

Influence of Edaphic Attributes on the Distribution of Tree Species in a Riparian Forest in Southern Brazil

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ABSTRACT

This study aims at identifying the formation of clusters and to evaluate the influence of chemical attributes in the soil on the groups and species in a riparian forest fragment in Campos de Cima da Serra, Rio Grande do Sul (RS). Thirteen plots (10 × 20 m) were demarcated to carry out the study. Forest inventory data were employed in a multivariate analysis using the Twinspan method and the correlation between vegetation data and chemical characterization of the soil was carried out by Canonical Correspondence Analysis (CCA). Thirty-one species were sampled (DBH ≥ 30 cm) and two floristic groups were identified. The results indicated a structural difference between the two environments, likely due to the steeper slope and less influence of groundwater. Variables such as sulfur, calcium and organic matter were explanatory of the vegetation grouping known as riparian forest of hillside and aluminum, aluminum saturation and copper of riparian forest with flat topography.

Keywords: conservation, cluster analysis, canonical correspondence analysis, Mixed Ombrophilous Forest.

1. INTRODUCTION AND OBJECTIVES

The vegetation found along watercourses is generally referred to as riparian (Brasil, 2012), however, when this vegetation is not characterized as a continuous forest, it is often referred to as a gallery forest (Rodrigues, 2009). Regardless of the denomination, riparian forests play an important biological filter role by retaining substances or by filtering water runoff (Kageyama & Gandara, 2009), as well as forming ecological corridors that are fundamental for preserving the diversity of flora and fauna (Brancalion et al., 2010). Due to its importance, the development of researches related to the phytosociological parameters of the vegetation present in riparian forests is an important subsidy for planning conservation actions and enrichment of these areas.

In this regard, the use of multivariate techniques such as cluster analysis is an important tool to characterize vegetation in forest fragments, since it aims to cluster elements in homogeneous groups (Felfili & Rezende, 2003). Among the implemented techniques, the Twinspan (Two-Way Indicator Species Analysis) grouping analysis (Gauch, 1982) has been used by Araujo et al. (2010), thus allowing the detection of distinct vegetation clusters in forest remnants, which were defined according to environmental characteristics and specific species.

Moreover, as important as characterizing floristic and vegetation structure, as well as evidencing groupings of species in natural ecosystems, is the correlation of this information with environmental characteristics. This is possible through sorting methods such as the Canonical Correspondence Analysis (CCA), Principal Component Analysis (PCA) and Detrended Correspondence Analysis (DCA), which were used by Rodrigues et al. (2007). According to these techniques, these authors determined preferential habitats for species occurrence which were correlated with the type and characteristics of soils, topography and drainage.

Similarly, Avila et al. (2011) also used cluster analysis and CCA, respectively, to identify the presence of floristic clusters in natural regeneration mechanisms and the influence of environmental factors on the distribution of species and plots in the seedling bank in a Mixed Ombrophilous Forest fragment in southern Brazil. In this forest typology,

the authors concluded that the formed clusters indicate differences in the regenerative processes of the forest. Understanding this information makes it possible to plan conservation and management strategies that are appropriate to each species and environment, and according to Rorato et al. (2015), allows one inferring about the biological conservation of these ecosystems, providing an indication of potential species to be used in programs and strategies for recovery and enrichment of degraded areas.

Thus, the objective of the present study was to identify and characterize groupings of species in the arboreal component and correlate them with soil variables in a riparian forest in Campos de Cima da Serra in RS, Brazil.

2. MATERIALS AND METHODS

The study was carried out in an area of riparian forest in a Mixed Ombrophilous Montana Forest fragment (IBGE, 2012) in the municipality of São Francisco de Paula, RS (29°26'52"S latitude and 50°35'02"W longitude), with average altitudes of 907 m. According to the Köppen climate classification, the climate in the region is Cfb (subtropical), constituting the coldest region of the state and with the greatest precipitation (Moreno, 1961).

The region is known as *Campos de Cima da Serra*, in which the fields form mosaics with the Mixed Ombrophilous Forest (Pillar et al., 2009) and the *Campos Sulinos* biome (IBGE, 2004). According to Streck et al. (2008), the predominant soils in the region are classified in the first categorical level as Cambisols and Neosols.

