Floresta e Ambiente 2018; 25(2): e00096514
https://doi.org/10.1590/2179-8087.096514
ISSN 2179-8087 (online)

Original article

Conservation of Nature

Heterogeneity of a Tree Species Community in an Alluvial Area of Santa Catarina, Brazil

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ABSTRACT

The aim of the present study was to characterize the floristic-structural heterogeneity of the tree species in an alluvial forest remnant considering three sectors: forest-river edge, forest interior and forest/non-forest matrix edge. Forty-eight plots of 200 m^2 were allocated and all tree individuals with a diameter at breast height (dbh) equal to or greater than 5 cm were measured and identified. Data was analyzed by Shannon's diversity index, Pielou evenness and phytosociological descriptors. Plots were ordered through NMDS. Sixty-six species were sampled and Myrtaceae was found to be the richest family. Diversity and evenness reached 2.96 and 0.71, respectively. *Sebastiania commersoniana* (Baill.) L.B.Sm. & Downs presented the highest importance value (21.22%). The NMDS showed that tree components are spatially partitioned according to sectors, therefore indicating floristic-structural heterogeneity.

Keywords: floodplain forest, phytosociology, Mixed Ombrophilous Forest.

1. INTRODUCTION

The Mixed Ombrophilous Forest (MOF) is located in the Atlantic Forest, occurring in the Brazilian southern plateau in fragmented areas in the southeast region and neighboring countries (Paraguay and Argentina) (Roderjan et al., 2002). This formation is known for a notable presence of Brazilian pine tree (*Araucaria angustifolia* (Bertol.) Kuntze) in a diverse association with important species, such as erva-mate (*Ilex paraguariensis* A. St.-Hil.), canela-lageana (*Ocotea pulchella* (Nees) Mez), and pinheiro-bravo (*Podocarpus lambertii* Klotzch ex Endl.), amongst others (Roderjan et al., 2002). Their high economic value has led to their exploitation, resulting in the fragmentation of such phytophysiognomy (Sevegnani et al., 2012).

MOF has different sub-formations. The Alluvial MOF occupies the alluvial lands associated with water courses. The abundant presence of *Sebastiania commersoniana* (Baill.) L.B.Sm. & Downs (IBGE, 2012), a species adapted to water stress (Kolb et al., 1998), stands out in this type of forest. Adaptation to environments that are subject to periodic flooding is necessary as the soil air (oxygen) is replaced by water, thus reducing the amount of oxygen available for plants and creating a hypoxic or anoxic environment (Lobo & Joly, 2000).

Alluvial forests play an important ecological role in maintaining water resources and species conservation, but they are threatened by different anthropic activities as they are located in strategic development areas (Silva et al., 2012a). Actions that aim to conserve and recover remnants are therefore necessary, so it is important to know which are suitable species and to learn the floristic-structural heterogeneity of the environment. The goal of this study was to carry out the phytosociological survey of an Alluvial MOF remnant as well as to characterize its floristic-structural heterogeneity by considering three forest sectors (forest-river edge, forest interior and forest/non-forest matrix).

2. MATERIAL AND METHODS

The study was carried out in an alluvial forest fragment of approximately 63 ha located on the banks of the Caveiras River, Lages, "Planalto Sul Catarinense" region, SC, Brazil. It is located at latitude 27°50'47.95"S and longitude 50°13'32.26"O, reaching an altitude of around 925 m. According to Köppen's classification, it presents a Cfb type climate where both mild winters and summers prevail. Its mean annual rainfall is 1,479.48 mm evenly distributed throughout the year and its mean annual temperature is 16°C (Brasil, 1992). Gleysols and Cambisols are its main soil classes. There is relief variation with alluvial plains being flooded during intense rainfall while sloping areas, mostly located in the sector bordering the opposite side of the river (forest/non-forest matrix edge) present no flooding.

