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STRUCTURE OF NATURAL REGENERATION IN RELATION TO SOIL PROPERTIES AND DISTURBANCE IN TWO SWAMP FORESTS

Keywords:
Plant diversity
Phytosociology
Tropical wet savannah
Degradation

ABSTRACT: Veredas (palm swamps) is a type of vegetation associated with watercourses, characterized by the presence of *Mauritia flexuosa* palm trees. These systems are not well understood and suffer from high anthropogenic pressure. The aims of this study were to describe the natural regeneration of two swamp forests in vereda systems with different anthropogenic impacts and investigate if the variation in these plant communities are associated to edaphic conditions. The study was performed in preserved and impacted sites located in the Environmental Protection Area of the Pandeiros River in northern Minas Gerais. At each site, one hundred 25 m^2 plots were established for surveying regenerating shrubs and trees (≥ 1 cm diameter at the base of the stem and < 3 cm diameter at breast height). Vegetation structure was evaluated by phytosociological parameters, similarity index, and size distribution of individuals. Regenerating strata was correlated with chemical and physical soil analyses. The vegetation at the preserved site was characterized by a higher number of individuals and a lower diversity but contained species that were typical of flooded areas. The results also showed differences in soil nutrient availability between sites that influenced the distribution of species at the two study sites.

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ESTRUTURA DA REGENERAÇÃO NATURAL EM RELAÇÃO ÀS PROPRIEDADES DO SOLO E DISTÚRBIO EM DUAS FLORESTAS HIGRÓFILAS

Palavras chave:
Diversidade de plantas
Fitossociologia
Savana tropical úmida
Degradação.

RESUMO: As veredas são um tipo de vegetação associada aos cursos d'água, caracterizada pela presença da palmeira arbórea *Mauritia flexuosa*. Estes sistemas não são bem compreendidos e sofrem grande pressão antrópica. Os objetivos deste estudo foram descrever a regeneração natural de duas florestas higrófilas em sistemas de veredas com diferentes impactos antropogênicos e investigar se a variação nesta comunidade de plantas está associada as condições edáficas. O estudo foi realizado em sítios preservado e impactado localizado na área de Proteção Ambiental do rio Pandeiros, norte de Minas Gerais. Em cada sítio, 100 parcelas de 25 m^2 foram estabelecidas para o levantamento dos arbustos e árvores regenerantes (≥ 1 cm de diâmetro na base do caule e < 3 cm de diâmetro na altura do peito). A estrutura da vegetação foi avaliada pelos parâmetros fitossociológicos, índice de similaridade e distribuição de tamanhos dos indivíduos. O estrato regenerativo correlacionou com as análises químicas e físicas do solo. A vegetação no sítio preservado foi caracterizada por um maior número de indivíduos e menor diversidade, mas continha espécies típicas de ambientes alagados. Os resultados também mostraram diferenças na disponibilidade de nutrientes do solo entre os sítios que influenciaram a distribuição de espécies nas duas áreas estudadas.

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INTRODUCTION

Vereda or palm swamps ecosystems in Brazil, which belong to the Cerrado (Brazilian savanna) biome, are not well understood. However, this ecosystem presents great importance because it plays a role in the hydrologic balance of water bodies (RAMOS et al., 2006). In addition, veredas have a relevant socioeconomic role as a source of livelihoods for surrounding communities (BAHIA et al., 2009). *Mauritia flexuosa* L.f., a palm tree commonly known as *buriti*, is characteristic of the vereda ecosystem. It occurs in flooded areas on peat soils and grows with other existing shrub and tree vegetation (FERRAZ-VICENTINI; SALGADO-LABOURIAU, 1996). In some cases, the geomorphological evolution of these ecosystems provide the formation of swamps forests (hygrophilous forests) near the water course (CARVALHO, 1991).

The species occurring in palm swamps vary with soil characteristics and the degree of water saturation (BOAVENTURA, 2007). Variation in the substrate, especially in soil humidity, fertility, and topography, influences the distribution of tree species (PINTO et al., 2005), and particular species may dominate in areas of environmental extremes (BOTREL et al., 2002). Soil fertility is directly influenced by nutrient concentrations and by the soil's resilience to disturbance (VARGAS; HUNGRIA, 1997) because some types of degradation modify biotic and abiotic conditions within a vereda ecosystem (MEIRELES et al., 2004).

Indiscriminate soil use in veredas causes siltation in water bodies and the drying up of water sources (BOAVENTURA, 2007). Anthropogenic pressures include not only agricultural and livestock grazing activities, in particular, but also the construction of small dams, embankments, drains and roads; peat and clay extraction; urban development; and excessive burning (ARAÚJO et al., 2002). These activities cause suppression of native vegetation and soil compaction, and consequently decrease the system's capacity for infiltration and retention of rainfall (MEIRELES et al., 2004), and compromise the functional equilibrium of veredas.

Knowledge about the floristic and structural characteristics of regenerating vegetation can contribute to understanding community dynamics and help predict the direction of ecological succession, thereby improving the management practices and restoration. There are few studies on vereda vegetation (ARAÚJO et al., 2002; GUIMARÃES et al., 2002; MEIRELES et al., 2004; OLIVEIRA et al., 2009), specially about the swamp forests in veredas (BAHIA et al., 2009) and no studies about natural regeneration

The aim of this study was to characterize the floristic structure of regenerating tree communities in two swamp forests with different environmental impacts histories. The following questions drove this study: (i) is there variation in the composition and structure of naturally regenerating plant communities between the two study sites?; and (ii) does edaphic variation between the sites determine the floristic and structural characteristics of naturally regenerating vegetation? It is believed that anthropogenic disturbances cause changes in soil, thereby degrading the ecosystem and negatively affecting its capacity for natural regeneration in a given environment.