Systematic sampling was used for the vegetation survey with random selection of the first sample unit (plot), and all other units were then systematically distributed from there (Péllico Neto & Brena, 1997). Thus, eight strips perpendicular to the water course were demarcated, parallel to one another at distances of 100 m. The strips were drawn in the perpendicular direction to the drainage line in order to obtain a vegetation gradient from the fragment edge to the riverbed (Figure 1).

A total of 13 plots of 10 × 20 m were demarcated throughout the eight strips in the fragment with a total area of 12.2 ha. Botanical identification and

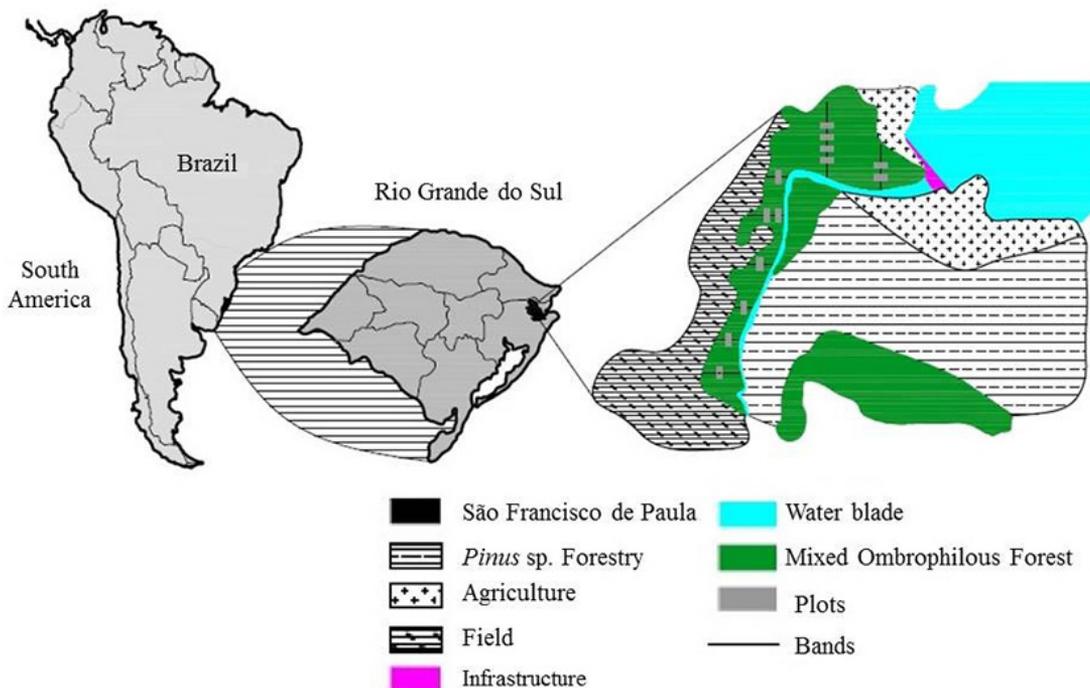


Figure 1. Location of the study area, highlighting the distribution of the strips and plots sampled in a Mixed Ombrophilous Forest fragment, São Francisco de Paula, RS, Brazil.

measurement of the individuals of the shrub-arboreal component of the diameter at breast height (DBH), according to class sizes, was carried out in each plot. All individuals with $DBH \geq 30$ cm (Class I) were evaluated in the total area of each plot (10×20 m), while all individuals with $15 \leq DBH < 30$ cm (Class II) were evaluated in the 10×10 m subplots. The species were classified into botanical families according to the Angiosperm Phylogeny Group (APG IV) (Chase, 2016) and the scientific name updating was determined according to the List of Species of the Brazilian Flora (JBRJ, 2014).

In addition to the vegetation survey, three simple soil samples in the 0-20 cm layer were collected from eight of the 13 plots studied to form the composite sample. These samples were submitted to chemical analysis at the Universidade Federal de Santa Maria (UFSM) Soil Analysis Laboratory according to the methodology proposed by Tedesco et al. (1995) for determining the pH in water, V% (base saturation), m% (saturation by aluminum), H+Al, effective cation exchange capacity (CEC), pH7 CEC, and content

of organic matter (OM), aluminum (Al), calcium (Ca), magnesium (Mg), potassium (K), sulfur (S), phosphorus (P), copper (Cu), boron (B) and zinc (Zn).