Forty-eight 200 m^2 (10 x 20 m) permanent plots were allocated for the phytosociological survey, constituting a total sampled area of 9,600 m^2. Plots were distributed in a stratified way in three sectors (strata) (16 plots per sector): forest-river edge (adjacent to the river), forest interior and forest/non-forest matrix edge (adjacent to the grassland) (Figure 1). Each individual tree with dbh (diameter at breast height, measured at 1.30 m from the soil) equal to or higher than 5.0 cm from each plot, were measured and identified. All multiple tree trunks from the field where the square root of the sum of the squares of the dbh values was equal to or higher than 5.0 cm were measured. Trees were identified by consulting the literature and experts. Species were classified according to the APG IV system (Angiosperm Phylogeny Group, 2016). The geographical coordinates of each plot were determined using GPS and the slope of the four sides of each plot was measured with a clinometer. Subsequently, the mean slope per plot was also calculated. Both the coordinate and slope means were used to draw a map of the area, with slopes being grouped into three classes (Figure 1).

Sampling sufficiency was determined through the species accumulation curve performed by the Vegan package (Oksanen et al., 2014) from the statistical programming language R (R Development Core Team, 2014). Diversity was estimated by the Shannon-Wiener index (H') and the evenness by the Pielou index (J) (Brower & Zar, 1984). The values of absolute and relative density, absolute and relative frequency, absolute and relative dominance, and the importance value (IV) were used as phytosociological descriptors in agreement to Mueller-Dombois & Ellenberg (1974). The multivariate Nonmetric Multidimensional Scaling (NMDS) (Minchin, 1987) with Bray-Curtis distance was used to order the plots to detect the floristic-structural heterogeneity of the fragment. All further analyses were performed using the R program (R Development Core Team, 2014) through the Vegan library (Oksanen et al., 2014).

