
FLORISTIC AND STRUCTURAL VARIATIONS OF THE ARBOREAL COMMUNITY IN RELATION TO SOIL PROPERTIES IN THE PANDEIROS RIVER RIPARIAN FOREST, MINAS GERAIS, BRAZIL

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SUMMARY

In the area comprised by the Brazilian semi-arid is included the north of the Minas Gerais state, in the transition area between the Caatinga and Cerrado biomes. In this region distinct phyto-physiognomies are observed, basically making it a mosaic, with the occurrence of a wide variety of vegetal formations, such as the Restricted Sense Savannah, Seasonal Deciduous Forests and riparian vegetation. This paper aims to present the structure of the shrubby-arboreal component of a section of the riparian vegetation of the Pandeiros river, Januária, Minas Gerais, Brazil, and to verify possible existent correlations between edaphic variables and the density distribution of species. Data was collected in 70 plots of 100m², in which five soil classes were found at the four sectors where 759 individuals, 31 families and 107 species were sampled. The most diverse families

were Fabaceae, Malvaceae, Myrtaceae, Apocynaceae, Bignoniaceae and Combretaceae. The most abundant species were *Hirtella gracilipes*, *Xylopia aromatica*, *Averrhoideum gardnerianum*, *Tapirira guianensis*, *Hymenaea eryogyne* and *Byrsonima pachyphylla*. *Hymenaea eryogyne*, *T. guianensis* and *Copaifera langsdorffii* showed the highest importance values. The results suggest that, in addition to Ca, K, organic matter and flooding regime, which correlated with some species, the combination of the plots into three groups is also related to the sectors' soil types. Thus, both the heterogeneity (provided by adjacent vegetation) and variety of soils and the flooding regime determine the formation of a unique riparian forest, with interactions between species that are characteristic of riparian forests, dry forests and savannah.

The Brazilian semi-arid encompasses 70% of the northeastern region and a small portion of southeastern Brazil, including the strip of land extending along the São Francisco river and the intermediate region of the Jequitinhonha rivers in the Minas Gerais state. This area is covered by a vegetation that is subjected to hydric deficit due to the uneven distribution of rainfall, which in turn is associated with high temperatures and high evapotranspiration

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(Santos *et al.*, 2012). Ecotone areas between the regions of the Caatinga (scrub dry forest) and Cerrado (savannah) biomes comprise a vegetation mosaic in the small section of the northern Minas Gerais semi-arid (Santos *et al.*, 2012). Included in this mosaic are the riparian forests that, in addition to having the characteristic species, present a set of species that are typical of a phytogeographic unit outside of the riparian matrix (Rodrigues and Nave, 2004). The occurrence of transitional situations can lead to the creation of a riparian forest with floristic and structural units with particular features (Rodrigues and Nave, 2004).

Riparian forests stand out for their botanical richness and diversity (Oliveira Filho *et al.*, 1990), in addition to their importance in maintaining waterways, conserving biodiversity and contributing to ecosystem balance (Lopes and Schiavini, 2007). However, fragmentation as a result of human actions transforms these extensive natural habitats into many isolated fractions, leading to the disruption of ecological corridors and the loss of biodiversity (Moro *et al.*, 2001).

Floristic and phytosociological studies on the remnants of riparian forests reveal the species diversity of these environments, which is a result of high environmental heterogeneity often associated with these forests (Battilani *et al.*, 2005). The diversity of soils and edaphic conditions are considered to be very important features responsible for this species diversity (van den Berg and Oliveira-Filho, 1999; Pinto *et al.*, 2005). Together with terrain and light intensity and availability, these features lead to the recognition of the riparian forests as diverse and unique environments (Camargos *et al.*, 2008).

Most botanical studies on riparian forests aim to understand the relationship between the heterogeneity of the physical environment and the floristic composition and structure of the vegetation (Durigan *et al.* 2004). Despite the existence of several consistent studies on the floristic and phytosociological descriptions of riparian forests in the state of Minas Gerais (Oliveira-Filho *et al.*, 1994a, van den Berg and Oliveira-Filho, 1999, Rodrigues *et al.*, 2003, Santos and Vieira, 2006; Fagundes *et al.*, 2007; Camargos *et al.*, 2008), some areas are still poorly known, such as the north and northwest of Minas Gerais (Drummond *et al.*, 2005). We highlight, in particular, the Pandeiros river riparian forest. The Pandeiros river is a major affluent of the São Francisco river (intermediate São Francisco), located in the extreme north of Minas Gerais.

Despite the importance and legal protection (Law N° 4.777/65) of the Pandeiros river, its riparian vegetation

has suffered profound changes as a result of intense and ongoing human activities, which affect the conservation of the local biodiversity (Nunes *et al.*, 2009). Therefore, studies conducting an inventory of existing species and indicating which species may aid in the restoration of these ecotone environments are essential. This paper aims to present the floristic composition of the shrubby-arboreal component of an area of the riparian vegetation of the Pandeiros river, Januária, MG, and to verify the possible correlations between the edaphic variables and the density distribution of the species.

Materials and methods

Study area

This research was conducted in Balneário (15°30'33"S; 44°45'12"W), on the banks of the Pandeiros river, in Januária, Minas Gerais state, Brazil. The Balneário of Pandeiros river is included in the *Refúgio de Vida Silvestre* (REVISE) of the Pandeiros river, inside the Environmental Protection Area (EPA). This is a 393,060,407ha EPA,

where phytophysiognomies, such as the Cerrado *sensu stricto*, deciduous seasonal forests and semi-deciduous seasonal forests can be found (Nunes *et al.*, 2009). The region soils are Neosols, Cambisols, Latosols and Gleysols (Nunes *et al.*, 2009). The climate is humid tropical (Aw), according to the Köppen classification, with well-defined dry and rainy seasons. The average temperature is 23°C, and the average precipitation is 1,000mm/year (Menino *et al.*, 2012).

