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Original Article

Conservation of Nature

Seed Bank from Abandoned Pastures in the Coastal Region of Paraná

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ABSTRACT

The aim of the present study was to evaluate the seed bank of three contiguous areas: pasture abandoned for ten years, with soil amended by partial beheading for two years at horizon A (area I); pasture identical to the previous example, but with recent mobilization of the topsoil (area II); area in the early stages of regeneration (area III). Field work was conducted in Morretes-PR, in an area of evergreen rain forest. In November 2013, seed bank samples were collected from ten points per area (0.30 × 0.30 m) and at three depths (0-3 cm + litter, 3.1 to 6.0 cm and 6.1 to 9.0 cm). We obtained 25.151 seeds m^{-2}, distributed between 85 species. The predominant life form was herbaceous (98%), with the Cyperaceae family being the most abundant. In the seed banks of the three areas, only a few seeds from a restricted number of woody species were found, which therefore, represents a limited resource for forest restoration purposes.

Keywords: rain forest, inhibitory grasses, *Urochloa*.

1. INTRODUCTION

Most regeneration of degraded ecosystems takes place in open areas that were abandoned or previously used as pasture (Sparovek et al., 2011). Grasses that grow aggressively modify the environment to such an extent that they impair seedling recruitment (Carpanezzi, 2005). In areas with a high degree of disturbance, seed rain contributes very little to forest succession (Myers & Harms, 2009) and the soil's seed bank is the main regeneration mechanism (Vieira & Pessoa, 2001).

A seed bank is defined as the stock of viable seeds present in the soil that accumulates over time through a dynamic input and output system, which varies according to species, consisting of transient and persistent banks (Thompson & Grime, 1979). The persistent bank is made up of dormant seeds, while the transient bank consists of seeds that germinate one year or less after dispersion (Leal et al., 2013). Input into this system includes seed rain, and soil turnover mechanisms, while the main exit routes are germination, physiological death, and transfer to deeper soil layers (Martins & Engel, 2007).

The rate of natural regeneration depends on factors such as availability of soil propagation material, the covering capacity of pioneer species, growth capacity and forage permanence, time of abandonment of the area, and soil disturbances (Cheung et al., 2009). In pastures with long periods of use under inadequate management practices, such as intensive use of heavy machinery, "supergrazing", and systematic herbicide application (Holl, 1999; Lanzanova et al., 2007), there is greater soil compaction and loss of surface layers, which reduces the amount of viable seeds in the seed bank and promotes unsustainable conditions for germination (Dias-Filho, 2006).

Studies into the influence of pastures on the availability of native and sub spontaneous species in the soil allow for the evaluation of the resilience potential of areas undergoing different types of disturbance (López-Toledo & Martínez-Ramos, 2011). The use of such information to manipulate natural processes for the benefit of applied purposes is of great importance considering the continuation of the expansion of anthropic landscapes in the tropics (Chazdon et al., 2009).

The objective of this study was to evaluate the composition and density of the seed bank of three contiguous areas with grasses of the genus *Urochloa* - pasture abandoned for ten years, with soil amended by partial beheading for two years at horizon A (area I); pasture identical to the previous example, but with recent mobilization of the topsoil (area II); area undergoing early stages of regeneration (area III) - to verify its potential for restoration of the original forest (lowland evergreen rainforest).

2. MATERIAL AND METHODS

The experiment was conducted between November 2013 and July 2014. Seed bank samples were collected at the Experimental Station of Embrapa Florestas in Morretes, coastal Paraná region (latitude 25°26'56"S and longitude 48°52'18"W, 21 m altitude). The relief is flat, with Dystrophic Haplic Cambisol - CXbd (Oxic Dystrudepts) soil with moderate A horizon and clayey texture. The phytoecological region is classified as lowland evergreen rain forest (IBGE, 2012). The climate is Cfa, humid sub-tropical according to the Köppen classification, reaching mean temperatures close to 17 °C in the coldest months and 24 °C in the warmest months, with infrequent frosts and a tendency toward concentration of rainfall in the summer, but without a defined dry season (IAPAR, 2015). The present vegetation corresponds to abandoned pasture dominated by *Urochloa* grasses, popularly known as "brachiaria", with some small patches of spontaneous herbs. The surrounding region is predominantly rural, with farms intended for livestock and agriculture, as well as many natural forest fragments located about 500 m away.

