Flood as a fine scale driver of both floristic and functional differentiation in a ripariansystem

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Abstract

Flood forests are vegetation subject to seasonal floods. Situated in flood plains, they are systems under continuous changes due to the pulses of flooding, following the watercourse. Although these are singular ecosystems, there are little publications that report the floristic structure in floodplains, especially in Southeastern Brazil. This study aimed to characterize the composition, structure and diversity of the arboreal community in a flooding gradient, comparing them with the non-flood adjacent formations, at the mouth of Paracatu River, a tributary of São Francisco River, Minas Gerais, Brazil. For the structural survey of the arboreal community, we used the plot method, installed on both sides of Paracatu River. The individuals were identified at the species level. We sampled 1,276 individuals belonging to 85 species and 32 families. The Shannon Index (H
$)regard \in g \rightarrow the \rightarrow talsampl \in gwasof3.40nat. \in d, with \Pi eloueve \cap ess \in dex(J)$ of 0.76. In terms of species importance, the six most important species comprised 46% of the total index of importance value. By means of similarity analysis, it was possible to verify the grouping of species along the ecounits, demonstrating the substitution of species along habitats, resulted of the temporal difference of the flooding in the environments. In conclusion, the flooding regimes, frequency and intensity determine the ecology of the river plains.

Introduction

Cerrado forests are a significant seasonally dry ecosystem, presenting great richness and diversity of species, with 44% of endemic plant species (Mendonça et al. 2008). It is an important biodiversity hotspot, and understanding its nature and dynamics is globally necessary to assure its conservation (Myers et al. 2000; Mittermeier et al. 2004). Cerrado contains the three major South American hydrographic basins, including poorly studied floodplains areas. These areas contribute to the recharge of countless watercourses in the country (Strassburg et al. 2017). Although its great importance, little has been investigated in forests of the Cerrado biome, especially in the floodplains.

Floodplains are dynamic systems that continually change due to subsidence, alternating in size as the watercourse changes. They may occur when the drainage capacity of a given watercourse is greater than the drainage of its current runway. Flood amplitude depends on periodic seasonal cycles, varying according to their frequency and intensity, and can last for days or even months (Ab'Saber 2000). This alternation caused by flood pulses induces a modification of the environment, generating meander formation, deposition and land survey, favoring a variety of habitats in the site (Junk et al. 1989). Because of this, along the floodplain, different ecounits are formed, like marginal dykes, lagoons, paleochannels, and terraces. Marginal dike arises along the river bed through the deposition of sediments from the upstream watercourse. The lagoons emerge when the water overflows the marginal dike towards the flatter areas (Ab'Saber 2000). The paleochannel is generally a flat geomorphic surface that suffers from flood, on average, once every 1–3 years (recurrence interval) near marginal lagoons or in depression areas varying in susceptibility to flooding according to the topographic position. The terrace corresponds to the deposition area of alluvial sediments from the past action of old active beds (Hupp and Osterkamp 1985).

The water in the floodplains contains dissolved inorganic compounds, providing nutrient cycling beyond the modifications in the relief due to the alternating flow of water that causes leaching (Vannote et al. 1980). These factors directly influence the present biota, requiring morphological, anatomical, and physiological adaptations of the plants to survive these different conditions from those found in the main channel of the river and the adjacent non-floodable formations (Junk et al. 1989). Therefore, floodplains harbor a floristic community that has evolved with adaptive strategies to flood, increasing the possibilities of success in occupying harsh habitats, thus favoring many endemic species in these areas (Joly and Crawford 1982; Budke et al. 2010). Also, it acts as nurseries for several species of the local fauna (Marçal-Simabuku and Peret 2002; Godinho and Godinho 2003; Wittmann et al. 2017).

The interaction between the flooding regime and the relief that exists along the floodplain, such as percolation and leaching, enables different ecounits emergence. As the flooding intensity varies, there is a modulation in the environment. Besides that, flooding regimes are stressful events for plants. Thus, we expect that the species present in these environments will functionally adapt to the environmental conditions, forming a floristic differentiation with species tolerant to flooding that presents evolutionary strategies to survive in these habitats. For example, the disturbance can cause the plants to regrow, stimulating new shoots after damage to existing stems as characteristics to survive in this environment under flooding regimes (Bond and Midgley 2001; Bellingham PJ and Sparrow AD 2009; Araujo and Santos 2019). Sprouting is widespread among extant species, and it is an ancient trait in many angiosperm clades (Joly and Crawford 1982; Marçal-Simabuku and Peret 2002; Bond and Midgley 2003; Godinho and Godinho 2003; Wittmann et al. 2017).

Floodplains exist worldwide, but they are in threat because of global climate change, the overuse of natural resources and, anthropogenic exploitation (Sanjerehei and Rundel 2017). It faces the exploitation of wood for firewood production, housing in floodplains, pasture formation, water catchment, hydroelectric plants, agricultural drainage (Wittmann et al. 2009). These factors can, directly and indirectly, affect, respectively, the distribution of precipitation and flow. In this context, all biodiversity that has these seasonally flooded systems as a niche (source of resources or habitats) may be affected by these modifications. Despite its great extent, ecological and economic importance, information on their plant communities is scarce. In Brazil, many studies were carried out in the Amazon floodplain forest, but, up to the moment, little is known about seasonally flooded areas in dry regions. This leads us to question whether the different ecounits' conditions affect the structure, composition, and diversity of the tree vegetation.

Since the arboreal component, or macrophytes, are important in the physical structure (damping function of rivers overflow), chemical structure (nutrient cycling, carbon, and nitrogen fixation), and also in the biological structure (habitat and source of resources), this research aims to characterize the floristic and structural composition of the tree species present in a floodplain. To assess the influence of seasonal flooding on the floristic composition of ecounits in a floodplain, we identified five ecounits according to their susceptibility to flooding: Riparian River Forest, Riparian Wetland Forest (annually flooded), Ocassionally Flooded Forests, Wetland Forest, Unflooded Forests.

Therefore, we focus on answer the following questions: is there any difference in floristic composition, diversity, and structure in the ecounits sampled? Since the different flooding regimes model different environmental conditions, we expect possible differences in the tree community of each of them; is there any difference in the density of sprouts among ecounits? Since regrowth in these environments is a strategy to survive stress, we expect environments that present different harsh levels to model different intensities of regrowth. From this questioning, the following hypothesis was elaborated: vegetation communities are distinct in the ecounits along the floodplain, due to the frequency of flooding. This peculiarity, if found, can bring new insight into the floristic diversity present in the ecounits and thus be able to treat them as a distinct unit that must be preserved.

Materials And Methods

Study area

The present study was carried out in patches of seasonally tropical dry forests scattered along the mouth area, in the Cerrado domain, located at the mouth of the Paracatu river (41,512 km² drainages), a tributary of the São Francisco river, between Santa Fé de Minas and Buritizeiro municipalities in Minas Gerais, southeast Brazil, between coordinates 17 ° 21'44.89 "S and 44 ° 57'58.87" W (Fig. 1). According to Köppen's classification, the climate in the region is tropical Aw type with a dry period lasting, on average, five months in the year. Precipitation occurs during the summer, characterized as low and much accumulated, not exceeding 1800 millimeters annually (Instituto Nacional de Metereologia 1992).