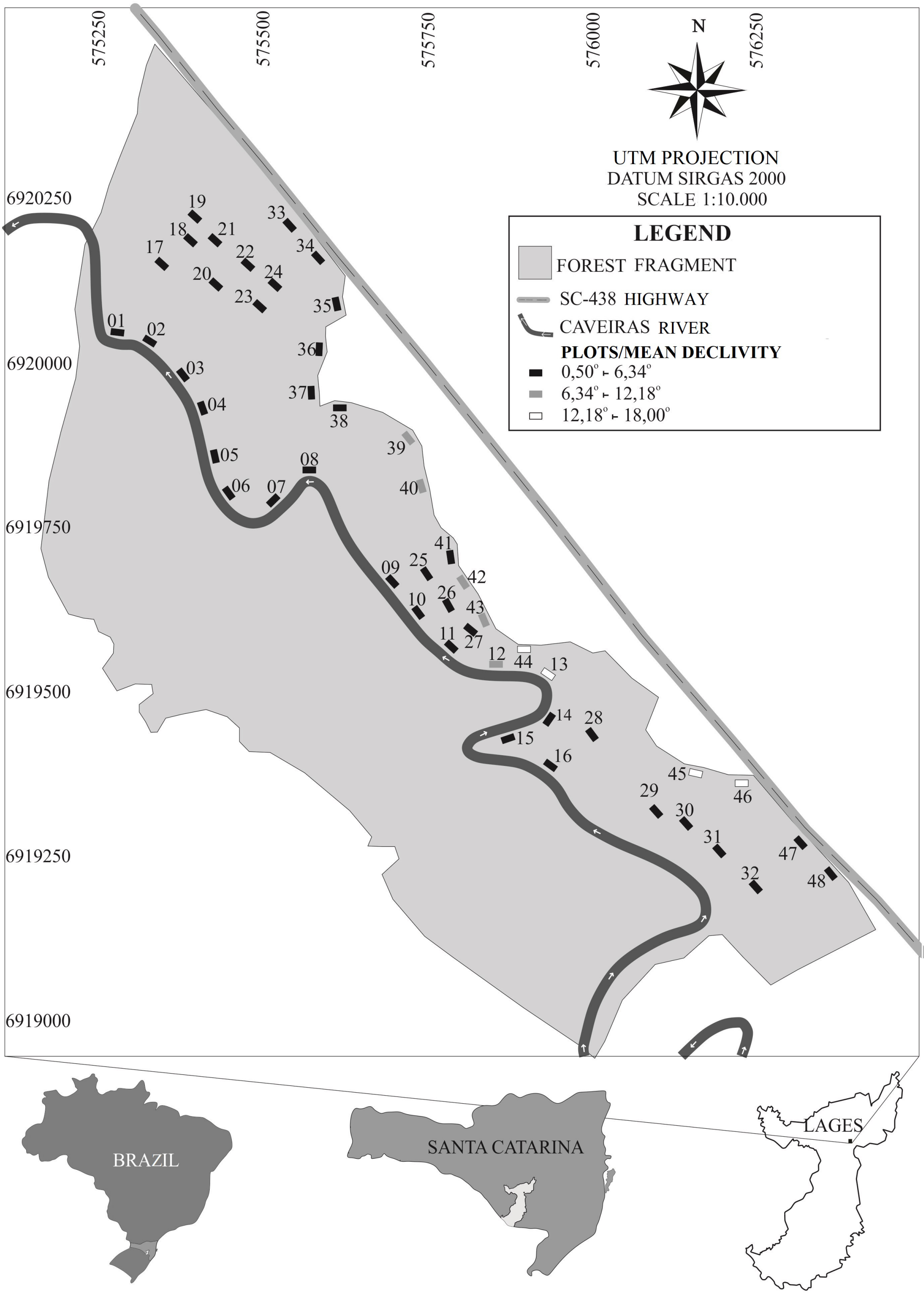

Figure 1. Location of the Alluvial MOF fragment, Lages, "Planalto Sul Catarinense" region, SC, Brazil. Plots from 1 to 16 belong to the forest-river edge sector; plots from 17 to 32 belong to the forest interior sector and plots from 33 to 48 belong to the forest/non-forest matrix sector.

3. RESULTS AND DISCUSSION

A total of 1,462 individuals, belonging to 66 species (Table 1), 51 genera and 32 botanical families were sampled. Myrtaceae was the richest family (17 species), followed by Asteraceae, Aquifoliaceae, Euphorbiaceae, Fabaceae, Lauraceae, Salicaceae and Sapindaceae (three species each). The richest genus was *Eugenia* (four species), followed by *Ilex* and *Myrcia* (three species each). The high richness of the Myrtaceae family has also been found in other fragments of the Mixed Ombrophilous Forest of this region (*e. g.* Klauberg et al., 2010; Nascimento et al., 2011; Higuchi et al., 2012a; Higuchi et al., 2012b, 2013; Negrini et al., 2012; Silva et al., 2012b) and in alluvial forests of different states in southern and southeastern Brazil (*e. g.* Dias et al., 1998,

Table 1. Phytosociological descriptors of tree species sampled in an Alluvial MOF area, Lages, "Planalto Catarinense" region, SC, Brazil, ordered by importance value (IV, in %).

