

Natural regeneration in a restored bauxite mine in southeast Brazil

Regeneración natural en mina de bauxita restaurada en el sureste de Brasil

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SUMMARY

The objective of the present study was to verify if, in floristic terms of natural regeneration, a restored bauxite mine in southeast Brazil can be considered successfully restored. Forty plots of 3.0 x 3.0 m were allocated in the area. All shrubs and trees with height ≥ 0.30 m and diameter at 1.30 m height (DBH) ≤ 5.0 cm were identified and classified into successional categories and dispersal syndromes; DSL (diameter at soil level) and height were measured. We use the canonical correspondence analysis (CCA) to verify the correlations between environmental variables (canopy openness, litter decomposition, soil penetration resistance) and vegetation. We found 705 individuals, 80 species and 30 families. The families with the highest species richness were Fabaceae and Melastomataceae. The specie with the highest importance value (IV) was *Myrcia splendens*. Most species are the early secondary successional category and the zoochoric dispersion syndrome. CCA ordination indicates the formation of a group of species associated with less soil compaction and with low litter decomposition rate and the formation of another group associated with intermediate values of soil penetration resistance and litter decomposition rate. The results obtained after ten years of implementation of the restoration project, in floristic terms, are suitable. In other words, the area can be considered as successfully restored.

Key words: bauxite, canonical correspondence analysis, floristic, forest restoration.

RESUMEN

El objetivo del presente estudio fue verificar si, en términos florísticos de la regeneración natural, una mina de bauxita restaurada en el sureste de Brasil puede considerarse restaurada con éxito. En el área, se distribuyeron 40 parcelas de 3,0 x 3,0 m, donde todos los arbustos y los árboles con altura $\geq 0,30$ m y diámetro a 1,30 m de altura (DAP) $\leq 5,0$ cm fueron identificados, medido el diámetro a nivel del suelo y la altura, y clasificados en categoría sucesional y dispersión de semillas. Se aplicó análisis de correspondencia canónica (CCA) para verificar las correlaciones entre variables ambientales y vegetación. Se encontraron 705 individuos, 80 especies y 30 familias. Las familias con mayor riqueza de especies fueron Fabaceae y Melastomataceae, y la especie con el mayor valor de importancia fue *Myrcia splendens*. La mayoría de las especies fueron de la categoría de sucesión secundaria inicial y con dispersión de semillas por zoocoría. Las variables ambientales mostraron los valores: constante de descomposición de la hojarasca (k) ($0,0033 \pm 0,0017$); apertura del dosel ($8,1 \pm 6,5$ %); resistencia a la penetración ($9,3 \pm 4,6$ MPa). La ordenación CCA indicó la formación de un grupo de especies asociadas con menos compactación del suelo y con una baja tasa de descomposición de la hojarasca, y la formación de otro grupo asociado con valores intermedios de resistencia a la penetración y la descomposición de la hojarasca. Los resultados obtenidos después de 10 años de ejecución del proyecto de restauración, en términos florísticos, son adecuados. Se puede considerar que el área fue restaurada con éxito.

Palabras clave: bauxita, análisis de correspondencia canónica, florística, restauración forestal.

INTRODUCTION

Forests have been degraded over time by increasing human activities and they are quickly shrinking (Lu *et al.* 2011). After undergoing a disturbance such as mining, the forest ecosystem loses its floristic composition and biotic means of regeneration, which will prevent it from returning to its original natural condition (Rodrigues *et al.* 2010). Ore extraction causes onus, evidenced by the in-

tense alteration of the environment, both with reference to the local landscape and physical and temporal depth. The mining of bauxite causes the destruction of vegetation, altering the soil and landscape conditions and disrupting the ecosystem (Moreira 2004).

In this scenario, it is necessary to recover the degraded ecosystem by forest restoration techniques considered effective tools of ecological engineering (Lu *et al.* 2011). Forest restoration aims at restoring natural ecological pro-

cesses and structures of a degraded or altered forest (Deluca *et al.* 2010), seeking the return of pre-disturbance conditions (van Andel and Aronson 2012).

To succeed in a forest restoration project, it is essential to perform the evaluation of the restored area by the analysis of indicators or environmental variables (Brancalion *et al.* 2012). The evaluation indicators of forest restoration most commonly used are the vegetative indicators or bioindicators such as natural regeneration, seed rain, soil seed bank, canopy openness, litter production and nutrient cycling (Martins 2013).

The study of natural regeneration can predict the subsequent behavior and development of the forest, because regeneration enables the understanding of the relationship and the number of species belonging to its stock, along with their dimensions and distributions in the forest (Carvalho 1982). This understanding provides important information about the ecology of individual species (Newton 2007), and whether there is the need for interventions aimed at accelerating the successional process as planting enrichment and elimination of exotic species (Martins and Kunz 2007).

In restoration projects conducted by planting tree and shrub species, natural regeneration has a key role in the occupation of spaces among seedlings by propagules that arrive in the area, coming from planted species and the surrounding forest fragments.

In trees, the most common age group evaluated in restoration projects is 1-15 years (about 70 %) (Wortley *et al.* 2013). Vegetation structure, species diversity and abundance, and ecological processes are the most commonly used attributes to indicate the ecosystem condition in the process of restoration (Wortley *et al.* 2013). Restoration of mined areas and their evaluation, as in bauxite mine, are becoming increasingly common and important throughout the world (Parrotta *et al.* 1997, Grant *et al.* 2007, Kew *et al.* 2007, Koch 2007).

Parrotta *et al.* (1997), in evaluating the understory of a bauxite mine 10 years after the planting of native tree species in the Brazilian Amazon region, showed that the restoration has been largely successful in establishing a dynamic and sustainable successional environment. In addition, the natural regeneration layer was formed from seed dispersal by planted trees and forest areas in the surroundings.

The present study investigates the relation of environmental variables with the floristic composition of natural regeneration layers in a restored bauxite mine, and tests the hypothesis that the area, in floristic terms, can be considered successfully restored.

METHODS

Study site. The current study was conducted in a restored bauxite mine by planting tree seedling (21°25'35" S, 42°56'08" W), in the county of Descoberto, Minas Gerais State, in southeast Brazil, with altitude between 618 - 633 m (figure 1).

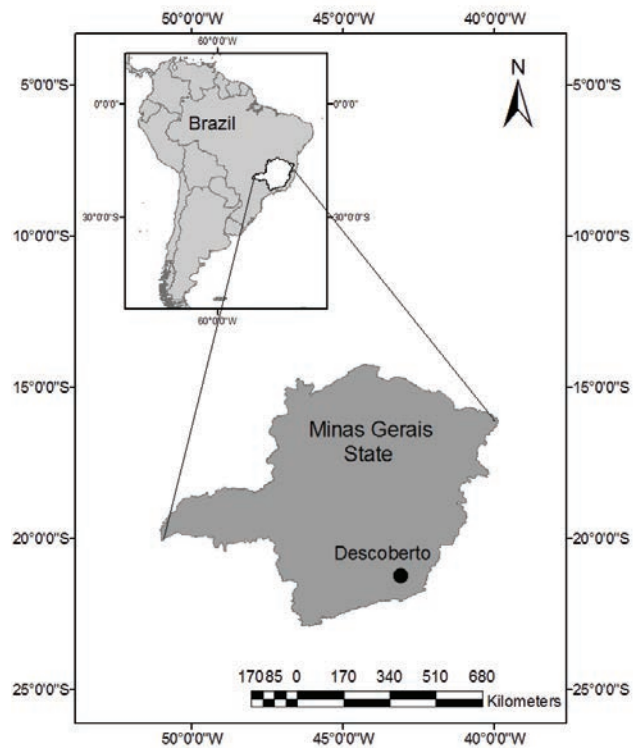


Figure 1. Study site, county of Descoberto, Minas Gerais State, Brazil.

