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Floristic and phytosociology in a physiognomic gradient of riverine forest in Cerrado, Campinas, SP

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Abstract: Knowledge on floristic composition and vegetation structure is essential to preserve plant biodiversity and environmental conditions. A floristic and structural survey of woody vegetation was carried out in a physiognomic gradient of riparian forest of Cerrado vegetation, Campinas - SP. We sampled 25 plots, distributed along five transects, located perpendicularly to a stream. We found 971 individuals (65 standing dead trees) distributed among 35 families and 80 species. We recorded one single individual of exotic species (*Citrus limon* – rangpur) and a large number of individuals of endangered species (*Luetzelburgia guaissara*, *Myroxylon peruiferum* and *Trichilia hirta*) indicating that the Santa Elisa study area retains much of the original characteristics of its native vegetation. The small number of exclusive Cerrado species in the study area indicates that riverine environments represent a very different condition in relation to that of the Cerrado. Except for swampy areas, which are more homogeneous and floristically similar to each other due to adaptations to greater environmental constraints, the riverine forest physiognomies showed greater internal floristic heterogeneity, even considering only those located in Cerrado areas. This emphasizes the importance of studying riverine forests flora for each particular region, especially when restoration or management actions are needed. At the Santa Elisa riverine-cerrado transition fragment, riparian species were found throughout gradient up to the limit of the study area showing that a distance of at least 50 m far from the stream should be preserved in order to keep the riparian environment.
Keywords: *ecotone, savanna, floristic similarity, riverine forest-cerrado transition, vegetation structure.*

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Resumo: Conhecer a composição florística e a estrutura da vegetação é imprescindível quando se trata da conservação da biodiversidade e das condições ambientais. Foi realizado um levantamento florístico e estrutural da vegetação arbórea em um gradiente fisionômico de mata ribeirinha em área de Cerrado, Campinas - SP, em 25 parcelas, distribuídas em cinco transectos, localizados perpendicularmente a um córrego. Foram encontrados 971 indivíduos (65 mortos em pé), pertencentes a 35 famílias e 80 espécies, sendo um único indivíduo de espécie exótica (*Citrus limon* – limão-vinagre) e um número muito maior de indivíduos de espécies ameaçadas (*Luetzelburgia guaissara*, *Myroxylon peruiferum* e *Trichilia hirta*) indicando que a área de estudo na Fazenda Santa Elisa mantém muito das características originais de sua vegetação nativa. O pequeno número de espécies exclusivas do Cerrado na área de estudo indica que ambientes ribeirinhos representam uma condição muito diferente em relação àquelas do Cerrado. Com exceção de áreas paludícolas, que são mais homogêneas e floristicamente semelhantes devido à adaptação a maiores restrições ambientais, as fisionomias florestais ribeirinhas comparadas mostraram grande heterogeneidade florística, mesmo considerando-se apenas aquelas localizadas em áreas de Cerrado. Isso enfatiza a importância de se estudar a flora das florestas ribeirinhas de cada região em particular, especialmente quando as ações de restauração ou de gestão são necessárias. No fragmento de transição floresta ribeirinha-cerrado da Fazenda Santa Elisa, as espécies exclusivas de florestas ribeirinhas, embora com diferentes densidades, foram encontradas em todo o gradiente até o limite da área de estudo, mostrando que a vegetação deve ser preservada até uma distância de pelo menos 50 m a partir do rio, a fim de manter o ambiente ribeirinho.
Palavras-chave: *ecótono, savana, similaridade florísitca, transição floresta ribeirinha-cerrado, estrutura da vegetação.*

Introduction

The Brazilian savanna, hereafter called cerrado (usual designation in Brazil) has a very wide distribution. From its core region in Central Brazil (Mantovani & Martins 1993) it extends continuously throughout the states of Goiás, Tocantins, Minas Gerais, Distrito Federal, Bahia, Mato Grosso, Mato Grosso do Sul, Piauí, Maranhão, Rondônia and São Paulo, also occurring in disjoint areas in the states of Amapá, Amazonas, Pará, Ceará, Paraná and Roraima (Ribeiro & Walter 1998). Because of its distribution in areas with different environmental conditions, the Cerrado is found as a mosaic of vegetation types, from grassland vegetation with greater presence of shrubs and grasses (such as scrub savanna – "campo cerrado" - and grassland savanna – "campo sujo" and "campo limpo"), throughout an intermediate vegetation (such as savanna *sensu stricto* – "cerrado *sensu stricto*"), and then to a forest vegetation (forested savanna – "cerradão") with continuous canopy (Coutinho 2002) that, according to Rizzini (1997), was originally associated with rainforests.

Due to the central position of the Cerrado in Brazil and its marginal areas of occurrence, it is associated with other physiognomic domains such as the Amazon and Atlantic Forests as part of the "diagonal of open formations", that also includes Chaco and Caatinga (Oliveira-Filho & Fontes 2000). The Amazon and the Atlantic Forests have intrusions into the Cerrado represented by alluvial or riverine forests (Oliveira-Filho & Ratter 1995), which can be considered a transition area.

There are several terms to characterize the forests on the margin of rivers and other water bodies. Rodrigues (2000) distinguishes them as swampy forests (where the soil is permanently waterlogged and there is constant flow of surface water in channels), gallery forests (inserted in areas with non-forest interfluve vegetation and along small rivers, forming the galleries), riparian forests (inserted in areas where interfluve vegetation is forested) and riverine forests (very generic term, can be used to designate the vegetation occurring on the edge of marginal levees, differing from gallery forests by not forming corridors of vegetation).

Considering only the Cerrado domain, Ribeiro & Walter (1998) recognize riverine forests, such as those surrounded by dry forests (matas secas) or "cerradão" – forest physiognomies floristically different from riverine forests –, and gallery forests, where the interfluve vegetation is not forest, with abrupt transition to savannic and grassland formations. According to Coutinho (2002) these forests are considered a non-cerrado vegetation.