Species	AD	RD	ADo	RDo	AF	RF	IV
Sebastiania commersoniana (Baill.) L.B.Sm. & Downs	404.17	26.54	8.56	27.98	87.50	9.13	21.22
Eugenia uniflora L.	160.42	10.53	3.25	10.64	66.67	6.96	9.38
Blepharocalyx salicifolius (Kunth) O.Berg	85.42	5.61	3.99	13.03	66.67	6.96	8.53
Allophylus edulis (A.St.-Hil., Cambess. & A. Juss.) Radlk.	141.67	9.30	1.41	4.61	72.92	7.61	7.17
Nectandra megapotamica (Spreng.) Mez	83.33	5.47	1.72	5.62	45.83	4.78	5.29
Calyptranthes concinna DC.	88.54	5.81	0.79	2.58	60.42	6.30	4.90
Casearia decandra Jacq.	62.50	4.10	0.35	1.15	45.83	4.78	3.35
Campomanesia xanthocarpa O.Berg	39.58	2.60	1.17	3.81	31.25	3.26	3.22
Prunus myrtifolia (L.) Urb.	39.58	2.60	0.66	2.16	29.17	3.04	2.60
Araucaria angustifolia (Bertol.) Kuntze	17.71	1.16	0.81	2.64	18.75	1.96	1.92
Banara tomentosa Clos	23.96	1.57	0.39	1.26	27.08	2.83	1.89
Lithrea brasiliensis Marchand	14.58	0.96	0.79	2.57	18.75	1.96	1.83
Annona rugulosa (Schltdl.) H.Rainer	27.08	1.78	0.19	0.64	29.17	3.04	1.82
Ocotea pulchella (Nees) Mez	15.63	1.03	0.81	2.64	16.67	1.74	1.80
Symplocos uniflora (Pohl) Benth.	25.00	1.64	0.36	1.18	14.58	1.52	1.45
Myrrhinium atropurpureum Schott	18.75	1.23	0.21	0.69	22.92	2.39	1.44
Jacaranda puberula Cham.	22.92	1.50	0.44	1.44	8.33	0.87	1.27
Ilex theezans Mart. ex Reissek	14.58	0.96	0.40	1.30	14.58	1.52	1.26
Matayba elaeagnoides Radlk.	18.75	1.23	0.39	1.29	10.42	1.09	1.20
Myrcia palustris DC.	21.88	1.44	0.13	0.43	14.58	1.52	1.13
Ocotea puberula (Rich.) Nees.	9.38	0.62	0.36	1.19	12.50	1.30	1.04
Myrceugenia euosma (O.Berg) D. Legrand	17.71	1.16	0.12	0.39	12.50	1.30	0.95
Podocarpus lambertii Klotzsch ex Endl.	6.25	0.41	0.47	1.54	6.25	0.65	0.87
Zanthoxylum rhoifolium Lam.	9.38	0.62	0.13	0.43	14.58	1.52	0.85
Sebastiania brasiliensis Spreng.	14.58	0.96	0.15	0.50	8.33	0.87	0.78
Ilex dumosa Reissek	7.29	0.48	0.22	0.71	10.42	1.09	0.76
Roupala montana Aubl.	10.42	0.68	0.14	0.46	8.33	0.87	0.67
Strychnos brasiliensis (Spreng.) Mart.	8.33	0.55	0.05	0.15	12.50	1.30	0.67
Erythrina cristagalli L.	10.42	0.68	0.11	0.36	8.33	0.87	0.64
Campomanesia rhombea O.Berg	5.21	0.34	0.15	0.48	10.42	1.09	0.64
Sapium glandulosum (L.) Morong	3.13	0.21	0.27	0.88	6.25	0.65	0.58
Dasyphyllum brasiliense (Spreng.) Cabrera	4.17	0.27	0.13	0.43	8.33	0.87	0.52
Xylosma ciliatifolia (Clos) Eichler	5.21	0.34	0.08	0.26	8.33	0.87	0.49
Schinus terebinthifolius Raddi	5.21	0.34	0.06	0.20	8.33	0.87	0.47
Dasyphyllum spinensis (Less.)	4.17	0.27	0.20	0.67	4.17	0.43	0.46
Eugenia pluriflora DC.	5.21	0.34	0.03	0.11	8.33	0.87	0.44
Dalbergia frutescens (Vell.) Britton	5.21	0.34	0.03	0.10	8.33	0.87	0.44
Vernonanthura discolor (Spreng.) H.Rob.	3.13	0.21	0.19	0.64	4.17	0.43	0.43

AD = absolute density (ind./ha); RD = relative density (%); ADo = absolute dominance (m^2/ha); RDo = relative dominance (%); AF = absolute frequency (%); RF = relative frequency (%); IV = importance value (%).

