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RESEARCH PAPER

Horizontal structure and floristic composition of the shrubby-arboreal strata in forests planted to rehabilitate a degraded area of the Brazilian Atlantic Forest, Rio do Janeiro

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Abstract

J. Farias dos Santos, C. Roppa, S.S. Holanda de Oliveira, and R. Valcarcel. 2011. Horizontal structure and floristic composition of the shrubby-arboreal strata on forests planted to rehabilitate a degraded area of the Brazilian Atlantic Forest, Rio do Janeiro. Cien. Inv. Agr. 38(1):95-106. The study was taken in a reclamation area where soil was removed up to 13 meters deep in 1979, near Itaguaí county, Brazil (23º 55' 07" S, 43º 49' 73" O). In 2007 the composition and horizontal structure of the shrubby-arboreal strata was evaluated in five 13 years old forest plantations with similar environment conditions. For rehabilitation, rustic pioneer species were used to guarantee a sustainable successional process, which depends on species selection and their functional complementarities. Treatments were: T_0 (control); T_1 (100 % of exotic species); T_2 (52% of exotic species); T_3 (50% exotic and 50% native); T_4 (39% exotic and 61% native); and T_5 (15% exotic and 85% native). Variables measured were height, DBH ($\geq$ 3.0 cm), basal area, canopy cover, horizontal structure (density, dominance, frequency and importance value) Diversity Index (Shannon-Weaver) and Similarity Index (Jaccard), on four permanent plots of 5 x 15 m (75m^2) per treatment. Fourteen species were planted in 1994 and 13 years later, 23 species of 21 genus and 11 botanical families were found. Treatment T5 had the greatest individual numbers and variability of canopy and density cover, T2 had the greatest species diversity and T4 the greatest height and individual basal area; on the other hand, T1 had the lowest individual number, density and mixture coefficient. All species combinations used were more efficient on rehabilitation than in the control area which didn't show any arboreal species in 28 years.

Keys words: Degradation area, mining, tree species, vegetal succession.

Introduction

Forest ecosystems are still being affected by anthropic activities, where soil and subsoil withdrawal contributes to environmental degradation, with consequences for society, which represents deficiencies affecting future generations (Rodrigues *et al.*, 2007; Valcarcel *et al.*, 2007).

The Brazilian Atlantic Forest biome is a vegetational complex from the combination of environmental effects from the ocean and the intricate Brazilian orography forming specific environments with wide endemism when affected, giving international relevance to the biome.

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This includes part of 17 Brazilian States, located along the Atlantic coast, extending from Río Grande do Sul to Río Grande do Norte, occupying only 7% of the original extension (Fundação SOS Mata Atlântica y INPE, 2009).

A wide range of economic factors generate environmental degradation, mining being one of them due to its strong operational procedures, which promote intense degradation in small sites (Pinheiro, 2004), removing soils and subsoils in different intensities and for diverse purposes, representing reclamation areas.

The challenge of modern engineering is the intervention of only indispensable areas which mitigates the environmental impacts collectively, using efficient and environmentally sustainable rehabilitation techniques (Valcarcel and Silva, 2000) and being able to rebuild ecosystems with similar functions to the original ecosystems (Bechara *et al*., 2007). The selection of appropriate species to trigger the successional processes is the first technological challenge of rehabilitation. The second is allowing individuals to build ecosystems with similar natural functions, forming stable and sustainable biodiversity communities (Bechara *et al*., 2007), where the phytosociological characterization enables the evaluation of the successional dynamics (Magurran, 1988).

The aim of this study was to evaluate the floristic composition and horizontal structure of the shrubby-arboreal strata, after 13 years, in five old plantations used as biological rehabilitation measures for degraded areas, where the main difference was the combinations of rustic species and their synergic effects on the ecosystems construction.

Materials and methods

Area under study

The area is in the district of Isla de Madeira (23º 55’ 07’’ South latitude and 43º 49’ 73’’ West longitude), municipality of Itaguaí, Estado do Rio de Janeiro (Brazil), where the Brazilian Atlantic Forest is dominant (Floresta Ombrófila Densa), separated from the other biomass by the ocean (270 degrees) and mangroves (90 degrees).