Transition areas aroused attention over time, especially in the search for understanding the distribution of its species and the factors that determine them. Ecotones frequently support high levels of biological diversity (Risser 1995, Van Rensburg et al. 2009), though it is controversial whether they represent special areas of speciation and diversity (Kark & Van Rensburg 2006). There are ecotone areas with different environmental characteristics that do not fit the expectation of greater biodiversity than limitrophe areas (Lloyd et al. 2000). Biodiversity is not intrinsic property of ecotones, since it depends on the particular ecological conditions of the site and on the ecology of the present species (Lloyd et al. 2000).

The Cerrado was degraded due to the establishment of pastures and other crops, which endangers its immense biodiversity and makes it a global hotspot (Myers et al. 2000). In São Paulo state, the remnants of "cerrado" are very fragmented (Durigan et al. 2004) and only 0.5% is protected by some type of conservation unit (Durigan et al. 2006). The Cerrado occupied 14% of State of São Paulo and were reduced to 1% of this area (Fiori & Fioravanti 2001), which motivated the development of protective legislation (Brasil 2009). With the exception of swampy forests, riverine forests are diverse from each other, due to different vegetation types with which they limit (Bernacci et al. 1998, Rodrigues & Nave 2000). Despite being protected by the Brazilian Forest Code (Código Florestal Brasileiro) as areas of permanent preservation, riverine forests have suffered from urbanization and implementation of agricultural crops and pastures. More recently, legislation has decreased the size of the areas to be maintained as protected (Brasil 2012).

Since riverine forests usually show similarities with the surrounding vegetation, despite their great heterogeneity, the aim of this study was to evaluate whether riverine forests in savanna areas are similar to each other. The analysis involved the composition, structure, biodiversity and the species distribution in a riverine forest-cerrado transition, as well as comparison with fragments in similar environments throughout Brazil.

Material and Methods

The study area (Figure 1A) is located at Campinas, SP, in between the coordinates 22° 51' 21" and 22° 51' 27" S, and 47° 05' 28" and 47° 05' 36" W, inside an agricultural research farm of Instituto Agronômico (IAC). The region has a subtropical climate (Cwa, Koeppen classification), with an annual mean temperature of 20.3 °C and annual rainfall of 1409.5 mm (Mello et al. 1994). Soils occurring in the area are Gleysols, Ferralsols and Cambisols, all of them of low base saturation, their distribution depending on proximity to water sources (Carvalho 2012). The area has been in a process of natural regeneration in the last 40-50 years, but during the study development circulation of cattle and of neighborhood residents was observed, in addition to burnt in the vegetation located very close to the study plots, caused by fire, what is supposed to have affected the area somehow.

The Campinas municipality territory, located in the Atlantic Forest domain, had originally Cerrado vegetation, seasonal forest and swampy forest, with predominance of forests and only about 5% of its area corresponding to Cerrado (Kronka et al. 2005). The study area represents a transition from riverine forest to drier Cerrado area. Twenty five plots of 10 × 10 m were set up in five distinct transects (each one with five contiguous plots) approximately perpendicular to the stream (Figure 1B). Distribution of plots is so that all transects represent the two physiognomies: riverine forest and "cerradão". In transects 3 and 4 (Figure 1B) the two plots farthest from the stream were spaced 10 m far from the other plots of the transect to avoid an existing walking path.

Woody plants, except lianas, with height greater than or equal to 1.5 m and diameter at ground level greater than or equal to 3 cm were collected and identified to determine the floristic composition and vegetation structure. The identification was made by identification keys and specialized bibliography, and by comparison with existing herbarium specimens and consultation with experts. Height was estimated, and perimeter at ground level (PGL) and at breast level (PBL) was measured for each individual.

The floristic list and its phytogeographic domains were checked in the List of Species of the Brazilian Flora (Jardim… 2013), which was also used to verify the synonymy of species names. This list was also compared to a floristic review made by Mendonça et al. (2008) for the Brazilian Cerrado, with the physiognomic types classified according to Ribeiro & Walter (1998), who studied "cerradão", "cerrado *sensu stricto*", "campo cerrado", "campo sujo" and grassland ("campo limpo") physiognomies, plus riverine and gallery forests. Forest physiognomies along watercourses were considered in this study as riverine forests (Rodrigues 2000), what is consistent with the term alluvial (Veloso et al. 1991).

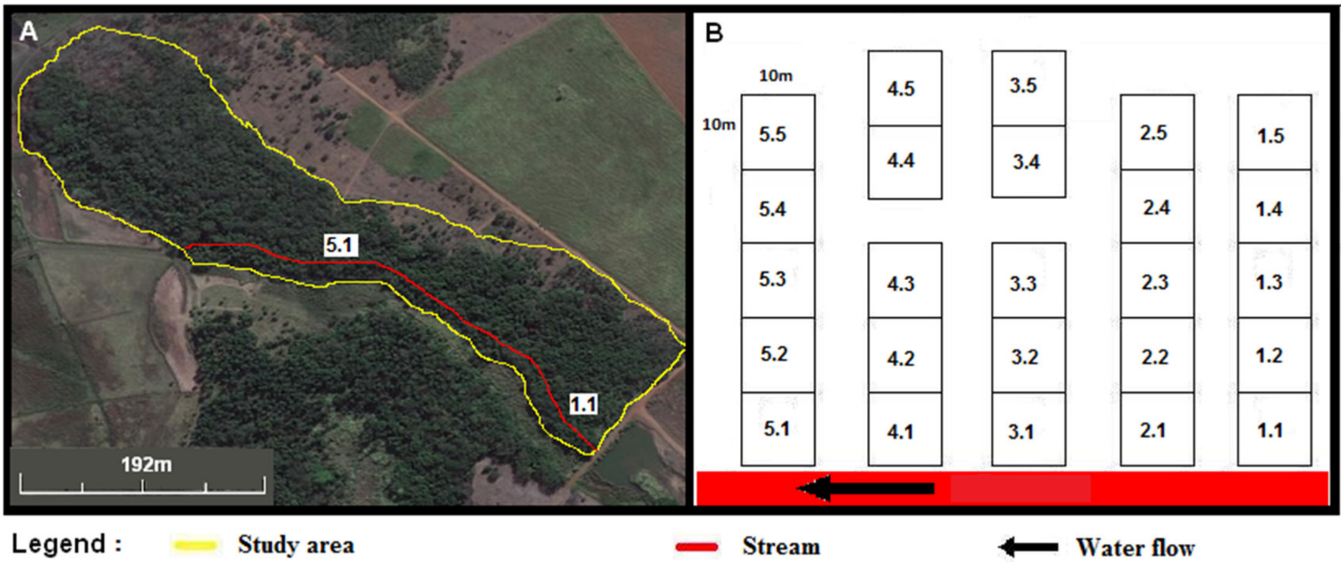

Figure 1. (A) Study area with approximate position of two plots closer to the stream (plots 5.1 and 1.1) from the two extreme transects (transects 1 and 5) (modified from GoogleEarth 2011) and (B) plots diagram, with relative position of the plots to the stream (B).