MATERIALS AND METHODS

Study sites

The study was performed in two swamp forests located in the Pandeiros River Environmental Protection Area (Fig. 1) in northern Minas Gerais, Brazil. The Pandeiros River EPA includes the entire hydrographic basin of this river (393,060 ha) and is an important left bank tributary of the São Francisco River (NUNES et al. 2009). The region is at the transition between the Cerrado and Caatinga (scrub dry forest) biomes and contains a variety of phytophysiognomies: riparian forest, dry forest, cerrado sensu stricto, and vereda (NUNES et al., 2009). The climate is tropical wet and dry (Köppen's Aw), with well-defined dry winters and rainy summers, and the average annual precipitation and temperature is 920 mm and 26.8o C, respectively (MENINO et al. 2012).

The study areas were located in the mid to upper reaches of the Pandeiros River. The first site, known as Água Doce (15°13'18.7" S and 44°55'21.2" W), was located in the municipality of Bonito de Minas. The second site, Buriti Grosso (15°26'26.6"S and 45°3'55"W), was located in the municipality of Januária. During the 1970s, government programs supported using drainage and irrigation techniques in veredas areas (NUNES et al., 2009), which was the case in Buriti Grosso. At the end of 1980s, these programs were interrupted, leaving abandoned areas (BOAVENTURA, 2007). Currently, the Buriti Grosso site still has artificial drainage channels and sparse and low vegetation resulted of deforestation and burning of the area for rice plantations. The Água Doce site has relatively minor anthropogenic interventions with small-scale grazing of bovine cattle, subsistence collection of *M. flexuosa* fruits, use of water for domestic supply, and selective removal of wood for domestic use. Therefore, the Buriti Grosso site was considered to be impacted by human activities (impacted site), while the Água Doce site was considered to be relatively well preserved (preserved site).

Sampling of regenerating vegetation

For the sampling of regenerating shrubs and trees, 100 plots of 5 × 5 m (25 m^2) size were established at each site along the water body with 15 m distance between plots. All shrub and tree individuals with ≥1 cm DBS (diameter at the base of the stem) and < 3 cm DBH (diameter at the breast height, measured at 1.30 m above the soil level) were recorded. Regenerating *M. flexuosa* individuals were counted, and their total height was measured. For the other species, DBS and total height were measured, using a caliper and a wooden ruler, respectively.

For each inventoried plant, a botanical material sample was collected for species identification. A specimen of each species was deposited at the Montes Claros Herbarium (MCMG) of the Universidade Estadual de Montes Claros. Identification of the collected plant material was performed with the help of specialists and by consulting specialized literature. The Angiosperm Phylogeny Group III (ANGIOSPERM PHYLOGENY GROUP III - APG III, 2009) classification for families of flowering plant species was used.

Soil characterization

Soil type classification was performed *in situ* by a specialist and soil sample of 0-20 cm depth was collected in each plot. The soil analyses were performed at the Soil Analysis Laboratory of the Instituto de Ciências Agrárias of Universidade Federal de Minas Gerais (UFMG), according to Empresa Brasileira de Pesquisa Agropecuária - EMBRAPA (2006). The following parameters were determined: soil pH in water; potassium (K; $mg \cdot kg^{-1}$), phosphorus (P-Mehlich-1; $mg \cdot kg^{-1}$), calcium (Ca; $cmolc \cdot dm^{-3}$), magnesium (Mg; $cmolc \cdot dm^{-3}$), and aluminum (Al; $cmolc \cdot dm^{-3}$) concentration; potential soil acidity (H+Al; $cmolc \cdot dm^{-3}$), sum of bases (SB; $cmolc \cdot dm^{-3}$), base saturation (V; %), organic matter (OM; $dag \cdot kg^{-1}$), aluminum saturation (m; %), effective cation exchange capacity (t; $cmolc \cdot dm^{-3}$), and total cation exchange capaciy (T; $cmolc \cdot dm^{-3}$); and coarse ($dag \cdot kg^{-1}$) and fine sand ($dag \cdot kg^{-1}$), silt ($dag \cdot kg^{-1}$) and clay ($dag \cdot kg^{-1}$) content.

Data analysis

The following phytosociology parameters were calculated: density, dominance and frequency, absolute and relative, importance value (IV) (MUELLER-DOMBOIS; ELLENBERG, 1974), and Shannon diversity (*H'*) and Pielou evenness (*J'*) indexes (BROWER; ZAR, 1984). Floristic similarity between sites was determined by comparing an abundance matrix of the existing