Table 1. Continued...

Species	AD	RD	ADo	RDo	AF	RF	IV
Lamanonia ternata Vell.	5.21	0.34	0.06	0.21	6.25	0.65	0.40
Scutia buxifolia Reissek	5.21	0.34	0.05	0.17	6.25	0.65	0.39
Drimys brasiliensis Miers	5.21	0.34	0.04	0.13	6.25	0.65	0.38
Myrcia laruotteana Camb.	5.21	0.34	0.03	0.09	6.25	0.65	0.36
Myrceugenia myrcioides (Cambess.) O. Berg	4.17	0.27	0.02	0.08	6.25	0.65	0.33
Eugenia pyriformis Cambess.	2.08	0.14	0.12	0.38	4.17	0.43	0.32
Myrcia guianensis (Aubl.) DC.	2.08	0.14	0.10	0.32	4.17	0.43	0.30
Myrciaria delicatula (DC.) O.Berg	3.13	0.21	0.04	0.15	4.17	0.43	0.26
Myrsine umbellata Mart.	2.08	0.14	0.02	0.08	4.17	0.43	0.22
Ilex paraguariensis A. St.-Hil.	2.08	0.14	0.02	0.06	4.17	0.43	0.21
Maytenus boaria Molina	2.08	0.14	0.02	0.05	4.17	0.43	0.21
Duranta vestita Cham.	2.08	0.14	0.01	0.03	4.17	0.43	0.20
Oreopanax fulvus Marchal	3.13	0.21	0.05	0.18	2.08	0.22	0.20
Maytenus dasyclada Mart.	2.08	0.14	0.01	0.02	4.17	0.43	0.20
Erythroxylum deciduum A.St.-Hil.	1.04	0.07	0.07	0.23	2.08	0.22	0.17
Cupania vernalis Cambess.	1.04	0.07	0.06	0.19	2.08	0.22	0.16
Escallonia bifida Link & Otto	2.08	0.14	0.03	0.10	2.08	0.22	0.15
Myrsine coriacea (Sw.) R.Br.	2.08	0.14	0.01	0.03	2.08	0.22	0.13
Mimosa scabrella Benth.	1.04	0.07	0.03	0.09	2.08	0.22	0.12
Solanum sanctaecatharinae Dunal	1.04	0.07	0.02	0.06	2.08	0.22	0.12
Myrcianthes gigantea (D. Legrand) D.	1.04	0.07	0.02	0.06	2.08	0.22	0.11
Clethra scabra Pers.	1.04	0.07	0.01	0.04	2.08	0.22	0.11
Bastardiopsis densiflora (Hook. & Arn.) Hassl.	1.04	0.07	0.01	0.04	2.08	0.22	0.11
Ligustrum sinense Lour.	1.04	0.07	0.01	0.03	2.08	0.22	0.11
Zanthoxylum kleinii (R.S.Cowan)	1.04	0.07	0.01	0.02	2.08	0.22	0.10
Acca sellowiana (O.Berg) Burret	1.04	0.07	0.01	0.02	2.08	0.22	0.10
Eugenia uruguayensis Cambess.	1.04	0.07	0.01	0.02	2.08	0.22	0.10
Dicksonia sellowiana Hook.	1.04	0.07	0.00	0.01	2.08	0.22	0.10
Total	1522.9	100.0	30.6	100.0	958.3	100.0	100.0

AD = absolute density (ind./ha); RD = relative density (%); ADo = absolute dominance (m^2/ha); RDo = relative dominance (%); AF = absolute frequency (%); RF = relative frequency (%); IV = importance value (%).