The phytosociological parameters number of individuals, frequency and absolute dominance, importance value index (IVI) and the Shannon-Wiener diversity index (H') were calculated with the software FITOPAC (Shepherd 2010) and compared to other studies in areas of Cerrado vegetation and riverine forests from the Southeast and other geographical regions of Brazil. The similarity analysis (cluster), using the Bray-Curtis coefficient and group average as hierarchical clustering method (UPGMA), was performed with data of the present paper and data of other scientific publications that presented the species abundance, considering only species occurring in at least three publications. To verify correlation between the species matrix and the geographic distance matrix, we used the Mantel Test with significance tested by Monte Carlo (1000 permutations) and performed by the PC-Ord software, version 5 (McCune & Mefford 2006).

Results

There were 971 individuals (65 individuals – 6.7% - of standing dead trees) in the study area, belonging to 35 families and 80 species. The richest families were Fabaceae *lato sensu* (13 species), Meliaceae and Myrtaceae (six species each), Lauraceae and Rutaceae (four species each), which represented 41% of the sampled species (Table 1). We found only one exotic species (*Citrus limon* (L.) Burm.f. - rangpur), represented by a single individual.

The species with the highest Importance Value Index (Table 2) were *Nectandra nitidula* (Lauraceae), *Gochnatia polymorpha* (Asteraceae), *Dendropanax cuneatus* (Araliaceae), *Protium heptaphyllum* (Burseraceae) and *Trichilia pallida* (Meliaceae). Of these species, just *Gochnatia polymorpha* is not among the five most abundant species and with the highest frequencies, being surpassed by *Guarea macrophylla* (Meliaceae) in abundance and *Cecropia pachystachya* (Urticaceae) in frequency, equaling to *Mollinedia widgrenii* (Monimiaceae), *Siparuna guianensis* (Siparunaceae) and *Ocotea velloziana* (Lauraceae) in the latter parameter. The Shannon-Wiener diversity index (H') was 3.49 nats/individual and the evenness (J) was 0.79 (Table 3).

According to the List of Species of the Brazilian Flora (Jardim… 2013) and considering both Atlantic Forest and Cerrado domains, only five of the identified species in the area were listed as occurring exclusively in the Atlantic Forest (*Alchornea sidifolia* - Euphorbiaceae, *Celtis pubescens* - Cannabaceae, *Cordia americana* - Boraginaceae, *Eugenia pluriflora* - Myrtaceae - and *Luetzelburgia guaissara* - Fabaceae) and only two were listed exclusively for the Cerrado domain (*Cordia trichotoma* - Boraginaceae - and *Guettarda pohliana* - Rubiaceae). The remaining species were listed as occurring in both domains. In the case of the 25 identified species with physiognomic type specified in the "Lista de Espécies da Flora do Brasil", 60% (15 species) occur in both Cerrado and in riverine/gallery forest, 20% (5) only in Cerrado, 12% (3) only in riverine/gallery forest and 8% (2) do not occur in any of these two groups of vegetation (Jardim… 2013).

Assuming the classification of Mendonça et al. (2008), it was noticed that 8.75% of the species (7 species) in this study are listed for Cerrado, 30% (24 species) for riverine/gallery forests, 45% (36 species) for both and 16.25% (13 species) were not listed for Cerrado nor for riverine/gallery forests. Others species, such as *Cestrum mariquitense* (Solanaceae) and *Zanthoxylum acuminatum* (Rutaceae) spread over several phytogeographic domains, including Cerrado and Atlantic Forest, while *Eugenia uniflora* and *E. paracatuana* (Myrtaceae), and *Persea willdenovii* (Lauraceae) occurred only in these two domains and *Cordia americana* (Boraginaceae) and *Luetzelburgia guaissara* (Fabaceae) only in Atlantic Forest. *Cordia americana* was sampled in riverine forests in Jardim (MS), where vegetation is influenced by deciduous and semideciduous forests, besides Cerradão (Battilani et al. 2005), and in Tibagi (PR), with influence of alluvial and montane mixed rain forest (Dias et al. 1998); *Cestrum mariquitense* and *P. willdenovii* occur in Cerrado physiognomy (*C. mariquitense* in Itirapina - SP, and *P. wildenovii* in Assis - SP), both in area of Atlantic Forest domain, or in riverine forests with contact with Cerrado (both in Lavras - MG). Still, in Campinas, *P. wildenovii* and *L. guaissara* were sampled in areas of "cerradão" (Viracopos and CEC, respectively) and transitional Cerrado with seasonal forest (Vila Holandia II), in the Anhumas River Basin (Torres et al. 2006; R.B. Torres, personal communication).

Considering the five most important species in the area (Table 2), Mendonça et al. (2008) listed *Dendropanax cuneatus* and *Nectandra*

Table 1. Trees species recorded in a physionomic gradient of riverine forest-cerrado at Campinas, SP, indicating number of inclusion in the IAC herbarium collection and those listed as belonging to cerrado – CE (Mendonça et al. 2008) – and/or riverine forest – MC/MG (Felfili et al. 2001).