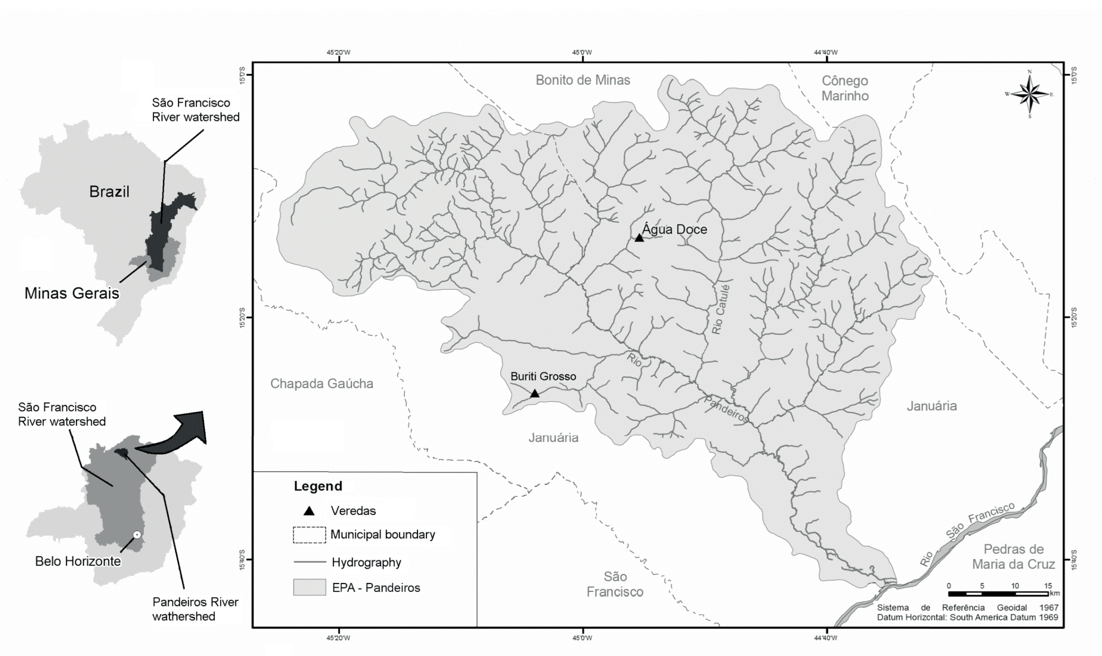

FIGURE 1 Location of the study sites (Água Doce and Buriti Grosso veredas), the Pandeiros River, and the Pandeiros River EPA in northern Minas Gerais, Brazil.

species using the Jaccard index (MUELLER-DOMBOIS; ELLENBERG, 1974). Diameter and height classes were grouped according to Botrel et al. (2002), with diameter values being grouped by increasing intervals to compensate for decreases in density of the higher diameter classes. The chi-square test for contingency tables (ZAR, 1996) was applied to compare the frequency distribution of individuals into the size classes between sites.

To compare soil variables, an Analysis of Variance (ANOVA) was performed using the GLM (General Linear Models) procedure (NELDER; WEDDERBURN, 1972). Correlations between edaphic and vegetation parameters were detected using a Canonical Correspondence Analysis (CCA) (MCCUNE; GRACE, 2002). Soil data were prior logarithm transformed to minimize the effects of the distribution of values. The species matrix contained the abundance values in each plot, and the environmental matrix contained the results of the soil analysis. Only 193 plots were used in the analysis. Seven plots were excluded because no regenerating plants were found. Species represented by a single individual were considered rare and were not included in the analysis. A Monte Carlo permutation test was performed (MCCUNE; GRACE, 2002) to determine the significance of the model, with correlation values from 0.0 to 0.39 being considered weak, values from 0.40 to 0.69 being considered moderate, and values from 0.7 to 1.0 being considered strong (CALLEGARI-JACQUES, 2003).

RESULTS

Structure of the regenerating vegetation

A total of 2264 individuals and 72 species from 37 families (Table 1 and 2) were recorded at the two study sites, with *H'* of 2.64 and *J'* of 0.62. Fabaceae was the family with the highest number of species (11), followed by Melastomataceae (seven).

At preserved site 1404 individuals belonging to 46 species and 28 families were found. The three most representative families, in terms of number of individuals, were Annonaceae (533 individuals), Myrtaceae (514), and Clusiaceae (83). Fabaceae was the family with the highest number of species (seven), followed by Meliaceae, Myrtaceae, and Rubiaceae (three species each), and Clusiaceae, Melastomataceae, Myrsinaceae, Piperaceae, Styracaceae, and Burseraceae (two species each). The remaining families accounted for 39.13% of the total number of species. The most abundant species were *Xylopia emarginata* (533 individuals), *Calyptranthes brasiliensis* (514), *Calophyllum brasiliense* (83), and *Blepharocalyx salicifolius* (54), which together comprised 84.33% of the total number of species sampled. Some of these same species also had high importance values and together accounted for 75% of the total IV, including *X. emarginata* (34%) and *C. brasiliensis* (29%), both with high density and dominance; and *C. brasiliense* (7%) and *B. salicifolius* (5%), due to their high density and frequency, respectively. Eighteen families were represented by only one species. Individuals of *M. flexuosa* were found distributed throughout the palm swamp, totaling 82 individuals between 10 cm and 1.4 m height, with 69.51% belonging to the > 10-50 cm height class.

At the impacted site 860 regenerating individuals from 29 species and 18 families were recorded. The three best represented families were Melastomataceae (527 individuals), Malpighiaceae (86), and Lamiaceae (54). Melastomataceae had the highest number of species (five species), followed by Fabaceae (four), Myrtaceae (three), and Anacardiaceae and Onagraceae (two each). The remaining families accounted for 44.83% of the total number of species. The most abundant species were *Trembleya* sp. (281 individuals) and *Miconia* sp.1 (193) (both belonging to the family Melastomataceae), *Byrsonima pachyphylla* (86), and *Aegiphila lhotskyana* (54). These species had the highest IV values and accounted for 71.4% of the total abundance and 66.33% of the total IV. *Miconia* sp.1 and *Trembleya* sp. had high density and dominance; and *B. pachyphylla* and *A. lhotskyana* had high density and frequency, respectively. Thirteen of the families sampled at impacted site were represented by a single species, and seven species were represented by a single individual. No *M. flexuosa* regenerating individuals were recorded at this site.

Floristic and structural variation between sites

The two study sites had distinctly flora (Table 1 and 2). Only three species (*Miconia* sp.1, *Vernonanthura phosphorica* and *Tapirira guianensis*) were common to both sites, which resulted in a low similarity index for the two sites (0.04). The diversity and evenness indexes were lower for preserved site (*H'*=1.83 and *J'*=0.48) than for impacted site (*H'*=2.23 and *J'*=0.66). Similarly, preserved site had a higher density (5616 ind·ha^{-1}) and basal area (66.89cm^2·ha^{-1}) than impacted site (3440 ind·ha^{-1} and 38.01cm^2·ha^{-1}, respectively).

