INFLUENCE OF PIONEER-SPECIES COMBINATIONS ON RESTORATION OF DISTURBED ECOSYSTEMS IN THE ATLANTIC FOREST, RIO DE JANEIRO, BRAZIL[1]

Erika Cortines[2] e Ricardo Valcarcel[2]

ABSTRACT – The analysis of species composition and its effects on sustainability restoration processes in the Atlantic Forest with poor environmental attributes is important to improve rehabilitation techniques for disturbed ecosystems. Reforestation projects were used as Biological Measures (BM) of rehabilitation, where treatments differ in the composition of exotic species, utilized as anthropic pioneers: BM1 – 82% (73% *Mimosa caesalpiniifolia* Benth, 9% *Eucalyptus citriodora* Hook.); BM2 – 91% (9%, 82%); and BM3 – 25% (15%, 10%). The monitoring of spontaneous regeneration was evaluated in three 12-year-old reforestation sites between thr rainy season of 2004 and 2005, and compared with an approximately 100-year-old native forest fragment and a grassland: ecosystems with inertial tendency toward recuperation and degradation, respectively. It was detected that exotic species used as anthropic pioneers strongly influenced regeneration: BM1 (75%), BM2 (85%), BM3 (55%), Forest (0%) and Grassland (50%). The highest similarity of species with forest regeneration (5%) was found for treatment BM3.

Keywords: Disturbed areas, resilience and spontaneous regeneration.

INFLUÊNCIA DA COMBINAÇÃO DE ESPÉCIES PIONEIRAS NA RESTAURAÇÃO DE ECOSSISTEMA PERTURBADO DA MATA ATLÂNTICA, RIO DE JANEIRO, BRASIL

RESUMO – A análise da composição de espécie e suas influências na sustentabilidade dos processos de restauração de Mata Atlântica, com exíguos atributos ambientais, é importante para aperfeiçoar as técnicas de reabilitação de ecossistemas perturbados. Foram utilizados reflorestamentos como Medida Biológica (MB) de reabilitação, em que os tratamentos diferem pela composição de espécies exóticas utilizadas como pioneiras antropizadas: BM1 – 82% (73% Mimosa caesalpiniifolia *Benth, 9%* Eucalyptus citriodora *Hook.); BM2 – 91% (9%, 82%); e BM3 – 25% (15%, 10%). O monitoramento da regeneração espontânea foi avaliado nos três reflorestamentos com 12 anos de idade entre estações chuvosas de 2004-2005 e comparado com um fragmento de floresta nativa de aproximadamente 100 anos e pastagem: ecossistemas com tendência inercial de recuperação e degradação, respectivamente. Foi constatado que as espécies exóticas utilizadas como pioneiras antropizadas ainda exercem forte influência na regeneração dos tratamentos: BM1 (75%), BM2(85%), BM3 (55%); Floresta (0%) e Pastagem (50%). A maior similaridade de espécies da regeneração da floresta (5%) foi encontrada no tratamento MB3.*

Palavras-chave: Áreas perturbadas, resiliência e regeneração espontânea.

1. INTRODUCTION

Disturbed ecosystems may have suffered anthropic damage, but are still capable of returning spontaneously to their former conditions (SER, 2002; PINHEIRO, 2004). They can resist spontaneously to outside disturbances KNOWLES, 1999; SER, 2002). However, degraded ecosystems may have their natural mechanisms of homeostatic balance regulation altered, which reduces their capacity to recover (BROWN and LUGO, 1994; NEPSTAD et al., 1996; MARTINS, 2001), leading them gradually further from the original point of homeostatic balance, as disturbances occur.

[1] Recebido em 05.11.2007 e aceito para publicação em 23.06.2009.
[2] Universidade Federal Rural do Rio de Janeiro, Instituto de Florestas, Departamento de Ciências Ambientais. E-mail: <ecortines@gmail.com>.

The restoration activities of degraded/disturbed and degraded ecosystems consist of human intervention to re-establish ecological functions, in order to attain a homeostatic balance similar to the one existing prior to disturbance (MINTER/IBAMA, 1990; VALCARCEL and SILVA, 2000), and to recover form and function (DIETRICH, 1990; ENGEL and PARROTA, 2003).

The use of reforestation as biological measures for ecosystem restoration is a feasible strategy in tropical environments, because it combines low-cost and high biotic potential (VALCARCEL and SILVA, 2000). The species used in reforestation have an effect on the establishment of new ecological relationships and determinate ecosystem construction, offering means to create different and emergent properties (BROWN and LUGO, 1994; AIDE et al., 1995; CHAPMAN and CHAPMAN, 1996; PARROTA et al., 1997 a, b; PARROTA, 1999; FLORENTINE and WESTBROOKE, 2004).