The cluster analysis only considered data from individuals of the arboreal stratum (Class I), while Class II was used to support possible biological and structural differences in each grouping based on the evaluated class sizes. Thus, tree vegetation data (individuals with $DBH \geq 30$ cm) gave rise to a matrix consisting of 13 plots (lines) and 14 species (columns). Rare species (considered as those with less than three individuals) were removed from the cluster analysis. Rare or low-density species have little or no influence on the results and can be removed from the analysis (Gauch, 1982).

This matrix was used in a multivariate analysis according to the Twinspan method (Gauch, 1982) using the PC-ORD™ program for Windows version 5.10 (McCune & Mefford, 1997).

For characterization of the pseudospecies, the cut levels were determined based on the densities observed

for the species in each plot with pseudospecies 1 (up to one individual), pseudospecies 2 (two to four), pseudospecies 3 (five to six), pseudospecies 4 (seven to nine) and pseudospecies 5 (10 or more individuals).

According to the formed groups, each one was then analyzed by parameters such as density, dominance, absolute frequency and value of importance regarding the species (Felfili & Rezende, 2003), seeking to distinguish differences in the forest structure, which in addition to density also allowed to infer about each group.

The correlation between vegetation data and soil chemical variables through the Canonical Correspondence Analysis (CCA) was carried out using the PC-ORD™ program for Windows version 5.10 (McCune & Mefford, 1997). The analysis was based on the formation of two matrices: one referring to the density of the individuals of each tree species in the eight plots from which soil samples were collected; and another one containing the chemical characteristics of the soil, in addition to the group as a categorical variable. However, the analysis is only possible when the number of environmental variables is smaller than the number of plots with vegetation data; a condition imposed by the software at the time of inserting the matrices in the program. Thus, a preliminary analysis was carried out to remove weakly correlated variables (correlation value less than 0.4).

As a result, CCA was processed using the main matrix of species density (Class I), composed by eight plots (lines) and 11 species (columns), and a secondary matrix with eight plots (lines) and seven environmental variables (columns). It was then possible to evaluate soil chemical variables that had the greatest influence on the groups according to the CCA results.

3. RESULTS AND DISCUSSION

For the arboreal vegetation (Class I, DBH \geq 30 cm) of the studied forest fragment, 31 species belonging to 27 genera and 19 botanical families were sampled, while for the smaller class size (Class II, $15 \leq$ DBH < 30 cm), the richness was represented by 19 species, 19 genera and 12 botanical families (Table 1). Ribeiro et al. (2007) verified the occurrence of 130 species with DBH \geq 30 cm belonging to 79 genera and 45 botanical families in an arboreal community characterization

of the Mixed Ombrophilous Forest in the National Forest (Flona) of São Francisco de Paula, RS, Brazil. These results differ from those found herein, probably due to the studied area belonging to a Flona and representing a typical Mixed Ombrophilous Forest, while the forest fragment in the present study is represented by a riparian forest remnant.

Two floristic groups (eigenvalue: 0.3133) were observed in the cluster analysis for Class I: Group 1 (G1) and Group 2 (G2) (Figure 2). According to the characteristic of the observed vegetation, the studied forest fragment shows a great number of species of riparian forests. However, G1 differed from G2 because it occurred on flat relief, thus being referred to as riparian forest with flat topography, using *Eugenia uruguayensis* as an indicator. The area in G2 has a more pronounced topography, which can be characterized as a hillside riparian forest, in which the indicator species of this environment was *Myrcianthes gigantea*. Both indicator species are typical of riparian forests, as evidenced by Rorato et al. (2015) for *Eugenia uruguayensis* and by Backes & Irgang (2009) for *Myrcianthes gigantea*.

The species *Casearia decandra*, *Eugenia uruguayensis*, *Myrciaria delicatula*, *Myrsine coriacea*, *Roupala brasiliensis* and *Styrax leprosus* are the preferential species of the riparian forest with flat topography (G1) (six plots) as represented by pseudospecies 1, which indicates a low density of individuals in the plots. In addition to these, we can highlight *Eugenia uruguayensis* and *Ocotea pulchella*, belonging to pseudospecies 2, which presented between two and four individuals; and *Eugenia uruguayensis* and *Podocarpus lambertii*, both of pseudospecies 3 with five to six individuals.

For the hillside riparian forest (G2) formed by seven plots, the species *Myrcianthes gigantea* was indicative of the group and also the preferred pseudospecies 1 and 2, while *Gymnanthes klotzschiana* was preferred as pseudospecies 2, 3, 4 and 5, considering that more than 10 individuals of this species were observed in both plots.