Structural and floristic survey

The vegetation survey was conducted in 70 plots measuring 10×10m (100m²), positioned side by side 3m from the river bank and spaced 10m apart, with 35 plots on the left bank (15°30'33"S; 44°45'12"W) and 35 on the right bank (15°30'27"S; 44°45'15"W) (Figure 1). Due to natural obstacles (limestone outcrop) and the anthropic area (bathing area), the plots were divided into four sectors. In the first transect of the left bank (Sector 1), 15 plots were allocated (P1 to P15); in the second (Sector 2), 20 plots (P16 to P35) were

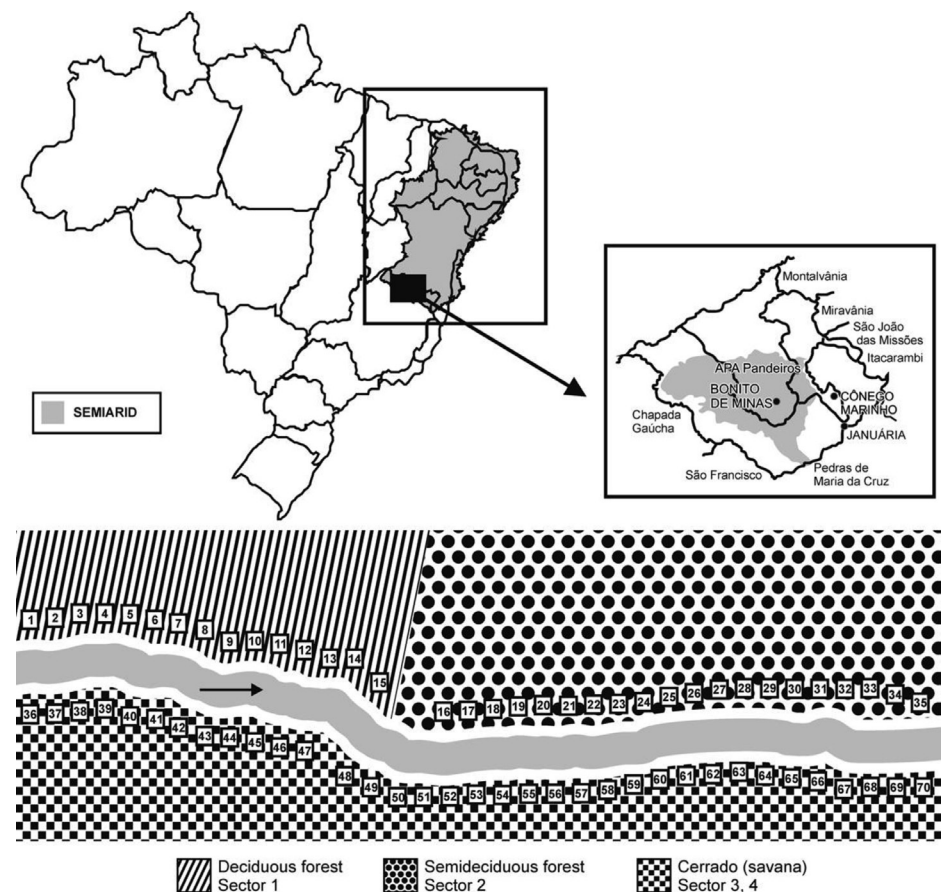


Figure 1. Location of the Pandeiros APA and the distribution of the sectors (1, 2, 3 and 4) and the sample units (70 parcels of 100m²) used in the phytosociological inventory of the Pandeiros river riparian forest at Balneário, Januária, Minas Gerais, Brazil.

allocated. Twelve (P36 to P47) and 23 plots (P48 to P70) were allocated on the right bank, corresponding to sectors 3 and 4, respectively.

All of the living shrub and tree individuals with DBH (diameter at breast height; 1.30m above the ground) ≥ 5 cm were inventoried. From these individuals, labeled with aluminum platelets, total height was estimated, the CBH (circumference at breast height; 1.30m above ground) measured and botanical material was collected. The survey was conducted between September and November 2007. The collected materials were incorporated into the Montes Claros Herbarium (MCMG). Identification of plant material was conducted *in loco* and with the aid of specialized literature. The system adopted for the classification of the species was the APG III (2009).

Soil and the edaphic variables

Composite samples of 500g of topsoil (0-20cm depth) were collected in each plot for soil analysis. For this purpose five soil samples were collected in each plot, and mixed to form one composite sample. The collected material was stored in plastic bags, which were labeled and sent to the *Laboratório de Análises de Solo*, at the *Instituto de Ciências Agrárias* of the *Universidade Federal de Minas Gerais*, where the samples were analyzed according to the procedures of Embrapa (1997). The following variables were measured: pH in water, K, P, residual P (P-res), Ca, Mg, Al, H+Al, total bases (TB), base saturation (V), effective cation exchange capacity (t), Al saturation (m), cation exchange capacity at pH 7.0 (T), organic matter (OM) and the proportions of coarse (2-0.2mm) or fine sand (0.2-0.05mm), silt (0.05-0.02mm) and clay (<0.02mm). Morphological characterization and classification of the soil were carried out according to Embrapa (2006) through *in loco* visits.

The characterization of flooding regime (FR) as described by Menino *et al.* (2012) was done at the same plots in the study area. This characterization was conducted by visual

observation; grading of several variables including flooding (1: absence, 2: presence), sand deposition (1: absence, 2: presence), embankment height (1: ≥ 3 m and <4m; 3: ≥ 2 m and <3m; 4: ≥ 1 m and <2m; 5: flat), water speed (visual scale between a lentic environment and the occurrence of rapids, assigning scores from 1 to 5) and location on the river bend (1: no curve; 2: erosion; 3: sedimentation). The product of the scores given to each variable is the flooding regime variable, and the higher its value the greater the influence of flooding on the plot (Menino *et al.*, 2012).

Data analysis

To describe the community structure, the following parameters were calculated: absolute density (AD), dominance (ADo) and frequency (AF), and relative density (RD), dominance (RDo) and frequency (RF), coverage value (VC) and importance value (IV) (Mueller Dombois and Ellenberg, 1974). To determine diversity, we calculated Shannon's diversity (H') and Pielou's evenness (J') indices using natural logarithmic bases (Brower and Zar, 1984).

A mixed gradient analysis was performed using the technique of canonical correspondence analysis (CCA; ter Braak and Smilauer, 1998) to study the correlation between the species, environmental variables and flooding regime. The data were processed in the PCORD program (ter Braak and Smilauer, 1998)

with two matrices, one of species and one of environmental variables. The Monte Carlo permutation test (ter Braak and Smilauer, 1998) was used to assess the significance level of the main axis of canonical ordering and to check the probability of correct relationships between environmental variables and plants. After preliminary analysis, non-significant (>0.05) environmental variables were eliminated, leaving only silt, organic matter, total bases and flooding regime.

Results and Discussion

Soil characterization

Five classes of soils were identified in the studied riparian forest: i) eutrophic Litholic Regosol (Sector 1), ii) eutrophic Haplic Cambisol (sector 1), iii) Dystrophic Red-Yellow Latosol (sectors 2 and 4), iv) association of Red-Yellow Latosol and Dystrophic Haplic Gleysol (sectors 2 and 4), and v) eutrophic Fluvic Regosol (sector 3).

The pH was significantly higher in sectors 1 and 2 compared to sectors 3 and 4 (Table I). Sector 1 is directly influenced by limestone rocks, with sometimes acidic eutrophic soil. The deposition of sediments derived from limestone rocks located upstream may contribute to the reduction of acidity. The sector has two acidic dystrophic soils (Naime, 1980); despite of this, the mean pH values fall within the classification of soils with low acidity (Tomé-Júnior, 1997).