Sitio de estudio, la ciudad de Descoberto, Minas Gerais, Brasil.

The climate of the region is classified as Aw (tropical humid) by the Koeppen system. The temperature is high in summer, reaching 40 °C, and in winter it is 20 - 22 °C. Average annual rainfall is 1,300 mm. It has a very rugged topography, with small plains and plateaus limited by mountains and rectilinear valleys (Lopes and Branquinho 1988). The predominant vegetation in the region where the study area is inserted is classified as semideciduous montane forest (IBGE 2012).

In 2003, Votorantim Metais Company explored bauxite in the study area. Subsequently, yet in 2003, the topographic reconstruction process was held with the return of topsoil removed before mining and the implementation of forest restoration through the planting of trees in the total area (1.0 ha), with spacing of 1.0 x 1.0 m (table 1). Maintenance activities were held: correction of soil acidity; phosphate fertilizer; topdressing around each seedling; regular combat to ants with granular bait. The study of the floristic composition of natural regeneration layer was performed in 2013.

Around the study area, there are areas undergoing restoration with different ages, grasslands and preserved forest fragments.

Vegetation characterization. In the study area, 40 permanent plots of 3.0 x 3.0 m were allocated, at intervals of 10 m between the plots. All the shrubs and trees with height

Table 1. List of tree species used in planting.

Lista de especies de árboles utiliza en la siembra.

Family	Specie	SC	DS
Achariaceae	<i>Carpotroche brasiliensis</i> (Raddi) A Gray	LS	Zoo
Arecaceae	<i>Euterpe edulis</i> Mart.	LS	Zoo
	<i>Syagrus romanzoffiana</i> (Cham.) Glassman	ES	Zoo
Bignoniaceae	<i>Handroanthus heptaphyllus</i> (Vell.) Mattos	LS	Ane
	<i>Zeyheria tuberculosa</i> (Vell.) Bureau ex Verl.	ES	Ane
	<i>Sparattosperma leucanthum</i> (Vell.) K.Schum.	ES	Ane
Cannabaceae	<i>Trema micrantha</i> (L.) Blume	P	Zoo
Chrysobalanaceae	<i>Licania tomentosa</i> (Benth.) Fritsch	ES	Zoo
Euphorbiaceae	<i>Joannesia princeps</i> Vell.	ES	Auto
Fabaceae	<i>Anadenanthera peregrina</i> (L.) Speg.	ES	Ane
	<i>Caesalpinia peltophoroides</i> Benth.	ES	Auto
	<i>Cassia ferruginea</i> (Schrad.) Schrad. ex DC.	ES	Auto
	<i>Clitoria fairchildiana</i> R.A.Howard	ES	Auto
	<i>Dalbergia nigra</i> (Vell.) Allemão ex Benth.	ES	Ane
	<i>Hymenaea courbaril</i> L.	LS	Zoo
	<i>Inga vera</i> Willd.	ES	Zoo
	<i>Senna multijuga</i> (Rich.) H.S.Irwin et Barneby	ES	Auto
	<i>Senna macranthera</i> (DC. ex Collad.) H.S.Irwin et Barneby	P	Auto
	<i>Plathymenia reticulata</i> Benth.	ES	Ane
	<i>Piptadenea gonoacantha</i> (Mart.) J. F. Macbr	ES	Auto
	<i>Anadenanthera colubrina</i> (Vell.) Brenan	ES	Ane
	<i>Cassia grandis</i> L. f.	ES	Ane
<i>Platypodium elegans</i> Vogel	ES	Ane	
Lecythidaceae	<i>Cariniana estrellensis</i> (Raddi) Kuntze	LS	Ane
Malpighiaceae	<i>Lophanthera lactescens</i> Ducke	LS	Nc
Malvaceae	<i>Luehea grandiflora</i> Mart. et Zucc.	ES	Ane
Melastomataceae	<i>Tibouchina granulosa</i> (Desr.) Cogn.	P	Zoo
Meliaceae	<i>Cedrela fissilis</i> Vell.	LS	Ane
	<i>Guarea guidonia</i> (L.) Sleumer	LS	Zoo
Moraceae	<i>Artocarpus heterophyllus</i> Lam.	Nc	Zoo
Myrtaceae	<i>Eugenia florida</i> DC.	LS	Zoo
	<i>Myrcia splendens</i> (Sw.) DC.	ES	Zoo
	<i>Syzygium cumini</i> (L.) Skeels	P	Zoo
	<i>Psidium guajava</i> L.	P	Zoo
Phytolaccaceae	<i>Gallesia integrifolia</i> (Spreng.) Harms	ES	Zoo
Rubiaceae	<i>Genipa americana</i> L.	LS	Zoo
Urticaceae	<i>Cecropia glaziovii</i> Snethl.	P	Zoo

SC: successional category (P: pioneer, ES: early secondary, LS: late secondary); DS: dispersal syndrome (Ane: anemochory; Zoo: zoochory; Auto: autochory).

SC: categoría sucesional (P: pionero, ES: secundario inicial; LS: secundario tardío); DS: dispersión de semillas (Ane: anemócora; Zoo: zoócora; Auto: autócora).

≥ 0.30 m and diameter at breast height (DBH = 1.30 m) ≤ 5.0 cm were identified and DSL (diameter at soil level) and height were measured.

For species not identified *in situ*, the botanical material was collected for comparison to the material deposited in the herbarium VIC Federal University of Viçosa, after consulting with experts and literature.

The classification of species into families followed Angiosperm Phylogeny Group III (APG III, 2009). The nomenclature of the species and the abbreviations follow available information on the Missouri Botanical Garden (2014) and Lista de Espécies da Flora do Brasil (2014).

Phytosociological parameters (Mueller-Dombois and Ellenberg 1974) for describing the community structure were determined using the software FITOPAC 2.1 (Shepherd 2010). Jaccard similarity index (Mueller-Dombois and Ellenberg 1974) was used to verify the floristic similarity between species of regeneration and species planting.

Successional categories and dispersal syndromes. The species sampled were classified as successional categories according Gandolfi *et al.* (1995) for Brazilian semi-deciduous forests. Four successional categories that correspond to shade tolerant species were adopted: pioneer, early secondary, late secondary and unclassified. The more shade-tolerant species were included at the late secondary category. The shade-intolerant species were included at the pioneer category.

Species were also classified as to dispersal syndromes in four categories: zoochory, anemochory, autochory (van der Pijl 1982) and unclassified.

Environmental variables. Canopy openness was determined by digital hemispherical photographs acquired at the center of each plot with CI-110 Digital Plant Canopy Imager® equipment.

The degree of soil penetration resistance was measured by resistance to vertical penetration into the soil by an impact penetrometer (digital model Penetrolog PLG1020 Falker), using the cone type 2 in the 0 to 10 cm depth in each plot. Medium value of resistance was used to penetration in profile.