The climate is “Aw” tropical hot and humid (rainy summer and dry winter), presenting an annual average maximum temperature in February (25.7 ºC) and minimum temperature in July (19.6 ºC), according to the Koopen classification. The highest precipitation occurs between December and January, sometimes reaching March, with a total of 1,500 mm/year (RJ, 1996).

Within the area under study (10.81 ha), 1.4 x10^6 m^3 of substrate were exploited during 1977 and 1979 for the construction of Retro-Puerto de Itaguaí, with a mean depth of 13 m of subsoil from the geological formation “Serra dos Órgãos”, with mineralogical classification composed by Biotite-Hornblende-granite, clayey texture and massive structure (Brazil, 1983). The predominant soils surrounding the area under study are low fertile Argissolos (UFRRJ, 1993).

The relief of the area was mechanically changed during the exploitation (1977-1979) and reconfigured by erosive processes (1980-1993), as no conservationist interventions were present (Neves, 2004). The physical-biological measures were implanted in 1994 (beds with organic substrate of invading herbaceous species) as well as biological measures (plant beds).

Treatments

The species were produced from the same matrices, cultivated in identical conditions of forest nurseries, planted in holes (0.40 x 0.40 x 0.40 m) with 2 litres of hardened bovine manure, with shed heights between 0.20 and 0.30 m, and plant bed density of 2,020 plants/ha (UFRRJ, 1993).

14 species were used; four exotic forest tropical Fabaceae, seven native pioneer species and three secondary native species, distributed among the families Fabaceae, Myrtaceae, Bignoniaceae, Cecropiaceae, Anacardiaceae.

Each treatment combined a group of arboreal species with different functions and habits (UFRRJ, 1993) (Table 1), where T_0 (control) remained without any conservationist intervention; T_1 was maintained 100% with one exotic species; T_2 with 52% exotic species (3 species) and 48% native species (5 species); T_3 with 50% exotic species (2 species) and 50% native species (2 species); T_4 39% exotic species (2 species) and 61% native species (4 species); T_5 15% exotic species (1 species) and 85% native species (7 species). Treatments 2, 3 and 4 presented a similar number of exotic and native species, T_2 had a semi-decidua species (*Caesalpinia ferrea* Mart) and two slow growing species (*C. ferrea* and *Tabebuia umbellata* (Sonder) Landwith) (Lorenzi, 2002). This variation is the difference of T_3 and T_4, where T_3 presented all the decidua and fast growing species (Lorenzi, 2002), while T_4 had an evergreen species (*Inga laurina*) and two semi-decidua species (*Piptadenia gonoacantha* Mart. J.F. Macbr. and *Psidium guajava* L). T_5 differed from T_1 by the reduced number of exotic species and the high number of native species.

Experimental sampling

The experimental area (6,250 m^2) was established in the interior of the populations, within the reclamation area, in 25 x 50 m plots (1,250 m^2), subdivided in four permanent 5 x 15 m sub plots (75 m^2). The control area had the same area, but without plant beds. All the plots presented similar litolic, hydro-geo-environmental characteristics, restricting other variables that eventually may affect the rehabilitation of the reclamation area.

Floristic composition

The floristic studies and the horizontal structure of the shrubby-arboreal strata were made between August and September, 2007. All the individuals planted and/or regenerated were surveyed, with a trunk circumference equal to or greater than 10 cm, at breast height. They were recorded (labelled with aluminium plates) and identified by the classification system APG II (2003).