TABLE I
COMPARISON OF SOIL PROPERTIES AMONG THE FOUR SECTORS OF 100m² PARCELS USED FOR THE SAMPLING OF THE ARBOREAL COMPONENT OF THE PANDEIROS RIVER RIPARIAN FOREST AT BALNEÁRIO, JANUÁRIA, MINAS GERAIS, BRAZIL

Soil properties	Sector					
	1	2	3	4	F	p
pH (em água)	6.25 ±0.20 a	6.41 ±0.21 a	6.00 ±0.09 b	6.03 ±0.17 b	21.423	<0.001
P (Mehlich 1 / mg·dm ⁻³)	1.91 ±0.44 a	3.68 ±3.64 a	1.95 ±0.78 a	2.14 ±1.06 a	3.070	<0.05*
K (mg·dm ⁻³)	50.65 ±30.24 a	33.91 ±16.19 ab	25.48 ±6.83 b	28.50 ±9.56 b	6.283	<0.001
Ca (cmol _c ·dm ⁻³)	2.83 ±1.19 ac	2.95 ±1.03 a	0.94 ±0.56 b	2.11 ±0.61 c	15.228	<0.001
Mg (cmol _c ·dm ⁻³)	0.89 ±0.43 a	0.87 ±0.23 a	0.41 ±0.12 b	0.83 ±0.29 a	8.226	<0.001
Al (cmol _c ·dm ⁻³)	0	0	0.05 ±0.06	0		
SB (cmol _c ·dm ⁻³)	3.84 ±1.59 a	3.91 ±1.16 a	1.42 ±0.67 b	3.02 ±0.82 a	15.029	<0.001
t (cmol _c ·dm ⁻³)	3.84 ±1.59 a	3.91 ±1.16 a	1.46 ±0.65 b	3.02 ±0.82 a	14.569	<0.001
m (%)	0	0	3.78 ±4.83	0		
T (cmol _c ·dm ⁻³)	5.42 ±1.86 a	5.46 ±1.09 a	2.99 ±0.80 b	4.57 ±0.88 a	12.560	<0.001
V (arsen %)	0.99 ±0.07 a	1.00 ±0.09 a	0.74 ±0.07 b	0.94 ±0.08 a	28.659	<0.001
OM (dag·kg ⁻¹)	2.66 ±1.59 a	2.43 ±0.89 ab	1.54 ±0.63 b	1.74 ±0.42 b	5.174	<0.01
Coarse sand (dag·kg ⁻¹)	23.54 ±10.08a	11.41 ±15.59 a	23.63 ±17.90 a	14.16 ±8.79 a	3.877	<0.05*
Fine sand (dag·kg ⁻¹)	65.79 ±11.51a	78.28 ±16.86 a	67.38 ±16.90 a	78.00 ±9.68 a	4.053	<0.05*
Silt (dag·kg ⁻¹)	5.87 ±2.77 a	5.05 ±1.93 a	4.33 ±2.67 ab	2.75 ±1.15 b	8.157	<0.01
Clay (dag·kg ⁻¹)	4.80 ±1.66	5.26 ±1.52	4.67 ±0.99	5.08 ±1.56	0.513	n.s

* Although ANOVA has shown significant differences among P, and coarse and fine sand levels, the Tukey test not detected these differences.

pH: pH in water, SB: sum of bases, V: base saturation, t: effective cation exchange capacity, m: Al saturation, T: cation exchange capacity at pH 7.0; OM: organic matter.

However, the differences detected did not show marked variations in the classification of these soils. The levels of Mg, TB (total bases), t (effective cation exchange capacity), T (cation exchange capacity at pH 7.0) and V (base saturation) showed lower values in Sector 3 as compared with the remaining sectors. Sector 3 is located in a low area, subject to constant flooding, which characterizes the local soil as alluvium. Alluvial soils are poorly developed due to recent fluvial deposits (Naime, 1980) and because of periodic flooding, whereby excess water limits aeration, the activity of microorganisms and the incorporation of organic matter (van den Berg and Oliveira-Filho, 1999). Furthermore, only some portions of this sector showed values of Al and m (Al saturation). Giehl and Jakenkow (2008) found that sites with high values of exchangeable Al and Mn have low pH, which was observed for the plots of Sector 3, the place where the portions adjacent to the savannah are found.

The values of P and coarse and fine sand significantly varied among the sectors, with the highest values of P found in Sector 2, coarse sand in sectors 1 and 3 and fine sand in sectors 2 and 4. Periodic flooding can cause changes in soil granulometry by the erosion of smaller particles (Johnson *et al.*, 1985). In addition, differences in the nutritional status and texture of alluvial soils can be caused by the dynamics of sedimentation and erosion (Oliveira Filho *et al.*, 1994). On the other hand, silt values were the lowest in Sector 4, K, and OM and Ca values were the highest in Sector 1 and 2, respectively. Only the variables of soil H+Al and Clay did not vary among the different sectors.

Floristic composition and structure

We sampled 759 individuals, 31 families, 75 genera and 107 species (Table II). The six most diverse families were Fabaceae (27 species), Malvaceae (9), Myrtaceae (6), Apocynaceae, Bignoniaceae and Combretaceae (5 each). These families together accounted for 52.8%, and Fabaceae for 25% of the flora sampled. The floristic vegetation found corroborates other studies conducted in

TABLE II
LIST OF FAMILIES AND SPECIES WITH DBH \geq 5cm AND THEIR RESPECTIVE STRUCTURAL PARAMETERS, SAMPLED ON THE PANDEIROS RIVER RIPARIAN FOREST

