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GALLERY FORESTS FLORA AND TREE STRUCTURE REINFORCE ATLANTIC FOREST OCCURRENCE IN BRAZILIAN CENTRAL PLATEAU

Nascimento NM[1], Guilherme FAG[2, 3, *] Ressel K[3], Ferreira GL[1], Carneiro SES[2,3] & Silva GE[2,3]

[1] *Departamento de Engenharia Florestal, Universidade Federal de Jataí, Jataí, GO, Brazil*
[2] *Unidade Acadêmica de Ciências Biológicas, Universidade Federal de Jataí, Jataí, GO, Brazil*
[3] *Programa de Pós-Graduação em Geografia, Universidade Federal de Jataí, Jataí, GO, Brazil*

**fredericoagg@ufj.edu.br*

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This study aimed to compare the phytosociological structure of two gallery forest patches; the flooded gallery forest and non-flooded gallery forest. Both were located in a forest remnant in the transition zone between Cerrado and Atlantic Forest biomes in south Goiás state of Brazil. For each physiognomy, twenty-five 20 m × 20 m permanent plots were allocated including tree individuals with $DBH_{1.3m} \geq 5.0$ cm. The whole survey recorded 2628 individuals, belonging to 108 species distributed in 41 families. Flooded gallery forest showed higher density and basal area, although larger trees occurred more in non-flooded gallery forest. Both physiognomies showed floristic similarity and similarity in species/abundance relationship, probably due to the geographical proximity between them. The diversity index in flooded gallery forest was significantly lower than in non-flooded gallery forest. It was probably due to the low equitability in flooded gallery forest caused by the predominance of *Euterpe edulis* plants with 42.2% of the total density. This palm tree is characteristic of the Atlantic Forest and had the highest importance value in the study with density of 633 individual ha^{-1} in flooded gallery forest and 178 individual ha^{-1} in non-flooded gallery forest. In addition to the predominance of *E. edulis*, other floristic components recorded in the study pointed to a strong floristic connection of these gallery forests in south Goiás between the Cerrado and Atlantic Forest.

Keywords: Cerrado-Atlantic Rainforest boundaries, *Euterpe edulis*, phytogeography, phytosociology, swamp forests, tropical forest ecology

INTRODUCTION

Among all savannas in the world, Cerrado is the most biodiverse place. Its biodiversity was not only due to its geographical extent, but mainly because of the vast zones of transition with all other Brazilian biomes excluding the Pampas (Melo et al. 2021). Presently, ecological studies in these border regions had gained prominence because of the composition and richness of species were distinct from the other adjacent ecosystems (Lloyd et al. 2012, Andriani et al. 2020). Although the Cerrado was represented by many endemic species, these ecotones allowed a wide distribution of several species along the Brazilian biomes (Françoso et al. 2016). This co-occurrence was due particular to the riverside or riparian forests, linking the Amazon and Atlantic Forest biomes (Oliveira-Filho & Ratter 1995, Chiminazzo et al. 2021). Therefore, from the floristic point of view, these forests in Cerrado had strong links with the Atlantic Forest further south or with the Amazon in the north-central Brazil region (Méio et al. 2003) Thus, they had become important for research on the influence of geographic and historical factors on their biota. These forest floristic links were mostly explained by the climatic fluctuations of the Quaternary period, which allowed successive expansions and retractions of forests in the Brazilian Central Plateau. Recent phytogeographic studies had shown these connections between biomes (Françoso et al. 2020), although most studies still focused on the Cerrado-Amazon transition.

In Central Brazil, one of these riverside environments was gallery forests, which originally covered an approximate area of 10.2 million ha, encompassing around 5% of the original territorial scope of the Cerrado (Guarino &

Walter 2005). These forests normally occupied valley bottoms, following the course of small rivers and streams, or even surrounding diffuse springs and zones of water accumulation without defined current flow (Chiminazzo et al. 2021). According to Ribeiro & Walter (2008), based on flood regimes, gallery forests could be classified as flooded gallery forests and non-flooded gallery forests, as adopted in the present study. Non-flooded gallery forests were found in soils with good drainage, normally rugged topography, bordering well-defined and constantly flowing watercourses. On the other hand, flooded gallery forests were also known as swamp forests, palustrine forests or hygrophilous broadleaved forests. Despite often appearing in riparian forests or associated with non-flooded gallery forests, flooded gallery forests were subjected to the presence of water in the soil on an almost permanent basis, established on hydromorphic soils (Oliveira-Filho & Ratter 1995, Ribeiro & Walter 2008). They also had long patches of flat topography and, therefore, had poorly defined drainage (Nogueira & Schiavini 2002, Guilherme et al. 2013). All these factors contributed to the selectivity of species in flooded gallery forests, mainly in relation to physiological, anatomical and morphological adaptability (Kurtz et al. 2014).

