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DISTRIBUTION OF TREE SPECIES IN AN EDAPHIC GRADIENT IN REFORESTATION AREAS IN RESTORATION PROCESS WITH DIFFERENT LEVELS OF DISTURBANCE

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ABSTRACT

This study aims at characterizing the correlations between tree communities and soil attributes in areas in restoration process with different levels of disturbance (DE = Degraded; DI = Disturbed and PRE = Preserved). A survey was performed with the allocation of 36 plots of 20 x 20 m, in which trees with DBH ≥ 5 cm were sampled. For the soil analysis, two samples were collected within each plot in order to form a composite sample. Correlations between biotic and edaphic arrays had their significance tested using the Monte Carlo permutation test. Edaphic and biotic variables were compared by unifactorial variance analysis (ANOVA), connected to a posteriori Tukey tes (5%). The soils in categories DE and DI showed aluminum content (Al) ranging from low to medium. The PRE category showed high aluminum content and low fertility. The ordering showed the separation of the plots into three groups (DE, DI and PRE) according to the proportion of disturbance levels. The areas in restoration process presented edaphic and tree community composition heterogeneity. The soils of all studied categories were characterized by its low nutrient availability and acidity ranging from medium (DE) to high (DI and PRE) and varying content of organic matter, which is more highly stored in the forest area. The fertility degree and other soil characteristics partially explain the floristic compositions and changes in the abundance of populations in the tree communities.

KEYWORDS: Semideciduous Seasonal Forest, multivariate analysis, floristic and edaphic attributes

DISTRIBUIÇÃO DE ESPÉCIES ARBÓREAS EM GRADIENTE EDÁFICO EM REFLORESTAMENTOS EM PROCESSO DE RESTAURAÇÃO COM NÍVEIS DIFERENCIADOS DE PERTURBAÇÃO

RESUMO

O presente trabalho tem como objetivo caracterizar as correlações entre as comunidades arbóreas e os atributos edáficos em áreas em processo de restauração com níveis diferenciados de perturbação (DE= Degradada; PE = Perturbada e CON = Conservada). Foi realizado um levantamento com alocação de 36 parcelas de 20 x 20 m, onde os indivíduos arbóreos com DAP ≥ 5 cm foram amostrados. Para a análise dos solos, foram coletadas duas amostras dentro de

cada parcela, para formar uma amostra composta. As correlações entre as matrizes biótica e edáfica tiveram a significância testada a partir do teste de permutação de Monte Carlo. As variáveis edáficas e bióticas foram comparadas por análises de variância uni-fatoriais (ANOVA), atreladas ao teste *a posteriori* de Tukey. Os solos das categorias DE e PE apresentaram teor de alumínio (Al) variando de baixo a médio. A categoria CON apresentou alto teor de alumínio e baixa fertilidade. A ordenação mostrou a separação das parcelas em três grupos (DE, PE e CON) de acordo com a proporção de nível de distúrbio. As áreas em processo de restauração apresentaram heterogeneidade edáfica e de composição da comunidade arbórea. Os solos de todas as categorias estudadas foram caracterizados por apresentarem baixa disponibilidade de nutrientes e acidez variando de média (DE) a elevada (PE e CON) e teores variáveis de matéria orgânica, que é mais armazenada na área sob mata. O grau de fertilidade e outras características edáficas explicaram parcialmente as relações florísticas e as alterações nas abundâncias das populações nas comunidades arbóreas.
PALAVRAS-CHAVE: Floresta Estacional Semidecidual, análise multivariada, atributos florísticos e edáficos.

INTRODUCTION

There is a lack of research involving evaluations of forest communities originated from the restoration of degraded areas implemented through reforestation projects, impeding the establishment of indicators to assess the quality of these reforestations (KAGEYAMA & CASTRO, 1989; PEÑA-CLAROS, 2003; REIS et al., 2003; MELO e DURIGAN, 2007; OLIVEIRA e ENGEL, 2011;).