Family	Species	CE	MC/MG	IAC number
Anacardiaceae	*Astronium graveolens* Jacq.	X	X	46513
	Lithrea molleoides (Vell.) Engl.	-	X	25873
	Tapirira guianensis Aubl.	X	X	21506
Apocynaceae	*Aspidosperma cylindrocarpon* Müll.Arg.	X	X	51936
Araliaceae	*Dendropanax cuneatus* (DC.) Decne. & Planch.	-	X	50858
Arecaceae	*Acrocomia aculeata* (Jacq.) Lodd. ex Mart.	X	-	-
Asteraceae	*Gochnatia polymorpha* (Less.) Cabrera	X	X	53542
Bignoniaceae	*Handroanthus* cf *heptaphyllus* Mattos	-	X	42630
	Handroanthus ochraceus (Cham.) Mattos	X	-	-
Boraginaceae	*Cordia americana* (L.) Gottschling & J.S.Mill.	-	-	29915
	Cordia trichotoma (Vell.) Arráb. ex Steud.	X	X	53543
Burseraceae	*Protium heptaphyllum* (Aubl.) Marchand	X	X	53522
Cannabaceae	*Celtis pubescens* (Kunth) Spreng.	X	-	53531
	Trema micrantha (L.) Blume	X	X	34804
Chlorantaceae	*Hedyosmum brasiliense* Miq.	-	X	45704
Erythroxylaceae	*Erythroxylum suberosum* A. St.-Hil.	X	-	53529
Euphorbiaceae	*Alchornea sidifolia* Müll.Arg.	X	X	53530
	Sapium glandulosum (L.) Morong	X	-	32142
	Sebastiania brasiliensis Spreng.	-	X	53540
Fabaceae	*Andira fraxinifolia* Benth.	X	X	41909
	Bauhinia longifolia (Bong.) Steud.	X	X	44585
	Copaifera langsdorffii Desf.	X	X	41045
	Dalbergia frutescens (Vell.) Britton	-	X	42242
	Inga sessilis (Vell.) Mart.	-	X	7293
	Lonchocarpus cultratus (Vell.)A.M.G.Azevedo & H.C.Lima	-	X	42065
	Luetzelburgia guaissara Toledo	-	-	18238
	Machaerium aculeatum Raddi	X	X	46444
	Machaerium brasiliense Vogel	X	X	23107
	Machaerium hirtum (Vell.) Stellfeld	-	X	19846
	Machaerium nyctitans (Vell.) Benth.	-	X	39849
	Myroxylon peruiferum L.f.	-	X	12914
	Platypodium elegans Vogel	X	X	29927
Lacistemataceae	*Lacistema hasslerianum* Chodat	X	X	53548
Lamiaceae	*Aegiphila integrifolia* (Jacq.) Moldenke	X	X	53521
Lauraceae	*Nectandra grandiflora* Nees	-	X	5047
	Nectandra nitidula Nees	-	X	53534
	Ocotea velloziana (Meisn.) Mez	X	X	53524
	Persea willdenovii Kosterm.	-	-	42066
Magnoliaceae	*Magnolia ovata* (A.St.-Hil.) Spreng.	-	X	46962
Malvaceae	*Ceiba speciosa* (A.St.-Hil.) Ravenna	-	X	42700
	Luehea candicans Mart. & Zucc.	X	X	53523
	Luehea grandiflora Mart. & Zucc.	X	X	42669
Meliaceae	*Cabralea canjerana* (Vell.) Mart.	X	X	41737
	Guarea macrophylla Vahl	-	-	53537
	Trichilia claussenii C. DC.	-	X	46546
	Trichilia elegans A.Juss.	-	X	53532
	Trichilia hirta L.	-	-	53533
	Trichilia pallida Sw.	X	X	53550
Monimiaceae	*Mollinedia widgrenii* A. DC.	-	X	45111
Moraceae	*Ficus enormis* Mart. ex Miq.	-	X	53536
	Ficus guaranitica Chodat	-	X	53552
	Ficus insipida Willd.	-	X	-
Myrsinaceae	*Rapanea gardneriana* (A.DC.) Mez	X	X	53546

Table 1. Continued...

Family	Species	CE	MC/MG	IAC number
Myrtaceae	*Campomanesia guazumifolia* (Cambess.) O.Berg	X	-	53551
	Eugenia florida DC.	X	X	45108
	Eugenia paracatuana O.Berg.	-	-	53528
	Eugenia pluriflora DC.	X	-	53527
	Eugenia uniflora L.	-	-	39328
	Myrciaria floribunda (H.West ex Willd.) O.Berg	X	X	41208
Nyctaginaceae	*Guapira opposita* (Vell.) Reitz	X	X	46601
Peraceae	*Pera glabrata* (Schott) Poepp. ex Baill.	X	X	35352
Piperaceae	*Piper aduncum* L.	X	X	53213
	Piper arboreum Aubl.	X	X	53541
	Piper mollicomum Kunth	-	X	53214
Rubiaceae	*Guettarda* cf. *uruguensis* Cham. & Schltdl.	-	-	53526
	Guettarda cf. *pohliana* Müll.Arg.	X	X	53525
Rutaceae	*Citrus limon* (L.) Burm.f.	-	-	-
	Zanthoxylum acuminatum (Sw.) Sw.	-	-	46360
	Zanthoxylum fagara (L.) Sarg.	-	-	46564
	Zanthoxylum riedelianum Engl.	X	X	31951
Salicaceae	*Casearia sylvestris* Sw.	X	X	53535
Sapindaceae	*Allophylus edulis* (A.St.-Hil.et *al.*) Hieron.ex Niederl.	-	X	41406
	Cupania vernalis Cambess.	X	X	46969
	Matayba elaeagnoides Radlk.	X	X	39351
Sapotaceae	*Chrysophyllum marginatum* (Hook. & Arn.) Radlk.	X	X	46931
Siparunaceae	*Siparuna guianensis* Aubl.	X	X	53538
Solanaceae	*Cestrum mariquitense* Kunth.	-	-	53547
Styracaceae	*Styrax camporum* Pohl	X	X	53544
Urticaceae	*Cecropia pachystachya* Trécul	X	X	53539
Verbenaceae	*Citharexylum myrianthum* Cham.	-	-	40888

nitidula just for riverine or gallery forests, whereas *Gochnatia polymorpha*, *Protium heptaphyllum* and *Trichilia pallida* are listed for both riverine/gallery forest and Cerrado, and in the current study all these species were observed in plots closer and in plots farther from the stream or in more well drained soils (Table 2). The data from "Lista de Espécies da Flora do Brasil" (Jardim… 2013) are different just for *Gochnatia polymorpha*, which is listed for Cerrado and also for rainforest, not being listed for riverine/gallery forests.