Practical problems to make functions of reforestation a viable means to reconstruct an ecosystem constructor agents begin with the selection of appropriate species. In location with exiguous levels of environmental attributes, only some species will be capable of surviving and resisting. The use of rustic species initiates the colonization process and development of ecological functions, similar to pioneers (CHAPMAN and CHAPMAN, 1996), generating a hydrological condition (BOSCH and HEWLETT, 1982) capable of supporting more demanding species in the watersheds.

In this study, we evaluated what composition and /proportion of rustic species are capable of generating the best ecological conditions for regeneration at the beginning of the restoration process, on areas with low offer of environmental attributes.

2. MATERIALS AND METHODS

The study area (22º45‘50“– 22º51‘ S and 43º26‘ - 43º36‘10“ W) is located on the north slope of the Madureira-Mendanha range, Nova Iguaçu county, metropolitan region of Rio de Janeiro, in southeastern of Brazil. The vegetation is a semi-deciduous Atlantic Forest, where different disturbances occurred from the beginning of the nineteenth century to the middle of the twentieth century, during the coffee, sugar-cane, and orange growing cycles. The crops were succeeded by grasslands, managed with fire, which resulted in clear degradation tendencies.

Annual precipitation (1.212 mm) is intense and concentrated in summer (BARBIERE and KRONEMBERGER, 1994; MATTOS et al., 1998). This heavy rainfall prevented the acquisition of environmental attributes for the ecosystem recovery. The climate is classified as Tropical from altitudes (Cwa) occurring at altitudes higher than 300 m, with temperatures between 17 and 22º C; and as Tropical (Aw) occurring at altitudes between 30 and 300 m, with temperatures between 22 and 24º C. The Litholic Neosoil (PALMIERI, 1980), includes environments with shallow soils and uniform aspect of terrain, with similar hydrological characteristics along the series. These environments that match these effects present edaphic and climatic limitations with minimization of pedogenetic soil development, water retention, and establishment of forest species.

The plot located in the least-disturbed ecosystem, Forest, was the most developed in terms of homeostatic balance and served as a parameter for restoration actions. The most disturbed site, Grassland, has poor environmental attributes and lacks any human conversational activity. At this site, ephemeral but intense cycles of growth and latency of the grass *Panicum maximum* Jacq. Are observed, conferring high flammability on the ecosystems, as well as erosion process and impoverished biodiversity, all characteristics that lead to inertial degradation tendencies. Three 12-year-old reforestation projects were used as Biological Measures (BM‘s), of restoration and were evaluated as strategies to reverse degradation tendencies. They where planted in 1994, and used different densities of pioneer species: BM1 used 82% of anthropic pioneer species, where 73% were *Mimosa caesalpiniifolia* Benth, and 9% were *Eucalyptus citriodora* Hook. and 18% were native species. BM2 used 91% of anthropic pioneer species, where the proportions were: 9%; 82% and; 9% respectively. BM3 used 25%, in a proportion of: 15% and 10% respectively, and 75% were distributed among 7 native species (Table 1).

Grassland represents areas where biotic components of ecosystem are less resilient and present inertial degradation tendencies. Forest represents a resilient environment with a natural tendency toward restoration. The BM’s represent treatments where the use of planted species can influence biotic components, modifying the levels of homeostatic balance, and defining trends toward degradation and/or restoration for 12 years (Figure 1).

Table 1 – Species utilized in different proportions in the biological measures implanted on an environment with low offer of attributes at Nova Iguaçu, RJ.
Tabela 1 *– Espécies utilizadas em diferentes proporções nas medidas biológicas implantadas em um ambiente com baixa oferta* de atributos ambientais em Nova Iguaçu, RJ.

Planted species	Dispersion	BM1	BM	BM3
Mimosa caesalpiniifolia Benth.	Autochoric	08	01	03
Eucalyptus citriodora Hook.	Anemochoric	01	09	02
Schinus terebinthifolius Raddi.	Zoochoric	-	-	02
Piptadenia gonoacantha (Mart.) J.F. Macbr.	Autochoric	01	-	05
Caesalpinia ferrea Mart.	Barochoric	-	-	02
Cybistax antisyphilitica (Mart.) Mart.	Anemochoric	-	-	01
Psidium guajava L.	Zoochoric	01	01	01
Senna sp.	Anemochoric	-	-	03
Machaerium aculeatum (Vell.) Stellfeld.	Anemochoric	-	-	01
Richness		4,0	3,0	9,0
Density (ind/ha)		1.923	2.222	2.000