After the region recognition, we verified that the water saturation determines five different ecounits (Fig. 1), which were identified and classified as: Riparian River Forest, Wetland Forest and Riparian Wetland Forest, Ocassionaly Flooded Forests and Unflooded Forests, adapted from Hupp and Osterkamp (1985). This flood regimes classification was based on local knowledge and also on observable signs in the landscape. Ecounits were defined using hydrological bases, being the duration of the flow (amount of time during which water reaches a level) as a determinant point in the location of the areas. For example, plots of annually flooded forests (Riparian River Forest, Riparian Wetland Forest, and Wetland Forest) are located in riparian habitats or depressions (Fig. 1). They present evidence of sedimentation deposits and short-lived still water ponds. Occasionally Flooded Forests occur in shallow valleys and flood about once every 30 years. Finally, areas that never flood (Unflooded Forests) are usually 500–1,900 m from watercourses, with no evidence of temporary lagoons.

Sample design and vegetation sampling

Sampling was distributed among the five ecounits that make up the floodplain. For the survey of tree individuals, we used the fixed area method, employing rectangular plots (400 m²) (Muller-Dombois and Ellenberg 1974), which were installed on both sides of the Paracatu river. The plots were distributed in two transects, one on each river bank. In total, 30 plots were installed at the mouth of the Paracatu river, a tributary of São Francisco river, 15 plots on the right bank, and 15 plots on the left bank. These were divided into 5 groups, with 3 plots each, arranged perpendicular to the direction of the transection, in order to describe the heterogeneity of each ecounit. The format of the plots varied, being 20 m x 20 m or 10 m x 40 m, depending on the environmental conditions, always making a total of 400 m^2 for each plot, totaling 1.2 hectares of the sample area.

Within each sample unit, all trees with a circumference at the height at breast height (dbh) (1,30m heigh) greater or equal to 10 cm were recorded. Trees with multiple stems were only included when the square root of the sum of the squares of the stems was higher than or equal to the inclusion (Scolforo 1998). The individuals were identified at the species level, measured, and marked with numbered aluminum plates. We followed the Angiosperm Phylogeny Group IV (2016) for family level classification and Flora do Brasil 2020 (REFLORA database) for standardizing species names and synonyms.

Data Collection and Analysis

To test our hypothesis and verify if the vegetation structure presents different characteristics among ecounits, the phytosociological parameters relative density (RD), relative frequency (RF), and relative dominance (RDo) were calculated (Felfili et al. 2013). We also generated the value of importance (VI) of each species (Mueller-Dombois and Ellenberg 1974). For all species sampled, we evaluated: basal area, density, and intensity of sprouting to analyze the floristic composition across ecounits, we applied a non-metric multidimensional scaling (NMDS) of species composition across ecounits (Mccune and Grace 2002) based upon Bray-Curtis distance. We also performed a Shannon-Wiener species diversity index (Whittaker 1972; Ludwig and Reynolds 1988; Spellerberg and Fedor 2003) followed by the Pielou Evenness Index (Pielou 1966), to verify the possible difference in species diversity among the ecounits. As the result of Shannon-Wiener species diversity index presented a normal distribution, we tested the difference among ecounits through an analysis of variance (Anova), followed by the Tukey test. Pielou Evenness Index, however, presented a non-parametric distribution, so the difference was tested by the Kruskal-Wallis test, followed by Dunn test. Also, to visualize whether the ecounits are different in terms of richness, they were compared by rarefaction and extrapolation curves constructed from 999 random permutations in each sampled area (Gotelli and Ellison 2011). We performed the analysis through vegan and Inext package (Oksanen et al. 2020) in the r Statistical Software (R Core Team 2020).

We performed an analysis of indicator species (ISA) (table 2) by the search method, which suggests groups of species related to subgroups within each area, which characterize the communities (Dufrêne and Legendre 1997). A frequency matrix of the species was generated, and the calculated indicative values (IV) were randomized 999 times associated with the Monte Carlo test (P = 0.05) by the PcOrd 4.0 program (Mccune and Mefford 2006).

To verify the possible difference in the density of sprouts among ecounits, we considered the intensity of sprouting as the ratio between the total numbers of sprouts by the total number of individuals present in each plot. Then, a similar procedure was performed to test the classes of sprouting. The first class comprises the individuals with only one sprout, the second those having two to three sprouts, the third class, four to five sprouts, the fourth class represents individuals with six and seven sprouts and the fifth class with more than eight sprouts. Graphs have been created with the classes of sprouting for better visualization of patterns.

The diametric classes were created from the inclusion criterion with class intervals with increasing amplitudes were used to compensate for the decrease in density in larger size classes, according to Botrel et al. (2002) in all analyzed ecounits (3 - 5.9 cm, 6 - 11.9 cm, 12 - 23.9 cm, 24 - 47.9). The G-test of adhesion was used to statistically compare the distributions between classes (Zar 2010).

Results

We found 1.276 individuals belonging to 85 species of 32 families (table 2). The Shannon diversity index (H') for total sampling was 3.40 nat.ind, with Pielou equability index (J') of 0.76. The highest diversity values were found in the Unflooded Forest (H'= 3.16 nat.ind) and Riparian Wetland Forest (H'= 2.87 nat.ind). The Wetland Forest had an intermediate index (H'= 2.16 nat.ind), while the lowest values remained for the Ocassionally Flooded Forests (H'= 1.49 nat.ind) and Riparian River Forest (H'= 1.63 nat.ind) (table 3). The only ecounits which presented different equability index are Unflooded Forests (J'= 0.83) and Occasionally Flooded Forests (J'= 0, 62) (table 4).

The ecounits presented different species with the highest importance value (IV). In Riparian River Forest, the species *Triplaris gardneriana* Wedd and *Celtis ehrenbergiana* (Klotzsch) Liebm., stood out with the highest value of importance (63.92%). The Wetland Forest presented the following species with the highest value of importance: *T. gardneriana, Albizia inundata* (Mart.) Barneby and J. W. Grimes, *Ruprechtia apetala* Weddell, *Casearia gossypiosperma* Briq. and *Manilkara salzmannii* (A.DC.) H.J.Lam., with 67.73% of the area. While in the Riparion Wetland Forest, the most important species were: *M. salzmannii, Inga vera* Willd, and *T. gardneriana*, with 44.54% of the area. In the Ocassionally Flooded Forests, the species with the highest importance were: *Tabebuia aurea* (Silva Manso) DC*, Callisthene fasciculata* Mart, and *Curatella americana* L., with 76.20% of the area. Finally, the species that stood out with the highest importance value in the Unflooded Forests were: *Erythroxylum nummularia* Peyr., *Copaifera langsdorffii* Desf., *Myracrodruon urundeuva* Allemão, *Amburana cearensis* (Allemão) ACSm., *Hymenaea martiana* Hayne and *Eugenia dysenterica* DC., totaling 41.12% of the area. In areas where flooding is more frequent and intense, few species showed greater dominance. For example, the species *Celtis ehrenbergiana* (Klotzsch) Liebm., *T. gardneriana, A. inundata, Casearia gossypiosperma* Briq. and *Ruprechtia apetala* Wedd. showed greater dominance in the flooded areas.