Table 1. Percentage of species composition on plantation areas at 1994 used as biological measures at a reclamation area at Ilha da Madeira, Itaguaí-RJ, Brazil.

n.	Scientific name	T_0	T_1	T_2	T_3	T_4	T_5
01	*Acacia auriculiformis* Sandw[1]	0	100	25	0	22	0
02	*Acacia mangium* Willd[1]	0	0	0	30	17	0
03	*Albizia lebbeck* (L) Benth.[1]	0	0	7	20	0	0
04	*Caesalpinia ferrea* Mart. [3]	0	0	13	0	0	0
05	*Cecropia pachystachya* Trec.[2]	0	0	0	0	0	8
06	*Clitoria fairchildiana* Howard [2]	0	0	0	20	20	17
07	*Inga laurina* (Sw.) Willd.[3]	0	0	0	0	20	15
08	*Leucaena leucocephala* (Lam.)[1]	0	0	20	0	0	15
09	*Mimosa bimucronata* (DC.)[2]	0	0	0	0	0	13
10	*Mimosa caesalpiniaefolia* Benth[2]	0	0	10	30	0	21
11	*Piptadenia gonoacantha* (Mart.) J.F. Macbr.[2]	0	0	15	0	10	5
12	*Psidium guajava* L.[2]	0	0	5	0	11	0
13	*Schinus terebinthifolius* Raddi [2]	0	0	0	0	0	6
14	*Tabebuia umbellata* (Sonder)[3] Landwith	0	0	5	0	0	0
	Total of species	0	1	8	4	6	8

[1]Exotic pioneer; [2]Native pioneer; [3]Native secondary. Source: UFRRJ (1993 modified).

Characterization of the horizontal structure

The circumference at breast height was obtained with a dendrometric ribbon and the total height of the plants was obtained with a 7 m retractile rod. The mean canopy diameter was determined from the average between the highest and lowest canopy projection, with the last variable used for the estimation of the total cover index (Greig-Smith, 1964). The phytosociological parameters (DA, DR, FA, FR, ADo, RDo, VC, VC (%), IV, IV (%)), the Shannon-Weaver Diversity indexes and the Jaccard Likelihood Index were calculated using the software Mata Nativa 2 (Universidad Federal de Viçosa, Brazil, 2006) and electronic worksheets.

Statistical analysis

A complete randomized design to evaluate treatments as well as the Tukey Test, at 5% likelihood between means was used. The analysis was made with the software SAEG 9.1 (Universidade Federal de Viçosa, Viçosa, 2007) using the procedures described in Ribeiro Junior (2001).

Results and discussion

Floristic composition

There were no forest species in the control area after the subsoil was abandoned to the environment action for 28 years, where all the processes affecting the site construction and/or degradation interfere freely. Small herbaceous species usually colonize for short periods and disappear with the geodynamics of the erosive processes of the system, following the inertial tendency of degradation.

In the areas planted with 14 species in 1994, 23 shrubby-arboreal species were observed, with 11 species from the initial plant bed (same individuals and/or descendents) and 12 colonizing banks of the natural propagules of the environment, as the area was not enriched. These were distributed in 21 genera, 12 botanical families and 276 individuals, in 13 years (Table 2). In 2001, there were only 5 families with DAP≥1 cm (Neves, 2004), showing that both biodiversity and rehabilitation sustainability increased during the following 6 years.

The family Fabaceae (11 species) presented the highest richness, with 239 individuals (86.59%), followed by Bignoniaceae with only 2 individuals (0.73%). In 2001, Neves (2004) observed the predominance of Fabaceae, describing that they act permanently in the ecosystems construction from degraded environments. These data are repeated in disturbed ecosystems (soils chemically poor and with physical features similar to the original soils) from the Atlantic Forest, according to the observations by Silva Jardim (Carvalho, 2006).

The distribution of the species by botanical families showed an ecosystem simplification after 13 years, and there was only one species per family in 10 families found, with a total of 35 individuals (12.68%) of the individuals surveyed.

Treatment T_5 presented the highest number of plants (109) and density (3,633 plants /ha); T_2 presented the highest number of species and genera (Table 3). Both treatments had 8 species planted since the beginning. T_1 had only one species in the plant bed, allowing the plantation of 8 individuals with low density (267 plants/ha) (Table 3).

The diversity of native species in the initial phase of the plantation may have allowed functional interactions among species, offering ecophysiological conditions able to promote emergence properties, which are enough to shelter demanding species, as all the other geo-environmental conditions were similar among treatments, as well as the offering propagule conditions. The absence of shrubby-arboreal species in T_0 reinforces this thesis. The environmental heterogeneity created by the cluster of species implanted in the treatments may have contributed to increase the synergic effect of the ecosystems construction, from the influences of their

Table 2. Forest species in reclamation area at Ilha da Madeira-RJ at 2007, planted on 1994.