in PR; Botrel et al., 2002, in MG; Bianchini et al., 2003, in PR; Araujo et al., 2004, in RS, Barddal et al., 2004, in PR; Budke et al., 2004, in RS; Rolim et al., 2006, in ES; Budke et al., 2007, in RS; Budke et al., 2008, in RS; Silva et al., 2009, in MG). The species richness values observed represent the fragment being studied, since the species accumulation curve tended to stabilize (Figure 2). According to Kersten & Galvão (2011), sufficiency is reached when the line tends towards stability and the addition of new species does not significantly alter the number of species – it is suggested that a 10% increase in the sample area results in an increase of up to 5% new species. Since richness has only increased 0.48% by adding the last plot, which corresponds to 2.08% of the sampled area, we concluded that sample sufficiency was therefore achieved.

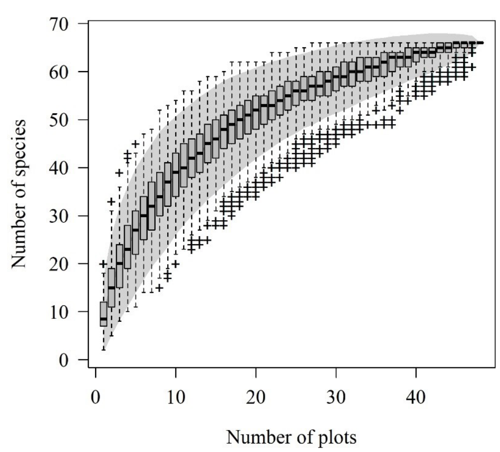

Figure 2. Accumulation curve of species sampled in an Alluvial MOF fragment, Lages, "Planalto Sul Catarinense" region, SC, Brazil.

A Shannon diversity (H') index of 2.96 and a Pielou's evenness (J) index of 0.71 were obtained. Studies in non-alluvial MOF of this region showed diversity and evenness values ranging from 2.79 and 0.70 in upper montane MOF (Higuchi et al., 2013) and 3.74 and 0.86 in montane MOF (Higuchi et al., 2012a), respectively. The low values observed in the upper montane forest are the result of a more restricted environment due to the intense cold found in the highest altitudes of this region. The limiting environment is also the reason why the diversity and evenness values are usually reduced in alluvial forests; in this case, the limitation is due to water excess. According to Junk (1993), flood stress and increased erosion and sedimentation rates reduce tree species diversity. Other studies in alluvial forests have also revealed low diversity values, such as Vilela et al. (2000), Budke et al. (2004) and Silva et al. (2009), who found H' values of 0.93, 2.73, and 2.36, respectively. A higher diversity value was probably observed because there are also slopes in this area (some plots from the forest/non-forest matrix edge), where non-common species have been found in flood areas, thereby increasing richness. In addition, a range of diversity values may be observed in response to the environmental heterogeneity of alluvial forests, which are found in different climates, soil conditions, vegetation matrices and disturbance histories, as well as factors related to flooding, such as the degree and time of flooding (Silva et al., 2012a).

Low diversity values are also influenced by high ecological dominance in addition to low species richness, which has been confirmed by a Pielou index value lower than those found in other non-alluvial forests of this region. High ecological dominance is common in flood environments (Silva et al., 2012a). Budke et al. (2004) reported a Pielou index of 0.69 in an alluvial environment whereas Marques et al. (2003) found a value of 0.71 in a swamp forest.

Myrtaceae (444), Euphorbiaceae (405), Sapindaceae (155), Lauraceae (104) and Salicaceae (88) showed the greatest representativeness in number of individuals in the community. Barddal et al. (2004), when studying a seasonally flooded area of an alluvial forest located in Araucaria, PR, Brazil, also found Euphorbiaceae and Myrtaceae to be the most abundant families, indicating that such a pattern may be common in alluvial MOFs.