As can be seen in Table 2, the majority of species was found in plots closer and farther from the stream. Considering the species with 10 or more individuals, *Gochnatia polymorpha* and *Chrysophyllum marginatum* were not found only in the first line of occurrence (until 10 meters from the stream) and *Copaifera langsdorffii* was not found in the line farther (line between 40 and 50 meters from the stream). *Styrax camporum* was not found in lines 4 (30 to 40 mesters) and 5 (40 to 50 meters), *Sebastiania brasiliense* in line 3 (20 a 30 meters) and *Erythroxylum suberosum* in lines 1, 2 and 3.

The basal area calculated from the PGL at Fazenda Santa Elisa (51.2 m^2/ha - Table 3) is the second largest of the compiled studies shown on Table 3. When we consider the PBL, the basal area decreases to 29.28 m^2/ha, i.e., intermediate to those other areas. The basal area reported for "cerrados" and riverine forests shows large variation depending on sampling sites (Table 3), from 5.6 m^2/ha (in a "campo cerrado" – Jaguariaíva, PR) to 75.33 m^2/ha (riverine forest – Cuiabá, MT). Overall, riparian forests basal areas were larger than that at "cerrados", but riverine forest of Coxim (MS) showed exceptionally small basal area (12.78 m^2/ha), whereas the "cerrados" of Uberlândia - MG (28.2 and 35 m^2/ha) and Pratânia - SP (41 m^2/ha) showed very high basal area values.

Shannon-Wiener diversity index at the transitional riverine forest/"cerradão" area of Fazenda Santa Elisa (H = 3.49 nats/ind) is very close to the indices found for a dystrophic-soil "cerradão" at Uberlândia, MG (Moreno et al. 2008) and a "cerradão" at Uberlândia, MG (Costa & Araujo 2001). The Shannon-Wiener diversity index at Fazenda Santa Elisa was intermediate to the maximum and minimum values (4.33 and 3.41 nats/ind) found at riverine forests in Bom Sucesso – MG (4.33 nats/ind) and Jardim – MS (3.41 nats/ind), very close to the index found in a riverine forest-Cerrado transition in Itirapina (SP) and larger than the values found for a "cerradão"-swampy forest transition in Brotas, SP (Gomes et al. 2004). In addition to similar diversity indices, the dystrophic-soil "cerradão" (Moreno et al. 2008) and the other "cerradão" (Costa & Araujo 2001), both at Uberlândia, MG, showed Pielou evenness values close to the one of Fazenda Santa Elisa (0.79 – Table 3).

From a similarity matrix composed by 665 species from the publications listed on Table 3 and Table 4, just 241 (36.2%) were selected for clustering since they occurred in three or more surveys. Among those species, none occurred in all surveys, being *Casearia sylvestris* (Flacourtiaceae) the one with the higher incidence (19 of 33 areas), followed by *Tapirira guianensis* (Anacardiaceae - 17 occurrences) and *Copaifera langsdorffii* (Fabaceae - 16 occurrences), all of the three sampled in the Santa Elisa study.

The Mantel's test (Monte Carlo $\rho = 0.001$) opposing geographical distance (geographic coordinates) and species abundance showed

Table 2. Phytosociological parameters of the species ordered by IVI (Importance Value Index) from measurements of perimeter at ground level (PGL), sampled in the physiognomic gradient of riverine forest in a Cerrado area in Campinas, SP. NInd - number of individuals; FA - absolute frequency; DoA - absolute dominance; Line – occurrence line from species individuals: 1 – line until 10 meters away from the stream, 2 – until 20 meters away from the stream, 3 – until 30 meters away from the stream, 4 – until 40 meters away from the stream, 5 – until 50 meters away from the stream.

Species	NInd	FA	DoA	IVI	Line
Nectandra nitidula	134	88	8.98	36.91	1, 2, 3, 4, 5
Gochnatia polymorpha	33	36	7.69	20.75	2, 3, 4, 5
Dendropanax cuneatus	85	52	1.73	15.42	1 2, 3, 4, 5
Protium heptaphyllum	72	64	1.73	14.90	1, 2, 3, 4, 5
Trichilia pallida	76	72	0.94	14.30	1, 2, 3, 4, 5
Styrax camporum	26	32	3.21	11.02	1, 2, 3
Guarea macrophylla	51	52	0.53	9.65	1, 2, 3, 4, 5
Copaifera langsdorffii	23	32	1.51	7.39	1, 2, 3, 4
Machaerium hirtum	8	12	3.07	7.60	1
Tapirira guianensis	16	32	1.53	6.74	1, 2, 3, 4, 5
Platypodium elegans	9	16	2.05	5.98	3, 4, 5
Mollinedia widgrenii	26	36	0.45	5.89	1, 2, 3, 4, 5
Cecropia pachystachya	20	40	0.39	5.44	1, 2, 3, 4, 5
Chrysophyllum marginatum	24	28	0.58	5.42	2, 3, 4, 5
Siparuna guianensis	24	36	0.29	5.39	1, 2, 3, 4, 5
Cordia trichotoma	15	32	0.78	5.16	1, 2, 3, 4, 5
Luehea candicans	11	32	0.93	5.06	1, 2, 3, 4, 5
Lonchocarpus cultratus	9	28	1.05	4.83	3, 4, 5
Trichilia claussenii	20	32	0.31	4.75	1, 2, 3, 5
Ocotea velloziana	14	36	0.25	4.30	1, 2, 3, 4, 5
Sebastiania brasiliensis	15	20	0.59	3.99	1, 2, 4, 5
Casearia sylvestris	10	28	0.45	3.75	1, 2, 3, 4, 5
Machaerium aculeatum	7	24	0.60	3.46	1, 2, 4
Myroxylon peruiferum	8	24	0.40	3.18	1, 2, 3
Eugenia pluriflora	12	24	0.15	3.09	1, 3, 4, 5
Zanthoxylum riedelianum	7	20	0.38	2.77	3, 4, 5
Aspidosperma cylindrocarpon	6	16	0.56	2.77	1, 2, 3
Piper arboreum	10	24	0.05	2.71	2, 3, 4, 5
Eugenia florida	7	24	0.06	2.42	1, 2, 3, 4
Erythroxylum suberosum	13	12	0.16	2.43	4, 5
Aegiphila integrifolia	5	20	0.25	2.32	1, 3, 5
Magnolia ovata	8	12	0.36	2.31	1, 2
Pera glabrata	4	16	0.34	2.14	2, 4
Myrciaria floribunda	8	16	0.05	1.96	1, 2, 3, 5
Dalbergia frutescens	6	12	0.19	1.77	1, 3, 5
Matayba elaeagnoides	4	16	0.13	1.73	3, 5
Bauhinia longifólia	3	12	0.32	1.72	1, 3
Citharexylum myrianthum	1	4	0.58	1.50	2
Ficus guaranitica	4	12	0.15	1.49	3, 5
Allophylus edulis	4	12	0.12	1.44	1, 3, 4
Piper mollicomum	4	12	0.02	1.24	2, 4
Zanthoxylum fagara	3	12	0.05	1.19	2, 4, 5
Persea willdenovii	3	12	0.05	1.19	1, 2, 5
Rapanea gardneriana	5	8	0.07	1.17	1, 2
Piper aduncum	3	12	0.03	1.17	1, 2, 3
Andira fraxinifolia	3	12	0.03	1.15	1, 2, 3
Cestrum mariquitense	3	12	0.01	1.13	1, 2, 3
Acrocomia aculeata	1	4	0.35	1.06	2
Nectandra grandiflora	3	8	0.05	0.93	1, 2
Campomanesia guazumifolia	2	8	0.08	0.89	3, 5
Luetzelburgia guaissara	2	4	0.22	0.89	3
Ficus enormis	1	4	0.27	0.89	3
Sapium glandulosum	2	8	0.04	0.80	1, 2