Family	Scientific name	Popular name	T_1	T_2	T_3	T_4	T_5
Anacardiaceae	*Schinus terebinthifolius* Raddi[1]	Aroeira-vermelha					x
Asteraceae	*Vernonia macrophylla Less.*[2]	Fumo-do-campo		x	x		
Bignoniaceae	*Cybistax antisyphilitica* (Mart.) Mart. [2]	Ipe-verde		x			
	Tabebuia umbellata (Sonder) Sandwith[1]	Ipe-amarelo		x			
Cannabaceae	*Trema micrantha* (L.) Blume[2]	Crindiuva		x	x		
Fabaceae/ Mimosoidae	*Acacia auriculiformis* Sandw[1]	Acacia		x		x	
	Acacia mangium Willd[1]	Acacia			x	x	
	Albizia lebbeck (L) Benth[1]	Albizia		x	x		
	Anadenanthera macrocarpa (Benth). Brenan[2]	Angico-vermelho					x
	Inga laurina (Sw.) Willd [1]	Inga				x	x
	Leucaena leucocephala (Lam.)[1]	Leucena		x	x	x	x
	Mimosa caesalpiniaefolia Benth[1]	Sabia		x	x	x	x
	Piptadenia gonoacantha (Mart.) J.F. Macbr.[1]	Pau-jacare		x		x	x
Fabaceae/ Faboideae	*Clitoria fairchildiana* Howard[1]	Sombreiro				x	x
	Machaerium aculeatum Raddi[2]	Bico-de- pato					
	Machaerium nyctitans (Vell.) Benth.[2]	Jacaranda-ferro				x	x
Malvaceae	*Luehea divaricata* Mart.[2]	Açoita-cavalo		x	x		
Melastomataceae	*Tibouchina granulosa* Cong.[2]	Quaresmeira				x	
Solanaceae	*Solanum inaequale* Vell.[2]	Guaxixin		x			
Urticaceae	*Cecropia pachystachya* Trec.[1]	Embauba	x				x
Verbenaceae	*Gmelina arborea* Roxb.[2]	Guimelina		x		x	
Euphorbiaceae	*Sapium glandulatum* (Vell.) Pax[2]	Pau-de-leite	x				
Lauracea	*Nectandra membranacea* (Sw.) Griseb.[2]	Canela		x			

[1]Planted species; [2]Colonizing species.

Table 3. Floristic composition on a reclaimed area at Ilha Madeira, Itaguaí-RJ/ Brazil on 2007, reforested at 1994.

Floristic composition	Treatments					
	T_0	T_1	T_2	T_3	T_4	T_5
Total indiviual samples	0	8	49	55	55	109
Species richness	0	2	13	7	10	9
Number of genus	0	2	13	7	9	9
Number of families	0	2	8	4	3	3
Density (ind/ha)	0	267	1,633	1,833	1,833	3,633
Mixture coefficient	0	0.8125	0.4414	0.3191	0.3814	0.1859

biotic components on the physical medium, and from this medium to the biotic medium and to the species diversity, as a higher diversity affects reproduction, recruitment, specialization, and division of the resources (Jones *et al.,* 1997; Ruschel *et al*., 2009).

The relation of intra-specific competence on the same T_1 species (homogeneous) may have contributed to the eradication from the ecosystem after 13 years, reducing the number of species, genera and families, as well as reducing the density of the floristic composition.

Characterization of the horizontal structure

The treatments presented differences in height, DAP, basal area and canopy cover, which shows that, in addition to the floristic composition, there were differences in the horizontal structures (Table 4), regardless of the high internal heterogeneity. The differences observed may represent complementary functions in the ecosystem development, as canopies with different dimensions restrict the entrance of energy and rain management, affecting water entrance, management and retention, factors that contribute to the processes of soil formation, in addition to reducing the erosive processes, volumes of surface runoff and organic matter offered to the substrate surface (Lepsch, 2002).