Families/Species	BA	RD	RDo	RF	IV	V
Anacardiaceae						
<i>Anacardium occidentale</i> L.	0.004	0.13	0.03	0.2	0.36	15
<i>Astronium fraxinifolium</i> Schott ex Spreng.	0.756	4.61	4.26	4.1	12.98	266
<i>Myracrodruon urundeuva</i> Allemão	0.412	2.64	2.33	2.15	7.11	259
<i>Tapirira guianensis</i> Aubl.	1.733	5.67	9.78	4.3	19.75	34
Annonaceae						
<i>Annona crassiflora</i> Mart.	0.007	0.13	0.04	0.2	0.37	326
<i>Rollinia leptopetala</i> R.E.Fr.	0.018	0.4	0.1	0.2	0.69	278
<i>Xylopia aromatica</i> (Lam.) Mart.	0.529	6.19	2.99	5.08	14.25	284
Apocynaceae						
<i>Aspidosperma cuspa</i> (Kunth) S.F. Blake ex Pittier	0.005	0.13	0.03	0.02	0.35	351
<i>Aspidosperma cylindrocarpon</i> Müll.Arg.	0.011	0.26	0.03	0.39	0.72	
<i>Aspidosperma macrocarpon</i> Mart.	0.009	0.26	0.05	0.39	0.7	334
<i>Aspidosperma multiflorum</i> A.DC.	0.088	1.05	0.5	0.98	2.53	3
<i>Aspidosperma subicanum</i> Mart. ex A.DC.	0.014	0.26	0.08	0.4	0.73	4
Apocynaceae						
<i>Jacaranda brasiliiana</i> (Lam.) Pers.	0.05	0.13	0.31	0.2	0.63	335
<i>Handroanthus impetiginosus</i> (Mart. ex DC.) Mattos	0.058	0.26	0.33	0.39	0.98	28
<i>Handroanthus ochraceus</i> (Cham.) Mattos	0.017	0.26	0.1	0.2	0.56	6
<i>Tabebuia aurea</i> (Manso) Benth. & Hook. f. ex S. Moore	0.055	0.92	0.31	1.17	2.41	27
<i>Tabebuia roseoalba</i> (Ridl.) Sandwith	0.057	0.53	0.32	0.59	1.44	282
Boraginaceae						
<i>Cordia glabrata</i> (Mart.) DC.	0.046	0.66	0.26	0.98	1.9	9
Burseraceae						
<i>Commiphora leptophloeus</i> (Mart.) J.B.Gillet	0.01	0.13	0.06	0.2	0.38	240
Cardiopteridaceae						
<i>Citronella paniculata</i> (Mart.) R.A.Howard	0.005	0.13	0.03	0.2	0.35	258
Celastraceae						
<i>Maytenus rigida</i> Mart.	0.018	0.4	0.1	0.39	0.89	251
<i>Maytenus robusta</i> Reissek	0.012	0.26	0.07	0.39	0.72	235
<i>Salacia elliptica</i> (Mart. ex Schult.) G. Don	0.055	0.4	0.31	0.39	1.1	257
Chrysobalanaceae						
<i>Couepia</i> sp.	1.332	0.53	7.52	0.59	8.63	39
<i>Hirtella gracilipes</i> (Hook. f.) Prance	1.16	6.99	6.58	5.47	19.02	36
<i>Licania rigida</i> Benth	0.409	0.13	2.31	0.2	2.64	
Clusiaceae						
<i>Calophyllum brasiliense</i> Cambess.	0.2	0.79	1.13	0.78	2.7	250
<i>Kielmeyera rubriflora</i> Cambess.	0.019	0.13	0.03	1.42	0.2	319
Combretaceae						
<i>Combretum duarceanum</i> Cambess.	0.014	0.26	0.08	0.39	0.73	232
<i>Terminalia argentea</i> (Cambess.) Mart.	0.049	0.53	2.78	0.78	1.59	35
<i>Terminalia fagifolia</i> Mart.	0.016	0.13	0.09	0.2	0.42	350
<i>Terminalia glabrescens</i> Mart.	0.255	0.53	1.44	0.59	2.55	2
<i>Terminalia phaeocarpa</i> Eichler	0.068	0.13	0.39	1.43	0.2	
Dilleniaceae						
<i>Curatella americana</i> L.	0.527	4.34	2.98	4.1	11.43	268
Ebenaceae						
<i>Diospyros hispida</i> A.DC.	0.186	1.19	1.05	1.56	3.8	227
Euphorbiaceae						
<i>Sapium glandulosum</i> (L.) Morong	0.003	0.13	0.02	0.2	0.34	30
<i>Sebastiania brasiliensis</i> Spreng	0.002	0.13	0.01	0.2	0.34	21
Fabaceae						
<i>Acacia polyphylla</i> DC.	0.003	0.13	0.01	0.2	0.34	336
<i>Acosmium dasycarpum</i> (Vogel) Yakovlev	0.056	0.92	0.31	1.17	2.41	11
<i>Anadenanthera colubrina</i> (Vell.) Brenan	0.647	3.43	3.66	2.54	9.62	281
<i>Anadenanthera peregrina</i> (L.) Speg.	0.016	0.4	0.09	0.39	0.88	263
<i>Bauhinia brevipes</i> Vogel	0.002	0.13	0.01	0.2	0.34	345
<i>Bauhinia rufa</i> (Bong.) Steud.	0.083	0.13	0.47	0.2	0.8	29
<i>Calliandra foliolosa</i> Benth.	0.002	0.13	0.01	0.2	0.34	20
<i>Copaifera langsdorffii</i> Desf.	2.13	3.56	12.02	3.71	19.29	7
<i>Copaifera martii</i> Hayne	0.214	0.26	1.21	0.2	1.67	283
<i>Dalbergia cearensis</i> Ducke	0.01	0.13	0.06	0.2	0.39	
<i>Dimorphandra gardneriana</i> Tul.	0.038	0.4	0.21	0.56	1.2	317
<i>Erythrina falcata</i> Benth.	0.005	0.13	0.03	0.2	0.35	16
<i>Guibourtia hymenaeifolia</i> (Morici.) J. Léonard	0.103	0.66	0.58	0.78		280
<i>Hymenaea eryogyne</i> Benth.	2.203	5.27	12.44	3.9	21.61	228
<i>Hymenaea martiana</i> Hayne	0.073	0.4	0.4	0.59	1.39	276