Table 2. Continued...

Species	NInd	FA	DoA	IVI	Line
Machaerium brasiliense	1	4	0.21	0.79	1
Machaerium nyctitans	2	8	0.01	0.76	1, 5
Eugenia paracatuana	2	8	0.01	0.75	1, 5
Trichilia elegans	2	8	0.01	0.75	1
Luehea grandiflora	1	4	0.18	0.73	4
Hedyosmum brasiliense	2	4	0.09	0.65	2
Guettarda cf *uruguensis*	2	4	0.04	0.54	1
Ficus insipida	2	4	0.03	0.54	2
Lithrea molleoides	1	4	0.09	0.54	5
Cordia americana	1	4	0.09	0.54	1
Trichilia hirta	1	4	0.07	0.51	5
Cabralea canjerana	1	4	0.05	0.46	1
Ceiba speciosa	1	4	0.04	0.45	2
Handroanthus ochraceus	1	4	0.04	0.44	5
Zanthoxylum acuminatum	1	4	0.03	0.42	5
Alchornea sidifolia	1	4	0.01	0.38	2
Celtis pubescens	1	4	0.00	0.38	5
Inga sessilis	1	4	0.01	0.38	2
Astronium graveolens	1	4	0.01	0.38	5
Citrus limon	1	4	0.01	0.38	2
Cupania vernalis	1	4	0.00	0.38	4
Eugenia uniflora	1	4	0.00	0.38	1
Handroanthus cf. *heptaphyllus*	1	4	0.01	0.38	5
Trema micrantha	1	4	0.01	0.38	5
Guapira opposita	1	4	0.00	0.37	1
Lacistema hasslerianum	1	4	0.00	0.37	4
Guettarda cf. *pohliana*	1	4	0.00	0.37	2

a positive association between the matrices (r = 0.282010; Z observed = $0.374977*10^2$; mean Z = $0.365916*10^2$), that means floristic similarity among areas is slightly influenced by their proximity. The dependence of similarity on distance between areas may be due to the great similarity among different areas of Campinas. However, this similarity is not distributed evenly among the different areas of Campinas. The similarity (Figure 2) is greater between the four Cerrado areas of Campinas (Synchrotron Laboratory, CEC, "Viracopos" and "São Marcos") and a "cerradão"-semideciduous forest transition (Vila Holândia). The dendrogram (Figure 2) shows that similarity of swampy areas is smaller with other phytophysiognomies at Campinas. Through ordination analysis (PCO), the study area was in an intermediate position between Cerrado areas and forests (including swampy areas), although the dendrograms (including ones with complete linkage and with minimum linkage) group swampy areas in opposition to other phytophysiognomies at Campinas (data not shown).

Discussion

In the study area, 22 species had more than 10 individuals each, and the five species with the highest IVI accounted for 41.2% of the total sampled individuals. This is common in Cerrado areas, where there are about 20 dominant species and the other species are scarce (Felfili et al. 2008). Likewise, in the case of gallery forests, most species occur at low densities, with few species contributing to most individuals (Silva Junior et al. 2001).

A large variation in species composition, basal area and other phytosociological parameters were found at the different compared studies. In the Jacaré-Pepira Basin, great structural variability was observed in different fragments along the river: in narrower fragments, the greater influence of the river decreases number of species (Bernacci et al. 1998). Even though forest vegetation near watercourses may have transitional structure, that differs according to the dominant environment (Metzger et al. 1998), which can range from waterlogged to well-drained, it was not possible to distinguish different phytophysiognomies in relation to vegetation structure in the Jacaré-Pepira Basin. In riparian conditions, the hydrology of the area is the main determinant of the distribution and composition of plant species (Rodrigues & Shepherd 2001). The Cerrado areas also have a huge structural variability determined by edaphic characteristics, that generates large differences in height and density of individuals (Rizzini 1997).

Occurrence of most of the sampled species in this study, including ones with greater local importance, both in riverine forest and in Cerrado (generalist species), and their distribution either in plots close to the stream or in more remote plots with better drained soil, indicates the gradient character of the area, mainly related to differences on species density distribution (Carvalho 2012). The small number of exclusive Cerrado species in study area indicates that riverine environment represents a very different condition in relation to that of Cerrado. In this same site, species common in savannas as *Copaifera langsdorffii*, *Erythroxylum suberosum* and *Gochnatia polymorpha* occurred preferentially where the soil had higher content of sand and water table was deeper, while common species in riparian forests, such as *Dendropanax cuneatus* and *Guarea macrophylla*, occurred where soil had higher content of clay and the water table was shallower (Carvalho 2012).