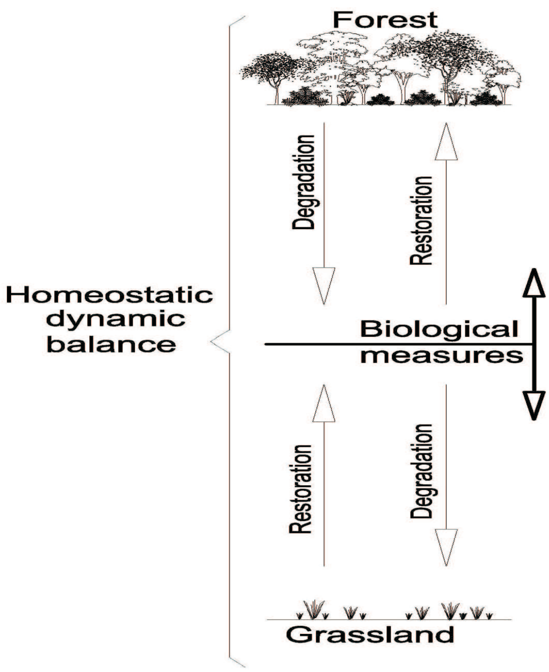

Figure 1 – Ecosystem evolutionary tendencies, and the role of reforestation projects as strategies to reverse degradation. The dark arrows represent possible paths of evolution ways of each Biological Measure over time, according to the biotic interactions among the planted species.
Figura 1 *– Tendências evolutivas do ecossistema e o papel dos reflorestamentos na reversão da degradação. As setas escuras representam os possíveis caminhos evolutivos de cada medida biológica ao longo do tempo, de acordo com as interações bióticas entre as espécies plantadas.*

The inventory of spontaneous regeneration in the BM's was carried out in February 2005, in the rainy season, utilizing the point method (MANTOVANI and MARTINS, 1991). The points where located so as to achieve representativeness of the plant community, which was determined by the collection curve adjusted by the best adjustment to the linear or logarithmic regression. The parameters used to characterize regeneration were : a) Relative Density (RD)**,** b) Relative Vigor (RV), c) Relative Frequency (RF), Importance Value (IV), d) Jaccard similarity index (C), and e) Shannon's diversity index (H') (MAGURRAN, 1988; RICKLEFS, 2003). The plants surveyed where identified by consulting the herbarium (RBR) of the Universidade Federal Rural do Rio de Janeiro and specialized bibliography.

3. RESULTS AND DISCUSSION

Natural regeneration included 74 species, distributed in 67 genera from 39 families. The area BM3 showed the highest species richness (33), surpassing the oldest and most-developed ecosystem (Forest) which contained 29 species, followed by BM2 (26), BM1 (24), and Grassland (16).

Characteristics of the Atlantic Forest such as high levels of biodiversity and endemism (MYERS et al., 2000) can contribute to the restoration of disturbed lands, because they improve functional complementarities of species optimizing results from restoration strategies (VALCARCEL and SILVA, 2000). In latitudes with low biodiversity offer, physical measures (constructions) and physical-biological measures (constructions with organic materials) of recuperation are the most important means of restoration and /rehabilitation (TRAGSA, 1994).

In tropical ecosystems, the use of native species that facilitate the return of biodiversity is recommended. The choice of the species at the beginning of a restoration project is important, as observed in studies of regeneration in the Amazonian forest (PARROTA and KNOWLES, 1999), where reforestation with native species allowed the admission of 141 species, and with commercial species (40) and with primary forest (157), and the diversity of planted species facilitated the appearance of many spontaneous species (PARROTA, 1995; PARROTA et al., 1997a).

On abandoned pasture lands, manipulation of structural complexity during the restoration process facilitates the arrival of seed-dispersing organisms that use different vegetation gradients as perches and shelter, thus intensifying the plant-disperser interaction and therefore the quality of restoration (MIRITI, 1998). Managing this ecosystem complexity so as to improve biodiversity in restoration projects involves the use of zoocoric species, because a large part of dispersion is affected by animals, which participate in about 50-90% of arboreal forest species dispersion (SILVA, 2003). This process increases genetic flows between populations, enhancing long-term sustainability during the restoration activities (BLEHER and BÖHNING-GAESE, 2001; SILVA, 2003; DARIO, 2004).

BM3 was also the treatment with the largest amount of regeneration from zoocoric arboreal species such as *Filicium decipiens* Thw, *Inga fagifolia* Willd., *Eugenia* sp., and, *Sorocea* sp. In environments under the phase of construction, the habit and function of each species contribute to the restoration sustainability. The composition and interaction between species develop distinct environmental attributes, modifying the species richness and ecosystem complexity.

A major difference between the BM's was due to the canopy-cover effect, which vary with composition and richness of the planted species. At BM3, the great richness of planted species may have affected the regeneration results, because it facilitates the entrance of light, filtrates radiation by alternation of their deciduous caducifoly period, modifying the soil physical-chemical conditions, improving the regeneration process. Studies with planted species at the Cerrado site indicated different soil properties according to the litter composition (GARAY et al., 2004).