The canopy structure is also responsible for forest dynamics, which determine the coexistence of species (Mori and Takeda, 2004). T_5 presented a higher canopy cover, affecting the impact management of rain cinematic energy, humidity and deposition of fallen leaves on the surface of the forest floor, which might affect the entrance and amount of newly established individuals.

T_4 had a higher height (8.48 m), DAP (11.98 cm) and basal area, compared to T_1, which obtained lower height (3.91 m), DAP (5.15 cm) and individual basal area (0.0024 m²).

Table 4. Average value for DBH, total height, basal area and canopy cover at a reclaimed area at Ilha Madeira-RJ/ Brazil, reforested at 1994, where CV corresponds to experimental variation coefficient with 5% of probability.

Treatments	Total hight (m)	DBH (cm)	Basal area (m²)	Canopy cover (%)
1	3.91 b*	5.15 c	0.0024 b	7.11 b
2	5.46 ab	5.64 bc	0.0025 b	177.81 ab
3	8.23 a	10.58 ab	0.0092 ab	300.54 ab
4	8.48 a	11.97 a	0.01199 a	385.31 ab
5	7.27 ab	8.73 abc	0.0062 ab	493.48 a
CV(%)	27.38	28.02	60.62	65.25
P (0.05)	0.013	0.003	0.013	0.014

*Averages followed by the same letter on column does not differ between then for the Tukey test (5%).

80% of the fast growing species were used in treatment T_4 (Lorenzi, 2002; Carvalho, 2003; Lorenzi *et al*., 2003): *A. auriculiformis* Sandw*, Acacia mangium* Wild, *I. laurina, P. gonoacantha and P. guajava*; and 20% of the extremely fast: *Clitoria fairchildiana* Howard (Lopes and Piña-Rodrigues, 1997; Lorenzi, 2002; Carvalho, 2003; Lorenzi *et al*., 2003).

The higher DAP and individual basal area in T_4 are explained by the presence of the species *A. mangiun* and *A. auriculiformis*, along with the fast growing DAP native species, which suggests a higher adaptation to the initial unfavorable conditions. This confirms observations from authors on rehabilitation of degraded areas (Franco *et al*., 1992; Lorenzi *et al*., 2003), regarding their association with micorrizic fungi from bacteria of the genus *Rhizobium* sp (Faria *et al*., 1997).

The individual behaviour of the species, according to Jones *et al*. (1997) reflects the two ecosystems, where the survival mechanisms through differentiated exploration of the ecosystems resources, represent different offerings of environmental attributes to the environment, which improves its development. The use of a few botanical species in the rehabilitation may inhibit the processes of vegetal succession (Kageyama *et al*., 1994).

The canopy cover for T_5 (493.48%) differs from T_1 (7.11%) by the implanted species and their adaptation to the environment, causing a differentiated offering of environmental functions: pollinating organisms, dispersers and natural predators, which is coherent with the literature (Kageyama and Gandara, 2000; Moraes, 2006).

In T_1, only one species represented 87.89% of IV, in comparison to the other treatments, two species represented 50.37% (T_2); 66.95% (T_3); 50.46% (T_4) and 50.42% (T_5) of IV. The density was 266.7; 1633.3; 1833.3; 1833.3 and 3633.3 individuals per hectare for T_1, T_2, T_3, T_4 y T_5, respectively (Table 5).

The species with the highest density in the treatment were: *Cecropia pachystachya* (233.3 ind/ha, T_1); *P. gonoacantha (*500 ind/ha, T_2); *Mimosa caesalpiniaefolia (*633.3 ind/ha, T_3); *I. laurina (*766.7 ind/ha, T_4) and; *M. caesalpiniaefolia (*1,500 ind/ha, T_5). Their IV in their treatments corresponded to 263.66 (T_1); 95.78 (T_2); 135.40 (T_3); 77.27 (T_4) and 85.04 (T_5), which shows their adaptation in the treatments and, in this regard, they are different in the offerings of environmental attributes, as the other environmental factors are similar in all the areas under study.