The greatest individual's height (7.5 m) and largest diameter (0.64 cm) were found at preserved site. At the impacted site, the greatest height was 5 m, and the largest diameter was 0.78 m. Average height and diameter were greater at preserved site (2.17 m and 0.22 cm, respectively) than at impacted site (1.51 m and 0.21 cm, respectively). Differences in the size of regenerating individual's distribution were not independent between the sites (Table 3). For the diameter classes, the frequency of individuals ≥ 1.0 to 1.5 cm and > 4.5 cm was lower than expected for the preserved site, and was higher than expected for the impacted site. The opposite was observed for the class >1.5-2.5 cm, while in preserved site the frequency of individuals was higher and in the impacted site was lower than expected. The frequency of individuals >2.5-4.5 cm interval did not differ between the sites. However, the preserved site community showed higher abundances of individuals across all diameter classes (Figure 2A).

Among height classes, significant differences in the observed and expected distribution frequencies of individuals between sites were found (Table 3). The frequency of individuals ≥ 0.2-1.0 m was lower than expected for the preserved site and higher than expected for the impacted site. The reverse was observed for the classes > 2.0-3.0 m, >3.0-4.0 m, >4.0-5.0 m, and >5.0 m, that showed higher frequency of individuals in the preserved site and lower frequency of individuals in the impacted site than expected. The height class >1.0 to 2.0 m had the largest number of individuals (Figure 2B), but the distribution frequency of individuals did not differ between sites.

TABLE 1 Regenerating species observed at the preserved site (Água Doce vereda, Environmental Protection Area of the Pandeiros River, northern Minas Gerais) in alphabetical order by family and species with their respective structure parameters. NI=number of sampled individuals; BA=basal area ($cm^2 \cdot ha^{-1}$); AD=absolute density ($ind \cdot ha^{-1}$); RD=relative density (%); ADo =absolute dominance ($m^2 \cdot ha^{-1}$); RDo=relative dominance (%); AF= absolute frequency (%); RF=relative frequency (%); IV=importance value (%); and V=voucher number (Montes Claros Herbarium).

Family	Species	NI	BA	AD	RD	ADo	RDo	AF	RF	IV	V
ANACARDIACEAE	*Tapirira guianensis* Aubl.	21	1.75	84	1.5	6.99	2.61	18	5.01	9.12	487
ANNONACEAE	*Xylopia emarginata* Mart.	533	28.39	2132	37.96	113.56	42.44	79	22.01	102.41	488
ARALIACEAE	*Dendropanax cuneatus* (DC.) Decne. e Planch.	3	0.17	12	0.21	0.69	0.26	3	0.84	1.31	489
ASTERACEAE	*Vernonanthura phosphorica* (Vell.) H.Rob.	1	0.01	4	0.07	0.03	0.01	1	0.28	0.36	486
BIGNONIACEAE	*Handroanthus chrysotrichus* (Mart. ex A.DC.) Mattos	1	0.07	4	0.07	0.28	0.11	1	0.28	0.46	490
BURSERACEAE	*Protium spruceanum* (Benth.) Engl.	3	0.15	12	0.21	0.61	0.23	3	0.84	1.28	449
	Protium brasiliense (Spreng.) Engl.	2	0.22	8	0.14	0.89	0.33	1	0.28	0.75	482
CHRYSOBALANACEAE	*Hieronyma alchorneoides* Allemão	1	0.1	4	0.07	0.41	0.15	1	0.28	0.5	474
CLUSIACEAE	*Calophyllum brasiliense* Cambess.	83	5.18	332	5.91	20.73	7.75	25	6.96	20.62	460
	Garcinia brasiliensis Mart.	6	0.58	24	0.43	2.31	0.86	5	1.39	2.68	483
EBENACEAE	*Diospyros sericea* A.DC.	1	0.02	4	0.07	0.06	0.02	1	0.28	0.37	478
ELAEOCARPACEAE	*Sloanea stipitata* Spruce ex Benth.	3	0.09	12	0.21	0.38	0.14	1	0.28	0.63	448
ERYTHROXYLACEAE	*Erythroxylum citrifolium* A.St.-Hil.	3	0.06	12	0.21	0.23	0.08	3	0.84	1.13	451
EUPHORBIACEAE	*Croton urucurana* Baill.	1	0.02	4	0.07	0.07	0.03	1	0.28	0.38	492
FABACEAE	*Bauhinia acuruana* Moric.	6	0.21	24	0.43	0.85	0.32	4	1.11	1.86	475
	Bauhinia cheilantha (Bong.) Steud.	14	0.52	56	1	2.09	0.78	7	1.95	3.73	470
	Bauhinia rufa (Bong.) Steud.	2	0.08	8	0.14	0.3	0.11	2	0.56	0.81	469
	Inga laurina (Sw.) Willd.	6	0.24	24	0.43	0.95	0.35	5	1.39	2.17	493
	Inga vera Willd.	2	0.06	8	0.14	0.23	0.09	2	0.56	0.79	464
	Machaerium hirtum (Vell.) Stellfeld	5	0.28	20	0.36	1.1	0.41	3	0.84	1.6	463
	Zollernia cowanii Mansano	10	0.57	40	0.71	2.29	0.86	9	2.51	4.08	485
LAURACEAE	*Nectandra membranacea* (Sw.) Griseb.	3	0.19	12	0.21	0.75	0.28	3	0.84	1.33	459
MELASTOMATACEAE	*Miconia* sp.1	14	0.42	56	1	1.67	0.62	12	3.34	4.96	480
	Miconia sp.2	12	0.47	48	0.85	1.87	0.7	8	2.23	3.78	481
MELIACEAE	*Guarea guidonia* (L.) Sleumer	3	0.08	12	0.21	0.32	0.12	3	0.84	1.17	468
	Guarea kunthiana A. Juss.	1	0.17	4	0.07	0.69	0.26	1	0.28	0.61	455
	Guarea macrophylla Vahl	1	0.02	4	0.07	0.07	0.03	1	0.28	0.38	479
MORACEAE	*Ficus obtusiuscula* (Miq.) Miq.	2	0.4	8	0.14	1.61	0.6	2	0.56	1.3	473
MYRTACEAE	*Calyptranthes brasiliensis* Spreng.	514	21.14	2056	36.61	84.58	31.61	67	18.66	86.88	477
	Blepharocalyx salicifolius (Kunth) O. Berg	54	1.55	216	3.85	6.2	2.32	32	8.91	15.08	461
	Myrcia splendens (Sw.) DC.	2	0.07	8	0.14	0.27	0.1	2	0.56	0.8	467
OLEACEAE	*Chionanthus crassifolius* (Mart.) P.S. Green	10	0.17	40	0.71	0.69	0.26	5	1.39	2.36	462
PHYLLANTHACEAE	*Hirtella gracilipes* (Hook. f.) Prance	11	0.64	44	0.78	2.57	0.96	9	2.51	4.25	465
PIPERACEAE	*Piper gaudichaudianum* Kunth	2	0.06	8	0.14	0.24	0.09	2	0.56	0.79	471
	Piper arboreum Aubl.	3	0.03	12	0.21	0.11	0.04	1	0.28	0.54	476
POLYGONACEAE	*Coccoloba declinata* (Vell.) Mart.	26	1.13	104	1.85	4.54	1.7	15	4.18	7.73	466
PRIMULACEAE	*Myrsine umbellata* Mart.	5	0.16	20	0.36	0.65	0.24	4	1.11	1.71	452
	Cybianthus cuneifolius Mart.	2	0.05	8	0.14	0.22	0.08	1	0.28	0.5	484
PROTEACEAE	*Euplassa inaequalis* (Pohl) Engl.	2	0.16	8	0.14	0.63	0.24	2	0.56	0.93	491
RUBIACEAE	*Ladenbergia cujabensis* Klotzsch	3	0.16	12	0.21	0.64	0.24	3	0.84	1.29	458
	Posoqueria latifolia (Rudge) Roem. e Schult.	2	0.19	8	0.14	0.77	0.29	2	0.56	0.99	447
	Posoqueria sp.	1	0.09	4	0.07	0.34	0.13	1	0.28	0.48	457
SAPOTACEAE	*Pouteria torta* (Mart.) Radlk.	20	0.58	80	1.42	2.32	0.87	4	1.11	3.41	453
SIPARUNACEAE	*Siparuna reginae* (Tul.) A.DC.	1	0.06	4	0.07	0.25	0.09	1	0.28	0.44	454
STYRACACEAE	*Styrax camporum* Pohl	2	0.12	8	0.14	0.46	0.17	2	0.56	0.87	456
	Styrax latifolius Pohl	1	0.01	4	0.07	0.05	0.02	1	0.28	0.37	472