Soil samples were collected in three similar topography areas: pasture abandoned for ten years, with soil amended by partial beheading for two years at horizon A (soil mechanization using a front blade to remove vegetation) (area I), pasture identical to the previous example, but presenting recent mobilization of the topsoil (area II), and an area in early stages of regeneration with high grasses, and without soil mobilization (area III). Samples from the seed bank were randomly collected from ten points per area (replicates), using a 0.30 × 0.30 m template, at three depths: 0 to 3 cm + litter; 3.1 to 6.0 cm; 6.1 to 9.0 cm.

The soil samples were placed in black plastic bags and taken to a greenhouse at Embrapa in Colombo-PR. Each sample was transferred to a plastic tray (37.5 × 26.5 × 6.0 cm) with perforations at the bottom, which contained < 2.5 cm of washed sand to enhance drainage. The trays with soil samples were distributed randomly on tables. To verify the presence of contaminated seeds, we used five trays containing only washed sand and commercial disinfested substrate. Contaminated seedlings were identified and excluded from density and floristic composition counts. Irrigation occurred four times a day for five min.

We evaluated seed banks weekly for eight months. The density and floristic composition of the seed banks were evaluated by counting and identifying emerged seedlings (Gross, 1990). Seedlings were discarded after counting. Unidentified seedlings were transplanted into 110 cm^3 tubes filled with commercial substrate and sieved earth (1:1 in v/v) for subsequent identification. Identification of botanical material was carried out using regional flora listings, specific bibliographies and specialists. Species names and their authors were confirmed with the Species List for Brazilian Flora (JBRJ, 2015).

The species were classified according to tree, shrub, and herbaceous life form (including grasses and creepers), as well as their origin (native and sub spontaneous) according to the Species List for Brazilian Flora (JBRJ, 2015). Within the sub spontaneous classification, we considered the so-called ruderal, cosmopolitan, and exotic invasive groups (Silva-Weber et al., 2012). They were also separated by the dispersal syndromes (zoochory, anemochory, and autochory) (Van der Pijl, 1982). In cases where the species could not be classified due to lack of information, the NC (unclassified) category was established. Subsequently, tree and shrub species were separated by successional categories of pioneer, early secondary, late secondary and climax species (Budowski, 1965). To compare the floristic composition of the seed bank of the three study areas, we calculated the Sorensen's similarity index (Brower & Zar, 1984).

Seed bank samples from the three areas and three depths (3 x 3 arrangement) were evaluated according to a completely randomized design, with ten replicates per treatment, totaling thirty samples per area (total sample area of 2.7 m^2). The homogeneity of the variances was verified through the Bartlett test and, later, the data was submitted to Analysis of Variance, in a split-plot design. The main plots corresponded to the three study areas and the subplots corresponded to the three soil depths. In situations of statistical significance ($p < 0.05$), means of the variables were submitted to the Tukey test at 5% probability.

3. RESULTS

In total, we obtained 67,908 germinated seeds (25,151 seeds m^{-2}), corresponding to 85 species, of which only sixteen were classified as sub spontaneous (Table 1). The predominant plant life form was

Table 1. List of species found in the seed bank (per family, life form, seed dispersal and origin), in the three study areas: abandoned pasture with soil amended by the partial beheading of the horizon A (I), pasture identical to the previous example, but presenting mobilization of the topsoil (II) and area in early stages of regeneration (III).

Family/ scientific name	LF	DS	OR	Number of individuals					
				Total			by m²		
				I	II	III	I	II	III
Anacardiaceae									
Schinus terebinthifolius Raddi	Tre	Zoo	Nat	1	0	0	1	0	0
Araliaceae									
Hydrocotyle leucocephala Cham. & Schltdl.	Her	Ane	Nat	197	162	133	219	180	148
Asteraceae									
Ageratum conyzoide L.	Her	Ane	Nat	21	13	9	23	14	10
Baccharis caprariifolia DC.	Shr	Ane	Nat	2	1	8	2	1	9
Baccharis trimera (Less) DC.	Her	Ane	Nat	0	0	2	0	0	2
Centratherum punctatum Cass.	Her	Ane	Nat	1	22	60	1	24	67

LF = life form; DS = seed dispersal syndrome; OR = origin; Tre = tree; Shr = shrub; Her = herbaceous; Ane = anemochoric; Aut = autochorous; Zoo = zoochorous; Nat = native; Sub = sub spontaneous; nc = not classified.