The Forest ecosystem contained 12 arboreal species: represented by *Tabebuia crysotricha* (Mart.) Standl., *Astronium graveolens* Jacq., *Erythroxylum pulchrum* A. St. Hil., *Croton urucurana* Baill., *Eugenia cuprea* (O. Berg.) Willd., *Eugenia fumicifolia* Dc., *Casearia sylvestris* SW., *Brosimum guianensis* (Aubl.) Huber, and others; where most, are secondary species. At treatment BM1, BM2, and BM3, most of the arboreal individuals from spontaneous colonization were autochthonous species come from the recruitment of planted species. However, six allochthonous arboreal species that had not come from planted species were found: *Inga fagifolia* Willd., *Filicium decipiens* Thw , *Myrocarpus fastigiatus* Allemao, *Sorocea* sp., *Eugenia* sp., and Sp27, which were not identified because they were seedlings on the initial development phase. Studies comparing seed bank in a forest, agriculture and grassland sites identified a higher number of viable arboreal seeds on the forest stand, predominance of invasive species on agriculture site and grasses on the pasture (GASPARINO et al., 2006).

The diversity of arboreal spontaneous regeneration among the five treatment areas reflects the strong influence of the species used in the reforestation in 1994 (Table 2). At BM1, even the low richness of the planted species (4) allowed 75% of arboreal regeneration from the planted species and 25% from allochthonous species, and it was the area that herbaceous species and grasses were best suppressed. BM1 showed 4% of similarity with Forest (Table 3), indicating that it had begun to reverse tendencies, constructing a sustainable ecosystem. BM2, with richness of 3 planted species, showed 85% of *Eucalyptus citriodora* regeneration, sharing no species with Forest. BM2 was the one with the most similar species to Grassland (31%) in regeneration , representing the least sustainable treatment over a medium term. BM3 had the highest richness of planted species (9), and reached 50% of regeneration from allochthonous species and a 5% species similarity with Forest.

Forest showed a high level of homeostatic balance, without the presence of grasses or colonization by planted species, unequivocal evidence of self-determination capacity. The absence of grasses at this site shows the maturity of this ecosystem, where the herbaceous species observed were: *Crypthantus* sp., *Bromelia antiacantha* Bertol., *Oceocladis maculata*

Tabela 2 – Índice de diversidade e riqueza da regeneração espontânea nas parcelas amostradas e porcentagem de regeneração de espécies arbóreas plantadas (autóctones) e não plantadas (alóctones).
Table 2 – *Spontaneous regeneration diversity index and richness in the sampling plots evaluated and the percentage of arboreal regeneration for planted (autochthonous) and non-planted (allochthonous) species.*

Shannon (H')	BM1	BM2	BM3	Forest	Grassland
Trees	0,72	0,38	0,48	0,87	0,03
Vines	0,59	0,66	0,72	0,76	0,73
Herbs	0,32	0,26	0,30	0,31	0,63
Shrubs	0,06	0,00	0,00	0,17	0,02
Grasses	0,36	0,31	0,34	0,00	0,37
TOTAL	2,06	1,57	1,80	2,10	1,78
Species Richness (S)					
Trees	9	8	11	12	2
Vines	8	5	8	8	5
Herbs	5	12	13	8	7
Shrubs	1	0	0	1	1
Grasses	1	1	1	0	1
TOTAL	24	26	33	29	16
Arboreal spontaneous regeneration					
Planted (%)	75	85	55	0	50
Non-planted (%)	25	15	45	100	50

Tabela 3 – Similaridade da regeneração espontânea em ambientes com exíguos atributos ambientais, Nova Iguaçu, Estado do Rio de Janeiro.
Table 3 – *Similarity of spontaneous regeneration species in treatments surveyed in ecosystems with poor environmental conditions, Nova Iguaçu, state of Rio de Janeiro.*

	BM1	BM2	BM3	FOREST	GRASSLAND
BM1		35%	50%	4%	21%
BM2			44%	0%	31%
BM3				5%	23%
FOREST					0%

(Lindl) Lindl., and *Philodendron* sp. The herbaceous species found in the BM's and Grassland were ruderal species, which is a strong competitive distinctiveness in relation to other species, with intense cycles of plant growth and senescence, producing a dry biomass that is highly flammable in hot and dry periods, inhibiting the competition by wood species.