Gallery forests stood out for their high genetic diversity and richness of plant species adapted specially to water stress (Nogueira & Schiavini 2002, Marimon-Junior et al. 2020). In addition to being home to plant species adapted to such environments, these forests were important for providing ecosystem services and maintaining the gene flow, due to their natural formation of ecological corridors and maintenance of water sources (Armenteras et al. 2021). However, logging and wood harvesting were the most critical swamp forests threats in Brazil, that impacted vulnerable and endangered species in the last years (Chiminazzo et al. 2021).

Presently, studies related to vegetation structure in gallery forests predominated in the Federal District and Southeast Region (Toniato et al. 1998, Nogueira & Schiavini 2002, Guarino & Walter 2005, Guilherme et al. 2013, Kurtz et al. 2014). For the states in the Brazilian Midwest, a preliminary study was conducted by Souza et al. (2018) in the southwestern Goiás and surveys in these ecosystems were not sufficient. Therefore, this work would be an important reference for future studies of the similar type in the Midwest Brazilian region. In addition, it aimed to complement phytogeographic information about these humid forests, which were potential floristic links between the many Brazilian biomes.

This study aimed to analyse the structure of the tree community in flooded gallery forests and non-flooded gallery forests in order to increase knowledge on gallery forests in Goiás state. Also in view of the small geographical portion that these physiognomies occupied but with the increasing anthropic advances in Central Brazil, especially due to the rise of agribusinesses. The study also intended to comparatively evaluate the two forest formations on the parameters of horizontal and vertical structure, richness, tree diversity, floristic composition and similarity. The results of the findings were compared the results of other already conducted similar studies. Due to the proximity of the study areas to the Atlantic Rainforest biome at approximately 65 km in a straight line, floristic links were discussed in a phytogeographic context especially considering the transition zones between Cerrado and Atlantic Forest. With reference to their distinctive characteristics especially the soil drainage conditions, the study worked with the hypothesis that flooded gallery forests and non-flooded gallery forests had differences in the parameters of structure, floristic composition, richness and diversity, despite being geographically close with each other.

MATERIAL AND METHODS

Study site

The study was carried out in physiognomies of flooded gallery forest and non-flooded gallery forest, which occurred in the lower part of a forest remnant with a total area of approximately 5,000 hectares in the municipalities of Itajá and Aporé (18° 55’ 55” S–51° 41’ 38” W) of south Goiás state. Due to the involvement in an agricultural matrix, the remnant native vegetation of the regions faced high environmental vulnerability and had great potential for the implementation of protected area (Carneiro et al. 2020). Due to the considerable extent and effort to preserved natural ecosystems and the variety of physiognomies it encompassed, in addition to the gallery forests studied, all the other forest physiognomies described for the Cerrado

(Ribeiro & Walter 2008) and in transition Cerrado-Atlantic Forest biomes (Ferreira et al. 2020) was also included.

Based on Köppen's classification, the regional climate was the seasonal Aw type with a dry and cold period from April to September and another rainy and warm period from October to March which were well defined in the year. The approximate average rainfall was 1500 mm year^{-1}, poorly distributed throughout the year with predominance of rains between October and March with average annual temperature between 24 °C and 25 °C (Wachholz et al. 2020). The predominant soil types where the gallery forests were essentially located were *Latossolos Vermelhos* (Oxisols), *Neossolos Quartzarênicos* (Entisols), *Argissolos* (Ultisols) and a small portion of *Gleissolos* (Entisols). The remnant area had an altitude varying between 520 and 650 m and the relief was characterised by steep slopes in the better drained areas and flattened surfaces in valley bottoms, showing basalt and sandstone decomposition with sandy plateau (Carneiro et al. 2020).

Survey of the tree community and data analysis

Twenty-five permanent plots of 400 m^2 (20 m × 20 m) were allocated with a total of one hectare in each physiognomy and two hectares of sampling in total. In flooded gallery forests, the plots were arranged contiguously, ensuring the allocation was under hydromorphic soil conditions and avoiding the inclusion of the surrounding vegetation on better drained soils. For non-flooded gallery forests, the soil drainage characteristics was one of the main distinguishing factors between the physiognomies of gallery forest. Thus, the plots were distributed on both banks along the watercourse in a non-contiguous way with an approximate distance of 500 m between the surveys.