To measure litter decomposition, 40 litterbags with 5.0 g of dry mass of leaf litter were distributed in the study area. Decomposition rates were estimated from the loss of dry mass, during one year. The material obtained was dried in forced air oven at 343 K for 48 hours and the dry mass was measured in electronic precision scale. Afterwards, decomposition rate k was estimated according to equation 1 (Olson 1963).

$$X_t = X_0 e^{-kt} \quad [1]$$

Where, X_t = weight of litter at time t ; X_0 = initial weight of litter; e = natural logarithm; k = decomposition rate constant; t = time of decomposition.

Statistical analyses. To analyze the correlations between the environmental variables and vegetation, the canonical correspondence analysis was employed; it was performed in software FITOPAC 2.1 (Shepherd 2010). Environmental variables and frequency values for 23 species (density \geq five individuals) were used for the calculations, with subsequent removal of the species with no significant scores on both axes for more robust analyses. Thus, the number of species was reduced to 19. Correlations between the species axes and environmental variable axes were tested using Monte Carlo tests to estimate the significance of correlations among canonical axes.

RESULTS

Floristic composition. The floristic of the restored area was represented by 80 species belonging to 30 families. A total of 705 individuals were sampled in this forest (19,583 individuals ha^{-1}), distributed in 13,555 trees ha^{-1} and 3,888 shrubs ha^{-1} (table 2).

The families with the highest species richness were Fabaceae (13) and Melastomataceae (12). The families with the most important number of individuals were Melastomataceae, with 263 individuals and Myrtaceae, with 182. They corresponded with 63.1 % of the total of plants sampled.

There are 21 common species between regeneration and species used in planting, with a Jaccard similarity index of 0.21 between planting and regeneration.

The species with the highest importance values (IV) that characterized this restored area were *Myrcia splendens*, *Hymenaea courbaril*, *Miconia tristis*, *Anadenanthera peregrina*, *Miconia cinnamomifolia*, *Licania tomentosa*, *Miconia* sp., *Siparuna guianensis*, *Miconia latecrenata* and *Syzygium cumini*, representing 65.6 % of the individuals (figure 2).

The average height value was 132 ± 122 cm, with minimum and maximum of 30 and 750 cm, respectively. The average diameter value was 1.20 ± 1.30 cm, with minimum and maximum of 0.02 and 7.92 cm, respectively.

Shannon diversity index (H') was 3.20 and evenness (J') was 0.73.

Successional categories and dispersal syndromes. The shrub and tree species sampled in the restored area are distributed in 14 pioneer species, 30 early secondary species and 20 late secondary species; while 16 species could not be classified. Of the total of individuals sampled in the restored area, 197 were pioneer, 314 early secondary and 90 were late secondary; while 104 individuals were species unclassified (figure 3).

Regarding dispersal syndrome, the shrub and tree species sampled in the restored area are distributed in 47 zoochoric species, 13 anemochoric species and seven autochoric species; while 13 species could not be classified. Of the total of individuals sampled in the restored area, 548 were zoochoric, 38 were anemochoric and 19 were autochoric; while 100 individuals were unclassified species (figure 3).

Table 2. Floristic and importance value (IV) of the species sampled in natural regeneration layer in restored area, Brazil.

Florística y valor de importancia (IV) de las especies muestreadas en el estrato natural de regeneración en la zona reforestada, Brasil.

Family	Specie	N	IV %	LF	SC	DS
Achariaceae	<i>Carpotroche brasiliensis</i> (Raddi) A Gray	2	0.34	T	LS	Zoo
Anacardiaceae	<i>Astronium concinnum</i> Schott	2	1.32	T	LS	Ane
	<i>Astronium graveolens</i> Jacq.	1	0.74	T	ES	Ane
	<i>Spondias mombin</i> L.	2	0.43	T	U	Zoo
	<i>Spondias venulosa</i> (Engl.) Engl.	1	0.21	T	U	Zoo
Annonaceae	<i>Xylopia sericea</i> A.St.-Hil.	13	2.12	T	ES	Zoo
	<i>Annona neosericea</i> H.Rainer	1	0.41	T	ES	Zoo
	<i>Annona sylvatica</i> A.St.-Hil.	1	0.39	T	ES	Zoo
Arecaceae	<i>Euterpe edulis</i> Mart.	1	0.17	T	LS	Zoo
	Asteraceae	3	0.72	U	U	U
Asteraceae	<i>Vernonanthura divaricata</i> (Spreng.) H.Rob.	1	0.17	S	P	Ane
Bignoniaceae	<i>Zeyheria tuberculosa</i> (Vell.) Bureau ex Verl.	3	1.36	T	ES	Ane
	<i>Tecoma stans</i> (L.) Juss. ex Kunth	2	0.70	T	P	Ane
	<i>Handroanthus heptaphyllus</i> (Vell.) Mattos	2	0.37	T	LS	Ane
Boraginaceae	<i>Cordia sellowiana</i> Cham.	1	0.34	T	ES	Zoo
Cannabaceae	<i>Celtis</i> sp.	1	0.20	T	U	U
Chrysobalanaceae	<i>Licania tomentosa</i> (Benth.) Fritsch	19	4.35	T	ES	Zoo
Erythroxylaceae	<i>Erythroxylum pelleterianum</i> A.St.-Hil.	12	1.39	T	ES	Zoo
	<i>Erythroxylum deciduum</i> A.St.-Hil.	6	0.93	T	ES	Zoo
Euphorbiaceae	<i>Aparisthium cordatum</i> (A.Juss.) Baill.	3	1.36	T	ES	Auto
	<i>Maprounea guianensis</i> Aubl.	6	1.02	T	ES	Auto
	<i>Alchornea glandulosa</i> Poepp. et Endl.	3	0.46	T	P	Zoo
Fabaceae	<i>Hymenaea courbaril</i> L.	11	5.56	T	LS	Zoo
	<i>Anadenanthera peregrina</i> (L.) Speg.	16	5.20	T	ES	Ane
	<i>Cassia ferruginea</i> (Schrad.) Schrad. ex DC.	5	1.55	T	ES	Auto
	<i>Dalbergia nigra</i> (Vell.) Allemão ex Benth.	3	1.44	T	ES	Ane
	<i>Inga vera</i> Willd.	2	1.26	T	ES	Zoo
	<i>Machaerium nyctitans</i> (Vell.) Benth.	2	0.81	T	ES	Ane
	<i>Senna multijuga</i> (Rich.) H.S.Irwin et Barneby	2	0.80	T	ES	Auto
	<i>Clitoria fairchildiana</i> R.A.Howard	1	0.70	T	ES	Auto
	<i>Apuleia leiocarpa</i> (Vogel) J.F.Macbr.	3	0.50	T	LS	Ane
	<i>Inga marginata</i> Willd.	1	0.49	T	ES	Ane
	<i>Caesalpinia leiostachya</i> (Benth.) Ducke	1	0.39	T	ES	Auto
	<i>Caesalpinia peltophoroides</i> Benth.	1	0.23	T	ES	Auto
	<i>Mimosa</i> sp.	1	0.17	U	U	U
Lacistemataceae	<i>Lacistema pubescens</i> Mart.	2	0.35	T	ES	Zoo
Lauraceae	<i>Nectandra rigida</i> (Kunth) Nees	4	0.71	T	LS	Zoo
Malpighiaceae	<i>Byrsonima sericea</i> DC.	3	0.68	T	ES	Zoo
	<i>Lophanthera lactescens</i> Ducke	3	0.51	T	LS	U
Malvaceae	<i>Luehea grandiflora</i> Mart. et Zucc.	1	0.18	T	ES	Ane
Melastomataceae	<i>Miconia tristis</i> Spring	66	5.42	S	P	Zoo