The stress value in the NMDS (Fig. 2) was 0.09, indicating that it was adequate to represent the variation. It corroborated with the previous analyzes, allowing to verify the grouping of the species along the environmental gradient. The Monte Carlo test was significant (p = 0.0010), showing high values of the Pearson correlation.

In the analysis of the average curve of extrapolation of species richness, it was possible to verify the presence of 3 distinct groups. The first showed higher species richness in the Unflooded Forests, followed by the Riparion Wetland Forest. On the other hand, the third group, composed by the Wetland Forest, Riparian River Forest and Occasionally Flooded Forests ecounits, presented lower species richness (Fig. 3).

Sprout intensity showed significant differences between the ecounits with $p < 0.001$. The highest intensity was found in the class of individuals with two and three stems (2 <4) (Fig. 4). The ecounits that presented the highest intensity of sprouts were the Wetland Forest and the Riparian Wetland Forest. Only the Ocassionally Flooded Forests, Wetland Forest and Unflooded Forests were not significantly different from each other. Figure 5 illustrates the diameter classes of tree individuals sampled in the plant community. The abundance of individuals was greater between the intermediate classes (6 - 11.9 cm) and (12 - 23.9 cm), and the distribution among the diametric classes was significantly different among all the ecounits with $p < 0.0001$.

Discussion

The analyzes presented corroborate our initial hypothesis, indicating that the flooding regime characterizes the ecounits and the present vegetation regarding the floristic composition, diversity, and structure of the floodplain. The index of diversity and equability in the plant community was considered high, but it was not observed when analyzing the ecounits separately with lower values in Ocassionally Flooded Forests, Riparian River Forest, and Wetland Forest. The Wetland Forest ecounit are located in an area with depression, which favors flooding during a period every year in the region, so the plants present in this place are more adapted to water stress (Wittman et al. 2017), which can reduce richness and diversity of these communities. A similar result was found by Araujo et al. (2002); Marques et al. (2003), which were found in humid forests, which presented low richness and high dominance of the species in flooded areas. As noted in the NMDS, when we can see each ecounits forming plot groups, small variations in frequency and intensity of flooding within the habitat may be sufficient to promote heterogeneity in ecounits. We believe that the ecounits had the ordering of the plots in distinct groups due to the difference in the flooding regime in the different areas. Temporally different water saturation in the environments can provides the differentiation in the distribution of the species between the plots and, therefore, there is discrepancy in the composition of species. Thus, we can infer that the environmental factor water saturation is responsible for the ordering of the plots.

According to Lobo and Joly (1998), the frequency and duration of flooding determine the spatial distribution of the species. The absence of oxygen in flooded soils also provides a large amount of organic matter in the soil due to the low oxygenation and subsequent reduction in the rate of decomposition by the microorganisms (Sahrawat 2005). These factors influence the distribution of individuals in the diametric classes and in the tiller classes, presenting distinct variations between the ecounits. There was a great difference in the proportion of profile individuals, in the intensity of sprouting, as well as in the diametric classes in the analyzed ecounits. In areas where the soil is more humid, there was more sprouting than in areas with drained soil. According to Peterson and Rebertus (1997); Walker (1991), the development of sprouting in woody plants is common after uprooting or disruption, a feature useful through natural disturbances, since the ability of sprouts can allow the regeneration of the plant and allow species trees survive even after damage has been sustained. As for the diametric classes, there was greater abundance of individuals in the intermediate classes, being larger in the Wetland Forest, ecounits with greater flood., affirming the environmental heterogeneity resulting from the flooding regime present in the areas, which may increase the persistence of these species in flooded areas (Bond and Midgley 2001).

In addition to high lineage diversity, flooded forests are composed of distantly related and flood-tolerant species lineages with less species diversity but high phylogenetic diversity at the family and genus level (Araújo and Santos 2019). Although regrowth is a randomly distributed feature across the phylogeny, a wide range of strains that can regrow can persist in flooded habitats. Trees with multiple stems in the persistence niche are selected for a lineage pool that can regrow in an unstable environment (Araújo and Santos 2019).

Considering the high floristic and structural heterogeneity in the floodplain, we emphasize the importance of the conservation of the landscape in its integrity (Chazdon and Guariguata 2016). Based on the analyzes presented, one can use the list of composition and distribution of ecounits indicative species with soaked or humid soils carried out in the study for environments with similar ecology to the analyzed area, being able to be used in reforestation projects of areas, which will allow the successful restoration of degraded environments (table 5). This success, to the best of our understanding, lies in the physiognomic and structural distinction of the ecounits presented here according to the frequency and intensity of flooding, besides the micro relief that conditions a high environmental heterogeneity, to which we have not yet known. Future work will allow us to infer about this pattern of habitat diversity along flooded systems, areas that a distinct biodiversity is threatened due to the exploitation of these natural resources.

To conclude, the plant species distribute along the lendforms according to their niche and changes in this gradient are observed in the structure of the tree community in the whole plain. Environmental policies should highlight the scientific information that has provided information and alternatives, giving guidelines for the use of flooded forests, and increasing the size of areas to protect this biodiversity.

This study contributes to understand the ecology of the tree communities in flooded environments, generating knowledge about the distribution of the species and the environment in which they are found, necessary information for the understanding of the habitat and application of the generated knowledge.

Floodplains have a high degree of endemism, acting as nurseries for many species of local fauna. Despite the great ecological importance of these areas, information about plant communities is scarce. In the article, we found that plant species are distributed across areas according to their niche and changes in the structure of the lowland tree community are observed. This work promotes the understanding of ecology in flooded environments, seeking to promote a conservation model of these areas.

Declarations

Competing interests

The authors declare that they have no conflict of interest.

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Statements & Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Author Contributions

All authors contributed to the study conception and design. Material preparation, data collection were performed by Kaline Fernandes Miranda, Felipe de Carvalho Araújo, Mariana Caroline Moreira Morelli *and* Rubens Manoel dos Santos*. The analysis were performed by Kaline Fernandes Miranda,* Diego Gualberto Sales Pereira, Polyanne Aparecida Coelho and Cléber Rodrigo de Souza. *The first draft of the manuscript was written by Kaline Fernandes Miranda and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.*

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Tables

Legend of tables

Table 1 Analysis of Indicator Species ISA - Indicator species of the five geoforms located at the mouth of the Paracatu River in the São Francisco River, MG, Brazil, where: IV = species indication value, p = level of significance by the Monte Carlo test. Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF).

Table 2 List of species found in the Paracatu River ecounits and their occurrence in the studied activities.

Table 3 Shannon-Wiener species diversity to verify species diversity in the ecounits. Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF). 95% family-wise confidence level.

Table 4 Pielou comparison the ecounits Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF). P-values adjusted with the Holm method.

Table 5 Structural characterization of the plant community of the Paracatu River floodplain, Minas Gerais.