Families/Species	BA	RD	RD ₀	RF	IV	V
<i>Hymenaea stignocarpa</i> Mart. ex Hayne	0.026	0.53	0.15	0.78	1.45	26
<i>Inga vera</i> Willd.	0.02	0.53	0.12	0.59	1.23	291
<i>Machaerium acutifolium</i> Vogel	0.01	0.13	0.06	0.2	0.39	241
<i>Machaerium hirtum</i> (Vell.) Stellfeld	0.18	0.4	1.02	0.59	1.99	272
<i>Machaerium opacum</i> Vogel	0.124	2.11	0.7	2.34	5.15	248
<i>Machaerium scleroxylon</i> Tul.	0.005	0.13	0.03	0.2	0.36	275
<i>Mimosa pulchra</i> Vell.	0.004	0.13	0.02	0.2	0.35	251
<i>Poeppegia procera</i> Presl	0.013	0.26	0.08	0.39	0.73	239
<i>Pterodon emarginatus</i> Vogel	0.17	1.32	0.96	1.56	3.84	17
<i>Tachigali paniculata</i> Aubl.	0.111	0.92	0.63	0.78	2.33	274
<i>Vaiterea macrocarpa</i> (Benth.) Ducke	0.135	0.26	0.76	0.39	1.41	310
<i>Zygia latifolia</i> (L.) Fawc. & Rendle	0.039	0.92	0.22	1.17	2.31	324
Lauraceae						
<i>Nectandra membranaceae</i> (Sw.) Griseb.	0.006	0.13	0.04	0.2	0.36	1
Malpighiaceae						
<i>Byrsonima pachyphylla</i> A.Juss.	0.489	4.87	2.76	4.69	12.33	12
<i>Byrsonima verbascifolia</i> (L.) DC.	0.081	0.53	0.46	0.78	1.77	233
<i>Ptilochaeta bahiensis</i> Turcz.	0.005	0.13	0.03	0.2	0.35	279
Malvaceae						
<i>Eriotheca gracilipes</i> (K.Schum.) A.Robyns	0.015	0.13	0.08	0.2	0.41	238
<i>Eriotheca macrophylla</i> (K.Schum.) A.Robyns	0.23	0.4	1.28	0.59	2.26	347
<i>Eriotheca pubescens</i> (Mart. & Zucc.) Schott & Endl.	0.007	0.13	0.04	0.2	0.37	346
<i>Guazuma ulmifolia</i> Lam.	0.014	0.26	0.08	0.39	0.73	379
<i>Luehea candicans</i> Mart. & Zucc.	0.004	0.13	0.02	0.2	0.35	234
<i>Luehea grandiflora</i> Mart. & Zucc.	0.003	0.13	0.02	0.2	0.34	10
<i>Luehea paniculata</i> Mart. & Zucc.	0.009	0.26	0.05	0.39	0.7	231
<i>Pseudobombax marginatum</i> (A.St.-Hil.) A.Robyns	0.024	0.4	0.14	0.2	0.73	19
<i>Pseudobombax tomentosum</i> (Mart. & Zucc.) A.Robyns	0.084	0.13	0.47	0.2	0.8	271
Moraceae						
<i>Brosimum guianense</i> (Aubl.) Huber	0.01	0.26	0.06	0.4	0.71	265
<i>Ficus obtusa</i> Hassk.	0.06	0.13	0.33	0.2	0.65	344
<i>Ficus obtusifolia</i> (Miq.) Miq.	0.04	0.13	0.22	0.2	0.55	348
Myrtaceae						
<i>Eugenia dysenterica</i> DC.	0.083	2.11	0.47	1.95	4.53	230
<i>Eugenia florida</i> DC.	0.16	1.19	0.92	1.37	3.47	267
<i>Eugenia ligustrina</i> (Sw.) Willd.	0.015	0.66	0.08	0.59	1.33	348
<i>Eugenia sonderiana</i> O.Berg	0.003	0.13	0.01	0.2	0.34	349
<i>Myrcia guianensis</i> (Aubl.) DC.	0.008	0.26	0.04	0.39	0.7	307
<i>Psidium myrtoides</i> O. Berg	0.002	0.13	0.013	0.2	0.34	333
Opliacae						
<i>Agonandra brasiliensis</i> Miers ex Benth. & Hook.	0.31	2.5	1.75	2.15	6.41	270
Poligonaceae						
<i>Coccoloba declinata</i> Mart	0.005	0.13	0.03	0.2	0.35	226
<i>Roupala montana</i> Aubl.	0.157	2.11	0.89	2.73	5.73	41
Rubiaceae						
<i>Cordia concolor</i> (Cham.) Kuntze	0.035	0.92	0.2	1.17	2.29	322
<i>Cordia rigida</i> (K.Schum.) Kuntze	0.006	0.13	0.03	0.2	0.36	273
<i>Machaonia brasiliensis</i> (Hoffmanns. Ex Humb.) Cham. & Schltdl.	0.01	0.13	0.06	0.2	0.39	277
<i>Tocoyena formosa</i> (Cham. & Schltdl.) K. Schum.	0.033	0.66	0.19	0.98	1.82	14
Rutaceae						
<i>Zanthoxylum riedelianum</i> Engl.	0.046	0.4	0.26	0.59	1.24	5
Salicaceae						
<i>Casearia rupestris</i> Eichler	0.005	0.26	0.03	0.2	0.49	21
Sapindaceae						
<i>Averrhoidium gardnerianum</i> Bail.	0.299	5.8	1.69	4.88	12.37	23
<i>Dilodendron bipinnatum</i> Radlk	0.317	3.16	1.79	3.32	8.27	37
<i>Magonia pubescens</i> A.St.-Hil.	0.044	0.53	0.25	0.78	1.56	13
<i>Talisia esculenta</i> (A.St.-Hil.) Radlk.	0.032	0.66	0.18	0.59	1.43	229
Sapotaceae						
<i>Chrysophyllum marginatum</i> (Hook. & Arn.) Radlk.	0.017	0.26	0.09	0.2	0.56	40
<i>Pouteria gardneriana</i> (A.DC.) Radlk.	0.015	0.53	0.08	0.78	1.39	236
<i>Pouteria ramiflora</i> (Mart.) Radlk.	0.037	0.26	0.21	0.39	0.86	301
Simaroubaceae						
<i>Simarouba versicolor</i> A.St.-Hil.	0.068	0.4	0.38	0.59	1.37	312
Urticaceae						
<i>Cecropia pachystachya</i> Trécul	0.172	1.19	0.97	1.56	3.72	269
Vochysiaceae						
<i>Callisthene fasciculata</i> (Spreng.) Mart.	0.071	1.45	0.4	0.98	2.83	24
<i>Qualea grandiflora</i> Mart.	0.017	0.13	0.1	0.2	0.42	33
<i>Qualea multiflora</i> Mart.	0.02	0.26	0.11	0.2	0.57	25

riparian forests of Minas Gerais, which found Fabaceae and Myrtaceae to be among the five most diverse families (Carvalho *et al.*, 2005; Fagundes *et al.*, 2007). The Fabaceae family is also prominent in studies of riparian forests near the São Francisco, Cochá and Carinhanha rivers, all in North Minas Gerais, presenting the largest diversity recorded in the three areas (Santos and Vieira, 2006). These data, as well as those found in the present study, confirm a large widespread of this family in Minas Gerais, highlighting its importance in the composition of riparian vegetations.

Regarding abundance, 10 species are highlighted, totaling 50.7% of the total number of individuals sampled (Table II). In the same manner, these 10 species presented higher basal area values, corresponding to 65.0% of the total basal area. The highest IVs ranged from 19.0 to 2.6% and belonged to the following species: *H. eryogyne*, the most dominant, *T. guianensis*, which was very frequent and dense, and *C. langsdorffii*, which had a dominance inferior only to *H. eryogyne* and *H. gracilipes*, which also presented the highest density and frequency values. Of the species sampled, only 36 showed a single individual, corresponding to 4.7% of individuals and 35.0% of the total species. *C. langsdorffii* and *T. guianensis* were considered to be abundant by Silva-Junior *et al.* (2001), being found in more than 18 riparian forests out of the 21 that were inventoried in the Distrito Federal. *C. langsdorffii* obtained the highest value for basal area (Oliveira Filho *et al.*, 1994a) in the riparian forest of the Grande river, Bom Sucesso, MG, and in the riparian forest of the Camargos reservoir, Itutinga, MG, which shows the broad occurrence of this species in the flora composition of riparian forests.