The low density of *C. pachystachya* in the treatments, in comparison to all the species, does not reflect its higher IV among the native species, a typical successional procedure of restoring disturbed ecosystem processes in the Atlantic Forest (Cortines and Valcarcel, 2009).

The Jaccard Index with values of 0.55 (T_1), 0.79 (T_2), 0.83 (T_3), 0.80 (T_4) and 0.75 (T_5), shows a high similarity among the cluster of species, however, they are within the range observed for the disturbed ecosystems in the region under study (Carvalho *et al.,* 2006), ranging between 0.05 and 0.79.

The Shannon-Weaver Diversity Index recorded is 0.38; 2.01; 1.61; 1.84 and 1.64 for T_1, T_2, T_3, T_4 e T_5, respectively, indicating a higher diversity in T_2. This value is considered medium for natural ecosystems (Nascimento *et al.,* 2001) and high for the Brazilian Amazonia, which registers a value of 1.03 in 10-year old populations (Parrota *et al.,* 1997). This is probably due to the wide diversity of species from the biome studied, facilitating the recruitment and fit of species to the different degradation types.

These results show that the adequate selection of the species for the rehabilitation of degraded areas is essential, considering that the wider the old plantation diversity is, in order to rehabilitate degraded ecosystems, the more heterogeneous the forest, diversified the horizontal structure and sustainable the rehabilitation processes will be.

Table 5. Phytosociological parameters observed at 2007 from the species planted in the area of loan Ilha da Madeira-RJ/ Brazil, reforested at 1994.

T	Scientific name	Popular name	N	U	AB	DA	DR	FA	FR	DoA	DoR	VC	VC (%)	VI	VI (%)
T1	*Cecropia pachystachya*	Embaúba	7	4	0.0199	233.333	87.5	100	80	0.664	96.16	183.657	91.83	263.657	87.89
T1	*Sapium glandulatum*	Pau-de-leite	1	1	0.0008	33.333	12.5	25	20	0.027	3.84	16.343	8.17	36.343	12.11
		Total	8	4	0.0207	266.667	100	125	100	0.69	100	200	100	300	100
T2	*Piptadenia gonoacantha*	Pau-jacaré	15	4	0.0707	500	30.61	100	17.39	2.358	47.78	78.387	39.19	95.779	31.93
T2	*Mimosa caesalpiniaefolia*	Sabiá	9	3	0.0354	300	18.37	75	13.04	1.18	23.9	42.271	21.14	55.315	18.44
T2	*Trema micrantha*	Crindiúva	9	4	0.016	300	18.37	100	17.39	0.534	10.82	29.185	14.59	46.577	15.53
T2	*Leocaena leucocephala*	Leucena	6	2	0.0086	200	12.24	50	8.7	0.288	5.84	18.086	9.04	26.782	8.93
T2	*Luehea divaricata*	Açoita-cavalo	2	2	0.0031	66.667	4.08	50	8.7	0.105	2.12	6.199	3.1	14.895	4.96
T2	*Gmelina arborea*	Guimelina	1	1	0.0042	33.333	2.04	25	4.35	0.14	2.84	4.884	2.44	9.232	3.08
T2	*Nectandra membranacea*	Canela	1	1	0.0026	33.333	2.04	25	4.35	0.086	1.74	3.782	1.89	8.13	2.71
T2	*Tabebuiaumbellata*	Ipê - amarelo	1	1	0.002	33.333	2.04	25	4.35	0.068	1.38	3.417	1.71	7.764	2.59
T2	*Solanum inaequale*	Guaxixin	1	1	0.0018	33.333	2.04	25	4.35	0.06	1.21	3.25	1.62	7.598	2.53
T2	*Acacia auriculiformis*	Acácia	1	1	0.001	33.333	2.04	25	4.35	0.032	0.65	2.691	1.35	7.039	2.35
T2	*Albizia lebbech*	Albízia	1	1	0.001	33.333	2.04	25	4.35	0.032	0.65	2.691	1.35	7.039	2.35
T2	*Cybistax antisyphilitica*	Ipê-verde	1	1	0.0008	33.333	2.04	25	4.35	0.027	0.54	2.578	1.29	6.926	2.31
T2	*Vernonia macrophylla*	Fumo-do-campo	1	1	0.0008	33.333	2.04	25	4.35	0.027	0.54	2.578	1.29	6.926	2.31
		Total	49	4	0.1481	1633.333	100	575	100	4.936	100	200	100	300	100
T3	*Acacia mangium*	Acácia	14	4	0.7501	466.667	25.45	100	22.22	25.003	87.73	113.181	56.59	135.403	45.13
T3	*Mimosa caesalpiniaefolia*	Sabiá	19	4	0.0742	633.333	34.55	100	22.22	2.474	8.68	43,225	21.61	65.447	21.82
T3	*Leocaena leucocephala*	Leucena	8	4	0.0123	266.667	14.55	100	22.22	0.411	1.44	15.988	7.99	38.21	12.74
T3	*Albizia lebbech*	Albízia	9	2	0.0096	300	16.36	50	11.11	0.319	1.12	17.481	8.74	28.592	9.53
T3	*Trema micrantha*	Crindiúva	2	2	0.0059	66.667	3.64	50	11.11	0.198	0.69	4.331	2.17	15.442	5.15
T3	*Luehea divaricata*	Açoita-cavalo	2	1	0.0018	66.667	3.64	25	5.56	0.059	0.21	3.842	1.92	9.398	3.13
T3	*Vernonia macrophylla*	Fumo-do-campo	1	1	0.0011	33.333	1.82	25	5.56	0.038	0.13	1.952	0.98	7.508	2.5
		Total	55	4	0.855	1833.333	100	450	100	28.501	100	200	100	300	100