Continue

Table 2 continue

	<i>Miconia cinnamomifolia</i> (DC.) Naudin	36	4.75	T	P	Zoo
	<i>Miconia</i> sp.	61	4.32	U	U	U
	<i>Miconia latecrenata</i> (DC.) Naudin	43	3.09	T	P	Zoo
	<i>Miconia pusilliflora</i> (DC.) Naudin	20	2.35	T	ES	Zoo
	<i>Ossaea</i> sp.	11	1.10	S	U	U
	<i>Leandra nianga</i> (DC.) Cogn.	6	0.83	S	LS	Zoo
	<i>Miconia sellowiana</i> Naudin	7	0.64	T	P	Zoo
	<i>Leandra sericea</i> DC.	3	0.51	S	LS	Zoo
	<i>Miconia discolor</i> DC.	3	0.41	S	U	Zoo
	<i>Ossaea marginata</i> (Desr.) Triana	4	0.41	S	U	U
	<i>Leandra</i> sp.	3	0.32	S	U	U
Meliaceae	<i>Cedrela fissilis</i> Vell.	1	1.02	T	LS	Ane
	<i>Trichilia pallida</i> Sw.	1	0.15	T	LS	Zoo
Moraceae	<i>Artocarpus heterophyllus</i> Lam.	1	0.58	T	U	Zoo
Myrtaceae	<i>Myrcia splendens</i> (Sw.) DC.	178	13.00	T	ES	Zoo
	<i>Syzygium cumini</i> (L.) Skeels	3	2.62	T	P	Zoo
	<i>Eugenia florida</i> DC.	1	0.15	T	LS	Zoo
Piperaceae	<i>Piper arboreum</i> Aubl.	8	0.95	S	LS	Zoo
	<i>Piper mollicomum</i> Kunth	3	0.38	S	ES	Zoo
	<i>Piper</i> sp.	1	0.15	S	U	U
Primulaceae	<i>Myrsine coriacea</i> (Sw.) R.Br. ex Roem. et Schult.	4	0.61	T	ES	Zoo
Rubiaceae	<i>Psychotria conjungens</i> Müll.Arg.	7	1.10	S	LS	Zoo
	<i>Psychotria nuda</i> Cham. et Schltdl.) Wawra	1	0.17	S	LS	Zoo
	<i>Amaioua guianensis</i> Aubl.	1	0.15	T	LS	Zoo
Rutaceae	<i>Zanthoxylum rhoifolium</i> Lam.	2	0.51	T	P	Zoo
Salicaceae	<i>Casearia gossypiosperma</i> Briq.	2	0.49	T	LS	Zoo
	<i>Casearia arborea</i> (Rich.) Urb.	2	0.43	T	ES	Zoo
Sapindaceae	<i>Matayba elaeagnoides</i> Radlk.	1	0.23	T	ES	Zoo
	<i>Allophylus edulis</i> (A.St.-Hil.) Radlk.	1	0.16	T	P	Zoo
	<i>Cupania ludowigii</i> Somner et Ferrucci	1	0.15	T	LS	Zoo
Siparunaceae	<i>Siparuna guianensis</i> Aubl.	30	4.23	T	LS	Zoo
Solanaceae	<i>Solanum leucodendron</i> Sendtn.	14	2.13	S	P	Zoo
	<i>Solanum cernuum</i> Vell.	9	1.18	S	P	Zoo
	<i>Solanum argenteum</i> Dunal	7	0.69	T	P	Zoo
Undetermined	Undetermined 1	3	0.40	U	U	U
	Undetermined 2	4	1.31	U	U	U
	Undetermined 3	3	0.29	U	U	U
	Undetermined 4	2	0.54	U	U	U
Urticaceae	<i>Cecropia glaziovii</i> Snethl.	3	1.02	T	P	Zoo
Total		705	100.00			

N: number of individuals; IV: importance value; LF: life form (T: tree, S: shrub); SC: successional category (P: pioneer, ES: early secondary, LS: late secondary); DS: dispersal syndrome (Ane: anemochory; Zoo: zoochory; Auto: autochory); U: unclassified.

N: número de individuos; IV: valor de importancia; LF: forma de vida (T: árbol, S: arbusto); SC: categoría sucesional (P: pionero, ES: secundario inicial; LS: secundario tardío); DS: dispersión de semillas (Ane: anemócora; Zoo: zoócora; Auto: autócora); U: sin clasificar.

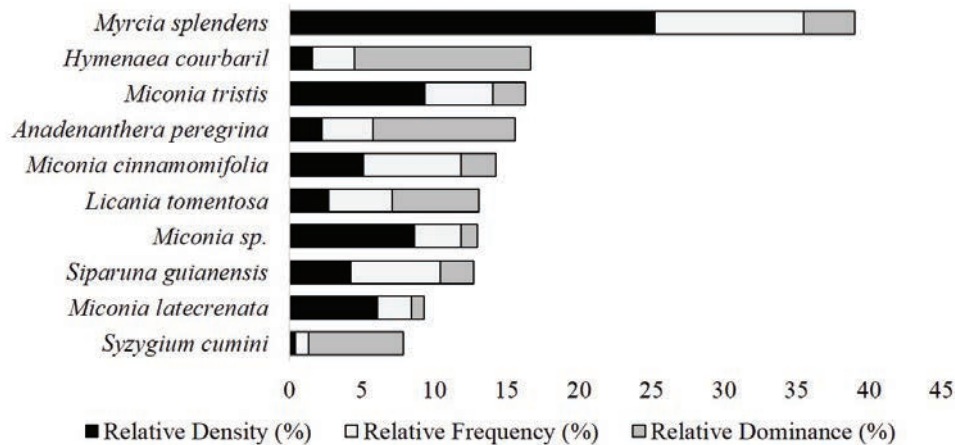


Figure 2. Species with the highest importance value (IV).

Especies con más altos valores de importancia (IV).

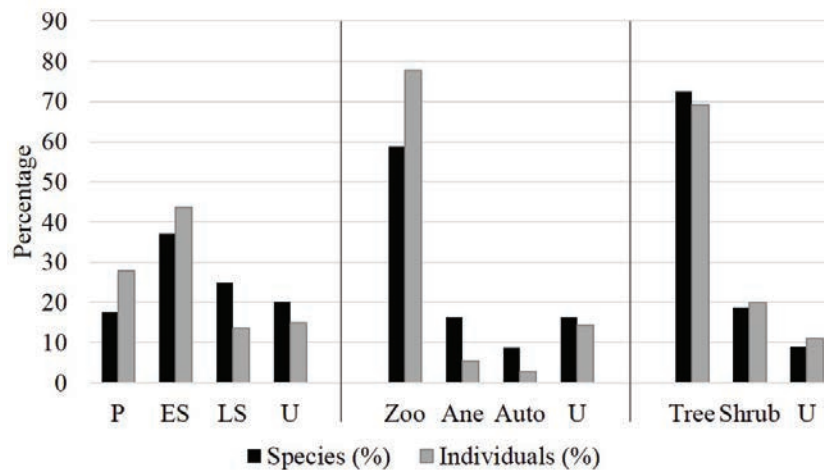


Figure 3. Percentual distribution of individuals and species to successional category (P: pioneer, ES: early secondary, LS: late secondary), dispersal syndrome (Ane: anemochory; Zoo: zoochory; Auto: autochory) and life form. U: unclassified.