Table 3. Comparison of density (Dens), basal area (AB), percentage of dead individuals, Shannon-Wiener diversity index (H') and Pielou evenness (J) between the present study, in a physiognomic riverine forest-cerrado gradient at Campinas (SP), and other studies in areas of transition, Cerrado and riverine forest, alphabetically ordered. Data of publications identified with code were also used for the similarity dendrogram. Cont - contiguous plots; Trans - plots in transects; Disj – disjoint plots; DAS - diameter at ground level; D30 – diameter at 30 cm from soil surface; DAP - diameter at breast height. PAS - perimeter at ground level; P30 - perimeter at 30 cm from soil surface; PAP - circumference at breast height.

Physiognomy	References	Municipality	Method	Area	Inclusion	Dens.	AB	H'	J	Code
				(m^2)		ind/ha	m^2/ha	nats/ind		
riverine forest-"cerradão"	Este trabalho	Campinas (SP)	Trans	2500	DAS ≥ 3cm	3964	DAS: 51.28 DAP: 29.28	3.49	0.79	**TCps**
riverine forest	Amaral et al. 2010	Coxim (MS)	Disj	6000	PAP ≥ 20cm	545	12.78	-	-	**FRCox**
riverine forest	Battilani et al. 2005	Jardim (MS)	Trans	9000	PAP ≥ 10cm	735	21.32	3.41	0.81	**FRJar**
"cerradão"	Costa & Araújo 2001	Uberlândia (MG)	Cont	10000	PAP ≥ 15cm	2071	17.06	3.54	0.78	**CUb1**
"cerrado *sensu stricto*"	Costa & Araújo 2001	Uberlândia (MG)	Cont	6800	PAP ≥ 15cm	1066	9.63	3.63	0.84	**CUb2**
riverine forest	Dias et al. 1998	Tibagi (PR)	Cont	10000	DAP ≥ 5cm	1594	-	3.67	-	**FRTib**
riverine forest–Cerrado	Giannotti 1988	Itirapina (SP)	Disj	6250	DAS ≥ 3cm	1413	36.12	3.43	-	**TIti**
"cerrado *sensu stricto*"	Giannotti 1988	Itirapina (SP)	Disj	6250	DAS ≥ 3cm	6165	36.12	3.64	-	**CIti**
"cerradão"-swampy forests	Gomes et al. 2004	Brotas (SP)	Disj	10000	DAS ≥ 3cm	3787	36.20	3.37	-	**TBro**
"cerradão"	Ishara 2010	Pratânia (SP)	Cont	5000	DAS ≥ 3cm	5832	41.00	3.14	0.75	**-**
"cerradão"	Marimon Junior & Haridasan 2005	Nova Xavantina (MT)	-	5000	D30 > 5cm	1884	21.40	3.67	0.84	**CNXa1**
"cerrado *sensu stricto*"	Marimon Junior & Haridasan 2005	Nova Xavantina (MT)	-	5000	D30 > 5cm	1890	14.90	3.78	0.87	**CNXa2**
dystrophic "cerradão"	Moreno et al. 2008	Uberlândia (MG)	Disj	2800	P30 ≥ 10cm	4404	28.20	3.47	0.78	**-**
mesotrophic "cerradão"	Moreno et al. 2008	Uberlândia (MG)	Disj	1000	P30 ≥ 10cm	3140	35.00	3.57	0.85	**-**
riverine forest	Oliveira-Filho et al. 1990	Cuiabá	Cont	2010	PAS ≥ 9cm	1487	75.33	-	-	**FRCui**
riverine forest	Oliveira-Filho et al. 1994a	Lavras (MG)	Cont	4800	PAS > 15.3 cm	2177	39.00	4.20	0.88	**FRLav**
riverine forest	Oliveira-Filho et al. 1994b	Bom Sucesso (MG)	Trans	5400	DAS ≥ 5cm	2991	47.60	4.33	0.86	**-**
"cerradão"	Pinheiro & Durigan 2012	Assis (SP)	Disj	10000	DAP ≥ 5cm	1779	21.40	3.19	0.75	**CAss**
"campo cerrado"	Uhlmann et al. 1998	Jaguariaíva (PR)	Cont	4000	PAS ≥ 15cm	857	5.63	1.90	0.66	**CJag1**
"cerrado *sensu stricto*"	Uhlmann et al. 1998	Jaguariaíva (PR)	Cont	4000	PAS ≥ 15cm	1372	12.38	2.78	0.80	**CJag2**
riverine forest	Van der Berg & Oliveira-Filho 2000	Itutinga (MG)	Disj	8400	DAS ≥ 5cm	2553	45.03	3.92	0.79	**FRItu**

Table 4. Areas from the municipality of Campinas used in the similarity matrix and for floristic comparison.

Physiognomy	Location	Code
semideciduous forest	Mata Santa Elisa	**FSMSE**
semideciduous forest	Parque Xangrilá I	**FSPX1**
semideciduous forest	Vila Holândia I	**FSVH1**
swampy forest	Recanto Yara	**FRRY**
swampy forest	Sítio San Martinho	**FRSM**
swampy forest	Tozan I	**FRT1**
swampy forest	Tozan II	**FRT2**
semideciduous forest- riverine forest	Condomínio Estância Paraíso	**FREP**
semideciduous forest- riverine forest	Parque Ecológico Hermógenes de Freitas Leitão Filho	**FRPHF**
semideciduous forest- riverine forest	Parque Xangrilá II	**FRPX2**
semideciduous forest- riverine forest	Parque Ecológico Monsenhor Jardim	**FRPMJ**
semideciduous forest-"cerradão"	Vila Holândia II	**TVH2**
"cerradão"	Viracopos	**CVira**
"cerradão"	São Marcos	**CSM**
"cerradão"	Laboratório Sincotron	**CLSin**
"cerradão"	CEC	**CCEC**