Table 1

Ecounits	Species	IV	P-value
	Albizia inundata (Mart.) Barneby & J.W.Grimes	81,8	0,001
WF	*Casearia gossypiosperma* Briq.	83,3	0,002
	Ruprechtia apetala Weddell	83,3	0,003
	Astronium fraxinifolium Schott ex Spreng.	40	0,039
OFF	*Callisthene fasciculata* (Spreng.) Mart.	78,3	0,001
	Curatella americana L.	84,2	0,001
	Tabebuia aurea (Manso) Benth. & Hook.f. ex S.Moore	100	0,001
RRF	*Celtis ehrenbergiana* (Klotzsch) Liebm.	62,1	0,003
	Triplaris gardneriana Weddell	45	0,034
RWF	*Genipa americana* L.	50	0,017
	Copaifera coriacea Mart.	50	0,026
	Dipteryx alata Vogel	50	0,024
	Erythroxylum nummularia Peyr.	50	0,033
UF	*Eugenia dysenterica* DC.	83,3	0,001
	Goniorrhachis marginata Taub.	50	0,033
	*Handroanthus impetiginosus (*Mart. ex DC.) Mattos	83,3	0,002
	Hymenaea martiana Hayne	50	0,025

Table 2 List of species found in the Paracatu River ecounits and their occurrence in the studied activities.

Family	Species	UF	RRF	WF	RWF	OFF
CELASTRACEAE	*Maytenus robustoides* Loes.		x			
CHRYSOBALANACEAE	*Hirtella gracilipe*s (Hook.f.) Prance	x				
COMBRETACEAE	*Combretum duarteanum* Cambess.				x	
DILLENIACEAE	*Curatella americana* L.	x			x	x
EBENACEAE	*Diospyros hispida* A.DC.				x	
ERYTHROXYLACEAE	*Erythroxylum nummularia* Peyr.	x				
EUPHORBIACEAE	*Croton urucurana* Baill. urucurana		x			
	Sapium argutum (Müll.Arg.) Huber					x
FABACEAE	*Albizia inundata* (Mart.) Barneby and J.W.Grimes			x	x	
	Albizia niopoides (Spruce ex Benth.) Burkart		x	x	x	
	Amburana cearensis (Allemão) A.C.Sm.	x				
	Anadenanthera colubrina (Vell.) Brenan	x				
	Bauhinia acuruana Moric.			x		

"Table 2, continues."

Family	Species	UF	RRF	WF	RWF	OFF
FABACEAE	*Bauhinia rufa* (Bong.) Steud.				x	
	Bowdichia virgilioides Kunth	x				
	Copaifera coriacea Mart.	x				
	Copaifera langsdorffii Desf..	x			x	
	Dimorphandra mollis Benth.	x				
	Dipteryx alata Vogel	x				
	Goniorrhachis marginata Taub.	x				
	Hymenaea martiana Hayne	x				
	Inga vera Willd.			x	x	
	Luetzelburgia bahiensis Yakovlev	x				
	Machaerium acutifolium Vogel	x			x	
	Machaerium opacum Vogel	x				
	Machaerium scleroxylon Tul.	x				

"Table 2, continues."

Family	Species	UF	RRF	WF	RWF	OFF
FABACEAE	*Peltophorum dubium* (Spreng.) Taub.		x	x	x	
	Platymiscium floribundum Vogel	x				
	Platypodium elegans Vogel				x	
	Pterodon emarginatus Vogel	x				
	Senegalia polyphylla (DC.) Britton and Rose	x			x	
	Senna spectabilis (DC.) H.S.Irwin and Barneby	x	x		x	
	Swartzia flaemingii Vogel	x				
	Tachigali paniculata Aubl.	x				
	Vachellia farnesiana (L.) Wight and Arn.		x			
	Vatairea macrocarpa (Benth.) Ducke	x				
LAURACEAE	*Nectandra megapotamica* (Spreng.) Mez			x	x	
MALPIGHIACEAE	*Byrsonima verbascifolia* (L.) DC.	x				
	Heteropterys byrsonimifolia A.Juss.	x			x	

"Table 2, continues"

Family	Species	UF	RRF	WF	RWF	OFF
MALVACEAE	*Guazuma ulmifolia* Lam.		x			
	Luehea paniculata Mart. and Zucc.					x
MELASTOMATACEAE	*Mouriri pusa* Gardner			x	x	
MELIACEAE	*Trichilia hirta* L.				x	
MORACEAE	*Brosimum gaudichaudii* Trécul	x			x	
	Maclura tinctoria (L.) D.Don ex Steud.		x			
MYRTACEAE	*Blepharocalyx salicifolius* (Kunth) O.Berg			x		
	Eugenia dysenterica DC.	x				
	Eugenia florida DC.			x	x	
	Eugenia ligustrina (Sw.) Willd.		x		x	
	Eugenia uniflora L.				x	
	Myrcia hebepetala DC.			x		
OCHNACEAE	*Ouratea castaneifolia* (DC.) Engl.	x				

"Table 2, continues"

Family	Species	UF	RRF	WF	RWF	OFF
PHYLLANTHACEAE	*Margaritaria nobilis* L.f.				x	
PIPERACEAE	*Piper aduncum* L.		x			
POLYGONACEAE	*Ruprechtia apetala* Weddell			x		
	Triplaris gardneriana Weddell		x	x	x	
RUBIACEAE	*Chomelia brasiliana* A.Rich.		x	x	x	x
	Genipa americana L.			x	x	x
	Randia armata (Sw.) DC.				x	
	Simira sampaioana (Standl.) Steyerm.	x				
	Tocoyena formosa (Cham. and Schltdl.) K.Schum.	x		x	x	x
SALICACEAE	*Casearia gossypiosperma* Briq.			x		
	Casearia rupestris Eichler	x				
	Casearia sylvestris Sw.	x			x	

"Table 2, continues"

Family	Species	UF	RRF	WF	RWF	OFF
SALICACEAE	*Xylosma ciliatifolia* (Clos) Eichler		x	x	x	
SAPINDACEAE	*Dilodendron bipinnatum* Radlk.	x				
	Magonia pubescens A.St.-Hil.	x				
SAPOTACEAE	*Manilkara salzmannii* (A.DC.) H.J.Lam.		x	x	x	
SIMAROUBACEAE	*Simarouba versicolor* A.St.-Hil.	x				
URTICACEAE	*Cecropia pachystachya* Trécul		x		x	
VOCHYSIACEAE	*Callisthene fasciculata* (Spreng.) Mart.	x			x	x
	Qualea grandiflora Mart.	x				
	Qualea multiflora Mart.	x				x
	Qualea parviflora Mart.					x

Table 3

Ecounits	diff	lwr	upr	p adj
OFF - UF	-1.1428262	-1.83134775	-0.4543047	0.0004564
WF - UF	-0.4877759	-1.17629739	0.2007456	0.2594546
RRF - UF	-0.9536325	-1.64215401	-0.2651110	0.0034881
RWF - UF	-0.3060273	-0.99454883	0.3824942	0.6904437
WF - OFF	0.6550504	-0.03347115	1.3435719	0.0677981
RRF - OFF	0.1891937	-0.49932777	0.8777153	0.9260129
RWF - OFF	0.8367989	0.14827741	1.5253204	0.0117676
RRF - WF	-0.4658566	-1.15437813	0.2226649	0.3009576
RWF - WF	0.1817486	-0.50677295	0.8702701	0.9353859
RWF - RRF	0.6476052	-0.04091633	1.3361267	0.0724502