Distribución porcentual de individuos y especies a la categoría sucesional (P: pionero, ES: secundario inicial; LS: secundario tardío), dispersión de semillas (Ane: anemócora; Zoo: zoócora; Auto: autócora) y forma de vida. U: sin clasificar.

Environmental variables and vegetation correlations. The environmental variables showed the following values: low leaf litter decomposition rate constant (k) = 0.0033 ± 0.0017 ; low canopy openness = 8.1 ± 6.5 %; high soil penetration resistance = 9.3 ± 4.6 MPa.

The species and the scores of axes 1 and 2 used in the canonical correspondence analysis are shown in table 3. The canonical correspondence analysis eigenvalues for the first two ordination axes were 0.354 (axis 1) and 0.145 (axis 2). In this analysis the first canonical axis explained 10.9 % of the variance and the second axis explained 4.5 %, together accounting for 15.4 % of the total variance. The Monte Carlo permutation test showed significance ($P = 0.05$) only for the species–environmental correlations between the first axes.

The environmental variables most strongly correlated with the first axis were leaf litter decomposition, and with the second axis were soil penetration resistance. The weighted correlations showed weak interrelations among the three variables, because they present eigenvalues lower than 0.5 (ter Braak 1995) (table 4).

The canonical correspondence analysis ordination (figure 4) indicates the formation of a group of species associated with less soil compaction and with low litter decomposition rate as *Maprounea guianensis* and *Solanum Cernuum*. And the formation of another group associated with intermediate values of soil penetration resistance and litter decomposition rate as *Miconia pusilliflora* and *Hymenaea courbaril*. *Solanum leucodendron* tended towards higher abundance in more open canopy. *Miconia latecre-*

Table 3. The species, abbreviated species name and scores of axes 1 and 2 used in the canonical correspondence analysis.
 Especies, nombre de las especies abreviado y las puntuaciones de los ejes 1 y 2 utilizadas en el análisis de correspondencia canónica.

Species	Abbreviated Species name	Scores	
		Axis 1	Axis 2
<i>Cassia ferruginea</i> (Schrad.) Schrad. ex DC.	Cas fer	-1.133	0.716
<i>Erythroxylum pelleterianum</i> A.St.-Hil.	Ery pel	0.322	-1.414
<i>Hymenaea courbaril</i> L.	Hym cou	-0.133	0.700
<i>Leandra nianga</i> (DC.) Cogn.	Lea nia	-1.960	-0.308
<i>Maprounea guianensis</i> Aubl.	Map gui	0.476	-1.085
<i>Miconia cinnamomifolia</i> (DC.) Naudin	Mic cin	0.109	0.640
<i>Miconia latecrenata</i> (DC.) Naudin	Mic lat	2.325	1.897
<i>Miconia pusilliflora</i> (DC.) Naudin	Mic pus	-1.419	0.695
<i>Miconia sellowiana</i> Naudin	Mic sel	-1.305	-1.951
<i>Miconia</i> sp.	Mic sp.	0.665	-0.919
<i>Miconia tristis</i> Spring	Mic tri	-1.470	0.400
<i>Myrcia splendens</i> (Sw.) DC.	Myr spl	0.214	-0.565
<i>Ossaea</i> sp.	Oss sp.	-0.558	1.018
<i>Piper arboreum</i> Aubl.	Pip arb	-1.150	2.060
<i>Psychotria conjungens</i> Müll.Arg.	Psy con	0.873	0.436
<i>Solanum argenteum</i> Dunal	Sol arg	-1.267	3.633
<i>Solanum cernuum</i> Vell.	Sol cer	0.537	-1.643
<i>Solanum leucodendron</i> Sendtn.	Sol leu	-0.809	-0.217
<i>Xylopia sericea</i> A.St.-Hil.	Xyl ser	-0.256	0.613

Table 4. Canonical correspondence analysis: internal correlations (intraset) in the first two ordination axes and correlation matrix weighted environmental variables used in the analysis. *Correlations with absolute values > 0.5.

Análisis de correspondencia canónica (CCA): correlaciones internas ('intraset') en los dos primeros ejes de ordenación y de la matriz de correlación ponderados de los variables ambientales utilizados en el análisis. Las correlaciones con valores absolutos > 0,5 se muestran en negrita.

Environmental variables	Internal correlations		k	Weighted correlations	
	Axis 01	Axis 02		Soil penetration resistance	Canopy openness
k	-0.9886*	0.0664	1.000	-	-
Soil penetration resistance	-0.1317	-0.9913*	0.196	1.000	-
Canopy openness	-0.3202	-0.2575	0.176	-0.215	1.000

nata and *Psychotria conjungens* tended to higher abundance in more closed canopy. *Piper arboreum* and *Solanum argenteum* tended to higher abundance at sites with more compacted soils.

Concerning the distribution of plots, the canonical correspondence analysis ordination (figure 5) indicates that there is not a formation of large patches in the area with predominant characteristics of the studied environmental variables. The study area shows environmental heterogeneity.

DISCUSSION

Floristic composition. Fabaceae, Melastomataceae and Myrtaceae are botanical families often found in floristic surveys of natural regeneration in semideciduous forests (Higuchi *et al.* 2006, Marangon *et al.* 2008) and in restored areas (Santos and Valcarcel 2011, Miranda Neto *et al.* 2012).

Fabaceae is an important family in restoration areas, because many species of this family can perform biological nitrogen fixation, which eases the regeneration on

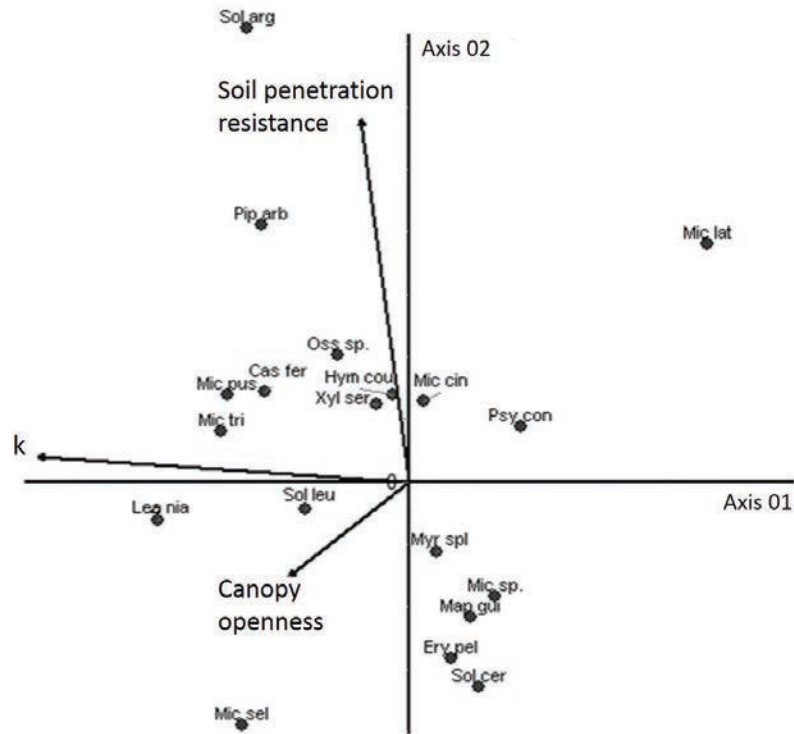


Figure 4. Canonical correspondence analysis ordination showing the distribution of species in relation to soil penetration resistance, leaf litter decomposition rate constant (k) and canopy openness. See table 2 for complete species names.