Table 1. Continued...

Family/ scientific name	LF	DS	OR	Number of individuals					
				Total			by m²		
				I	II	III	I	II	III
Chromolaena maximilianii (Schrad. ex DC.) R.M.King & H.Rob.	Shr	Ane	Nat	2	8	5	2	9	6
Eclipta alba (L.) HASSK	Her	Ane	Nat	0	2	0	0	2	0
Erechtites hieracifolius (L.) Raf. ex DC.	Her	Ane	Nat	58	38	44	64	42	49
Erechtites valerianifolius (Wolf) DC.	Her	Ane	Nat	44	34	8	49	38	9
Gnaphalium pensylvanicum Willd.	Her	Ane	Nat	67	76	117	74	84	130
Hypochaeris radicata L.	Her	Ane	Sub	1	5	2	1	6	2
Hyptis pectinata (L.) Poit.	Her	Aut	Nat	1	1	38	1	1	42
Jaegeria hirta (Lag.) Less	Her	Zoo	Nat	0	2	0	0	2	0
Mikania micrantha Kunthv	Her	Ane	Nat	42	103	75	47	114	83
Senecio brasiliensis (Spreng.) Less.	Her	Ane	Nat	3	6	4	3	7	4
Sonchus oleraceus L.	Her	Ane	Nat	5	6	1	6	7	1
Sphagneticola trilobata (L.) Pruski	Her	Ane	Sub	5	5	8	6	6	9
Vernonia beyrichii Less.	Shr	Ane	Nat	42	24	100	47	27	111
Youngia japonica (L.) DC.	Her	Ane	Sub	10	19	20	11	21	22
Begoniaceae									
Begonia cucullata Willd.	Her	Ane	Nat	42	1	2	47	1	2
Caryphyllaceae									
Drymaria cordata (L.) Willd. ex Roem. & Schult.	Her	Zoo	Sub	18	15	3	20	17	3
Commelinaceae									
Commelina diffusa Burm.	Her	Zoo	Nat	5	11	0	6	12	0
Cucurbitaceae									
Melothria pendula L.	Her	Zoo	Nat	1	0	0	1	0	0
Cyperaceae									
Cyperus rotundus L.	Her	Zoo	Nat	121	313	32	134	348	36
Kyllinga brevifolia Rottb.	Her	Ane	Nat	12441	7469	1894	13823	8299	2104
Cyperus iria L.	Her	Ane	Nat	411	6	0	457	7	0
Pycreus lanceolatus (Poir.) C.B.Clarke	Her	Aut	Nat	61	11	98	68	12	109
Cyperus luzulae (L.) Retz.	Her	Ane	Nat	54	180	188	60	200	209
Cyperus meyenianus Kunth	Her	Ane	Nat	260	194	70	289	216	78
Eleocharis sellowiana Kunth	Her	Zoo	Nat	16	26	311	18	29	346
Fimbristylis miliacea (L.) Vahl.	Her	Ane	Nat	2165	9689	980	2406	10766	1089
Cyperus mundtii (Nees) Kunth	Her	nc	Nat	374	73	1359	416	81	1510
Pycreus flavescens (L.) Rchb.	Her	Ane	Nat	6712	6273	1691	7458	6970	1879
Fabaceae									
Mimosa bimucronata (DC.) Kuntze	Tre	Aut	Nat	0	2	28	0	2	31
Mimosa pudica L.	Her	Zoo	Nat	35	20	4	39	22	4
Aeschynomene rudis Benth.	Her	Aut	Nat	81	12	5	90	13	6
Desmodium triflorum (L.) DC.	Her	Zoo	Sub	26	13	13	29	14	14
Hypericaceae									
Hypericum brasiliense Choisy	Her	Aut	Nat	14	2	4	16	2	4
Hypoxidaceae									

LF = life form; DS = seed dispersal syndrome; OR = origin; Tre = tree; Shr = shrub; Her = herbaceous; Ane = anemochoric; Aut = autochorous; Zoo = zoochorous; Nat = native; Sub = sub spontaneous; nc = not classified.

Table 1. Continued...