Sebastiania commersoniana obtained the highest relative importance in the fragment studied, with an IV of 21.22%. Such a high IV is the result of the species' high density (RD = 26.54%), dominance (RDo = 27.50%) and frequency (it was observed in 87.5% of the plots) in this area. According to Silva et al. (2007), species such as *Sebastiania commersoniana* may be found in flood-free environments but are more abundant in alluvial forests, where interspecific competition is lower thanks to water selection. The occurrence of this species with a high IV in alluvial forests, especially in southern and southeastern Brazil, is therefore common. Barddal et al. (2004) and Carvalho et al. (2016) have respectively found an IV (transformed into percentage) of 48.2% and 67.9% in PR, Brazil; and Silva et al. (2009) found an IV of 28.36% in MG, Brazil.

Eugenia uniflora presented the second highest IV (9.38%), mainly due to its high density (RD = 10.53%). According to Rotman (1995), this species inhabits different vegetation formations, being common in humid soils. *Blepharocalyx salicifolius* (Kunth) O.Berg, presented lower density (RD = 5.61%) than *Allophylus edulis* (RD = 9.30%), but higher IV (the third highest value: 8.53%) due to its significant dominance (13.03%), thus indicating larger individuals. The three species with the highest IV corresponded to 40% of the total IV of the area therefore demonstrating their dominance.

The NMDS ordering presented a 17.36% stress value, thereby proving acceptable for interpretation (<20%). This showed that the tree component is spatially partitioned according to the sectors (forest-river edge, forest interior and forest/non-forest matrix), indicating heterogeneity in the community's organization (Figure 3). NMDS axis 1 has indicated the highest floristic-structural segregation in the forest/non-forest matrix sector. This sector also showed the highest plot dispersion, therefore indicating high internal variation, which means higher beta diversity. The highest slope variation at the forest/non-forest matrix edge (Figure 1) suggests a highly heterogeneous environment, which may have contributed to the results. The forest-river edge and forest interior sectors presented greater similarity to each other, with partial overlapping of plots. However, the forest interior sector showed greater plot dispersion in axis 2, while plots adjacent to the river were grouped more cohesively, therefore indicating a higher internal homogeneity along the forest-river edge. It is therefore possible to infer the