Ordenación del análisis de correspondencia canónica que muestra la distribución de las especies en relación a resistencia a la penetración, constante de velocidad de descomposición de hojarasca (k) y la apertura del dosel. Ver cuadro 2 para los nombres de especies completas.

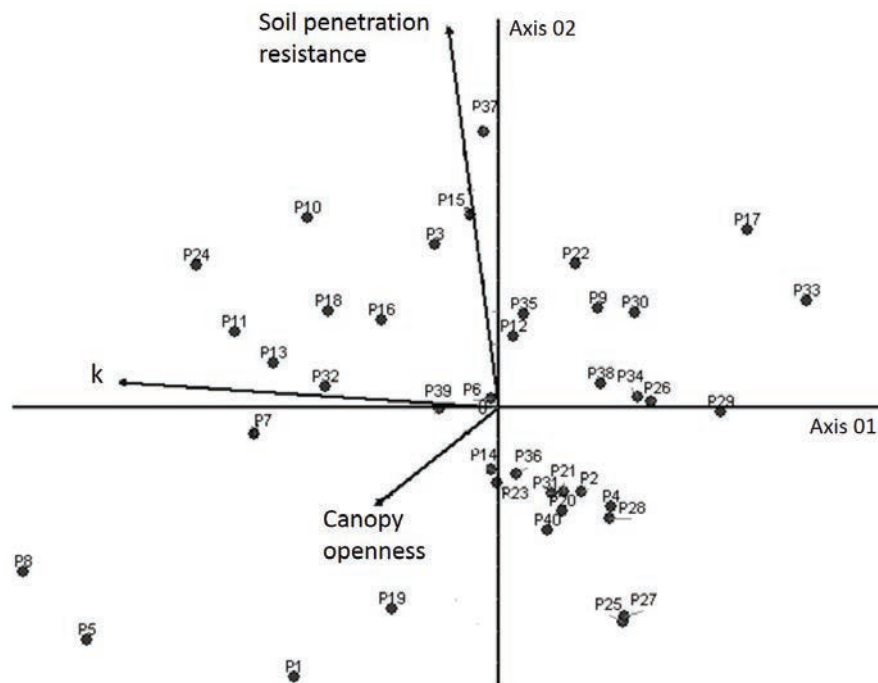


Figure 5. Canonical correspondence analysis ordination showing the distribution of plots in relation to soil penetration resistance, leaf litter decomposition rate constant (k) and canopy openness.

Ordenación del análisis de correspondencia canónica que muestra la distribución de las unidades de muestreo en relación a resistencia a la penetración, constante de velocidad de descomposición de hojarasca (k) y la apertura del dosel.

degraded soils (Campello 1998), as *Dalbergia nigra* (Dias *et al.* 2006), *Inga marginata* and *Inga vera* (Moreira e Siqueira 2006).

Melastomataceae gathers individuals with several life forms, with distribution in all Brazilian forest types (Baumgratz *et al.* 2010) and in degraded areas (Clausing and Renner 2001). It is considered the sixth largest family of angiosperms in Brazil (Forzza *et al.* 2010). In the Atlantic Forest, region of this study, this family is considered an important group due to the density of its populations (Baumgratz *et al.* 2006).

Myrtaceae is a botanical family with high occurrence in tropical and subtropical regions of the world (Lamarca *et al.* 2011) with about 3,800 species worldwide (Lucas *et al.* 2005) and about 1,000 species in Brazil (Sobral *et al.* 2010). Most species of this family are part of a late successional category (Hüller and Schock 2011).

There is no floristic similarity between the regeneration layer and the species used in planting since the degree of floristic similarity between two communities considered by the Jaccard index (Mueller-Dombois and Ellenberg 1974) has not been reached: values equal to or higher than 0.25. Nevertheless, Fabaceae and Myrtaceae families are represented mainly by the species used in planting. This demonstrates an important contribution in the floristic composition of regeneration. Melastomataceae and Solanaceae have their most important representation of species from the surrounding forest fragments. This demonstrates that the restored area receives propagules of the forest matrix where it is inserted and provides a favorable environment for the development of these species from the surrounding.

The outstanding importance value presented by species *Myrcia splendens* is mainly related to its high relative density. This species was also sampled with emphasis on natural regeneration in secondary forest fragments in southeastern Brazil (Alves and Metzger 2006, Higuchi *et al.* 2006) and in restored areas (Miranda Neto *et al.* 2012).

Hymenaea courbaril and *Anadenanthera peregrina* stood out for their high basal area value. Despite the low number of individuals, these have large size, with high values of height and diameter compared with other species.

Hymenaea courbaril has a vast geographical distribution with adaptation to different environments (Silva-Júnior *et al.* 2001). Individuals of this species in the seedling and young stages are tolerant to shading. Young individuals also have good development in disturbed environments and in environments with high light incidence. This maximizes their use in conservation tactics and forest restoration projects (Oliveira *et al.* 2011).

Anadenanthera peregrina occurs in dry and wet soils; it tolerates shallow, compacted, poorly drained and soggy soils, with medium to clayey texture and shows moderate growth (Carvalho 2003). However, a strong dominance and allelopathic effects of *Anadenanthera peregrina* can contribute to a selective effect on the seed bank and re-

generation, and decrease the diversity of shrub and tree species in monospecific plantations for forest restoration (Souza *et al.* 2012).

The values of Shannon diversity (H') and evenness (J') define a forest with medium diversity, low ecological dominance heterogeneous floristic to Semi-deciduous forest (Souza *et al.* 2013).

Successional categories and dispersal syndromes. The percentage of species and individuals by successional category in the restored area shows that the early secondary species were the most abundant ones. This result corroborates with findings in a 40-year-old restored forest by Miranda Neto *et al.* (2012) and forest fragment by Higuchi *et al.* (2006), both located in the same region of this study, in which the larger proportion of the verified species was from the early secondary category. These data show an average successional stage for such environments and that the restored area got successional progress in the dynamics of ecological relations.

The percentage of species and individuals by dispersal syndromes in the restored area shows that the zoochoric species were the most abundant ones. More than 75 % of trees in tropical forests have zoochoric dispersion (Beaune *et al.* 2013). This large presence of species with zoochoric dispersion is important for the maintenance of propagules disperser fauna, and shows a significant resource and shelter supply for the fauna (Franco *et al.* 2012).

Environmental variables and vegetation correlations. The average value of canopy openness did not present high-value. It collaborates with the large presence in natural regeneration layer of species of secondary ecological group, which need shaded environment at least in the initial growth phase.

According to the classification of soil penetration resistance in forest environments proposed by Arshad *et al.* (1996), the average value found in this study falls under high compaction. This probably happened because the study area was severely altered by the bauxite mining and topsoil removal and, thus, it reached the lower layers in the soil profile with higher resistance to penetration. This severe alteration of the study area may also have a direct action on the low leaf litter decomposition rate constant. In an environment possessing high compaction, as the study area, the speed of lixiviation is low, and thus the leaf litter decomposition rate will be slower.

The first and second eigenvalue can be considered low, less than 0.5 (ter Braak 1995), showing the existence of a short gradient on the first and second axes (Carvalho *et al.* 2005).

The low eigenvalues show a remaining variance that is not explained by the environmental variables used. However, it is a common feature in vegetation data and does not affect the significance of the species-environment relationships (ter Braak 1995). This fact is proven by the Monte

Carlo permutation test which showed that the abundances of species and environmental variables were significantly correlated, at least on the first axis.