Table 4

Ecounits	Z	P. unadj	P. adj
UF - OFF	3.1151727	0.001838372	0.01838372
UF - WF	0.6558258	0.511936191	1.00000000
OFF - WF	-2.4593469	0.013919006	0.11135205
UF - RRF	2.6233033	0.008708170	0.07837353
OFF - RRF	-0.4918694	0.622811688	0.62281169
WF - RRF	1.9674775	0.049128187	0.34389731
UF - RWF	1.8035210	0.071306423	0.42783854
OFF - RWF	-1.3116517	0.189637690	0.94818845
WF - RWF	1.1476952	0.251094408	1.00000000
RRF - RWF	-0.8197823	0.412340226	1.00000000

Table 5

Species	BA	RF	RD	RDo	VI
Triplaris gardneriana Weddell	7.94	4.71	18.81	22.34	15.29
Manilkara salzmannii (A.DC.) H.J.Lam.	6.61	4.71	6.82	18.60	10.04
Inga vera Willd.	5.71	2.75	1.10	16.07	6.64
Chomelia brasiliana A.Rich.	0.36	5.10	7.29	1.00	4.46
Callisthene fasciculata (Spreng.) Mart.	1.16	3.14	6.43	3.26	4.27
Tabebuia aurea (Manso) Benth. & Hook.f. ex S.Moore	1.53	2.35	5.56	4.29	4.07
Celtis ehrenbergiana (Klotzsch) Liebm.	1.31	3.53	4.31	3.69	3.84
Albizia inundata (Mart.) Barneby & J.W.Grimes	0.78	2.35	4.31	2.20	2.96
Genipa americana L.	0.90	3.53	1.57	2.53	2.54
Casearia gossypiosperma Briq.	0.29	1.96	4.78	0.82	2.52
Ruprechtia apetala Weddell	0.67	1.96	3.45	1.89	2.43
Myracrodruon urundeuva Allemão	0.66	2.35	1.41	1.85	1.87
Curatella americana L.	0.28	3.14	1.49	0.80	1.81
Erythroxylum nummularia Peyr.	0.21	1.18	3.45	0.60	1.74
Peltophorum dubium (Spreng.) Taub.	0.72	2.35	0.78	2.04	1.72
Mouriri pusa Gardner	0.61	2.35	0.94	1.72	1.67
Cecropia pachystachya Trécul	0.76	1.57	1.02	2.15	1.58
Copaifera langsdorffii Desf..	0.81	0.78	1.41	2.27	1.49
Albizia niopoides (Spruce ex Benth.) Burkart	0.21	2.35	0.78	0.60	1.24
Eugenia dysenterica DC.	0.06	1.96	1.25	0.16	1.13
Hymenaea martiana Hayne	0.31	1.18	1.25	0.87	1.10
Astronium fraxinifolium Schott ex Spreng.	0.28	1.57	0.78	0.79	1.05
Amburana cearensis (Allemão) A.C.Sm.	0.56	0.78	0.63	1.57	0.99
Handroanthus impetiginosus (Mart. ex DC.) Mattos	0.13	1.96	0.63	0.36	0.98
Eugenia florida DC.	0.02	1.96	0.63	0.06	0.88
Simira sampaioana (Standl.) Steyerm.	0.17	0.39	1.72	0.47	0.86

‘Table 5 continues, ”

Species	BA	RF	RD	RDo	VI
Copaifera coriacea Mart.	0.08	1.18	1.10	0.22	0.83
Eugenia ligustrina (Sw.) Willd.	0.06	1.57	0.71	0.18	0.82
Combretum duarteanum Cambess.	0.23	0.39	1.41	0.65	0.82
Dipteryx alata Vogel	0.21	1.18	0.47	0.60	0.75
Anadenanthera colubrina (Vell.) Brenan	0.23	0.78	0.78	0.64	0.74
Margaritaria nobilis L.f.	0.07	0.78	1.10	0.19	0.69
Machaerium scleroxylon Tul.	0.17	0.78	0.78	0.47	0.68
Xylosma ciliatifolia (Clos) Eichler	0.01	1.57	0.39	0.04	0.67
Goniorrhachis marginata Taub.	0.07	1.18	0.63	0.18	0.66
Tocoyena formosa (Cham. & Schltdl.) K.Schum.	0.01	1.57	0.31	0.04	0.64
Handroanthus ochraceus (Cham.) Mattos	0.07	0.78	0.71	0.19	0.56
Senna spectabilis (DC.) H.S.Irwin & Barneby	0.02	1.18	0.39	0.05	0.54
Senegalia polyphylla (DC.) Britton & Rose	0.03	1.18	0.31	0.08	0.52
Heteropterys byrsonimifolia A.Juss.	0.02	1.18	0.31	0.05	0.51
Simarouba versicolor A.St.-Hil.	0.07	0.78	0.47	0.21	0.49
Nectandra megapotamica (Spreng.) Mez	0.01	1.18	0.24	0.03	0.48
Annona coriacea Mart.	0.03	0.78	0.47	0.09	0.45
Blepharocalyx salicifolius (Kunth) O.Berg	0.21	0.39	0.31	0.58	0.43
Machaerium opacum Vogel	0.04	0.78	0.31	0.11	0.40
Vatairea macrocarpa (Benth.) Ducke	0.06	0.78	0.24	0.16	0.39
Eugenia uniflora L.	0.02	0.78	0.31	0.06	0.39
Casearia sylvestris Sw.	0.01	0.78	0.31	0.04	0.38
Machaerium acutifolium Vogel	0.04	0.78	0.16	0.11	0.35

Table 5 continues,

Species	BA	RF	RD	RDo	VI
Qualea multiflora Mart.	0.02	0.78	0.16	0.05	0.33
Schinopsis brasiliensis Engl.	0.01	0.78	0.16	0.03	0.32
Brosimum gaudichaudii Trécul	0.00	0.78	0.16	0.01	0.32
Annona sylvatica A.St.-Hil.	0.00	0.78	0.16	0.01	0.32
Pterodon emarginatus Vogel	0.16	0.39	0.08	0.46	0.31
Bauhinia acuruana Moric.	0.02	0.39	0.47	0.04	0.30
Guazuma ulmifolia Lam.	0.12	0.39	0.16	0.32	0.29
Tachigali paniculata Aubl.	0.07	0.39	0.24	0.20	0.28
Aspidosperma cuspa (Kunth) S.F.Blake ex Pittier	0.02	0.39	0.31	0.05	0.25
Myrcia hebepetala DC.	0.01	0.39	0.31	0.04	0.25
Magonia pubescens A.St.-Hil.	0.02	0.39	0.24	0.05	0.23
Hirtella gracilipes (Hook.f.) Prance	0.01	0.39	0.24	0.04	0.22
Cordia glabrata (Mart.) A.DC.	0.07	0.39	0.08	0.18	0.22
Platypodium elegans Vogel	0.04	0.39	0.16	0.10	0.22
*Randia armata (*Sw.) DC.	0.01	0.39	0.24	0.02	0.21
*Maclura tinctoria (*L.) D.Don ex Steud.	0.01	0.39	0.16	0.04	0.20
Croton urucurana Baill. urucurana	0.01	0.39	0.16	0.02	0.19
Diospyros hispida A.DC.	0.01	0.39	0.16	0.02	0.19
Bauhinia rufa (Bong.) Steud.	0.00	0.39	0.16	0.01	0.19
Swartzia flaemingii Vogel	0.00	0.39	0.16	0.01	0.19
Maytenus robustoides Loes.	0.02	0.39	0.08	0.07	0.18
Bowdichia virgilioides Kunth	0.02	0.39	0.08	0.06	0.18
Byrsonima verbascifolia (L.) DC.	0.02	0.39	0.08	0.06	0.18
Qualea parviflora Mart.	0.01	0.39	0.08	0.03	0.17
Luehea paniculata Mart. & Zucc.	0.01	0.39	0.08	0.02	0.16
Vachellia farnesiana (L.) Wight & Arn.	0.01	0.39	0.08	0.02	0.16