The discrepancy of scientific information is accentuated when the restoration of forest ecosystems in dramatically affected areas, such as loaned areas, are pondered (BARBOSA, 2006). These areas are degraded ecosystems that were eliminated along with vegetation, biotic attributes of their regeneration, such as the seed bank, seedling bank and seed rain, and the fertile soil layer (horizon A) (BROWN e LUGO, 1994; FERREIRA et al., 2007). Because of this, issues such as soil compaction, low infiltration rates and water storage capacity, oxygen deficiency, high resistance to root penetration, increased density and lack of soil organic matter, occur (BROWN e LUGO, 1994; REIS & KAGEYAMA, 2003). In order to recover, it is necessary to select and identify species suited to the new soil conditions and to hasten the formation of soil horizons (GONÇALVES, 2008).

The characterization of relations between the soil variables and with the vegetation composition enables the improvement of forest restoration models, and the identification of species to be used in forest planting arrangements (RODRIGUES & GANDOLFI, 1998). In degraded areas, these studies also assist in verifying the efficiency of ecosystem rehabilitation interventions , in addition to elucidating the degree of stability of the studied areas (TILMAN, 1996).

The evaluation of environmental restoration activities evolves from the selection and analysis of a set of indicators, such as physical, chemical and biological soil attributes (DUARTE & CASAGRANDE, 2006).

One of the strategies widely used is the multivariate analysis of the data (HIGUCHI et al., 2008). These analyzes are procedures used to explore patterns of vegetation-environment relations (FELFILI, 2007) and are recommended when the goal is to obtain a view of the relations between environmental variables and species abundance (DYGBY & KEMPTON, 1996).

The studied areas in restoration process suffered different levels of degradation due to the construction of the Hydroelectric Reservoir of Camargos and , Itutinga (MG) in the 1950`s. One area was used as the loan, with horizon C exposed, lasting for about 30 years without any recovery process. The recovery of the areas occurred between 1992 and 1995, using mechanical restoration and vegetative practices by planting woody species. Due to current needs, the present study evaluated the distribution of tree species in restoring forest ecosystems with different levels of disturbance. It also aimed at characterizing the correlations between the inventoried tree communities and soil attributes in order to demonstrate the influence of physical and chemical characteristics of the soil on the tree synusiae. Thus, the central hypothesis of this paper proposes that the areas in recovery process present floristic differentiation connected to past pressures and also soil peculiarities. To guide the search, the following questions were put: i) what are the physical and chemical characteristics of the soils in between the areas in recovery process with different levels of disturbance? ii) the chemical and physical properties of soils in these environments influence the distribution of tree species?; and iii) what are the floristic dissimilarities between the tree communities in recovery process with different levels of disturbance?

MATERIAL AND METHODS

Characterization of the study areas

The research was conducted in six areas located upstream and downstream of the Hydroelectric Reservoir of Camargos and Itutinga of the Companhia Energética de Minas Gerais – CEMIG (Figure 1), on the right bank of the Rio Grande, Itutinga (Minas Gerais). Among the areas surveyed, five are recovery areas which have been in environmental restoration process for 19 years (Table 1). The natural vegetation of the region has semideciduous forest formations interspersed with grassland and savanna physiognomies. Regional climate incorporates the transition between Cwb and Cwa, according to Köppen’s classification (ANTUNES, 1986). The average temperature of the coldest month is below 18°C and of the hottest month, exceeding 22°C.

Vegetation sampling

The method to evaluate the distribution of the vegetation in recovering process used in this study was the plot method (MUELLER-DOMBOIS; ELLENBERG, 1974). This procedure consisted in the allocation of 36 plots, measuring 20 x 20 m (400 m²), corresponding to a total sampling area of 1.44 ha, distributed over the areas (Figure 1). All trees with the height of 1.30 m above ground level (DBH ≥ 5 cm) were considered. The botanical material was identified based on literature and by comparison in the Herbarium at the Universidade Federal de Lavras (UFLA). The species index was updated with the specific binomens from the Royal Botanic Gardens, Kew (1993), and Missouri Botanical Garden Web site (available at: http:// http://www.missouribotanicalgarden.org/). The classification system used was APG II (SOUZA & LORENZI, 2005).