The floristic composition of the studied area presents typical species of riparian forests, such as *Aspidosperma subcanum*, *Brosimum guianense*, *Calophyllum brasiliense*, *Eugenia ligustrina*, *Inga vera*, *Machaonia brasiliensis*, *Nectandra membranaceae*, *Pouteria gardneriana* and *Zygia latifolia*, as well as species common to the Cerrado, such as *Aspidosperma multiflorum*, *Copaifera martii*, *Curatella*

Americana, *Dimorphandra gardneriana*, *Handroanthus ochraceus*, *Hymenaea stignocarpa*, *Kielmeyera rubriflora* and *Machaerium opacum*. It also presented exclusive species from Deciduous Seasonal Forests, such as *Commiphora leptophloeus* and *Ficus obtusifolia* (Sano *et al.* 2008). Riparian forests have interphase with several types of vegetation and are subjected to varied floristic influences (Oliveira-Filho and Ratter, 2004). There is a strong contribution from the environmental heterogeneity on the riparian vegetation, produced not only by the adjacent vegetation (Carvalho *et al.*, 2005) but also by the local edaphic conditions. This inference becomes clear because some of the species found here are characteristic of different phytophysiognomies that coexist in environments bordering the riparian forests. *C. langsdorffii* and *T. guianensis* stand out in studies of riparian forests outside of Brazil's Amazon Region, being found in more than 50% of the research conducted there (Rodrigues and Nave, 2004). *T. guianensis* has great adaptive amplitude (Silva-Junior *et al.*, 2001), occurring in the Neotropics (Oliveira-Filho and Ratter, 2004), from the flood areas of the riparian forests to the Cerrado. The presence of this species in different environments may be related to its pioneering feature of adaptive amplitude. *C. langsdorffii* is also a widely occurring species (Oliveira-Filho *et al.*, 1994b), showing the behavior typical of species that inhabit regions of the transition cerrado/forest (Lorenzi, 1992) in addition to its generalist nature (van den Berg and Oliveira Filho, 1999).

Shannon's diversity index (H') and Pielou's evenness index (J') were 3.87 and 0.83, respectively. These indices indicate that the diversity of species inventoried in the Pandeiros river riparian forest, at Balneário, is high. These rates exceed the values found in riparian forests located in areas of the Cerrado in Minas Gerais, such as in Conquista ($H' = 3.85$; Carvalho *et al.*, 1996), Martinho Campos ($H' = 3.77$; Carvalho *et al.* 2000a) and Três Marias ($H' = 2.89$; Carvalho *et al.*, 2005), being inferior to the indices found for the riparian forest in Itambé do Mato Dentro ($H' = 4.32$; Carvalho *et al.*, 2000b), which is located in a region under the domain of the Mata Atlântica (Carvalho *et al.*, 2005). Thus, the diversity observed is significant and based on phytosociological and floristic results. It also points out the ecotonal characteristic of the area and the influence of adjacent phytophysiognomies.

Species distribution

According to the results of the CCA, the eigenvalues were low for both axes, 0.416 for the first and 0.331

for the second, which means that the gradients are short, with low species replacement (ter Braak, 1995). In the matrix of weighted correlations between environmental variables (Table III), strong interrelationships can be observed between the variables K and OM, and between OM and Ca. The Monte Carlo permutation test was significant ($p > 0.01$) for all of the ordination axes, and the species-environment correlations were high (> 0.89). The first two axes explained 12.34% of the total data variance. This result shows that the variables contain unexplained residual variance. However, this is a common occurrence in vegetation data, and it does not influence the analysis (ter Braak, 1986), considering that there exists a series of environmental factors that might be associated to the behavior of the vegetation under study and that were not evaluated in this analysis. The environmental variables most strongly correlated with the first axis were, in descending order, K, OM and Ca. In the second axis, FR and MO stood out (Table III). We observed an arrangement of three distinct groups originating from the four sectors that were sampled (Figure 2a). The first group (Sector 1) consists of plots located in areas that are under the influence of limestone rocks, which have soils of the eutrophic Litholic Neosol and eutrophic Haplic Cambisol classes. In this sector, the species were *C. leptophloeus*, *Couepia* sp., *Luehea candicans*, *Machaerium acutifolium* and *Terminalia glabrescens* (Figure 2b). These species are more demanding with regard to the substrate and are therefore typical of rich soils found in areas of transition from Deciduous Forest to Caatinga (Naime, 1980). According to Jacomine (2004) Litholic Neosol and Haplic Cambisol have higher nutrient availability than other classes of soils, due to the influence of limestone rocks and plant biomass deposits. This feature enables the existence of large tree species, such as those found in the present study.

The second group is formed by the parcels of Sector 3, which

are located adjacent to the cerrado, in the eutrophic Fluvic Neosol. The especially fertile soil in this sector may be related to the deposition of sediments derived from limestone located upstream and carried by river flooding. This group is mainly represented by plots P37, P39, P40, P42 and P43 (Figure 2a), in which the species *Bauhinia rufa*, *C. americana*, *Luehea grandiflora*, *H. martii*, *Tachigali paniculata* and *Terminalia fagifolia*, among others, were found (Figure 2b). These findings suggest that these species are most abundant in Sector 3, indicating adaptation to some areas of the cerrado, as well as sandy areas with periodic water saturation. We observed a sandy recessed area in this sector, which constantly floods, and another area slightly upstream, which does not flood.

The third group was composed of portions of sectors 2 and 4, which were plotted in areas of the cerrado, had soils of the dystrophic Red-Yellow Latosol and dystrophic Haplic Gleysol classes and differed little from one another (Figure 1a). We observed the formation of a cluster of plots with a predominance of *Acosmium dasycarpum*, *A. colubrina*, *A. fraxinifolium*, *B. pachyphylla*, *Eriotheca pubescens*, *H. gracilipes*, *H. eryogyne*, *M. opacum*, *Pouteria ramiflora*, *H. ochraceus*, *T. guianensis* and *Tocoyena formosa* (Figure 2b). The aggregation of the plots was probably caused by soil classes that correlated with the species groups. These species, which were clustered into these two sectors, are undemanding species with respect to the availability of nutrients. For example, *A. dasycarpum* predominates in soils of medium fertility (Lorenzi, 1992); *A. colubrina* can occur in shallow soils and soils with low chemical fertility (Carvalho, 2003); *A. fraxinifolium* is found in soils with low Ca levels (Almeida *et al.*, 1998); *E. pubescens* is adapted to dry and poor soils (Almeida *et al.*, 1998); *M. opacum* exists in clay soils of medium fertility (Lorenzi, 1998); *P. ramiflora* is positively influenced by

TABLE III
CANONICAL CORRESPONDENCE ANALYSIS OF THE 107 SPECIES ABUNDANCE, SAMPLED IN 70 PARCELS (100m²), ON A STRETCH OF THE PANDEIROS RIVER RIPARIAN FOREST*