In the G1 structure, represented by the riparian forest present in areas with flat topography, approximately 1,008 individuals.ha⁻¹ were found for Class I (DBH \geq 30 cm), belonging to 24 species, 23 genera and 14 botanical families (Table 2).

The species present in the riparian forest with flat topography (G1) that showed the highest values of importance were: *Podocarpus lambertii* (21.6%), *Eugenia uruguayensis* (13.5%), *Araucaria angustifolia* (9.3%) and *Ilex brevicuspis* (7.6%), representing 52% of the group's horizontal structure (Table 2). Of these,

Podocarpus lambertii and *Ilex brevicuspis* were not represented in Class II ($15 \leq \text{DBH} < 30 \text{ cm}$), while *Eugenia uruguayensis* and *Araucaria angustifolia* were found in both studied classes, thus suggesting the greater possibility of preserving these species in the environment. In this group, it should also be

Table 1. Families and species observed in Class I (DBH $\geq 30 \text{ cm}$) and Class II ($15 \leq \text{DBH} < 30 \text{ cm}$) in a Mixed Ombrophilous Forest fragment. São Francisco de Paula, RS, Brazil.

Family	Species	Popular name in Brazil	Class
Anacardiaceae	<i>Lithraea brasiliensis</i> Marchand	Aroeira-brava	I and II
	<i>Schinus lentiscifolia</i> Marchand	Aroeira-cinzenta	I and II
Aquifoliaceae	<i>Ilex brevicuspis</i> Reissek	Caúna	I and II
	<i>Ilex dumosa</i> Reissek	Caúna	I
Araucariaceae	<i>Araucaria angustifolia</i> (Bertol.) Kuntze	Araucária	I and II
Asteraceae	<i>Gochnatia polymorpha</i> (Less.) Cabr.	Cambará	I
Celastraceae	<i>Maytenus aquifolia</i> Mart.	Cancorosa	I
Cunoniaceae	<i>Lamanonia ternata</i> Vell.	Guaraperê	I
Dicksoniaceae	<i>Dicksonia sellowiana</i> Hook.	Xaxim	I
Euphorbiaceae	<i>Sebastiania brasiliensis</i> Marchand	Leiteiro	I and II
	<i>Gymnanthes klotzschiana</i> Müll.Arg.	Branquilha	I and II
Lauraceae	<i>Cinnamomum amoenum</i> (Nees & Mart.) Kosterm.	Canela	I
	<i>Ocotea corymbosa</i> (Meisn.) Mez	Canela	I
	<i>Ocotea porosa</i> (Nees & Mart.) Barroso	Imbúia	I
	<i>Ocotea pulchella</i> (Nees & Mart.) Mez	Canela-lageana	I and II
Melastomataceae	<i>Miconia cinerascens</i> Miq.	Pixirica	II
Myrtaceae	<i>Acca sellowiana</i> (O.Berg) Burret	Goiaba-da-serra	II
	<i>Blepharocalyx salicifolius</i> (Kunth) O.Berg	Murta	I
	<i>Calyptanthus concinna</i> DC.	Guamirim-ferro	I and II
	<i>Eugenia uruguayensis</i> Cambess.	Guamirim	I and II
	<i>Myrceugenia cucullata</i> D. Legrand	Guamirim	I and II
	<i>Myrcianthes gigantea</i> (D. Legrand) D. Legrand	Araçá-do-mato	I and II
Podocarpaceae	<i>Myrciaria delicatula</i> (DC.) O.Berg	Camboim	I and II
	<i>Podocarpus lambertii</i> Klotzsch ex Endl.	Pinheiro-bravo	I and II
Primulaceae	<i>Myrsine coriacea</i> (Sw.) R.Br. ex Roem. & Schult.	Capororoca	I
Proteaceae	<i>Roupala brasiliensis</i> Klotzsch	Carvalho-brasileiro	I and II
Quillajaceae	<i>Quillaja brasiliensis</i> (A.St.-Hil. & Tul.) Mart.	Pau-sabão	I and II
Rosaceae	<i>Prunus myrtifolia</i> (L.) Urb.	Pessegueiro-do-mato	I
Salicaceae	<i>Casearia decandra</i> Jacq.	Guaçatunga	I and II
	<i>Casearia sylvestris</i> Swartz.	Chá-de-bugre	I
Sapindaceae	<i>Allophylus edulis</i> (A.St.-Hil. et al.) Hieron. ex Niederl.	Chal-chal	I
Styracaceae	<i>Styrax leprosus</i> Hook. & Arn.	Carne-de-vaca	I
Symplocaceae	<i>Symplocos uniflora</i> (Pohl) Benth.	Sete-sangrias	I and II