Soil analysis

A soil survey was conducted in the studied areas. For the characterization of the chemical and physical properties of the soils, two samples were collected at a depth of 0-20 cm within each plot to form a composite sample. Analyses were performed in the laboratory of the Soil Department of the UFLA. The following soil characteristics were determined: pH in water, total organic carbon, phosphorus (P), potassium (K), calcium (Ca^{+2}), magnesium (Mg), aluminum (Al^{+3}), potential acidity (H+Al), sum of bases (SB), cation exchange capacity [CEC (t)] effective cation exchange capacity at pH 7.0 (T), base saturation index (V), Al saturation index (m) and soil particles size (sand, silt and clay) to define the texture class (EMBRAPA, 1997).

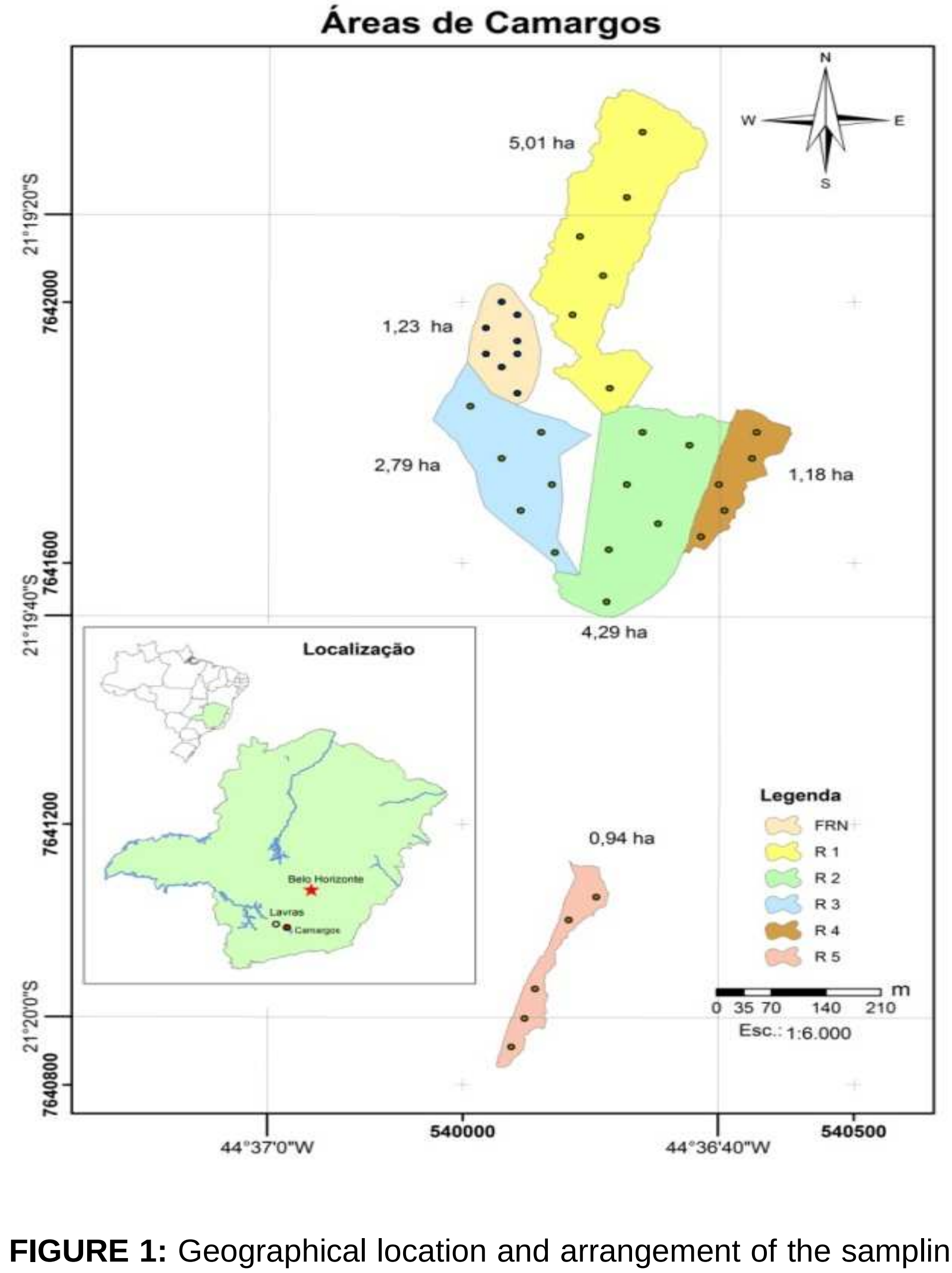

FIGURE 1: Geographical location and arrangement of the sampling plots in the areas at the margin of the Hydroeletric Reservoir of Camargos and Itutinga, MG.

Ordination of soil and vegetation data

To test the hypothesis that the areas in recovery process present floristic differentiation connected to pressures and also soil attributes, the vegetation data were analyzed together with data from the soil analysis, based on the canonical correlation analysis (CCA) (TER BRAAK, 1987). The Monte Carlo permutation test was used to evaluate the significance level of the main axis of canonical ordination, in order to assess the probability of matches found in the relationships among biotic and edaphic attributes (TER BRAAK, 1986). Two matrices were prepared for this analysis: the first, containing the abundances of tree species in the plots and, a second, with data containing data of the soil attributes. The analyzes were performed using the program PC-ORD (MCCUNE & MEFFORD, 1999).

After a preliminary analysis, the soil variables H+Al, Mg, Ca, V, MO and silt, which showed weak correlations between plots ($r < 0.3$), were eliminated. The normality of the normality was verified by the D'Agostino-Pearson test. Data expressing reason relation were previously processed by the function X'=ARCSEN(X/100, in order to adjust the statistical assumptions, while discrete or continuous quantitative data were transformed by square root or logarithmic functions, respectively. The biotic and soil attributes of the areas with different levels of disturbance were compared by unifactorial variance analysis (ANOVA), connected to a posteriori test of Tukey.

TABLE 1: Characterization of the study areas at the margin of the Hydroeletric Reservoir of Camargos and Itutinga, MG.

AREA	HISTORY OF USE	CODE	AREA (m^2)