The BM1 presented the highest species diversity among the reforestation areas, with a diversity index with values close to the native diversity of Forest. Although similar in species richness, these sites have different taxonomy and ecological functions in the succession process and site occupation. The BM3 favored ingress and colonization of allochthonous arboreal species from other seed sources, showing that, even though it is located at the same distance from seed sources as the other treatments, it offered the best conditions to facilitate functional connectivity and genetic flow, even at 634 m distance from Forest and isolation by Pasturelands. This information emphasizes the importance of using different species to guarantee the restoration sustainability in disturbed ecosystems. At BM1, the regeneration of *Mimosa caesalpiniifolia* Benth, *Eucalyptus citriodora* Hook and, *Leucaena leucocephala* (Lam.) de Wit were predominant, indicating a smaller increment of emergent properties, and that the sustainability of this restoration measure may be jeopardized in the medium term. BM2 showed a diversity index lower than Grassland, making it evident that *E. citriodora* contributed little to the generation of emergent properties and establishment of spontaneous colonization in the first 12 years, slowly acting to reverse degradation tendencies. These results differ from those found for a seasonal forest in Minas Gerais (SOUZA et al., 2007), which supported the use of *Eucalyiptus grandis* as an anthropic pioneer in a degraded ecosystem rehabilitation. Grassland had two arboreal species regenerating; however, *Eugenia jambolana* Lam. was a sprout from a burned tree and *Pisidium guajava* L. regenerated from a cut tree, evidencing a continuous human disturbance, accelerating the trend toward inertial degradation. These environments have an imminent risk of fire, where, the low offer of environmental conditions together with fire management as pastures renovation, halt the successional mechanisms and the self-sustainability process in ecological restoration.

The Jaccard similarity index, applied among species from all treatments can indicate tendencies toward spontaneous regeneration (MAGURRAN, 1988) and demonstrates the sustainability of restoration treatments. The areas under reforestation were somewhat similar for species composition ranging from 35 to 50% (Table 3); they were closer to the Grassland, with species similarity ranging between 21 and 31%. The BM3 (5%) was the area most similar to the Forest, followed by BM1 (4%). The BM2, with predominance of 82% of *E. citriodora* Hook did not show similarity of species with Forest, indicating little emergent property acquisition that could aid the entrance and establishment of propagules over 12- year periods, even with the artificial control of fire.

The low similarity between species from the Forest, located 640 m far from the reforestation areas may indicate: a) a lack of ecological attributes that permit colonization and establishment of the most demanding stages of succession; b) Internal forces from ecosystems have stronger degradation tendencies than the sum of efforts from vegetation to construct ecosystems, indicating that using only biological measures does not guarantee the sustainability of restoration over a medium to long-term; d) there are different levels of homeostatic balance, and the ones created by the effects of reforestation do not move on a clear way from inertial degradation tendencies in ecosystems with poor environmental condition attributes. The ecosystems may have changed so far from their original level of homeostatic balance that even after 12 years of restoration measures, it was observed the admission of only 5 % of native plant species.

The BM1 and BM3 had one arboreal species in common with Forest, showing a functional connectivity with the seed source. Forest did not present similarities with Grassland, demonstrating that these environments have opposite evolutionary tendencies even though they are only 655 m apart from each other. The variation of similarity in the BM's, from 35 to 50%, shows the difference between treatments, where the choice of species affected restoration quality.

Amongst the similar species, the grass *Panicum maximum* Jacq. was notable for appearing in four of the five treatments as the species with the highest Value of Importance (Fig. 2). The BM1 was the measure that best suppressed the grass *P. maximum*, which might be related to the high litter cover in winter, which reduces the chances of small seeds to reach the soil, or because in summer, when grasses increase their biomass and grow vigorously, *M. caesalpiniifolia* provides offers great amount of shadow, reducing the density of *P. maximum*. At BM2; the *E. citriodora* did not play the same role and the grass *P. maximum* had an exceptionally high IV, influencing directly the regeneration process and species interactions in this plot. Vines were recorded in all the treatment areas; and in the BM's, they were represented by three species (*Vigna vexillata* (L.) A. Rich., *Clitoria macrophylla* Wall., and *Arrabidea* sp.). Although vine plants increase organic matter and the structural complexity of the understory, they can strangulate some arboreal individual trees and even slow the overall development of trees. This effect was observed at BM3 with *Senna* sp., which suffered 100% of mortality.

The sustainability achieved may be jeopardized by other factors such as competition, seed and seedling predation, distance from seed source, and exotic species invasion (NEPSTAD et al., 1991; AIDE and CAVALIER, 1994; GUARIGUATA et al., 1995; NEPSTAD et al., 1996). Most ruderal species have physiological mechanisms that optimize energy utilization and resistance to climatic stress and poor environmental condition of ecosystem attributes (LARCHER, 1977). These attributes confer an advantage on their establishment which can retard restoration activities. Grasses, for example, constitute one of the major problems for spontaneous regeneration, because it is an aggressive colonizer that competes for nutrients and water, impeding the establishment of native species (NEPSTAD et al., 1991; VIEIRA et al., 1994; NEPSTAD et al., 1996; FLORENTINE and WESTBROOKE, 2004; SOUZA and BATISTA, 2004). Grasses form a vegetal covering mantel that prevents seeds from reaching the soil (WHELAN et al., 1991; AIDE et al., 1995), and even if the seeds reach the soil, their viability is impaired by high