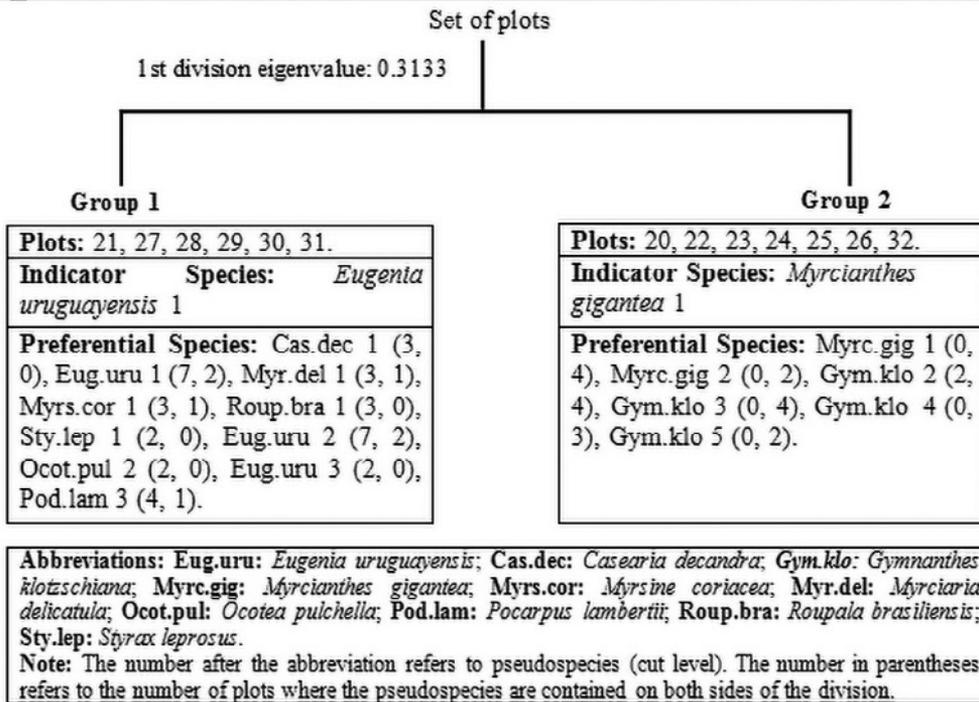


Figure 2. Classification of sampling units in two floristic groups for Class I (DBH \geq 30 cm) in a Mixed Ombrophilous Forest fragment. São Francisco de Paula, RS, Brazil, as follows: Group 1: riparian forest with flat topography; Group 2: hillside riparian forest.

noted that *Casearia decandra*, *Myrciaria delicatula*, *Myrceugenia cucullata* and *Roupala brasiliensis* were also found represented in both classes, with their propagation being favored in this environment.

For Class I (DBH \geq 30 cm) of the hillside forest (G2), it was found the occurrence of 900 individuals. ha⁻¹ belonging to 18 species, 17 genera and 11 botanical families (Table 3). The species that presented the highest value of importance were *Araucaria angustifolia* (20.6%), *Gymnanthes klotzschiana* (19.6%), *Lithraea brasiliensis* (14.1%) and *Podocarpus lambertii* (9.6%), representing 63.9% of the forest structure. Of these species, except for *Araucaria angustifolia*, all the others are present in both evaluated classes, indicating the possibility of their propagation over time.

The riparian forest with flat topography (G1) had a basal area expressed by absolute total dominance (ADo) of 48.28 m².ha⁻¹ (Table 2), while it was ADo = 37.73 m².ha⁻¹ for the hillside riparian forest (G2) (Table 3). The highest values found for G1 in relation to G2 regarding the number of species and number of individuals indicate a structural difference of these

two environments, probably due to the greater slope and less influence of the water table on G2. On the other hand, even though G2 is located on higher ground, it clearly reflects the condition of a riparian forest considering the predominance of *Gymnanthes klotzschiana*, a typical species of these environments. The soil of the studied forest area was classified by Rorato et al. (2015) as Litholic Neosols. This soil class is characterized by recent pedogenesis and its occurrence on steep slopes (Streck et al., 2008), and it imposes root growth restrictions due to low depth and low nutritional content, thereby experiencing consequent colonization by plant species, as can be evidenced by differences in the phytosociological parameters of Classes I and II in both clusters.