Canonical correspondence analyses showed that the species analyzed have different behaviors in relation to environmental variables.

Miconia latecrenata is a pioneer species found in open areas (Fonseca *et al.* 2013). However, this species was associated with a more closed canopy sites. This was probably due to the concentration of 77 % of individuals of this species in a single installment, where the value of canopy openness was only 4.3 %. This result shows that *Miconia latecrenata* can also develop and survive, at least in the initial phase, in environments with high levels of shading.

Piper arboreum is an understory plant (Bizerril and Raw 1998), found in disturbed areas. Its fruits are dispersed by bats (Mikich 2002). *Solanum argenteum* is a frequent species in natural regeneration layers of reforested degraded areas (Santos and Valcarcel 2011) and its main mechanism of dispersal is by fruit bats (Mikich 2002). These facts can explain the preference of these species for sites with high soil penetration resistance.

CONCLUSIONS

The floristic composition of the natural regeneration layer, mostly, can be divided into two groups. The first group is associated with less soil compaction and low litter decomposition rate and the second is associated with intermediate values of soil penetration resistance and litter decomposition rate.

The natural regeneration layer of the restored area shows progress in forest succession, and it can be classified as intermediate successional stage. For the mined area, the results obtained after ten years of implementation of the restoration project, in floristic terms, are suitable. In other words, we can consider that the area was successfully restored.

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REFERENCES

- Alves LF, JP Metzger. 2006. A regeneração florestal em áreas de floresta secundária na Reserva Florestal do Morro Grande, Cotia, SP. *Biota Neotropica* 6(2). Consultado 27 nov. 2013. Disponível em <http://www.biotaneotropica.org.br/v6n2/pt/abstract?article+bn00406022006>
- APG III (Angiosperm Phylogeny Group III). 2009. An update of the Angiosperm Phylogeny Group classification for the order and families of flowering plants. *Botanical Journal of the Linnean Society* 161: 105-121.
- Arshad MA, B Lowery, B Grossman. 1996. Physical tests for monitoring soil quality. In Doran JW, AJ Jones eds. *Methods for assessing soil quality*. Madison, USA. Soil Science Society of America. p. 123-141.
- Baumgratz JFA, KFR Bernardo, B Chiavegatto, R Goldenberg, PJF Guimarães, R Kriebel, AB Martins, FA Michelangeli, M Reginato, R Romero, MLDR Souza, E Woodgyer. 2010. Melastomataceae. In Forzza RC ed. *Catálogo de plantas e fungos do Brasil*. v. 02. Rio de Janeiro, Brasil. Jardim Botânico do Rio de Janeiro. p. 1236-1277.
- Baumgratz JFA, MLDR Souza, DC Carraça, BA Abbas. 2006. Melastomataceae na Reserva Biológica de Poço das Antas, Silva Jardim, Rio de Janeiro, Brasil: aspectos florísticos e taxonômicos. *Rodriguésia* 57: 591-646.
- Beaune D, F Bretagnolle, L Bollache, G Hohmann, M Surbeck, B Fruth. 2013. Seed dispersal strategies and the threat of defaunation in a Congo forest. *Biodiversity and Conservation* 22: 225-238.
- Bizerril MXA, A Raw. 1998. Feeding behaviour of bats and the dispersal of *Piper arboreum* seeds in Brazil. *Journal of Tropical Ecology* 14(1): 109-114.
- Brançalion PHS, RAG Viani, RR Rodrigues, S Gandolfi. 2012. Avaliação e monitoramento de áreas em processo de restauração. In Martins SV ed. *Restauração ecológica de ecossistemas degradados*. Viçosa, Brasil. Editora UFV. p. 262-293.
- Campello EFC. 1998. Sucessão vegetal na recuperação de áreas degradadas. In Dias LE, LWV Mello eds. *Recuperação de áreas degradadas*. Viçosa, Brasil. Editora UFV. p. 183-196.
- Carvalho DA, AT Oliveira-Filho, E van den Berg, MAL Fontes, EA Vilela, JGGSM Marques, WAC Carvalho. 2005. Variações florísticas e estruturais do componente arbóreo de uma floresta ombrófila alto-montana às margens do rio Grande, Bocaina de Minas, MG, Brasil. *Acta Botanica Brasílica* 19(1): 91-109.
- Carvalho JOP. 1982. Análise estrutural da regeneração natural em floresta tropical densa na região do Tapajós no Estado do Pará. Tesis Magíster en Engenharia Florestal. Curitiba, Brasil. Universidade Federal do Paraná. 128 p.
- Carvalho PER. 2003. Espécies arbóreas brasileiras. Colombo, Brasil. Embrapa Florestas. 1039 p.
- Clausing G, SS Renner. 2001. Molecular phylogenetics of Melastomataceae and Memecylaceae: implications for character evolution. *American Journal of Botany* 88: 486-498.
- Deluca TH, GH Aplet, B Wilmer, J Burchfield. 2010. The unknown trajectory of forest restoration: a call for ecosystem monitoring. *Journal of Forestry* 108(6): 288-295.
- Dias PF, SM Souto, MEF Correia, GP Rocha, JF Moreira, KM Rodrigues, AA Franco. 2006. Árvores fixadoras de nitrogênio e macrofauna do solo em pastagem de híbrido de *Digitaria*. *Pesquisa Agropecuária Brasileira* 41(6): 1015-1021.
- Fonseca SN, JHC Ribeiro, FA Carvalho. 2013. Estrutura e diversidade da regeneração arbórea em uma floresta secundária urbana (Juiz de Fora, MG, Brasil). *Floresta e Ambiente* 20(3): 307-315.
- Forzza RC, JFA Baumgratz, CEM Bicudo, AA Carvalho Júnior, A Costa, DP Costa, M Hopkins, PM Leitman, LG Lohmann, LC Maia, G Martinelli, M Menezes, MP Morim, MAN Coelho, AL Peixoto, JR Pirani, J Prado, LP Queiroz, VC Souza, JR Stehmann, LS Sylvestre, BMT Walter, D Zappi. 2010. *Catálogo de plantas e fungos do Brasil*. v. 01. Rio de Janeiro, Brasil. Jardim Botânico do Rio de Janeiro. 1702 p.
- Franco BKS, SV Martins, PCL Faria, GA Ribeiro. 2012. Den-