Degraded (DE)	Intense erosion, movement of heavy machinery during construction of Hydroeletric Reservoir, vegetation was destroyed, horizon C exposed.	**R_1 –** Area used as airport	42.900
		R_2 – Loaned area	11.800
Disturbed (DI)	Moderate to mild disturbance with removal of the original vegetation, without intervention of the soil.	**R_3 –** Storage area	50.100
		R_4 - Area without any construction or vehicle traffic	27.900
		R_5 - Area without any construction or vehicle traffic	9.400
Reference (PRE)	Area of Semideciduous Forest	Reference	10.200

RESULTS AND DISCUSSION

Physicochemical soil characterization

The results of the chemical properties and texture of the soil are given in Table 2. The soils presented medium (DE) to high (DI and PRE) acidity and essential elements such as P, K, Ca and Mg showed up at very low levels (ROSSI & POLIDORO, 2008). The Al^{3+} content was very high and calcium availability was very low in the under forest area. Among the edaphic variables (P, K, S, Al, T, T, V, pH, clay and sand), there was significant difference between the areas with different levels of disturbance. The low nutrient availability in category DE is probably due to the degradation caused by the removal of vegetation (in the case of the loaned area) and by removing the topsoil, exposing the horizon C (FERREIRA et al., 2007). It should be noted that the original soil was removed from this area to a depth of up to 5 m and, only after about 30 years, this soil, during the recovery practices, was upturned, causing landfills and cuts in the recovery area. Therefore, the substrate resulted from this process is very different from the original soil.

The pH found ranged from 4.01 to 5.03. There was a wide variation in levels of aluminum (Al^{3+}), with low levels in the DE category , medium levels in DI areas and high levels in the fragment of native vegetation (PRE). There are medium amounts of organic matter in the areas in restoration process. In the PRE category, organic matter content (OM) was high, probably due to the fact that the place is preserved without any soil alteration, with great litterfall and a large shading area (GONÇALVES et al., 2008). This contributes to low organic matter (OM) decomposition rates. The sum of bases (SB) and the saturation index (V) values were low in all categories and . The base saturation index (V) showed a significantly higher average in the DI category, however, the sum of bases (SB) was low (Table 2) but these are values that, in general, attest to the high acidity levels and low availability of basic cations in the assessed areas.