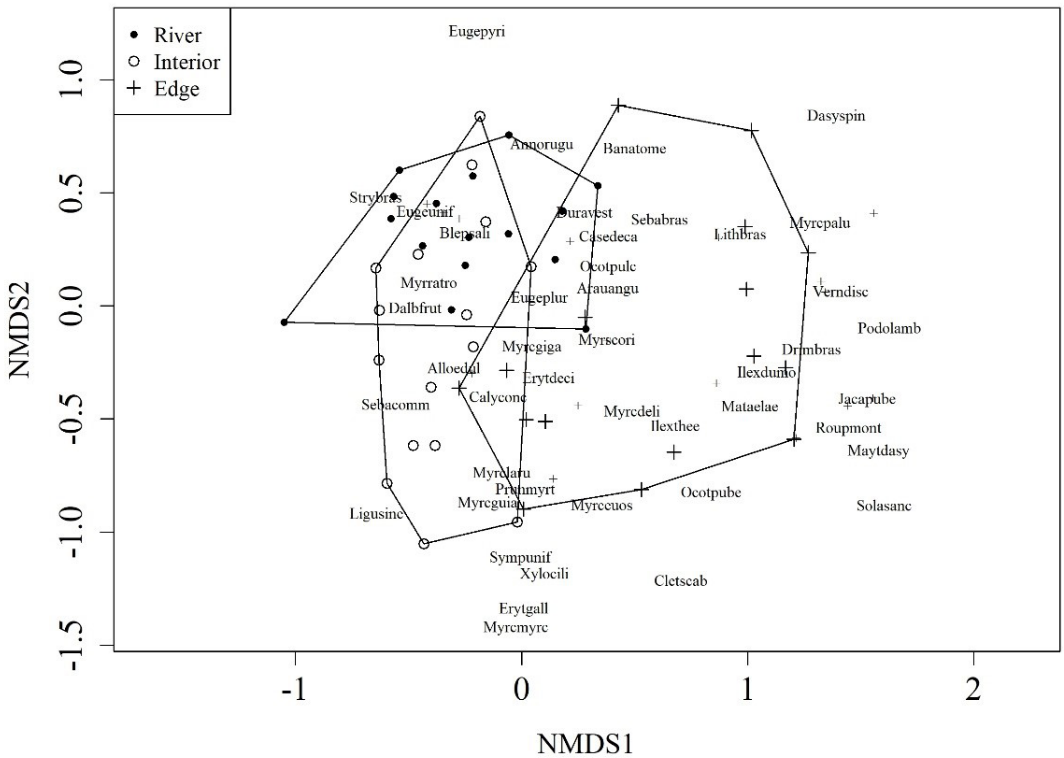

Figure 3. Plots and species ordination through NMDS (Nonmetric Multidimensional Scaling) in an Alluvial MOF fragment, Lages, "Planalto Sul Catarinense" region, SC, Brazil.

existence of a more selective environment adjacent to the river, which may be due to the sector's higher susceptibility to flood events.

Species like *Strychnos brasiliensis* (Spreng.) Mart. and *Blepharocalyx salicifolius* have shown a greater association with the forest-river edge and forest interior sectors (NMDS overlapping area). Ribeiro et al. (2007) also classified *Blepharocalyx salicifolius* as a species with a preference for moist soils. Several species were exclusive to the forest/non-forest matrix edge, such as *Lithrea brasiliensis* Marchand, *Vernonanthura discolor* (Spreng.) H.Rob., *Jacaranda puberula* Cham., *Myrceugenia euosma* (O.Berg) D. Legrand, *Myrciaria delicatula* (DC.) O.Berg, *Roupala montana* Aubl., *Drimys brasiliensis* Miers, etc. These species are probably exclusive to this sector for two main reasons: i) because they are early successional species (as pioneers or light-demanding climax species) since the forest/non-forest matrix edge receives more light; ii) because they are water stress intolerant species, since less flooding is expected in the sector farther away to the river – with the environment being well drained in the slope area. Such species have been observed in former studies in non-alluvial MOF areas, such as Nascimento et al. (2001), Rondon et al. (2002), Klauberg et al. (2010), Higuchi et al. (2012a), and Silva et al. (2012b). The species with the highest importance value in the community – *Sebastiania commersoniana, Eugenia uniflora* and *Blepharocalyx salicifolius* –occurred throughout all sectors, proving to be habitat generalists.

4. CONCLUSIONS

The tree community has shown a floristic-structural composition similar to that of other alluvial forests already studied in southern and southeastern Brazil, with a high richness of the Myrtaceae family, but with a low total richness, which along with the high ecological dominance resulted in low diversity. The high dominance reflected the significant participation of three main species – *Sebastiania commersoniana, Eugenia uniflora* and *Blepharocalyx salicifolius. Sebastiania commersoniana* is mentioned in the literature on alluvial forests from southern and southeastern Brazil as one of the most common species in such environments.

The tree community organization presented a floristic-structural variation associated with the sectors considered for the study, suggesting the influence of environmental gradients that may be related to the river's hydrological cycles, soils, topography and edge effect. A group of species better adapted to periodic flooding is observed closer to the river and in the forest interior, while areas with steeper topography and a group of exclusive species, including some early successional ones, are observed in the sector bordering the opposite side of the river. Future studies focusing on environmental characterization of the area, natural regeneration and long term monitoring of the tree component are necessary to better understand the forest fragment's ecology.

ACKNOWLEDGEMENTS

We would like to thank the CNPq for providing a research productivity grant to the second and third authors, and the FAPESC for the financial support granted through the PAP/UDESC notice.

SUBMISSION STATUS

Received: 16 may, 2014
Accepted: 27 oct., 2017

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FINANCIAL SUPPORT

CNPq, FAPESC, PAP/UDESC.

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