“ Table 5 continues.”

Species	BA	RF	RD	RDo	VI
Piper aduncum L.	0.01	0.39	0.08	0.01	0.16
Platymiscium floribundum Vogel	0.00	0.39	0.08	0.01	0.16
Casearia rupestris Eichler	0.00	0.39	0.08	0.01	0.16
Luetzelburgia bahiensis Yakovlev	0.00	0.39	0.08	0.01	0.16
Dilodendron bipinnatum Radlk.	0.00	0.39	0.08	0.01	0.16
Dimorphandra mollis Benth.	0.00	0.39	0.08	0.00	0.16
Sapium argutum (Müll.Arg.) Huber	0.00	0.39	0.08	0.00	0.16
Qualea grandiflora Mart.	0.00	0.39	0.08	0.00	0.16
Trichilia hirta L.	0.00	0.39	0.08	0.00	0.16
*Ouratea castaneifolia (*DC.) Engl.	0.00	0.39	0.08	0.00	0.16
Grand total	35.55	100	100	100	100

Figures

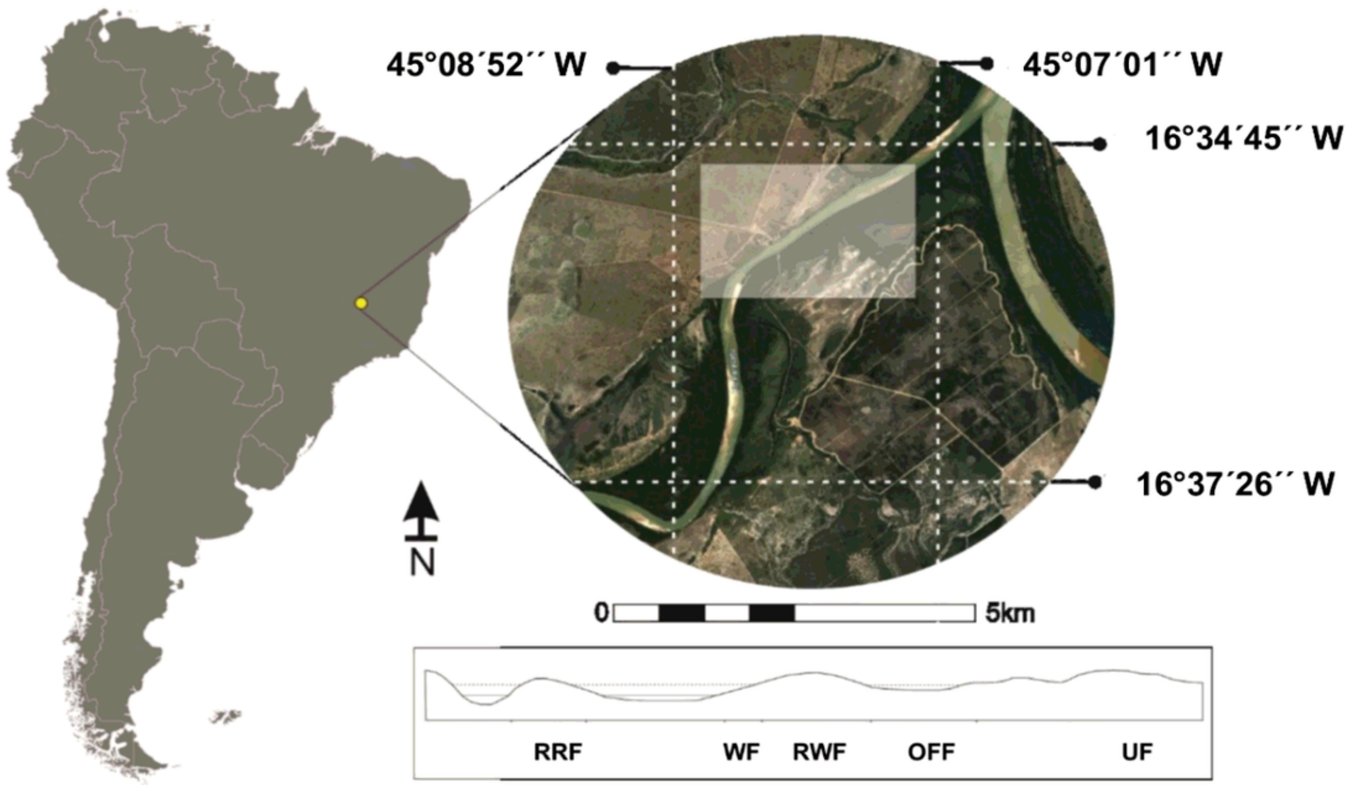

Figure 1

Map of the study area showing the distribution of plots along the course of the Paracatu River at its mouth in the São Francisco River. Representing the ecounits: Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF).