- sidade e composição florística do banco de sementes de um trecho de floresta estacional semidecidual no campus da Universidade Federal de Viçosa, Viçosa, MG. *Revista Árvore* 36(3): 423-432.
- Gandolfi S, HF Leitão Filho, CLF Bezerra. 1995. Levantamento florístico e caráter sucessional das espécies arbustivo-arbóreas de uma floresta semidecidual no município de Guarulhos, SP. *Revista Brasileira de Biologia* 55: 753-767.
- Grant CD, SC Ward, SC Morley. 2007. Return of Ecosystem Function to Restored Bauxite Mines in Western Australia. *Restoration Ecology* 15(4): S94-S103.
- Higuchi P, MGF Reis, GG Reis, AL Pinheiro, CT Silva, CHR Oliveira. 2006. Composição florística da regeneração natural de espécies arbóreas ao longo de oito anos em um fragmento de Floresta Estacional Semidecidual, em Viçosa, MG. *Revista Árvore* 30(6): 893-904.
- Hüller A, AA Schock. 2011. Avaliação do potencial alelopático de três espécies de *Eugenia* L. (Myrtaceae) sobre o processo germinativo de *Lactuca sativa* L. *Revista de Ciências Ambientais* 5(1): 25-37.
- IBGE (Instituto Brasileiro de Geografia e Estatística, BR). 2012. Manual Técnico da Vegetação Brasileira. 2ª ed. Manuais Técnicos em Geociências. Rio de Janeiro, Brasil. Instituto Brasileiro de Geografia e Estatística. 275 p.
- Kew GA, FC Mengler, RJ Gilkes. 2007. Regolith strength, water retention, and implications for ripping and plant root growth in bauxite mine restoration. *Restoration Ecology* 15(4): S54-S64.
- Koch JM .2007. Restoring a Jarrah Forest Understorey Vegetation after Bauxite Mining in Western Australia. *Restoration Ecology* 15(4): S26-S39.
- Lamarca EV, CV Silva, CJ Barbedo. 2011. Limites térmicos para a germinação em função da origem de sementes de espécies de *Eugenia* (Myrtaceae) nativas do Brasil. *Acta Botanica Brasilica* 25(2): 293-300.
- Lista de Espécies da Flora do Brasil. Jardim Botânico do Rio de Janeiro. Consultado 11 mar. 2014. Disponível em <http://floradobrasil.jbrj.gov.br/>
- Lopes RF, JA Branquinho. 1988. Jazidas de bauxita da Zona da Mata de Minas Gerais. In Schobbenhaus C, CES Coelho coords. Principais depósitos minerais do Brasil, v.3. Brasília, Brasil. Departamento Nacional da Produção Mineral. p. 599-619.
- Lu HF, ZH Wang, DE Campbell, H Ren, J Wang. 2011. Emergy and eco-emergy evaluation of four forest restoration modes in southeast China. *Ecological Engineering* 37: 277-285.
- Lucas EJ, SR Belsham, EM Nic Lughadha, DA Orlovich, CM Sakuragui, MW Chase, PG Wilson. 2005. Phylogenetic patterns in the fleshy-fruited Myrtaceae – preliminary molecular evidence. *Plant Systematics and Evolution* 251: 35-5.
- Marangon LC, JJ Soares, ALP Feliciano, CFLS Brandão. 2008. Regeneração natural em um fragmento de Floresta Estacional Semidecidual em Viçosa, Minas Gerais. *Revista Árvore* 32(1): 183-191.
- Martins SV, SH Kunz. 2007. Use of evaluation and monitoring indicators in a riparian forest restoration project in Viçosa, southeastern Brazil. In Rodrigues RR, SV Martins, S Gandolfi eds. High diversity forest restoration in degraded areas. New York, USA. Nova Science Publishers. p. 261-273.
- Martins SV. 2013. Recuperação de áreas degradadas: ações em áreas de preservação permanente, voçorocas, taludes rodoviários e de mineração. Viçosa, Brasil. Aprenda Fácil. 264 p.
- Mikich SB. 2002. A dieta dos morcegos frugívoros (Mammalia, Chiroptera, Phyllostomidae) de um pequeno remanescente de Floresta Estacional Semidecidual do sul do Brasil. *Revista Brasileira de Zoologia* 19: 239-249.
- Miranda Neto A, SV Martins, KA Silva, JM Gleriani. 2012. Estrato de regeneração natural de uma floresta restaurada com 40 anos. *Pesquisa Florestal Brasileira* 32(72): 409-420.
- Missouri Botanical Garden. Consultado 10 mar. 2014. Disponível em <http://www.tropicos.org>.
- Moreira FMS, JO Siqueira. 2006. Microbiologia e bioquímica do solo. 2. ed. Lavras, Brasil. Editora UFLA. 729 p.
- Moreira PR. 2004. Manejo do solo e recomposição da vegetação com vistas a recuperação de áreas degradadas pela extração de bauxita, Poços de Caldas, MG. Tesis Doctor em Ciências Biológicas. Rio Claro, Brasil. Universidade Estadual Paulista. 155 p.
- Mueller-Dombois D, H Ellenberg. 1974. Aims and methods of vegetation ecology. New York, US. John Wiley & Sons. 547 p.
- Newton AC. 2007. Forest ecology and conservation: a handbook of techniques. Oxford, UK. University Press. 454 p.
- Oliveira WL, MB Medeiros, P Moser, R Pinheiro, LB Olsen. 2011. Regeneração e estrutura populacional de jatobá-damata (*Hymenaea courbaril* L.), em dois fragmentos com diferentes graus de perturbação antrópica. *Acta Botanica Brasilica* 25(4): 876-884.
- Parrotta JA, OH Knowles, JM Wunderle Jr. 1997. Development of floristic diversity in 10-year-old restoration forests on a bauxite mined site in Amazonia. *Forestry Ecology and Management* 99: 21-42.
- Rodrigues ER, R Monteiro, L Cullen Junior. 2010. Dinâmica inicial da composição florística de uma área restaurada na região do Pontal do Paranapanema, São Paulo, Brasil. *Revista Árvore* 34(5): 853-861.
- Santos JF, R Valcarcel. 2011. Avaliação florística do estrato regenerante de reflorestamentos em área reabilitada na Mata Atlântica. *Floresta e Ambiente* 18(4): 390-401.
- Shepherd GJ. 2010. Fitopac 2.1 – Campinas, Brasil. Departamento de Botânica, Universidade Estadual de Campinas.
- Silva-Júnior MC, JM Felfili, BMT Walter, PE Nogueira, AV Rezende, RO Morais, MGG Nobrega. 2001. Análise da flora arbórea de Matas de Galeria no Distrito Federal: 21 levantamentos. In Ribeiro JF, CEL Fonseca, JC Sousa-Silva eds. Cerrado: caracterização e recuperação de Matas de Galeria. Planaltina, Brasil. Embrapa Cerrados. p. 143-191.
- Sobral M, C Proença, M Souza, F Mazine, E Lucas. 2010. Myrtaceae. In Forzza RC et al. eds. Catálogo de plantas e fungos do Brasil. v. 02. Rio de Janeiro, Brasil. Jardim Botânico do Rio de Janeiro. p. 1301-1329.
- Souza PB, AL Souza, WS Costa, RV Del Peloso, JM Lana. 2012. Florística e diversidade das espécies arbustivo-arbóreas regeneradas no sub-bosque de *Anadenanthera peregrina* (L.) Speg. *Cerne* 18(3): 413-421.
- Souza PB, JAA Meira Neto, AL Souza. 2013. Diversidade florística e estrutura fitossociológica de um gradiente topográfico em floresta estacional semidecidual submontana, MG. *Cerne* 19(3): 489-499.
- ter Braak CJF. 1995. Ordination. In Jongman RHG, CJF ter Braak, OFR van Tongeren eds. Data analysis in community and landscape ecology. Cambridge, UK. Cambridge University

- Press. p. 91-173.
- van Andel J, J Aronson. 2012. Getting started. *In* van Andel J, Aronson J eds. Restoration ecology: the new frontier. Oxford, UK. Wiley-Blackwell. p. 3-8.
- van der Pijl L. 1982. Principles of dispersal in higher plants. 3 ed. Berlin, Germany and New York, US. Springer-Verlag. 214 p.
- Wortley L, J Hero, M Howes. 2013. Evaluating ecological restoration success: a review of the literature. *Restoration Ecology* 21(5): 537-543.

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