Tables 2 and 3 show that species belonging to Class I with the highest value of importance are common for both groups, indicating the similarity of the floristic composition between these environments. Regarding Class II, we can verify that only 10 of the 24 species present in Class I are represented in this class in G1 (Table 2).

Table 2. Phytosociological parameters of the species belonging to Group 1, considering Class I and Class II in a Mixed Ombrophilous Forest fragment. São Francisco de Paula, RS, Brazil.

SCIENTIFIC NAME	CLASS I				CLASS II			
	AD	ADo	AF	VI	AD	ADo	AF	VI
<i>Podocarpus lambertii</i>	225	15.1796	100	21.6				
<i>Eugenia uruguayensis</i>	183.3	5.6272	100	13.5	50	0.4161	33.3	14.6
<i>Araucaria angustifolia</i>	75	7.3202	50	9.3	33.3	0.1391	16.7	6.8
<i>Ilex brevicuspis</i>	83.3	4.4565	50	7.6				
<i>Lithraea brasiliensis</i>	58.3	3.548	66.7	6.7	16.7	0.0613	16.7	4.2
<i>Gymnanthes klotzschiana</i>	50	1.4577	66.7	5				
<i>Ocotea pulchella</i>	25	3.0763	33.3	4.1				
<i>Casearia decandra</i>	33.3	0.7983	50	3.4	66.7	0.3507	50.0	16.7
<i>Roupala brasiliensis</i>	33.3	0.7957	50	3.4	16.7	0.0454	16.7	3.9
<i>Ocotea porosa</i>	25	0.9721	50	3.3				
<i>Myrciaria delicatula</i>	33.3	0.5764	50	3.3	66.7	0.2915	33.3	13.9
<i>Myrsine coriacea</i>	41.7	0.8915	33.3	3.2				
<i>Myrceugenia cucullata</i>	33.3	0.4373	50	3.2	33.3	0.1025	33.3	8.1
<i>Styrax leprosus</i>	25	0.8268	33.3	2.6				
<i>Schinus lentiscifolia</i>	8.3	0.6765	16.7	1.3				
<i>Dicksonia sellowiana</i>	8.3	0.2155	16.7	1				
<i>Symplocos uniflora</i>	8.3	0.1725	16.7	1	33.3	0.1767	16.7	7.5
<i>Calypttranthes concinna</i>	8.3	0.1434	16.7	1	16.7	0.0590	16.7	4.2
<i>Cinnamomum amoenum</i>	8.3	0.1226	16.7	0.9				
<i>Lamanonia ternata</i>	8.3	0.117	16.7	0.9				
<i>Ocotea corymbosa</i>	8.3	0.0998	16.7	0.9				
<i>Sebastiania brasiliensis</i>	8.3	0.0722	16.7	0.9	33.3	0.1460	16.7	7.0
<i>Casearia sylvestris</i>	8.3	0.0637	16.7	0.9				
<i>Gochnatia polymorpha</i>	8.3	0.0597	16.7	0.9				
<i>Miconia cinerascens</i>					16.7	0.052	16.7	4.1
<i>Myrcianthes gigantea</i>					33.3	0.1599	33.3	9.0
TOTAL	1008.3	48.283	950	100	416.7	2.0004	300	100

AD: absolute density (individuals.ha⁻¹); ADo: absolute dominance (m².ha⁻¹); AF: absolute frequency (%); VI: value of importance (%); Class I (DBH ≥ 30 cm); Class II (15 ≤ DBH < 30 cm).

We can probably consider that the greater shading within the vegetation grouping characterized as hillside riparian forest (G2), due to its slope in relation to facing south and associated with the canopy cover, has created a better condition for the natural regeneration of *Podocarpus lambertii* in this environment than in that of riparian forest with flat topography (G1) (Table 3). On the other hand, *Araucaria angustifolia* had a higher natural

regeneration in G1 due to the more heliophilous character in that region (Table 2).