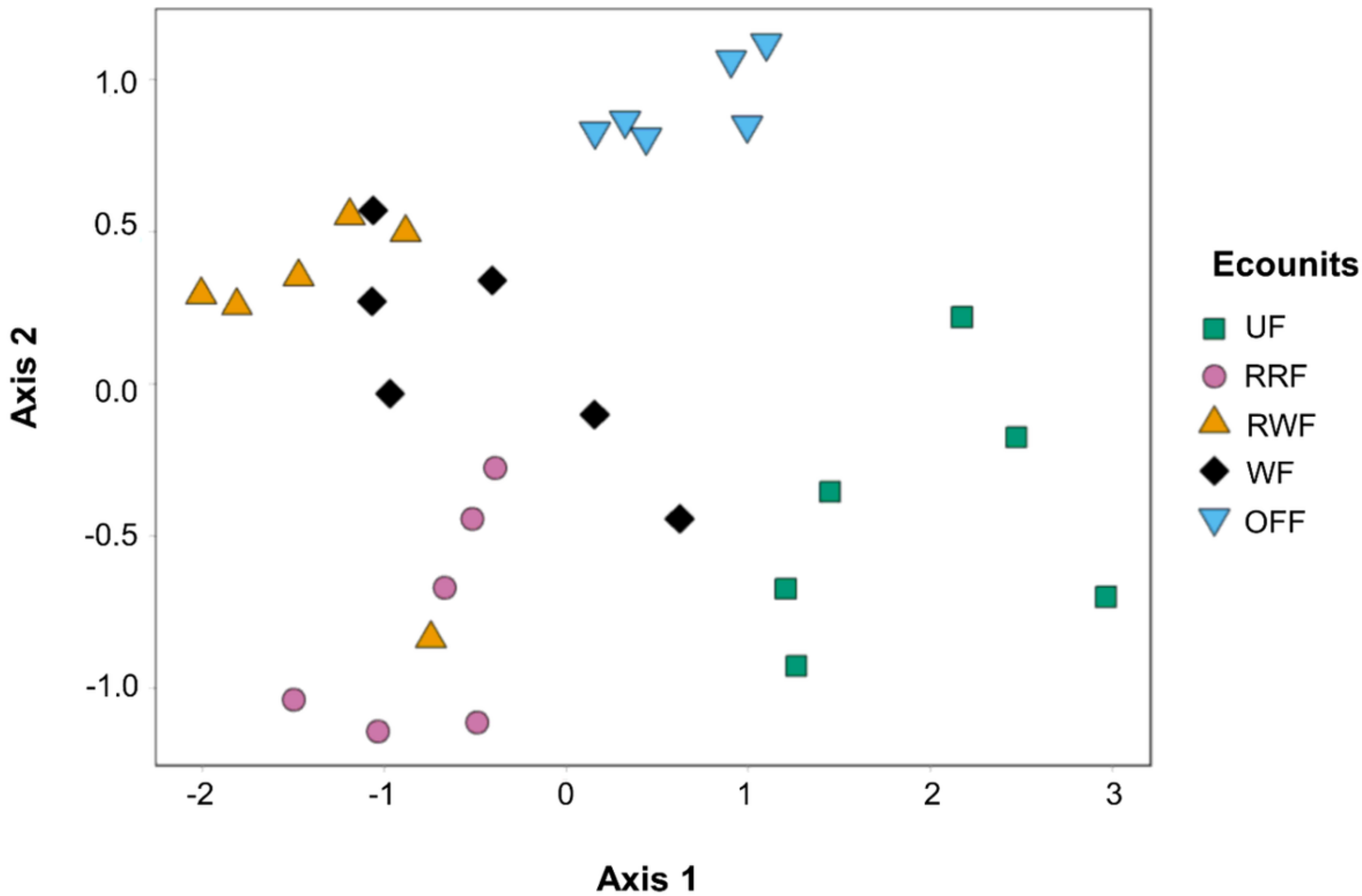

Figure 2

Non-metric multidimensional scaling (NMDS) of species composition across the ecounits: Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF).

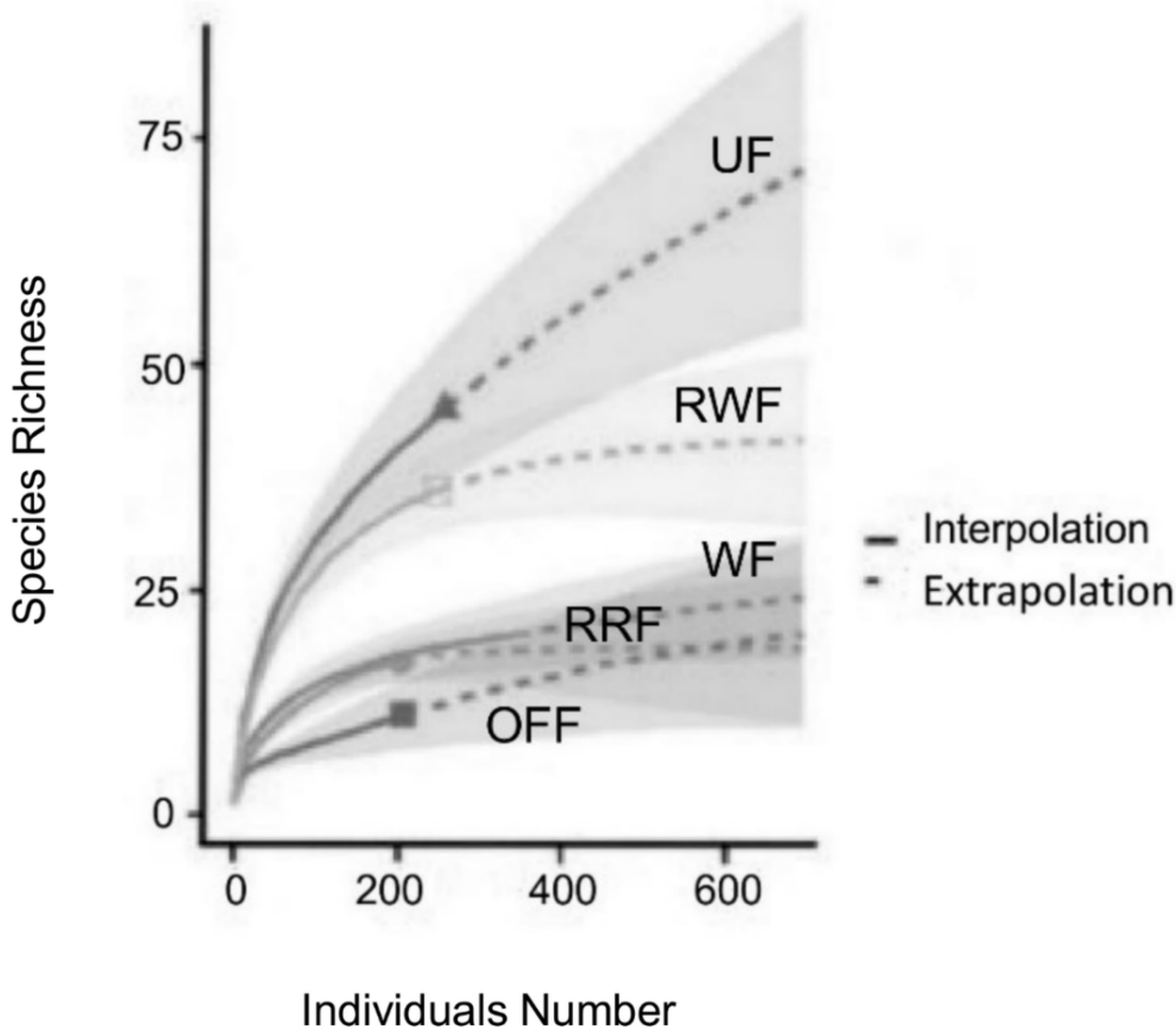

Figure 3

Average curve of species richness rarefaction of the ecounits in the floodplain of the mouth of the Paracatu River (MG). Margins represent a range of significance at the 95% level. Subtitle: Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF).