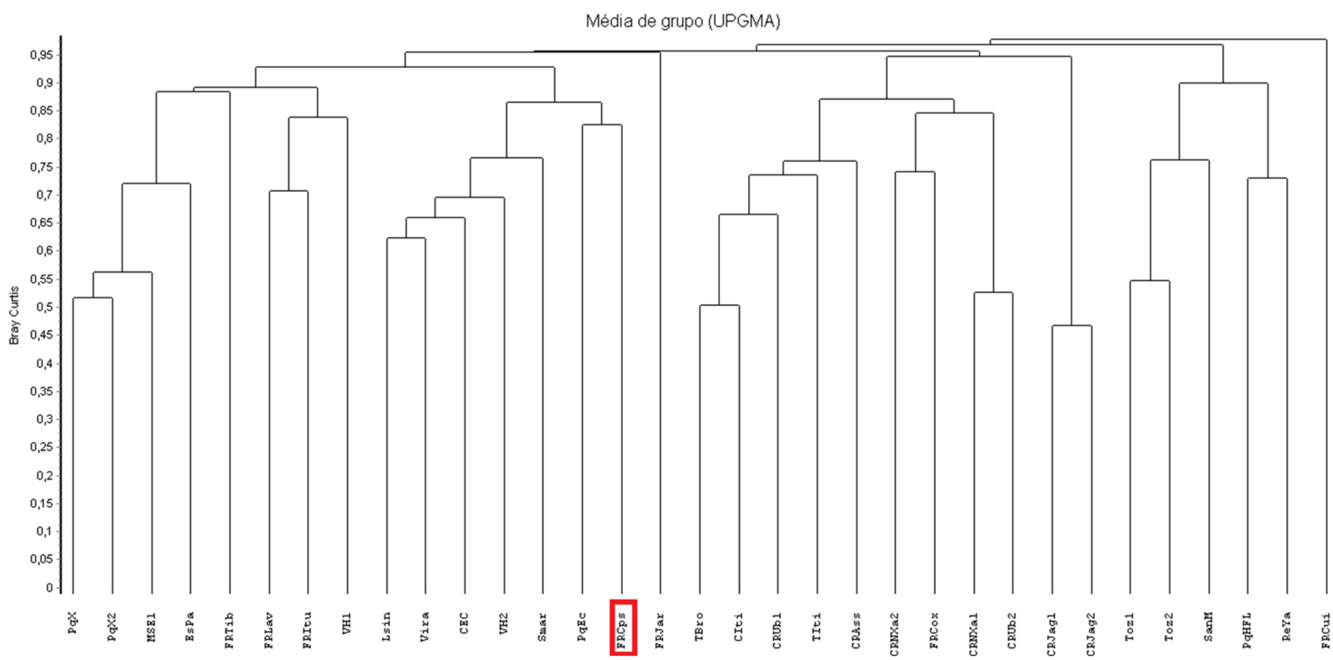

Figure 2. Similarity analysis using Bray-Curtis coeficient and group average as hierarchical clustering method (UPGMA) to compare the study area to other areas of cerrado, riverine forests and transitional physiognomies of Brazil. □ Study area.

Except for the swampy forest fragments from Campinas, that formed a single similar group, there was low floristic similarity among the riverine forests compared on Table 4. They did not form a homogeneous group, nevertheless showing greater similarity to the cerrado fragments of different regions of Brazil. According to Rodrigues & Nave (2000), the riverine forests exhibit high floristic heterogeneity, with low values of similarity among themselves and low frequency of species, showing higher floristic similarities with the surrounding non-riparian vegetation than with riparian forests farther away (Rodrigues & Shepherd 2001). Certainly, the fact that riparian forests are present in several domains of different regions in Brazil, contributes for this physiognomy to have species from other physiognomic domains, thus favoring the high floristic diversity among them. Additionally, our results indicate that even considering riverine forests within a single vegetation type such as Cerrado, the diversity among different riparian forests is very large. This result must be due to the diversity of "cerrados", considered a global hotspot, that even when its local diversity (α) is not very large, it shows large diversity of endemic species, the ones that occur in restricted regions, typical of a particular environment. Still, our results support to state that only swampy areas are more homogeneous and floristically similar (Bernacci et al. 1998, Rodrigues & Nave 2000), being very important forests since their species support major environment constraints.

The transition between riparian forests and savannas did not present particular floristic and phytosociological structure. This transition was very variable one to the other, as already observed between different ecotonal areas (Lloyd et al. 2000, Kark & Van Rensburg 2006). Small similarity among the analyzed riverine forests highlights particularities of this type of vegetation and the importance of studying these areas for knowing their flora in each region, especially when considering restoration or management actions. Brazilian former forest legislation ("Código Florestal Brasileiro" - Brasil 1965) states that rivers less than 10 m wide should have a permanent preservation area of 30 m on each side, represented by riparian vegetation. However, current legislation (Brasil 2012) provides the possibility of reducing the width of areas along watercourses depending on the property size. This study showed that riparian species occur along the entire 50 m distance from the stream, i.e., the whole study area, corroborating the indication that 30 m of riparian vegetation is still a small number, regardless biome, taxonomic group, soil or topography, and that at least 50 m of riparian vegetation should be kept at each side of the drainage channel to ensure maintenance of biodiversity (Metzger 2010). Because riverine forests have different functions, the vegetation width considered has to be sufficient for fulfilling, at least, the more demanding ecosystem services, thus including biodiversity conservation (Silva et al. 2011)

We observed large number of individuals from three different endangered species (São Paulo 2004) in the study area: *Luetzelburgia guaissara* and *Myroxylon peruiferum* (Fabaceae) and *Trichilia hirta* (Meliaceae), with 2, 8 and 1 individuals, respectively. The occurrence of rare and endangered species and the importance of maintaining biodiversity conservation has been highlighted for fragments of native vegetation in areas of cerrado (Felfili et al. 2008). Although the study area is under regeneration and has received traffic of people with non-research purposes, the occurrence of one single exotic individual and high number of individuals of endangered species shows the area retains much of the original characteristics of the native vegetation and reinforces the importance of this small ecotonal area of riverine forest transitional to Cerrado.

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