colonization of nearby areas. Usually, these studies have stated that the areas closer to forest fragments may have higher colonization possibilities than isolated areas, for disperser agents visit them more often and present higher propagule sources. Birds and bats particularly play a special role in this process because they can connect forest fragments and disperse both pioneer and

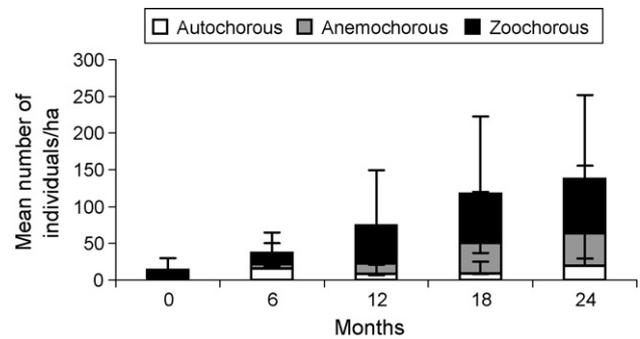


Fig. 4. Mean number of woody individuals according to the dispersal syndrome and the time.

primary species, thus bringing contributions to the area diversity (Galindo-González et al., 2000).

Among regenerating plants, zoochory was a highlight and the most abundant dispersal syndrome (57.5%) in both areas “A” ($F = 11$, $gl = 2$, $p = 0.0001$) and “B” ($F = 3.76$, $gl = 2$, $p = 0.03$), followed by anemochory (28.6%) and autochory (13.9%) (Fig. 4). In another study, carried out in the adjacent forest fragment, zoochory (59.3%) and anemochory (36.3%) were also the predominant dispersal syndromes, considering only shrubby-arboreal species (Bertoncini, 2003). Among the regenerating species of the pasture land, 50% were anemochoric, 36.1% zoochoric and 13.9% autochoric. For the three-dispersal syndrome the abundance rate decreased according to the forest fragment distance (Fig. 5), but only in zoochoric regenerating species it was statistically significant (area “A”: $F = 7.93$, $gl = 2$, $p = 0.01$ and area “B”: $F = 4.43$, $gl = 2$, $p = 0.05$). The increase of zoochory during the regenerating process, which was observed in the current work and in other studies carried out in forest areas (Tabarelli and Mantovani, 1999), has been related to a higher resource offer in this period.

Besides all of the mentioned difficulties to detect forest remnant species in the seed rain and seed bank when considering the distance in which samples were collected, we present the testable hypotheses that woody and zoochoric species have some advantage when establishing on an area so that the few individuals originated from the seed rain may pile up over the regenerating vegetation.

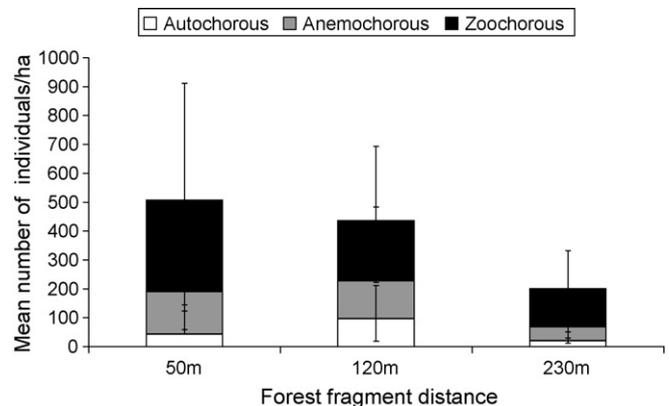


Fig. 5. Mean number of woody individuals according to the dispersal syndrome and the forest fragment distance.

Another explanation to the weak similarity among seed rain, seed bank and regeneration species can be partly given because the seed rain and, to some extent, the seed bank are point-centered processes that generally occurred weeks or months ago, whereas the survey on regenerating species reflects what has occurred for years. Thus, part of the woody regenerating species was already in the area as the first sampling was carried out and probably originated through direct or indirect dispersal with birds, bats or cattle itself, which had been in transit within the area some years before the current study. Budding from underground vegetative structures, though less probable to happen due to the kind of cultivation in the place, might have also contributed to the regenerating process. According to Bormann and Likens (1979), the floristic composition at the time abandonment occurred, in areas where trees had been cut down and in abandoned pasture lands, was responsible for 95% of the vegetation developed afterwards.

Despite adverse conditions under which succession has taken place, related mainly to soil degradation and removal of the original forest cover, diversity and specially abundance of woody regenerating individuals within the indigenous pasture land have shown the regeneration potential in the area when disturbance factors, like cattle and fire, are eliminated. The significant effect of the forest remnant vicinity on established plants reinforces the participation of the fragment and highlights the importance of maintaining propagule sources near one to another to regenerate disturbed areas.

The establishment of the shrubby-arboreal vegetation on the pasture land, though predominantly represented by pioneer or invader species, may supply birds and bats that are in transit among fragments with resting sites, protection and food sources and favor the increment of the seed rain and local diversity. Not only are such regeneration cores important recruitment sites (Guevara and Laborde, 1993; Galindo-González et al., 2000; Holl et al., 2000; Ortiz-Pulido et al., 2000; Slocum and Horvitz, 2000; Carrière et al., 2002; Zanini and Ganade, 2005), but they can also favor the establishment of forest species for they modify both local edaphic and microclimatic conditions, provide higher litter stacking, higher possibilities of interaction with mycorrhizae and light levels, humidity and nutrient supply which are more appropriate to germination and growth of new species (Nepstad et al., 1991; Vieira et al., 1994; Holl, 2002).

Other actions that would speed such process up and be implemented by local inhabitants themselves comprehend the digging up of non-regenerating area soils to stimulate germination in the seed bank, and the monitoring of woody individuals through pruning and crowning up to the point when canopy shading starts to inhibit the development of invader herbaceous species. The introduction of late successional species and even species that could potentially be used for handicraft activities and the extraction of non-timber forest products, which in turn would contribute to the local economy and uplifting of the indigenous culture, might enrich diversity afterwards.

It can be concluded that the preservation of forest remnants can intensely contribute to the regeneration process in properly managed areas, and would certainly prevent most costs and

risks involved in the introduction of species during forest re-composition projects.

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