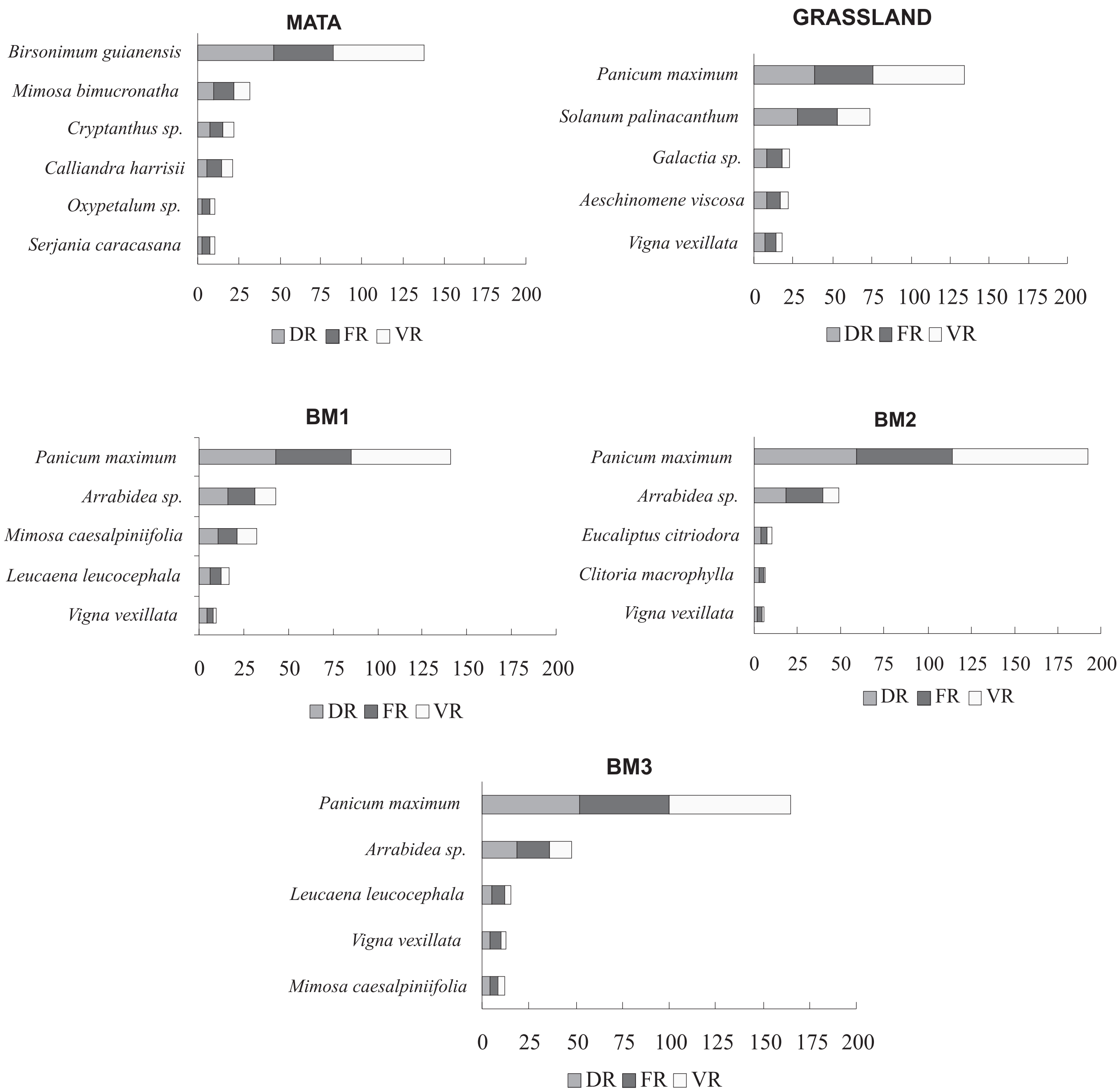

Figura 2 – Cinco espécies de maior valor de importância em cada tratamento. IV = RD+RF+RV, onde: IV = Valor de Importância; RD = Densidade Relativa; RF = Frequência Relativa; RV = Vigor Relativo.

Figure 2 – *Five species with the highest Importance Value in each treatment. IV= RD+RF+RV, where: IV= Importance Value; RD= Relative Density; RF= Relative Frequency; RV= Relative Vigor.*

levels of predation (NEPSTAD et al., 1991; WHELAN et al., 1991). Associated with these problems, there is a risk of biomass combustion, because grasses grow and dry rapidly, providing good conditions for fires, incinerating species that spontaneously colonize the area, volatilizing nutrients and humic acids, and altering the physical-chemical properties of the soil. All these difficulties favor grasses, so they become abundant in disturbed ecosystems.