Environmental variables	Internal correlations		Environmental variables		
	Axe 1	Axe 2	K	Ca	Organic matter
Potassium	0.279	0.076			
Calcium	0.587	0.176	0.521		
Organic matter	0.625	0.445	0.554	0.690	
Flooding regime	0.059	0.915	0.168	0.080	0.194

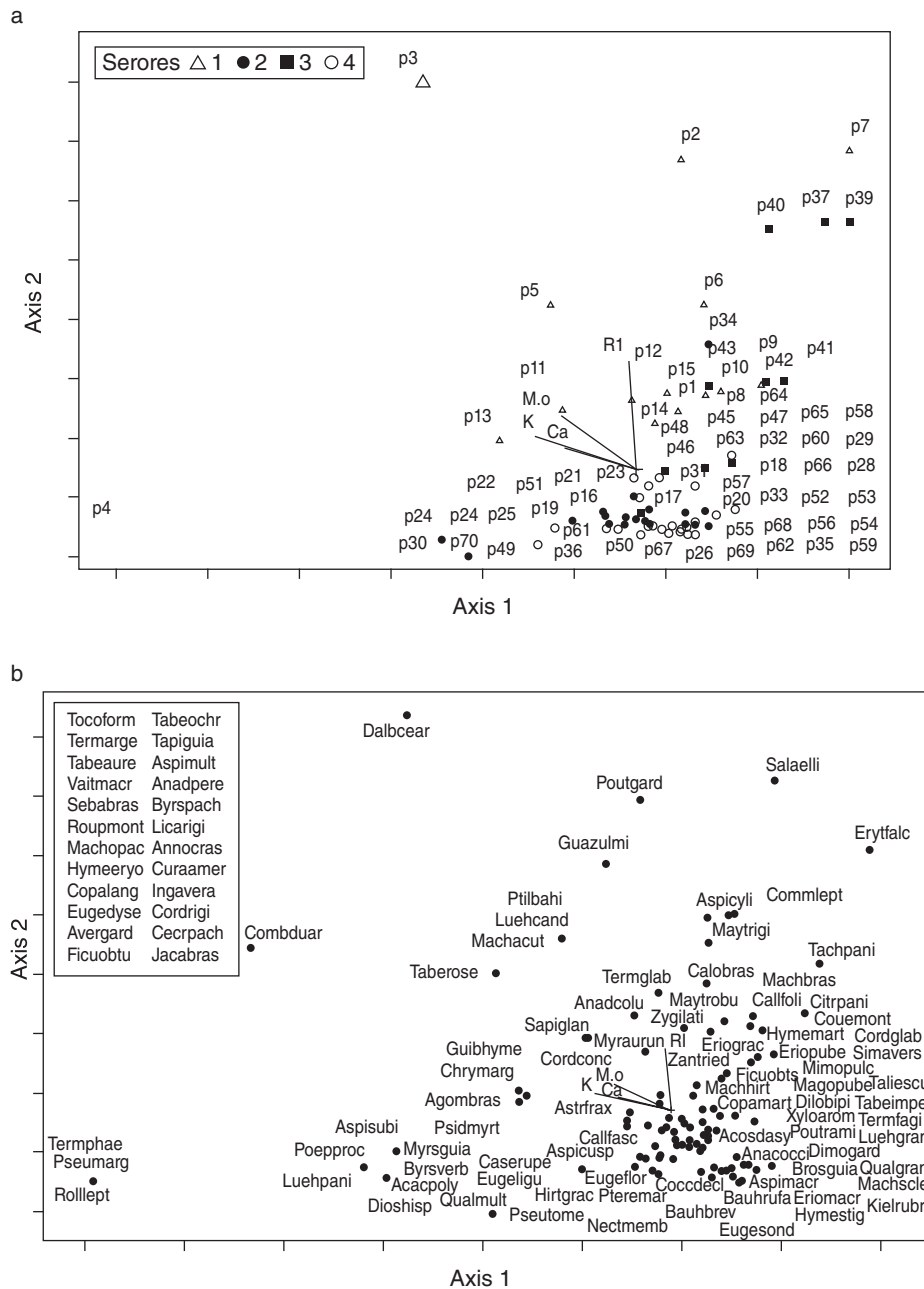


Figure 2. Diagram of the canonical correspondence analysis (CCA) ordering of the parcels (a) and species (b) according to the distribution of the number of individuals from 107 species sampled in the 70 parcels (100m²) from the Balneário of the Pandeiros river riparian forest and the correlation with the variables flooding regimen (FR), organic matter (MO), K and Ca.

the sand and fine sand fraction (Almeida *et al.*, 1998); *H. ochraceus* is selectively xerophytic, a characteristic of the cerrado (Lorenzi, 1992); *T. guianensis* is adapted to high soil acidity and low chemical fertility, aside from being tolerant to Al (Carvalho, 2006); and finally, *T. formosa* is indifferent to the presence of Ca (Almeida *et al.*, 1998). Moreover, because they originate from sandstone, these soils have a low availability of micronutrients (Jacomine, 2004).

The environmental variables C, K, OM and FR showed the strongest correlations with species. In fact, K, Ca and OM showed negative correlations with axis one and positive correlations with axis two, whereas FR correlated positively with axis two and negatively with axis one (Figure 2). While ordering the species with environmental variables through the CCA, we observed that *A. colubrina*, *L. candicans*, *M. acutifolium*, *Guazuma ulmifolia*, *P. gardneriana*, *Z.*

latifolia and *Ptilochaeta bahiensis* had a positive relationship with FR, demonstrating that these species may have developed strategies to adapt to water-saturated soils (Pinto *et al.*, 2005), with the consequent deficiency of oxygen, and are probably undemanding species with respect to nutrients, considering that the soil nutrient content in these environments can decrease due to excess water and probable leaching (van den Berg and Oliveira-Filho, 1999). Likewise, the species *Tabebuia roseoalba* and *Sapium glandulosum* were found in portions of Sector 1 in a drawdown area where there was likely the entrainment of plant biomass, allowing the accumulation of organic matter. Thus, there is a positive correlation with these species, suggesting that, in addition to nutrients that may have come from the highest points of this sector, the storage of organic matter in the lower area favored the development and adaptation of these species. Moreover, *Guibourtia hymenaeifolia*, *Chrysophyllum marginatum*, *Combretum duarteianum*, *Agonandra brasiliensis*, *Aspidosperma cuspa* and *Poeppigia procera* correlated positively with Ca and K. Thus, these species have demonstrated preferences for areas where soils have high levels of those nutrients. This can be confirmed from the results of the soil analysis done on the plots located in Sector 2, which showed the highest levels of Ca, and in Sector 1, in which K was fairly representative. However, despite the considerable number of species that have shown positive correlations with the environmental variables mentioned, most of the species sampled, including *Annona crassiflora*, *Eugenia dysenterica* and *Bauhinia brevipes*, established negative correlations with FR. *Anadenanthera peregrina*, *Qualea grandiflora*, *H. stagnocarpa*, *L. grandiflora*, *A. fraxinifolium* and *Eriotheca macrophylla* also correlated negatively with OM, Ca and K. Regardless of the correlations between groups of species and environmental variables, several species, such as *C. langsdorffii*, *Dilodendron bipinnatum*, *Diospyros hispida*, *X. aromatica*, *Eugenia florida*, *M. opacum*, *Magonia pubescens*, *N. membranacea*, *P. ramiflora*, *Pseudobombax tomentosum*, *Roupala montana* and *T. formosa* clustered in the center of the axis, without establishing any relationship with the mentioned variables. This allows to suggest that these species are undemanding with respect to nutrient content, a fact that characterizes them as generalist species. Oliveira-Filho *et al.* (1994b) found *C. langsdorffii* in soils of low fertility in studies of a riparian forest on the banks of the Grande river (MG) and found a significant relationship with the soil chemical components in that area, highlighting its