The CCA results indicated the influence of the chemical attributes (Al, OM, S, Ca, Cu, m%) on formation of the groups (Figure 3). The eigenvalues of 0.431 for the 1st axis and of 0.285 for the 2nd axis were indicated in analyzing the distribution of plots and species in relation to environmental factors for the arboreal vegetation belonging to Class I

Table 3. Phytosociological parameters of the species belonging to Group 2, considering Class I and Class II in a Mixed Ombrophilous Forest fragment. São Francisco de Paula, RS, Brazil.

SCIENTIFIC NAME	CLASS I				CLASS II			
	AD	ADo	AF	VI	AD	ADo	AF	VI
<i>Araucaria angustifolia</i>	128.6	13.3374	85.7	20.6				
<i>Gymnanthes klotzschiana</i>	292.9	6.0145	71.4	19.6	257.1	1.1212	28.6	27.8
<i>Lithraea brasiliensis</i>	107.1	6.0347	100.0	14.1	28.6	0.1278	28.6	5.9
<i>Podocarpus lambertii</i>	85.7	3.4423	71.4	9.6	28.6	0.1484	28.6	6.1
<i>Ilex brevicuspis</i>	28.6	2.0645	42.9	4.9	14.3	0.0604	14.3	2.9
<i>Myrcianthes gigantea</i>	42.9	0.6563	57.1	4.9	14.3	0.0891	14.3	3.2
<i>Eugenia uruguayensis</i>	50.0	0.8867	42.9	4.7	57.1	0.2859	28.6	9.0
<i>Myrceugenia cucullata</i>	35.7	0.8953	42.9	4.2	100.0	0.7281	57.1	18.9
<i>Ocotea pulchella</i>	28.6	0.5401	42.9	3.6	14.3	0.0555	14.3	2.9
<i>Myrsine coriacea</i>	14.3	0.8684	28.6	2.7				
<i>Myrciaria delicatula</i>	28.6	0.4493	14.3	2.1	14.3	0.0360	14.3	2.7
<i>Quillaja brasiliensis</i>	7.1	1.2467	14.3	2.0	14.3	0.2718	14.3	5.1
<i>Prunus myrtifolia</i>	14.3	0.2909	14.3	1.5				
<i>Cinnamomum amoenum</i>	7.1	0.3869	14.3	1.3				
<i>Ilex dumosa</i>	7.1	0.3396	14.3	1.2				
<i>Allophylus edulis</i>	7.1	0.1365	14.3	1.1				
<i>Blepharocalyx salicifolius</i>	7.1	0.0909	14.3	1.0				
<i>Maytenus aquifolia</i>	7.1	0.0529	14.3	1.0				
<i>Acca sellowiana</i>					42.9	0.1628	14.3	5.4
<i>Casearia decandra</i>					14.3	0.0860	14.3	3.2
<i>Miconia cinerascens</i>					28.6	0.0636	14.3	3.7
<i>Schinus lentiscifolia</i>					14.3	0.0745	14.3	3.1
TOTAL	900.0	37.7339	700.0	100.0	642.9	3.3111	300.0	100.0

AD: absolute density (individuals.ha⁻¹); ADo: absolute dominance (m².ha⁻¹); AF: absolute frequency (%); VI: value of importance (%); Class I (DBH ≥ 30 cm); Class II (15 ≤ DBH < 30 cm).

(DBH ≥ 30 cm). Monte Carlo permutation test was significant, presenting an error probability of 0.004, thus indicating precision in the calculation of the correlations between the analyzed matrices.

All the analyzed chemical attributes showed higher correlation with the first ordering axis. Figure 3 shows the “biplot” ordination diagram obtained as a result of the CCA with the distribution of environmental variables in relation to the phytosociological groups.

Despite presenting high sulfur (S) levels for both groups (10.1 mg.dm⁻³ for the riparian forest with flat topography (G1) and 12.1 mg.dm⁻³ for the hillside riparian forest (G2)) (Table 4), its higher values in G2 represent an explanatory variable for classifying this group. Regarding organic matter, this variable

reached an average of 8.7% in G2, higher than that of G1 (5.8%) (Table 4). These are interpreted as high values (SBCS, 2004), being the consequence of a greater humidity in the soil, presence of basaltic material, altitude and cold climate, resulting in slow decomposition of organic matter, and consequently acidic pH (5.4) (Table 4).

The diagram of Figure 3 shows that the soil chemical variables that most correlated the riparian forest with flat topography (G1) were Al, m% and Cu. In this group, the concentration of exchangeable aluminum in the soil (Al³⁺) was 3.9 cmol_c.dm⁻³, higher than the one found in G2 (1.3 cmol_c.dm⁻³), which can be attributed to the greater weathering of this environment and higher soil pH values.