Family/ scientific name	LF	DS	OR	Number of individuals					
				Total			by m²		
				I	II	III	I	II	III
Hypoxis decumbens L.	Her	Aut	Nat	101	129	145	112	143	161
Iridaceae									
Sisyrinchium sp.	Her	nc	Nat	85	26	7	94	29	8
Lamiaceae									
Hyptis brevipes Poit.	Her	Aut	Nat	49	53	32	54	59	36
Mesosphaerum suaveolens (L.) Kuntze	Her	Aut	Nat	35	10	20	39	11	22
Linderniaceae									
Lindernia diffusa (L.) Wettst.	Her	Ane	Nat	1	11	0	1	12	0
Micranthemum umbrosum (Walter ex J.F.Gmel.) S.F.Blake	Her	Ane	Nat	2	3	34	2	3	38
Torenia thouarsii (Cham. & Schltdl.) Kuntze	Her	nc	Nat	0	4	3	0	4	3
Lythraceae									
Cuphea carthagenensis (Jacq.) J.Macbr.	Her	Ane	Nat	404	408	318	449	453	353
Malvaceae									
Sida rhombifolia L.	Her	Ane	Nat	80	154	55	89	171	61
Mazaceae									
Mazus pumilus (Burm.f.) Steenis	Her	nc	Sub	5	19	2	6	21	2
Melastomataceae									
Clidemia hirta (L.) D.Don	Her	Zoo	Nat	157	109	479	174	121	532
Tibouchina cerastifolia Cogn.	Her	nc	Nat	12	42	202	13	47	224
Tibouchina clinopodifolia Cogn.	Her	Ane	Nat	27	2	26	30	2	29
Onagraceae									
Ludwigia longifolia (DC.) H.Hara	Her	Aut	Nat	701	1382	2	779	1536	2
Ludwigia octovalvis (Jacq.) P.H.Raven	Shr	Aut	Nat	490	312	281	544	347	312
Oxalidaceae									
Oxalis debilis Kunth	Her	Aut	Nat	33	46	6	37	51	7
Phyllanthaceae									
Phyllanthus niruri L.	Her	Aut	Nat	36	138	18	40	153	20
Phyllanthus tenellus Roxb.	Her	Aut	Nat	29	86	14	32	96	16
Phyllanthus urinaria L.	Her	Aut	Nat	29	786	1	32	873	1
Plantaginaceae									
Scoparia dulcis L.	Her	Ane	Nat	528	227	351	587	252	390
Stemodia vandellioides (Benth.) V.C.Souza	Her	Zoo	Nat	53	120	2	59	133	2
Poaceae									
Digitaria sp.	Her	Ane	Nat	34	15	26	38	17	29
Eragrostis ciliaris (L.) R.Br.	Her	nc	Sub	24	6	44	27	7	49
Poa annua L.	Her	nc	Sub	104	29	14	116	32	16
Paspalum conjugatum P.J.Bergius	Her	Ane	Nat	6	2	19	7	2	21
Paspalum urvillei Steud.	Her	Ane	Nat	8	0	9	9	0	10
Urochloa decumbens (Stapf) R.D.Webster	Her	Ane	Sub	29	8	66	32	9	73
Urochloa humidicola (Rendle) Morrone & Zuloaga	Her	Ane	Sub	32	6	3	36	7	3
Urochloa subquadripara (Trin.) R.D.Webster	Her	Ane	Sub	25	20	16	28	22	18

LF = life form; DS = seed dispersal syndrome; OR = origin; Tre = tree; Shr = shrub; Her = herbaceous; Ane = anemochoric; Aut = autochorous; Zoo = zoochorous; Nat = native; Sub = sub spontaneous; nc = not classified.

Table 1. Continued...