4. CONCLUSION

The role of species as ecosystem constructors at the five treatment areas were distinct and reflected evolutionary adjustments of these ecosystems, where the approximately 100-year-old Forest achieved a rearrangement of species that propitiates effective entrance and retention of rainwater from precipitation, guaranteeing the maintenance of the functional structure. The BM's showed different degrees in the reconstruction process and distinct levels of sustainability. Grassland presents a tendency toward inertial degradation, making it very difficult the spontaneous reversion of this trend.

The quality of disturbed ecosystems restoration depends on the composition of rustic species at the beginning of the reforestation process implantation.

5. ACKNOWLEDGEMENTS

To Vignè Ltda for allowing the access to the Recuperation of Degraded Areas Program, and to the Conselho Nacional de Desenvolvimento Científico e Tecnológico for the financial support.

6. REFERENCES

AIDE, T. M.; CAVELIER, J. Barriers to lowland forest restoration in the Sierra Nevada de Santa Marta, Colombia. **Restoration Ecology**, v.2, n.4, p.219-229, 1994.

AIDE, T. M. et al. Forest recovery in abandoned tropical pastures in Puerto Rico. **Forest Ecology and Management**, v.77, n.1, p.77-88, 1995.

BARBIÉRE, E. B.; KRONEMBERGER, D. M. P. Climatologia do litoral sul-sudeste do Rio de Janeiro. **Cadernos de Geociências**, v.12, p.57-73, 1994.

BLEHER, B.; BÖHNING-GAESE, K. Consequences of frugivore diversity for seed dispersal, seedling establishment and the spatial pattern of seedlings and trees. **Oecologia**, v.129, n.3, p.385-394, 2001.

BOSCH, J. M.; HEWLETT, J. D. A review of catchment experiments to determine the effect of vegetation changes oin water yield and evapotranspiration. **Journal of Hydrology**, v.55, n.1, p.3-23, 1982.

BROWN, S.; LUGO, A. E. Rehabilitation of tropical lands: a key to sustaining development. **Restoration Ecology,** v.2, n.1, p.92-111, 1994.

CHAPMAN, C. A.; CHAPMAN, L. J. Exotic tree plantations and the regeneration of natural forest in Kibale National Park, Uganda. **Biological Conservation,** v.76, n.3, p.253-257, 1996.

DARIO, F.R. A importância da fauna na dinâmica da floresta. 2004. Available at <URL **http://port.pravda.ru/brasil**> accessed on 16 May 2005.

DIETRICH, N. L. European rehabilitation projects reflect cultural and regional diversity. **Rock Products**, v.93, n.1, p.45-47, 1990.

ENGEL, V. L.; PARROTA, J. A. Definindo a restauração ecológica: tendências e perspectivas mundiais. In: KAGEYAMA, P. et al. (Eds.) **Restauração ecológica de ecossistemas naturais**. Botucatu: FEPAF, 2003. p.1-26

FLORENTINE, S. K.; WESTBROOKE, M. E. Restoration in abandoned tropical pasturelands - do we know enough? **Journal for Nature Conservation**, v.12, n.1, p.85-94, 2004.

GARAY, I. et al. Evaluation of soil conditions in fast-growing plantations of *Eucalyptus grandis* and *Acacia mangium* in Brazil: a contribution to the study of sustainable land use. **Applied Soil Ecology**, v.27, n.2, p.177-187, 2004.

GASPARINO, D. et al. Quantificação do banco de sementes sob diferentes usos do solo em área de domínio ciliar. **Revista Árvore**, v.30, n.1, p.1-9, 2006.

GUARIGUATA, M.R.; RHEIGANS, R.; MONTAGNINI, F. Early wood invasion under tree plantation in Costa Rica: Implications for forest restoration. **Restoration Ecology**, v.3, n.4, p. 252-260, 1995.

LARCHER, W. **Ecofisiologia vegetal**. Barcelona: Omega, 1977. 305p.

MAGURRAN, A. E. **Ecological diversity and its measurements.** Princeton: Princeton University Press, 1988.179p.

MANTOVANI, W.; MARTINS, F. R. O método de pontos. **Acta Botânica Brasílica,** v.4, n.2, p.95-122, 1991.

MARTINS, S. V. **Recuperação de matas ciliares**. Viçosa, MG: Aprenda Fácil, 2001.146p.

MATTOS, C. C. L. V. et al. Boletim agrometeorológico, UFRRJ, 1996. **Floresta e Ambiente**, v.1, p.208-215, 1998.

MINTER/IBAMA. **Manual de recuperação de áreas degradadas pela mineração**: técnicas de revegetação. Brasília: IBAMA, 1990. 96p.