TABLE 2 Regenerating species observed at the impacted site (Buriti Grosso vereda, Environmental Protection Area of the Pandeiros River, northern Minas Gerais), in alphabetical order by family and species with their respective structure parameters. NI=number of sampled individuals; BA=basal area ($cm^2 \cdot ha^{-1}$); AD=absolute density ($ind \cdot ha^{-1}$); RD=relative density (%); ADo=absolute dominance ($m^2 \cdot ha^{-1}$); RDo=relative dominance (%); AF=absolute frequency (%); RF=relative frequency (%); IV=importance value (%); and V=voucher number (Montes Claros Herbarium).

Family	Species	NI	BA	AD	RD	DAo	RDo	AF	RF	IV	V
ANACARDIACEAE	*Astronium fraxinifolium* Schott ex Spreng.	1	0.01	4	0.12	0.03	0.02	1	0.28	0.42	1142
	Tapirira guianensis Aubl.	8	0.22	32	0.93	0.86	0.57	6	1.69	3.18	1163
ANNONACEAE	*Xylopia aromatica* (Lam.) Mart.	1	0.03	4	0.12	0.14	0.09	1	0.28	0.49	1169
ASTERACEAE	*Vernonanthura phosphorica* (Vell.) H. Rob.	10	0.14	40	1.16	0.56	0.37	8	2.25	3.78	1167
CLUSIACEAE	*Kielmeyera rubriflora* Cambess.	1	0.13	4	0.12	0.5	0.33	1	0.28	0.73	1150
ERYTHROXYLACEAE	*Erythroxylum suberosum* A.St.-Hil.	1	0.1	4	0.12	0.41	0.27	1	0.28	0.67	1149
FABACEAE	*Copaifera coriacea* Mart.	24	0.94	96	2.79	3.77	2.48	17	4.78	10.05	1146
	Dimorphandra gardneriana Tul.	1	0.03	4	0.12	0.13	0.08	1	0.28	0.48	1148
	Plathymenia reticulata Benth.	1	0.03	4	0.12	0.13	0.08	1	0.28	0.48	1158
	Senna macranthera (Collad.) H.S. Irwin e Barneby	14	0.7	56	1.63	2.79	1.84	8	2.25	5.71	1161
LAMIACEAE	*Aegiphila lhotskyana* Cham.	54	3.69	216	6.28	14.78	9.72	33	9.27	25.27	1141
MALPIGHIACEAE	*Byrsonima pachyphylla* A. Juss.	86	3.76	344	10	15.04	9.89	32	8.99	28.88	1143
MELASTOMATACEAE	*Miconia albicans* (Sw.) Triana	37	1.65	148	4.3	6.6	4.34	20	5.62	14.26	1153
	Miconia sp.1	193	10.94	772	22.44	43.75	28.78	70	19.66	70.89	1154
	Tibouchina sellowiana (Cham.) Cogn.	5	0.17	20	0.58	0.66	0.44	5	1.4	2.42	1164
	Tibouchina sp.	11	0.41	44	1.28	1.62	1.07	8	2.25	4.59	1165
	Trembleya sp.	281	6.91	1124	32.67	27.64	18.18	66	18.54	69.4	1166
MYRTACEAE	*Myrcia guianensis* (Aubl.) DC.	5	0.2	20	0.58	0.82	0.54	4	1.12	2.24	1155
	Psidium firmum O. Berg	10	0.85	40	1.16	3.39	2.23	6	1.69	5.08	1159
	Psidium guajava L.	5	0.15	20	0.58	0.61	0.4	4	1.12	2.11	1160
OCHNACEAE	*Ouratea hexasperma* (A.St.-Hil.) Baill.	12	0.87	48	1.4	3.47	2.28	9	2.53	6.21	1156
ONAGRACEAE	*Ludwigia elegans* (Cambess. ex A. St.-Hil.) H. Hara	8	0.42	32	0.93	1.69	1.11	7	1.97	4.01	1151
	Ludwigia speciosa (Brenan) Hoch	32	0.82	128	3.72	3.28	2.16	16	4.49	10.38	1152
PIPERACEAE	*Piper aduncum* L.	2	0.06	8	0.23	0.23	0.15	2	0.56	0.95	1157
SALICACEAE	*Casearia sylvestris* Sw.	19	1.35	76	2.21	5.39	3.54	9	2.53	8.28	1144
SAPINDACEAE	*Diatenopteryxs orbifolia* Radlk.	1	0.02	4	0.12	0.07	0.05	1	0.28	0.44	1147
SOLANACEAE	*Solanum lycocarpum* A. St.-Hil.	2	0.09	8	0.23	0.37	0.24	2	0.56	1.04	1162
URTICACEAE	*Cecropia pachystachya* Trécul	33	3.18	132	3.84	12.74	8.38	16	4.49	16.71	1145
VOCHYSIACEAE	*Vochysia tucanorum* Mart.	2	0.15	8	0.23	0.59	0.39	1	0.28	0.9	1168