Table 5 continued

T	Scientific name	Popular name	N	U	AB	DA	DR	FA	FR	DoA	DoR	VC	VC (%)	VI	VI (%)
T4	*Inga laurina*	Ingá	23	4	0.1258	766,667	41.82	100	20	4.194	15.45	57.267	28.63	77.267	25.76
T4	*Acacia auriculiformis*	Acácia	9	3	0.348	300	16.36	75	15	11.601	42.73	59.097	29.55	74.097	24.7
T4	*Acacia mangium*	Acácia	6	2	0.2129	200	10.91	50	10	7.098	26.15	37.056	18.53	47.056	15.69
T4	*Clitoria fairchildiana*	Sombreiro	4	3	0.024	133.333	7.27	75	15	0.8	2.95	10.221	5.11	25.221	8.41
T4	*Tibolchina granulosa*	Quaresmeira	4	2	0.0497	133.333	7.27	50	10	1.658	6.11	13.38	6.69	23.38	7.79
T4	*Leocaena leucocephala*	Leucena	2	2	0.012	66.667	3.64	50	10	0.402	1.48	5.116	2.56	15.116	5.04
T4	*Gmelina arborea*	Guimelina	2	1	0.0288	66.667	3.64	25	5	0.96	3.54	7.173	3.59	12.173	4.06
T4	*Mimosa caesalpiniaefolia*	Sabiá	2	1	0.0058	66.667	3.64	25	5	0.192	0.71	4.344	2.17	9.344	3.11
T4	*Piptadenia gonoacantha*	Pau-jacaré	2	1	0.0052	66.667	3.64	25	5	0.174	0.64	4.277	2.14	9.277	3.09
T4	*Machaerium nyctitans*	Jacarandá-ferro	1	1	0.002	33.333	1.82	25	5	0.068	0.25	2.068	1.03	7.068	2.36
		Total	55	4	0.8144	1833.333	100	500	100	27.147	100	200	100	300	100
T5	*Mimosa caesalpiniaefolia*	Sabiá	45	3	0.2405	1500	41,28	75	15.79	8.017	27.97	69,255	34,63	85,045	28.35
T5	*Clitoria fairchildiana*	Sombreiro	11	4	0.3015	366,667	10,09	100	21.05	10.05	35,06	45.156	22.58	66.209	22.07
T5	*Leocaena leucocephala*	Leucena	20	2	0.183	666.667	18.35	50	10.53	6.1	21.28	39.633	19.82	50.159	16.72
T5	*Inga laurina*	Ingá	15	3	0.0903	500	13.76	75	15.79	3.01	10.5	24.261	12.13	40.051	13.35
T5	*Anadenanthera macrocarpa*	Angico-vermelho	13	2	0.0315	433.333	11.93	50	10.53	1.05	3.66	15,589	7.79	26.115	8.7
T5	*Machaerium aculeatum*	Bico-de- pato	2	2	0.0021	66.667	1.83	50	10.53	0.07	0.25	2.08	1.04	12,606	4.2
T5	*Piptadenia gonoacantha*	Pau-jacaré	1	1	0.0046	33.333	0,92	25	5.26	0.153	0.53	1.45	0.73	6.714	2.24
T5	*Cecropia pachystachya*	Embaúba	1	1	0,0032	33.333	0.92	25	5.26	0.106	0.37	1.288	0.64	6.551	2.18
T5	*Schinus terebenthifolius*	Aroeira-vermelha	1	1	0.0032	33.333	0.92	25	5.26	0.06	0.37	1.288	0.64	6.551	2.18
		Total	109	4	0.8599	3633.333	100	475	100	28.662	100	200	100	300	100