The cation exchange capacity (t) was low in all categories, while the effective cation exchange capacity at pH 7.0 (T) ranged from average (DE and DI) to high (PRE). There is a direct relation between organic matter content (OM) and CTC at pH 7, in which the higher content of organic matter in the forest fragment accounts for the soil's increased cation retaining capacity. According to DUARTE & CASAGRANDE (2006), the most important chemical property of the soil is the cation exchange capacity (T). According to these authors, this is due to the fact that T is responsible for the magnitude of cation (Na, K, Ca and Mg) retention and leaching rate along the soil profile, keeping them in the root system's environment. In general, the soil in DE and DI categories is dystrophic. In other words, it has low fertility, and an aluminum index (Al) ranging from low to medium (DUARTE & CASAGRANDE, 2006). The category PRE differed from the others, presenting alic soils, due to the high aluminum index and low fertility. There was no significant difference between the three classes of soil regarding soil particle size: sand, silt and clay. The soil particle size analysis showed clayey soil in 64% of the plots, this prevailing in the PRE category (Table 2).

TABLE 2: Mean values of soil attributes of the areas in restoration process with different levels of disturbance on the margin of Hydroelectric Reservoir of Camargos and Itutinga (MG). Values are means ± standard deviations of *N* samples of each category, where DE = Degraded, DI = Disturbed and PRE = Preserved.

Environmental variables	DE	DI	PRE
pH	5,03±0,35 a	4,68±0,28 b	4,01±0,37 c
P^{+} (mg/dm^3)	1,16±0,37 a	0,89±0,30 a	1,88±0,53 b
K^{+} (mg/dm^3)	3,50±0,32 a	3,36±0,38 a	4,23±0,20 b
Ca^{+2} (cmolc/dm^3)	0,57±0,44 a	0,17±0,17 b	0,10±0,18 cb
Mg^{+2} (cmolc/dm^3)	0,26±0,15 a	0,10±0,08 b	0,13±0,04 cb
Al^{+3} (cmolc/dm^3)	0,32±0,32 a	0,64±0,32 b	1,46±0,43 c
H+AL(cmolc/dm^3)	5,78±2,97 a	7,41±2,25 ad	11,6±1,92 bc
SB (cmolc/dm^3)	0,75±1,44 a	0,32±0,20 b	0,44±0,15 ab
t (cmolc/dm^3)	0,92±0,35 a	0,70±0,20 a	1,10±0,08 ab
T (cmolc/dm^3)	7,13±7,13 a	7,83±2.30 a	12,4±2,06 b
V (%)	4,88±0,20 a	19,7±0,08 b	4,5±0,07 bc
O.M. (dag/kg)	2,84±0,93 a	3,01±0,94 a	4,0±0,77 ba
P-Rem	14,3±9.66	14,1±8,59	10,4±2,91
Textural Class	Mean (58%) to clayey (42%)	Mean (38%) to clayey (62%)	Clayey (100%)

Associated with the soil characteristics observed in CON, was the distribution of populations of *Actinostemon concolor, Andira fraxinifolia*, *Cheiloclinium cognatum, Cordia sellowiana, Daphnopsis fasciculata*, *Gochnatia polymorpha*, *Guatteria nigrescens*, *Machaerium hirtum*, *Myrcia splendens*, *Protium pilosissimum* e *Terminalia fagifolia*, suggesting that these species have affinity for clay soils, low pH and aluminum. These species have excelled in abundance and were correlated with the levels of P and K.