TABLE 3 Contingency tables of frequency distribution of observed and expected (in parenthesis) individuals of regenerating species sampled in two swamp forests (preserved and impacted) in Pandeiros River EPA (Minas Gerais, Brazil) among diameter and height classes. The results of the chi-square (χ^2) test and the probability (P) are provided for each table and for rows and columns separately.

Classes	Sites					
Diameter (cm)	Preserved		Impacted		χ^2	*P*
≥1.0-1.5	398	(475.6)	369	(291.4)	33.37	<0.001
>1.5-2.5	593	(539.5)	277	(330.5)	13.95	<0.001
>2.5-4.5	369	(336.7)	174	(206.3)	8.14	<0.05
>4.5	44	(52.1)	40	(31.9)	3.31	>0.05
χ^2	22.33		36.45			
P	<0.001		<0.001		<0.001	
Height (m)	Preserved		Impacted		χ^2	*P*
≥0.2-1.0	253	(339.8)	295	(208.2)	58.42	<0.001
>1.0-2.0	609	(653.6)	445	(400.4)	8.02	>0.05
>2.0-3.0	321	(258.6)	96	(158.4)	39.64	<0.001
>3.0-4.0	132	(93.6)	19	(57.4)	41.37	<0.001
>4.0-5.0	59	(38.4)	3	(23.6)	28.92	<0.001
>5.0	30	(19.8)	2	(12.2)	13.68	<0.05
χ^2	72.19		117.85			
P	<0.001		<0.001		<0.001	

Correlations between environmental conditions and vegetation

The results of the soil analysis indicated significant variation in all parameters measured especially for soil pH (Table 4). Soil pH was lower and aluminum concentrations were higher at impacted site compared to the preserved site soils, which had an average pH of 6.7 and almost no detectable Al. In addition, K, P, Ca, and Mg concentrations and organic matter were higher at preserved than at impacted site. The soil at both sites was dystrophic Mesic Histosol with flat relief and a sandy texture. A Haplic Gleisol was also present at preserved site. The CCA resulted in eigenvalue of 0.922 (Axis 1) and 0.124 (Axis 2). The first axis was a long gradient and the second was a short gradient. The axes explained 9.0% (Axis 1) and 1.2% (Axis 2) of the total variance in the edaphic variables (10.29%) for the 56 species from the 193 sampling plots. The species-environment correlations were strong for Axis 1 (0.977) and moderate (0.526) for Axis 2. The Monte Carlo permutation test indicated that there was a significant correlation between species composition and the edaphic variables for Axis 1 (p = 0.001). The edaphic variables most strongly correlated with the first axis were, in decreasing order, Ca, pH, Al, Mg, H + Al, and K (Table 5).

The ordination of the plots along the first axis shows a clear separation of edaphic characteristics between the two sites, with soils with a lower pH (Al and H + Al) at impacted site and a higher pH (Mg, Ca, pH, and K) at preserved site. This result was confirmed by