The variables S, Ca and MO showed correlation with the hillside riparian forest (G2). Ca had the highest correlation of these, with mean values of 9.5 $\text{cmol}_c.\text{dm}^{-3}$ for this group (Table 4), which is considered a high value according to Sociedade Brasileira de Ciência do Solo (SBCS, 2004).

The correlation of saturation by aluminum (m%) and of copper with the riparian forest with flat topography (G1) may be related to higher concentrations of OM, since Cu is retained in the organic matter, forming stable complexes that play an important role in the mobility and availability of this micronutrient to plants (Abreu et al., 2007).

Therefore, it can be observed that specific environmental conditions in the studied riparian forest fragment have an influence in forming ecological niches, which despite being represented by similar species, occur in a differentiated manner in terms of density, dominance and frequency. A clear example was the *Araucaria angustifolia*, which stood out in the environment with less influence of the water table.

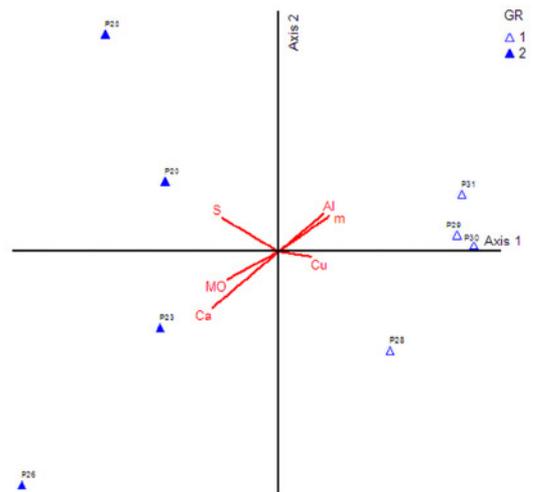


Figure 3. Ordination diagram produced by Canonical Correspondence Analysis for the first two axes for groups analyzed with the environmental variables in a Mixed Ombrophilous Forest fragment. São Francisco de Paula, RS, Brazil. GR: Group; Axis: axes; P: Plots; Al: Aluminum; m: Aluminum saturation; Cu: Copper; Ca: Calcium; OM: organic matter; S: Sulfur.

Table 4. Soil chemical attributes for phytosociological groups in Mixed Ombrophilous Forest Fragment. São Francisco de Paula, RS, Brazil.

Attributes	Groups	
	Riparian forest with flat topography	Hillside Riparian forest
Active acidity (water pH)	4.8	5.4
Potential acidity (H+Al) ($\text{cmol}_c.\text{dm}^{-3}$)	17.5	9.6
Aluminum ($\text{cmol}_c.\text{dm}^{-3}$)	3.9	1.3
Calcium ($\text{cmol}_c.\text{dm}^{-3}$)	2.9	9.5
Magnesium ($\text{cmol}_c.\text{dm}^{-3}$)	1.3	2.5
Potassium ($\text{mg}.\text{dm}^{-3}$)	77.0	90.0
Phosphorus ($\text{mg}.\text{dm}^{-3}$)	3.0	3.5
Sulfur ($\text{mg}.\text{dm}^{-3}$)	10.1	12.1
Copper ($\text{mg}.\text{dm}^{-3}$)	3.5	2.5
Zinc ($\text{mg}.\text{dm}^{-3}$)	2.6	4.7
Boron ($\text{mg}.\text{dm}^{-3}$)	0.5	0.5
Organic matter (%)	5.8	8.7
Saturation by aluminum (m%)	49.5	13.9
Base saturation (V%)	26.3	56.6
Effect CEC ($\text{cmol}_c.\text{dm}^{-3}$)	8.2	13.6
pH7 CEC ($\text{cmol}_c.\text{dm}^{-3}$)	21.8	21.9

Phosphorus extracted by Mehlich method; Effect CEC: Effective cation exchange capacity; pH7 CEC: Potential cation exchange capacity.

4. CONCLUSIONS

In the studied riparian forest fragment, there are two clusters of arboreal components, which despite having similarity in the floristic composition, presented differences in the vegetation structure due to topographic and consequently edaphic aspects.

Soil chemical attributes are indicators of ecological niches that even when represented by similar species, occur in different manners in terms of density, dominance and frequency.

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