Family/ scientific name	LF	DS	OR	Number of individuals					
				Total			by m²		
				I	II	III	I	II	III
Polygonaceae									
Polygonum persicaria L.	Her	Aut	Sub	0	7	0	0	8	0
Rubiaceae									
Borreria latifolia (Aubl.) K.Schum.	Her	Aut	Nat	1	0	0	1	0	0
Borreria palustris (Cham. & Schltdl.) Bacigalupo & E. L. Cabral.	Her	Aut	Nat	509	414	290	566	460	322
Diodia saponariifolia (Cham. & Schltdl.) K.Schum.	Her	Ane	Nat	204	68	11	227	76	12
Scrophulariaceae									
Veronica persica Poir.	Her	nc	Sub	67	296	4	74	329	4
Solanaceae									
Solanum americanum Mill.	Her	Zoo	Nat	6	5	3	7	6	3
Umbelliferae									
Centella asiatica (L.) Urban	Her	Zoo	Sub	20	2	25	22	2	28
Urticaceae									
Phenax sonneratii (Poir.) Wedd.	Her	nc	Nat	68	66	1	76	73	1
Urtica dioica L.	Her	Zoo	Sub	0	0	1	0	0	1
Verbenaceae									
Stachytarpheta cayennensis (Rich.) Vahl	Shr	Ane	Sub	3	2	25	3	2	28
Verbena litoralis Kunth.	Her	Zoo	Nat	298	84	35	331	93	39
Undetermined									
Undetermined 1	Her	nc	nc	5	80	50	6	89	56
Undetermined 2	Her	nc	nc	9	4	7	10	4	8
Undetermined 3	Her	nc	nc	12	2	3	13	2	3
Undetermined 4	Her	nc	nc	0	1	1	0	1	1
Undetermined 5	Her	nc	nc	4	65	168	4	72	187

LF = life form; DS = seed dispersal syndrome; OR = origin; Tre = tree; Shr = shrub; Her = herbaceous; Ane = anemochoric; Aut = autochorous; Zoo = zoochorous; Nat = native; Sub = sub spontaneous; nc = not classified.

herbaceous, representing 98% of the seedlings, with 66,572 seeds (24,656 seeds m^{-2}), the majority being native (96%). Amongst these were 663 Poaceae grass seeds (24% native) and 53,472 Cyperaceae seeds (100% native). Cyperaceae represented 79% of the germinated individuals. Other life forms were 31 arboreal seeds and 1,305 shrub seeds, with all being classified as native pioneers.

The three areas (I, II, and III) presented similar species richness values: 76, 78, and 75 species, respectively, with floristic similarity ranging from 0.98 to 1.00. Thirty families were identified, with Asteraceae (18) and Cyperaceae (10) showing greatest species richness (Table 1).

In relation to the dispersion syndrome, anemochory predominated in 46% of species. Autochory and zoochory were present in 20 and 17% of the species identified, respectively. Dispersal syndrome was undetermined for 17% of species (Table 1).

Area II had the highest density (Table 2) with 33,440 seeds m^{-2}, including 2 tree seeds, 386 shrub seeds, 92 Poaceae seeds, 27,102 Cyperaceae seeds, and 5,858 other herbaceous seeds. Area I presented 30,748 seeds m^{-2}, including 1 tree seed, 599 shrub seeds, 270 Poaceae seeds, 25,356 Cyperacea seeds, and 4,522 other herbaceous seeds. Area III presented a significantly lower density, with 11,266 seeds m^{-2}, including 31 tree seeds, 466 shrub seeds, 211 Poaceae seeds, 7,536 Cyperaceae seeds, and 3,022 herbaceous.

Table 2. Number of seeds m^{-2} in the seed bank of the three study areas: abandoned pasture with soil amended by the partial beheading of the horizon A (I), pasture identical to the previous example, but with mobilization of the topsoil (II) and area in early stages of regeneration (III). Three depths: 0-3 cm + litter (D1), 3.1-6 cm (D2) and 6.1-9 cm (D3).

Depth /Area		I			II			III	
D1	15.198	a	A	9.853	a	AB	3.840	a	B
D2	8.949	ab	AB	12.342	a	A	3.351	a	B
D3	6.601	b	AB	11.244	a	A	4.074	a	B
Total seeds in trays		27.673			30.096			10.139	
Total seeds m^{-2}		30.748			33.440			11.266	
CV (areas) = 67.13% / CV (depths) = 69.56%									

CV = coefficient of variation. Averages followed by the same lower-case letter in the column and capital letter in the line did not differ by Tukey test at 5% probability.

4. DISCUSSION

A dominance of Cyperaceae and even herbaceous non-grass plants is commonly found in seed banks of abandoned pastures or fragmented environments (Wijdeven & Kuzee, 2000; Miranda et al., 2014). Factors that contribute to this pattern include efficient dispersion mechanisms, reduced size, dormancy, and high seed production (Guimarães et al., 2014). The greater availability of space and luminosity favors the persistence of existing grasses and the emergence of other ruderal species with clear vegetative propagation, which can cover an area rapidly when pasture pressure is reduced (Vieira & Pessoa, 2001).