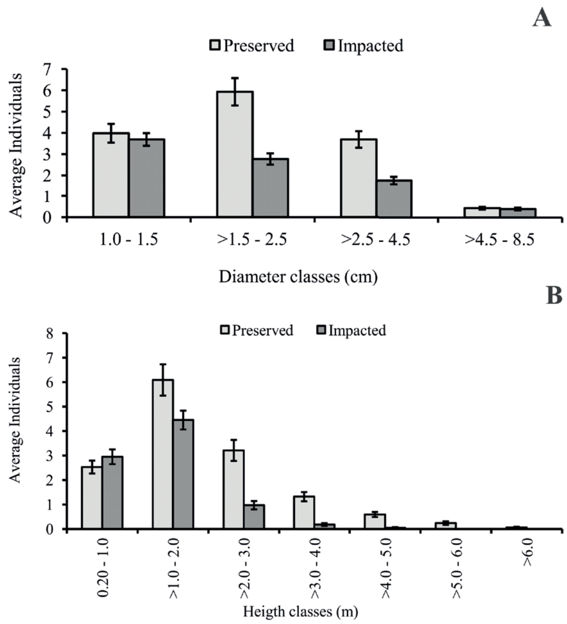

FIGURE 2 Distribution of diameter (A) and height (B) classes of regenerating individuals at the two study sites (preserved and impacted site) in the Pandeiros River EPA (Minas Gerais, Brazil)

the soil chemical characteristics determined for the two sites (Table 5). The ordination of the species along the first axis (Figure 3B) indicated that floristic composition also differed between the sites. At the impacted site, *Ouratea hexasperma* and *Psidium guajava* were strongly correlated with H+Al, and *Solanum lycocarpum* was strongly correlated with Al. At the preserved site, *Pouteria torta* and *Ladenbergia cujabensis* were strongly correlated with K, and *Cybianthus cuneifolius* was more correlated with Mg.

DISCUSSION

Veredas are surrounded by cerrado vegetation (BOAVENTURA, 2007) and a large number of species from the Fabaceae family, typically found in cerrado (MANTOVANI; MARTINS, 1993), occur this ecosystem (ARAÚJO et al., 2002). Menino et al. (2012) studied a regenerating stratum of the Pandeiros River riparian forest, located in the same region of this study, and found the family Fabaceae to be the most species rich. Species belonging to the family Melastomataceae are also commonly found in forest and cerrado areas, and these species are considered to be one of the largest groups of species in Brazil (SOUZA; LORENZI, 2005). However, the number of families represented by a single species was high, both at preserved (18) and at impacted (13) sites. According to Araújo et al. (2002), a large number of families with a single species are restricted to wetter environments, which may be due to their potentially higher sensitivity to anthropogenic disturbance.

The differences observed in floristic composition between the study sites may have reflected differences in the level of environmental degradation. Of the 46 species observed at the preserved site, the two best-represented species, *Xylopia emarginata* and *Calyptranthes brasiliensis*, are associated with flooded environments or water saturated soils. These species occur in large numbers in a given location but have restricted distributions and prefer hydromorphic soils (DURIGAN et al., 2004).

The most abundant species at the impacted site were typical of the surrounding vegetation. These species may have spread into the interior of the swamp forest following site disturbance, like vegetation opening and decreased drainage and organic matter. The presence of *Byrsonima pachyphylla*, with the second highest IV, and *Aegiphila lhotskyana*, with the third highest IV, reflected these environmental changes. These species typically occur in fields and cerrado *sensu stricto* (SILVA-JUNIOR, 2005; SOUZA; LORENZI, 2005). Therefore, the events that occurred at the impacted site appear to have resulted in changes in vegetation composition, because the most abundant species at this site (including *Trembleya* sp., *Miconia* sp.1, *B. pachyphylla*

TABLE 4 Analysis of Variance with General Linear Models procedure of edaphic variables at the two swamps forests (preserved and impacted sites), in the Pandeiros River EPA (Minas Gerais, Brazil). All variables were significant at p < 0.01.

Edaphic variable	Preserved	Impacted	F
pH	6.77 ± 0.04	4.93 ± 0.04	295.40
P	15.92 ± 1.16	10.74 ± 1.16	114.20
K+	143.44 ± 7.66	19.14 ± 7.70	56.02
Ca++	14.2 ± 0.29	0.57 ± 0.29	286.13
Mg++	1.82 ± 0.07	0.28 ± 0.07	147.92
Al	0.01 ± 0.11	1.92 ± 0.11	54.28
Potential soil acidity (H + Al)	1.38 ± 0.33	11.50 ± 0.34	133.46
Sum of bases (SB)	16.28 ± 0.34	0.90 ± 0.35	269.76
Effective cation exchange capacity (t)	16.29 ± 0.35	2.82 ± 0.35	210.84
Aluminum saturation (m)	0.03 ± 1.51	62.08 ± 1.52	326.84
Cation retention capacity (T)	17.67 ± 0.43	12.40 ± 0.43	37.79
Base saturation (V)	91.49 ± 1.40	9.59 ± 1.41	534.14
Organic matter	14.86 ± 0.32	11.32 ± 0.32	34.87
Coarse sand	3.80 ± 1.14	1.63 ± 1.14	56.72
Fine sand	81.68 ± 1.24	79.70 ± 1.25	64.80
Silt	8.54 ± 0.45	10.66 ± 0.45	10.10
Clay	5.98 ± 0.33	6.87 ± 0.33	86.41

TABLE 5 Correlations of two first CCA ordination axes (intraset correlations) and matrix of weighted correlations for the edaphic variables from 193 plots. Correlations in * had significance values > 0.5 according to the Monte Carlo test.

Edaphic variable	Intraset correlations		Edaphic variable				
	Axis1	Axis2	Ca	pH	Al	Mg	H+Al
Ca	0.909*	-0.027	-				
pH	0.879*	-0.119	0.821*	-			
Al	-0.839*	-0.099	-0.731*	-0.823*	-		
Mg	0.835*	0.080	0.844*	0.737*	-0.692*	-	
H+Al	-0.805*	-0.139	-0.702*	-0.766*	0.842*	-0.657*	-
K	0.691*	-0.136	0.826*	0.668*	-0.576*	0.651*	-0.567*

and *A. lhotskyana*) are commonly found in the cerrado phytophysiognomy (MENDONÇA et al., 2008) and not in hydromorphic environments. Furthermore, *Trembleya* sp. and *Miconia* sp.1 belong to a family that is important in poorly preserved environments suffering from human impacts, suggesting that these species are common in open conditions (GUIMARÃES et al., 2002).