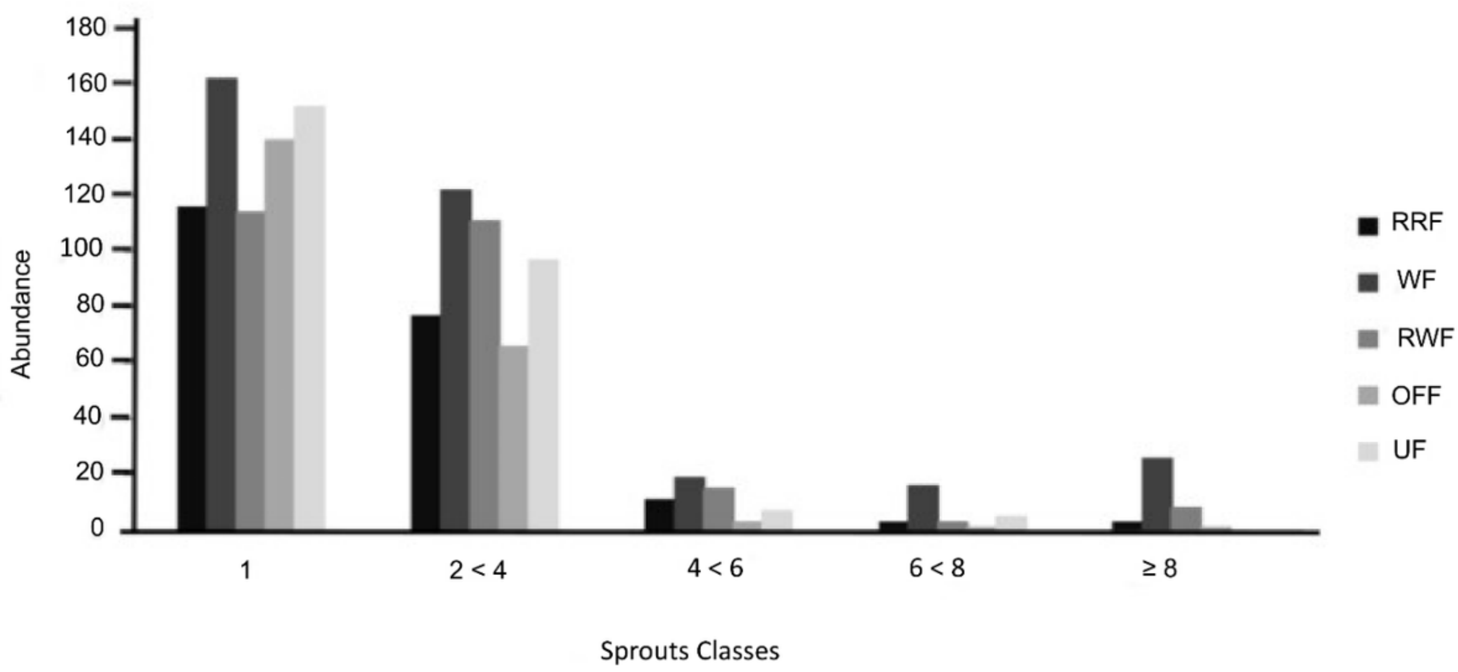

Figure 4

Distribution by classes with intensity of sprouts of the arboreal individuals sampled in the ecounits of the floodplain of the Paracatu River. Riparian River Forest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF). Adhesion test G between ecounits with $P < 0.0001$.

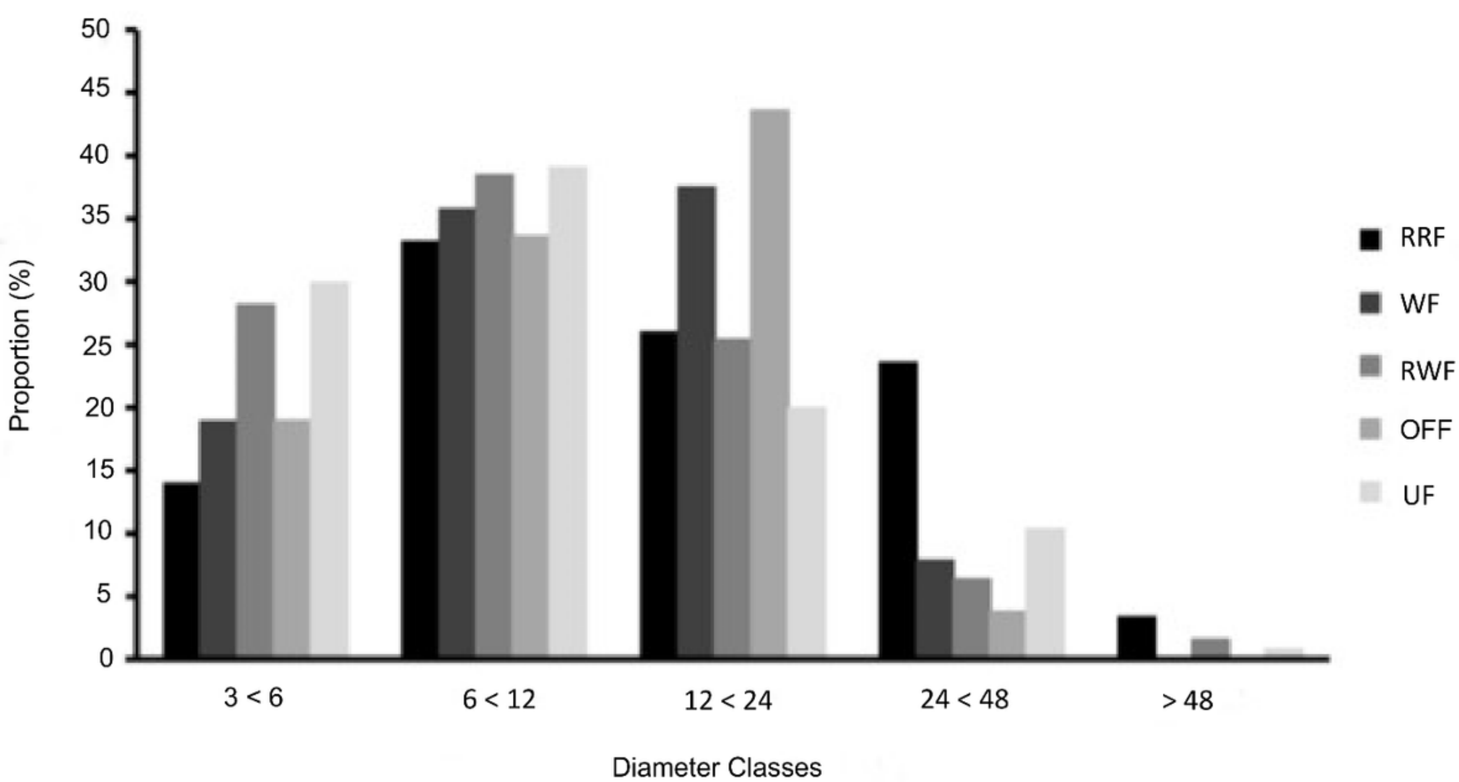

Figure 5

Diameter classes of the arboreal individuals sampled in the ecounits of the floodplain of the Paracatu River. Riparian River Rorest (RRF), Wetland Forest (WF), Riparian Wetland Forest (RWF), Ocassionally Flooded Forests (OFF), Unflooded Forests (UF).