T= Treatments; N= number of individuals; U= survey unit on witch specie occur; BA= basal area; AD= absolute density; RD= relative density; AF= absolute frequency; RF= relative frequency; ADo= absolute dominance; RDo= relative dominance; IV= importance value; IV(%)= percentage of importance value; VC= extended importance value; VC(%)= percentage of extended importance value.

After the five clusters of forest species and the control area had survived 13 years, an increased floristic composition was observed with the inclusion of 12 species, where the family Fabaceae was the most abundant. The treatments are efficient in comparison to the control area, which did not present bush-like-forest size individuals in 28 years, assuring sustainability to rehabilitation.

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Resumen

J. Farias dos Santos, C. Roppa, S. S. Holanda de Oliveira y R. Valcarcel. 2011. Estructura horizontal y composición florística del estrato arbóreo-arbustivo de repoblaciones establecidas para rehabilitar áreas degradadas en la Mata Atlántica Brasileña, Río de Janeiro. Cien. Inv. Agr. 38(1): 95-106. El estudio se realizó en un área de préstamo, donde se retiró durante el año 1979, una profundidad promedio de 13 metros, en el sector de Itaguaí, Brasil (23º 55' 07'' S, 43º 49' 73'' O). En el año de 2007 se evaluó la estructura horizontal y composición florística de los estratos arbóreos-arbustivos, en cinco repoblaciones forestales de 13 años, establecidas sobre ambientes similares. Se utilizó especies rústicas con función de pioneras en la fase inicial, para garantizar los procesos sucesionales sostenibles de la rehabilitación, que depende de la selección de especies y su complementariedad funcional. Los tratamientos (T_i) fueron: T_0 (testigo); T_1 (100% especie exótica); T_2 (52% exótica y 48% nativas); T_3 (50% exótica y 50% nativa); T_4 (39% exótica y 61% nativa); y T_5 (15% exótica y 85% nativa). Las variables medidas fueron: altura, DAP ($\geq$ 3,0 cm), área basal, cobertura de copas, estructura horizontal (densidad, dominancia, frecuencia y valor de importancia), además de Índices diversidad (Shannon-Weaver) y similitud (Jaccard), en 4 parcelas permanentes de 5 x 15 m (75 m^2) por tratamiento. Fueron plantadas 14 especies y encontradas 23 especies, distribuidas en 21 géneros de 11 familias botánicas. El T_5 presentó más individuos y se destacó en las variables cobertura de copa y densidad, T_2 mayor diversidad de especies y T_4 mayor altura y área basal individual, en cambio el T_1 presentó menor número de individuos, densidad y coeficiente de mezcla. Todas las combinaciones de especies fueron más eficientes en la rehabilitación cuando se compararon con el área testigo, que no presentó individuos arbóreos en 28 años.

Palabras clave: Áreas degradadas, especies rústicas, minería, sucesión.

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