Grass seeds, such as those belonging to the genus *Urochloa*, may also remain dormant and viable in the soil for several years (Miles & Valle, 1998). This has been observed in some studies with seed banks (Severino et al., 2006; Ikeda et al., 2007), which have shown that *Urochloa* grasses are dominant and reduce the establishment of other plants. Despite this, there was a low density of *Urochloa* species from the seed banks in the three study areas, contradicting the predominance of these species' vegetative phase in the above-ground stratum, particularly in areas I and II (Table 1). This was because the dominant grass in the area, *Urochloa subquadripara*, is mainly propagated through vegetative means, and seed formation is infrequent (Kissmann & Groth, 1997).

The seed density in each area was higher than that found in other studies carried out in pasture areas using the seedling emergence method, which ranged from 304 to 11,603 m^{-2} seeds in humid equatorial climate pasture (Silva & Dias-Filho, 2001; Costa et al., 2013), 241 to 1,998 seeds in tropical climate pastures (Costalonga et al., 2006; Calegari et al., 2013) and 3,792 to 6,312 m^{-2} seeds in humid subtropical climate (Chapla & Campos, 2011). The seed density was also higher than that obtained in other environments, such as remnants of Mixed Ombrophilous Forest and Semideciduous Seasonal Forest, which presented 5,732 and 589 m^{-2} seeds, respectively (Martins & Engel, 2007; Silva-Weber et al., 2012).

In tropical forests, the amount of seed in the soil is high at the beginning of succession, decreasing gradually (Chapla & Campos, 2011), and the density of the seed bank increases considerably during the transition from forest to pasture, due to the presence of grasses and other herbaceous plants (Costalonga et al., 2006; Calegari et al., 2013). In fact, the species with the highest relative density were *Cyperus brevifolius* and *Pycreus flavescens* in areas I (45 and 24%) and III (19 and 17%) and *Fimbristylis miliacea* in area II (32%) (Table 1). When disregarding the Cyperaceae family, density values fall significantly and fall within the range of commonly found values (around 5,153 m^{-2} seeds), considering the average of the three areas.

In areas I and II, despite the high seed density values, there was a low occurrence of shrubs and trees (Table 1). These densities are compatible with seed banks of anthropic landscapes (Wijdeven & Kuzee, 2000), and the low occurrence of woody species in these areas may be related to the partial decapitation of horizon A. In pastures, higher soil compaction makes it difficult for seeds to penetrate, keeping them on the surface (Dias-Filho, 2006) and by removing the horizon A the seed stock of the bank is carried away.

The woody species found in areas I and II corresponded to only 1% and 2% of the total germinated seedlings, respectively. Even before removal of horizon A two years ago, the vegetation was dominated by *Urochloa*, although it was abandoned about ten years ago. In abandoned pastures, natural re-composition is quite slow due to modifications caused by aggressively growing grasses that inhibit natural regeneration (Costa et al., 2013). Therefore, although woody propagules are dispersed in pastures, there are no suitable sites for their germination, with some seeds that die and are no longer part of the seed bank (Holl, 1998).

Area III also presented a low number of woody seeds in the seed bank, making up only 4% of the germinated seedlings. Other studies, in similar environments, found a reduced stock of shrub-tree species and observed a predominance of herbaceous plants (Tres et al., 2007; Pereira et al., 2010; Miranda et al., 2014). Some authors point out that the results may be influenced by the method used - germination or direct counting - due to errors associated with seed dormancy and mortality (Pereira et al., 2010; Silva et al., 2011).

We found only two tree species, *Mimosa bimucronata* (areas II and III) and *Schinus terebinthifolius* (area I), both presenting pasture colonization potential. These species are often recommended for the recovery of degraded ecosystems due to their ease of installation and action as facilitators of natural regeneration (Carvalho, 1994; Bitencourt et al., 2007; Lorenzi, 2008). In area III, in the initial stage of regeneration, we observed a higher density of *Mimosa bimucronata*. This is due to the lower occupation of grasses in the above-ground stratum, which provides conditions for the installation of more selective and shrubby herbaceous plants and allows a greater establishment of arboreal individuals.