potential as a generalist species, which is corroborated in this research.

The present results suggest that the species distribution into three groups is related, primarily, to the soil types and edaphic conditions in the existing sectors. Each species shows a range of tolerances to environmental variables, and almost invariably the limits of this tolerance are not defined by a steep environmental gradient (Rodrigues *et al.*, 2003). Jacomine (2004) argues that there is significant variation in the soils of the riparian forests, which is reflected in the various types of forest formations. This variation occurs from the wettest to the driest terrains, where forests have distinct physiognomic and floristic characteristics (Jacomine, 2004). Indeed, we were able to notice a great variation of soils in an area of the Pandeiros river riparian forest that was <1ha (0.7ha), supporting Jacomine's claim.

The diversity of interactions between environmental factors (here, the soil) and the responses of the different species results in a heterogeneous environment, which causes the formation of a mosaic of habitats (Hutchings *et al.*, 2003). Due to the environmental heterogeneity in areas adjacent to Balneário at the Pandeiros river riparian forest and the wide variety of soils found and the humidity in the area, this riparian forest is an environment with unique vegetation, especially with respect to structural and floristic composition; it displays species that are typical of riparian forests, dry forests and savanna (cerrado) vegetation. The restoration of these environments is therefore complex, given that even in small areas there is a noticeable variation in the flora and the structure of the trees. Thus, these results highlight the importance of conservation and the preservation of these plant communities. In addition, considering how difficult it is to categorize the vegetation heterogeneity even in short stretches of the river, understanding these diverse communities must become a priority for conservation.

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VARIAÇÕES FLORÍSTICAS E ESTRUTURAIS DA COMUNIDADE ARBÓREA EM RELAÇÃO ÀS PROPRIEDADES DO SOLO NA MATA CILIAR DO RIO PANDEIROS, MINAS GERAIS, BRASIL

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RESUMO

Na área de abrangência do semiárido brasileiro, encontra-se o norte de Minas Gerais, zona de transição entre os biomas Caatinga e Cerrado. Nesta região são observadas fitofisionomias distintas, constituindo-se basicamente em um mosaico, com ocorrência de formações vegetais diversas como o Cerrado Sentido Restrito, Florestas Estacionais Deciduais e Matas Ciliares. Este estudo tem como objetivo apresentar a estrutura do componente arbóreo-arbustivo de um trecho de mata ciliar do rio Pandeiros, Januária, Minas Gerais, e verificar possíveis correlações entre as variáveis edáficas e a distribuição e densidade das espécies. O levantamento foi realizado em 70 parcelas de 100m², onde foram encontradas cinco classes de solos nos quatro setores e amostrados 759 indivíduos, 31 famílias e 107 espécies. As famílias mais ricas foram Fabaceae, Malva-

ceae, Myrtaceae, Apocynaceae, Bignoniaceae e Combretaceae. *Hirtella gracilipes*, *Xylopia aromatica*, *Averrhoidium gardnerianum*, *Tapirira guianensis*, *Hymenaea eryogyne* e *Byrsonima pachyphylla* foram as espécies mais abundantes e *H. eryogyne*, *T. guianensis* e *Copaifera langsdorffii* apresentaram os maiores valores de importância. Os resultados sugerem que além das variáveis Ca, K, matéria orgânica e regime de inundação, que correlacionaram com algumas espécies, a agregação das parcelas em três grupos está relacionada ainda aos tipos de solo dos setores. Desta forma, tanto a heterogeneidade, propiciada pela vegetação adjacente, como a variedade de solos e o teor de umidade em alguns pontos, determinam a formação de uma mata ciliar peculiar, com interações entre espécies características de matas ciliares, mata seca e cerrado.

VARIACIONES FLORÍSTICAS Y ESTRUCTURALES DE LA COMUNIDAD ARBÓREA Y SU RELACIÓN CON LAS PROPIEDADES DEL SUELO, EN LA ZONA RIBEREÑA DEL RÍO PANDEIROS, MINAS GERAIS, BRASIL

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RESUMEN

Entre las áreas del semiárido brasileño se incluye el norte del estado de Minas Gerais, zona de transición entre los biomas Cerrado y Caatinga. Allí se observan distintos tipos de vegetación, llegando a constituir básicamente un mosaico donde aparecen diversas formaciones vegetales, como el cerrado stricto sensu, bosques secos estacionales y bosque ribereño. Este estudio tiene como objetivo presentar la estructura del componente arbóreo y arbustivo de una parte del bosque ribereño del río Pandeiros, Januária, Minas Gerais, e investigar posibles relaciones entre las variables del suelo y la distribución y densidad de especies. El estudio de vegetación se realizó en 70 parcelas de 100m², donde se encontró cinco clases de suelo, en los cuatro sectores donde se muestrearon 759 individuos, 31 familias y 107 especies. Las familias más ricas fueron Fabaceae, Malvaceae,

Myrtaceae, Apocynaceae, Combretaceae y Bignoniaceae. *Hirtella gracilipes*, *Xylopia aromatica*, *Averrhoidium gardnerianum*, *Tapirira guianensis*, *Hymenaea eryogyne* y *Byrsonima pachyphylla* fueron las especies más abundantes, y *H. eryogyne*, *T. guianensis* y *Copaifera langsdorffii* tuvieron los más altos valores de importancia. Los resultados sugieren que, además de las variables ambientales, Ca, K, materia orgánica y régimen de inundación, que se relacionaron con algunas especies, la agregación de las parcelas en tres grupos también está relacionada con los tipos de suelo. Así, tanto la heterogeneidad proporcionada por la vegetación circundante, como la variedad de suelos y contenido de humedad en algunos puntos, determinan la formación de un bosque de ribera peculiar, con interacciones entre especies características de los bosques de ribera, bosque seco y cerrado.