MIRITI, M. N. Regeneração florestal em pastagens abandonadas na Amazônia central: competição, predação e dispersão de sementes. In: GASCON, C.; MOUTINHO, P. R. S. (Eds.) **Floresta Amazônica:** dinâmica, regeneração e manejo. Manaus: Ministério de Ciência e Tecnologia and Instituto Nacional de Pesquisas da Amazônia, 1998. p.179-190.

MYERS, N. et al. Biodiversity hotspots for conservation priorities. **Nature**, v.403, p.853-858, 2000.

NEPSTAD D.; UHL, C.; SERRÃO, E. A. S. Recuperation of a degraded Amazonian Landscape: Forest recovery and agricultural restoration. **Ambio**, v.20, n.6, p.248-255, 1991.

NEPSTAD, D. C.; PEREIRA, C. A.; SILVA, J. M. C. A comparative study of tree establishment in abandoned pasture and mature forest of eastern Amazonia. **Oikos**, v.76, n.1, p.25-39, 1996.

PALMIERI, F. **Levantamento semi-detalhado e aptidão agrícola dos solos no município do Rio de Janeiro**. Rio de Janeiro: Embrapa/SLNCS, 1980.

PARROTA, J. A.; KNOWLES, O. H.; WUNDERLE Jr., J. M. Development of floristic diversity in 10-year-old restauration forests on bauxite mined site in Amazonia. **Forest Ecology and Manageme**nt, v.99, n.1, p.21-42, 1997a.

PARROTA, J. A. Productivity, nutrient cycling, and succession in single and mixed-species plantations of *Casuarina equisetifolia, Eucalyptus robusta and Leucaena leucocephala* in Puerto Rico. **Forest Ecology and Management**, v.124, n.1, p.45-77, 1999.

PARROTA, J. A. The influence of overstory composition on understory colonization by native species in plantations on a degraded tropical site. **Journal Vegetal Science**, v.6, n.5, p.627-636, 1995.

PARROTA, J. A.; TURNBULL, J. W.; JONES, N. Catalyzing native forest regeneration on degraded tropical lands. **Forest Ecology and Management**, v.99, n.1, p.1-7, 1997b.

PARROTA, J. A.; KNOWLES, O. H. Restoration of tropical moist forest on bauxite-mined lands in the Brazilian Amazon. **Restoration Ecology,** v.7, n.2, p.103-116, 1999.

PARROTA, J. A.; KNOWLES, O. H.; WUNDERLE Jr., J. M. Development of floristic diversity in 10 - year-old restoration forests on a bauxite mined site in Amazonia. **Forest Ecology and Management**, v.99, n.1, p.21-42, 1997a.

PINHEIRO, C. A.A. **Dinamismo dos processos erosivos em fontes pontuais de emissão de sedimentos para a baía de Sepetiba.** 2004 68f. Dissertação (Mestrado em Ciências Ambientais e Florestais) - Universidade Federal Rural do Rio de Janeiro, Seropédica, 2004.

RICKLEFS, R. E. **Economia da natureza.** Rio de Janeiro: Guanabara Koogan, 2003. 542p.

SOCIETY FOR ECOLOGICAL RESTORATION – SER. Science & Policy Working Group. 2002. **The SER Primer on Ecological Restoauration.** URL <www.ser.org > accessed on 10 Sep. de 2003.

SILVA, W. R .A. Importância das interações planta-animal nos processos de restauração. In: KAGEYAMA, P. et al. (Eds.). **Restauração ecológica de ecossistemas naturais.** Botucatu: FEPAF, 2003. p.77-90.

SOUZA, F.M.; BATISTA, J.F.L. Restoration of semi deciduous forest in Brazil: influence of age and restoration design on forest structure. **Forest Ecology and Management,** v.191, n.1-3, p.185-200, 2004.

SOUZA, P. B. et al. Florística e estrutura da vegetação arbustivo-arbórea do sub-bosque de um povoamento de *Eucalyptuos grandis* W. Hill ex Maiden em Viçosa, MG, Brasil. **Revista Árvore**, v.31, n.3, p.533-543, 2007.

TRAGSA. **Restauración hidrológico forestal de cuencas y control de la erosión**. Madri: Mundi – Prensa, 1994. 902p.

VALCARCEL, R.; SILVA, Z. Eficiência conservacionista de medidas de recuperação de áreas degradadas: proposta metodológica. **Floresta**, v.21, n.1/2, p.101-114, 2000.

VIEIRA, I. C. G.; UHL, C.; NEPSTAD, D. C. The role of the shrub *Cordia multispicata* Cham. as a “succession facilitator” in an abandoned pasture, Paragominas, Amazonia. **Vegetation,** 115, n.1, p.91-99, 1994.

WHELAN, C.J.; WILLSON, M.F.; TUMA, C.A.; SOUZA-PINTO, A. Spatial and temporal patterns of post dispersal seed predation. **Canadian Journal of Botany**, v.69, p. 428-436, 1991.