Ludwigia octovalvis and *Vernonia beyrichii* were among the shrub species found. *Ludwigia octovalvis* was mainly present in areas I and II. Characteristic of pastures, the *Ludwigia* species is considered to have the widest geographic distribution in Brazil (Lorenzi, 2008). *Vernonia beyrichii* is also present in these areas, and is also a pasture colonizer (Cheung et al., 2009). This species occurred in the area at the beginning of natural regeneration (area III), where it was found in the stratum above the ground forming dense clusters about 2.5 m high. This shrub is frequently found in the Atlantic Forest biome as the first species to establish after pasture abandonment, generally with a higher density than the other woody species (Scheer et al., 2009).

Higher numbers of Asteraceae and Cyperaceae species are commonly observed in field areas and anthropic regions. This has been attributed to the ease of colonizing open areas, clearings, or borders of fragments and the formation of persistent seed banks (formed by seeds that present dormancy) (Silva-Weber et al., 2012; Costa et al., 2013). These families were also the most frequent in floristic surveys of natural regeneration from other studies about abandoned pastures of the genus *Urochloa* (Silva & Dias-Filho, 2001; Costa et al., 2013).

Despite the lower occupation of grasses in the above-ground stratum, the area III seed bank suffered significant influence from the herbaceous vegetation of adjacent pastures, which is reflected in the marked floristic similarity between the seed banks of the three areas. Some studies (Hall & Swaine, 1980; Lopes et al., 2006) have found that floristic similarity between seed banks in nearby areas tends to be higher than that between seed bank and vegetation above the soil of the same area. This may be related to the limitation on seed dispersal caused by the proximity of pastures, which would not only affect the quantity of seeds that are dispersed, but also the diversity of species, which is restricted to the plants already present in the pasture (Harms et al., 2000). Likewise, there were no seeds in area II coming from nearby forest remnants, even with soil rotation and temporary removal of grasses, which could facilitate the deposition of seeds in the soil.

The limitation of seed rain may be due to reduced seed density, changes in fruiting seasonality, and absence of dispersal fauna (Murray, 1988). Although less affected, wind dispersal also declines in relation to forest edge distance (Holl, 1999). The predominance of a certain dispersion mechanism is related to the type of environment. In the study sites, we predicted a higher number of species dispersed by wind, since these areas were abandoned pastures, at the beginning of regeneration (Table 1), and also because visitation of dispersing fauna is infrequent or non-existent in this type of environment. Anemochory and autochory are typical of open environments, such as sites in the initial stages of succession (Tomazi et al., 2010; Guimarães et al., 2014).

In terms of differences within the soil profile (Table 2), the lower amount of seed in the first layer of the soil of area II in comparison with deeper layers was possibly due to soil turning. Tilling promoted the mixing of the soil layers, resulting in a more homogeneous distribution of the seeds throughout the soil profile. With the soil temporarily free of competition by the *Urochloa* grasses, there was probably greater germination of the seeds in the first layers, causing a reduction in the seed bank.

In area I, which did not undergo recent upheaval, seed distribution decreased as the soil layers deepened, showing a more than 50% seed reduction. Vertical seed distribution occurs due to the action of biotic and abiotic mechanisms of incorporation into the soil and as a result of the life span of the seeds of different species (Costa et al., 2013). The area at the initial regeneration stage (area III) did not show a significant difference between the depths, which suggests, although it has not been evaluated, a low incorporation of propagules into the seed bank of the first soil layer (0 to 3 cm).

Low seed availability in pastures is a limiting factor for recruitment of native species (Harms et al., 2000). In addition to the other factors mentioned, the large biomass of grasses in the soil makes it difficult for allogeneic propagules to be incorporated into the seed bank. Thus, in pastures characterized by strongly inhibitory vegetation, greater efforts are required to induce natural regeneration. Methods to improve seed rain and seedbed improvement practices should be combined to overcome both dispersive and competitive barriers, without which native species will be unlikely to survive (Tomazi et al., 2010; Reid & Holl, 2013).

5. CONCLUSION

The seed densities found in the present study are compatible with those of seed banks of anthropic landscapes. In the seed banks of the three areas, there were only a few seeds of a restricted number of woody species, which therefore represents a limited resource for forest regeneration purposes.

Although the seed bank consists of mainly herbaceous species, we also found important colonizing shrubs that facilitate natural regeneration.

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