The predominance of a small number of species in the regenerating communities at the study sites reflects the selective nature of water saturation in these environments. Specific abiotic characteristics resulting from the duration and frequency of soil water saturation strongly affect biotic processes (e.g., decomposition rate, germination, and individual recruitment), which ultimately define the spatial distribution, composition, and structure of the vegetation (LOBO; JOLY, 2004). The diversity and evenness indexes for the two sites show a low diversity of these environments compared to the results of other studies on natural regeneration (SANTIAGO et al., 2005; MENINO et al., 2012). Although it was more disturbed, the impacted site had a higher diversity index than the preserved site. However, the species observed at impacted site are not typical of wet forests environments.

The size distribution of individuals showed the typical "inverted-J", except for the first class, both in diameter, for the preserved site, and height, for the preserved and impacted site. This pattern indicates the existence of a stock of young plants that will replace the senile ones (LOPES et al., 2002). Besides, the minimum inclusion criteria may have excluded many individuals within the first class (LOPES et al., 2002). The greater plant sizes observed at the preserved site may have been due to the lower degree of human impacts at this site.

The origin and deposition processes of sediments, the stability of the water table, and anthropogenic impacts are factors that can influence the physical and chemical attributes of veredas soils (RAMOS et al., 2006). The type of soils found at the studied sites may be related to relief, as observed by Ramos et al. (2006), who reported a gradual change from a Mesic Histosol to a Haplic Gleisol. In this study, the sites were located in flatter zones, , because only the lowest area of vereda's systems (lower area, according to ARAÚJO et al., 2002) was sampled. This area was characterized by swampy, water saturated soil, and thicker vegetation. The two types of soils found are formed from plant residues in different stages of decomposition and were located in flooded areas (EMBRAPA, 2006; RAMOS et al., 2006).

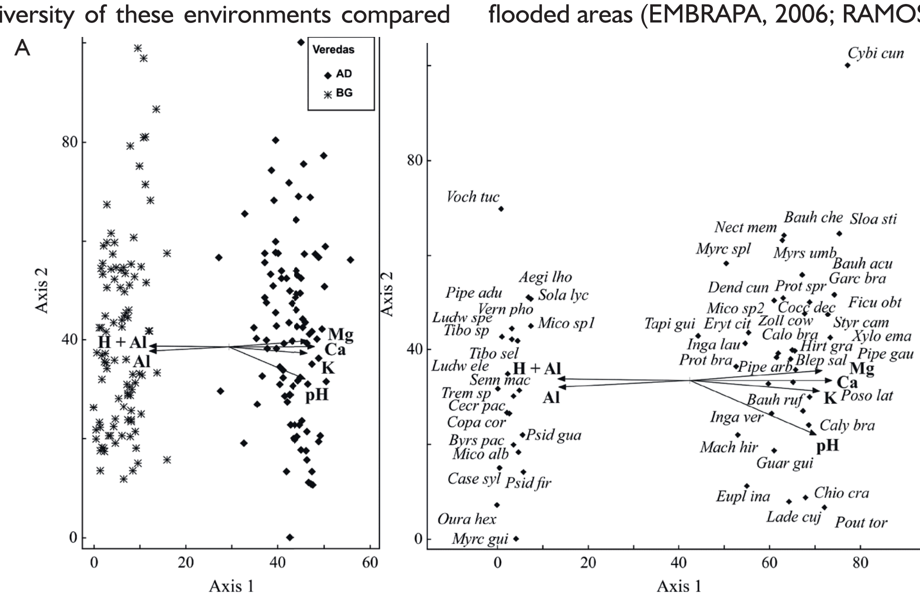

FIGURE 3 CCA ordination diagram of sampling plots (A) and species (B) based on a distribution of 156 individuals from 193 plots at the preserved (AD) and impacted (BG) sites (Pandeiros River EPA, Minas Gerais, Brazil).

The more acidic soil found at the impacted site may be related to the observed establishment of species from surrounding areas (cerrado), which are better adapted to soils with a low pH. *Ouratea hexasperma*, which was an important component of the impacted site, is frequent in areas with low water availability that had been burned (FONSECA; SILVA-JÚNIOR, 2004). *Psidium guajava*, a species that typically occupies slight to strongly acidic soils, can be frequently found in open areas such as cerrado or in disturbed areas (ORWA et al., 2009). *Solanum lycocarpum*, a woody species typical of the cerrado, occurs frequently in open areas and is considered opportunistic (LORENZI, 1998). The presence of these three species, which were correlated with low soil pH at the impacted site, suggest that the area is being overtaken by the surrounding vegetation (typical cerrado vegetation), leading to a loss of the typical characteristics of the veredas hydromorphic formation.

The study sites showed differences in vegetation composition that resulted from differences in soil characteristics, such as soil pH and macronutrient concentrations, as well as the impacts of anthropogenic activities on the sites. The availability of Mg, Ca, and K, which are required in large amounts by plants, are higher at a pH of 6-6.5 (LARCHER, 2000). This may be one of the factors determining the vegetation structure at the preserved site. The soil pH at the preserved site was very close to this value, and Mg, Ca, and K concentrations were higher than those of the impacted site. Organic matter content contributes to the solid soil phase in swamp areas by increasing soil aeration (RAMOS et al., 2006). Soil water saturation can limit the establishment of some species and favor species that are better adapted to wetter conditions (MUNHOZ et al., 2008). This pattern was observed in the preserved site, where poorly drained soils were associated with higher species richness compared to the more well-drained soils at the impacted site.

CONCLUSION

The regenerating flora in the preserved site consists of typical species of wetland environments and in the impacted site was related to the surrounding vegetation (cerrado). This result is probably associated to anthropogenic impacts to the impacted site, which led to colonization by species from surrounding areas. The soils at the two study sites showed differences in pH and nutrient availability, possibly due to the different degrees of anthropogenic impact.

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