At the other end of the gradient, in areas where the acidity was lower, occurred larger representations of silt and sand, and also low cation exchange capacity and base saturation, the grouping of plots related to a larger abundance of species *Calophyllum brasiliense* (shade tolerant swamp species– VILELA et al., 2000), *Caryocar brasiliense, Eremanthus incanus*, *Eugenia florida, Luehea grandiflora, Mimosa bimucronata e Platypodium elegans*. *E. incanus* e *P. elegans* are species common in seasonal forests of Atlantic domain (OLIVEIRA-FILHO & FONTES, 2000), while *Caryocar brasiliense* is typical of the Cerrado area (RATTER et al., 2003). Seen as the region is presented as an ecotone area between the Cerrado and Atlantic areas (LIMA et al., 2006), the occurrence is not surprising and shows the process of natural regeneration. Other species which showed progress in forest regeneration were *Calophyllum brasiliense* and *Mimosa bimucronata*, which comprise of species associated to humid environments, usually connected to water bodies (RODRIGUES & NAVE, 2000), as is the case of the reservoir margins. Finally, *E. florida* e *L. grandiflora* comprise of species of wide distribution in the forests of Minas Gerais (OLIVEIRA-FILHO & FONTES, 2000).

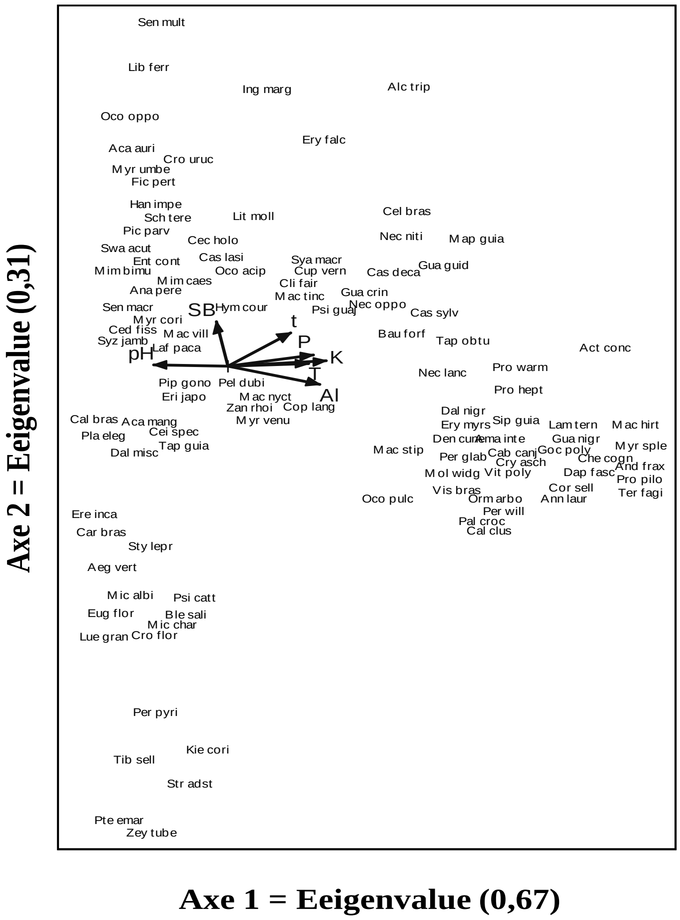

FIGURE 2: Diagram of species in the first two ordination axes produced by the CCA in areas in restoration process with different levels of disturbance (DE and DI) and the Semideciduous Forest (PRE) at the margin of the Hydroeletric Reservaoir of Camargos and Itutinga, MG. Edaphic variables: sulfur (S), phosphorus (P), potassium (K), aluminum (Al^{+3}), cation exchange capacity [CTC (t)], effective cation exchange capacity at pH 7.0 (T), base saturation index (V) and pH in water.

CONCLUSION

The areas in recovery process analyzed, corresponding to different levels of disturbance, had edaphic and tree community composition heterogeneity, which corroborated the premise of this work. The soils of all studied categories were characterized by its low nutrient availability and acidity ranging from medium (DE) to high (DI and PRE), and varying amounts of organic matter, which is further stored in the forest area. The fertility degree and other soil characteristics partially explain the floristic composition and changes in the abundance of population in the tree communities. The research may represent a source of information for the restoration of areas where environmental conditions are similar.

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