All living woody individuals with diameter at breast height ($DBH_{1.30m}$) ≥ 5cm except lianas, were included in the survey and measured with a diameter tape. For individuals with tillering, those only with stems within the inclusion criterion were included. The height of the individuals was estimated using graduated sticks. For the purpose of future monitoring, all plants were marked with numbered aluminum platelets and botanical identification was generally made in the field. Individuals with dubious identification, had samples collected for later identification and registration in the *Herbarium Jataiense* (HJ) of the Federal University of Jataí. Plant species classification in families were based on the Angiosperm Phylogeny Group system (APG IV, 2016).

The tree structure data were calculated with reference to methods by Mueller-Dombois & Ellenberg (1974). Phytosociological parameters such as relative density, relative frequency, relative dominance and importance value were calculated for every species in each physiognomy. Sørensen's qualitative and Morisita's quantitative similarity indices were also calculated and compared between the two gallery forests. Data processing and analysis were performed in a spreadsheet in Microsoft Office Excel. Student's t-test was used to compare height, density and mean basal area per plot between non-flooded gallery forests and flooded gallery forests. Shannon diversity index and Pielou equitability index were calculated for both physiognomies using the BioEstat 5.0 software (Ayres et al. 2007). Hutcheson's t-test was used to compared diversity in pairs for each physiognomy. Tree density distributions by diameter and height classes for each physiognomy were calculated and frequencies were compared by chi-square test (χ^2) using the BioEstat 5.0 software. In order to enable better representation of classes with larger diameter and lower density, diameter class intervals with increasing amplitudes were used to compensate for the decrease in density in larger size classes.

RESULTS

A total of 2,628 individuals were recorded in the two gallery forests. The 1,492 individuals in flooded gallery forests and 1,136 individuals in non-flooded gallery forests were consisted of 108 species and 41 botanical families, whereas the basal areas in flooded gallery forests and non-flooded gallery forests were 35.7 m^2 ha^{-1} and 23.2 m^2 ha^{-1}, respectively. Therefore, both density (t = 3.63; P < 0.01) and mean basal area (t = 3.36; P < 0.01) in flooded gallery forests were significantly higher than in non-flooded gallery forests (Table 1). The mean heights of the trees did not differ significantly between the physiognomies. Species richness was markedly higher in non-flooded gallery forests at 87 species than in flooded gallery forests at 66 species. These

Table 1 Tree structure parameters in flooded (FLG) and non-flooded (NFG) gallery forests, south Goiás state

Gallery forests	Individuals number	Basal area (m^2 ha^{-1})	Height (m)	Nsp	H'	J'
Flooded (FLG)	57.7 ± 12.1	1.34 ± 0.52	7.9 ± 0.52	66	2.49	0.60
Non-flooded (NFG)	43.3 ± 10.1	0.95 ± 0.36	8.3 ± 0.36	87	3.51	0.79
Total				108	3.15	0.65

Values are means (± standard deviation); Nsp = species number, H' = diversity, J' = equitability indexes

results directly influenced the diversity which was significantly higher in non-flooded gallery forests ($t = 17.61$; $P < 0.0001$) as a consequence of the low equitability and lower number of species recorded in flooded gallery forests (Table 1).

In flooded gallery forests, the richest families in terms of species were Moraceae with 7 species, Meliaceae with 6 species, Fabaceae and Myrtaceae with 5 species, and Lauraceae with 4, which accounted for 40% of the total species richness. Interestingly, none of these families had a representative species among the five with the highest importance value. Families such as Calophyllaceae, Anacardiaceae and Burseraceae, represented by only one species each. Emerged among the most important for this physiognomy, particularly Arecaceae with two species recorded was predominantly due to *Euterpe edulis* with highest importance value (Table 2). On the other hand, in non-flooded gallery forests the most representative families were Fabaceae with 12 species, Lauraceae and Myrtaceae with 11 species, Meliaceae with 8 species and Salicaceae with 7 species. For non-flooded gallery forests, out of the five richest families three have representative species among the most important ones (Table 2). However, Fabaceae had no species among those with highest importance value. At the genus level, *Nectandra* with 7 species, *Eugenia* with 5 species, *Ficus* with 5 species and *Trichilia* with 4 species were among the ones with the highest number of species in the total survey.

The test of χ^2 (Figure 1A) showed that flooded gallery forests had significantly higher density in the smallest diameter class from 5.0 cm to 10.0 cm compared to non-flooded gallery forests ($\chi^2 = 11.75$, $P < 0.001$), while non-flooded gallery forests showed significantly higher density than flooded gallery forests in the diameter classes from 10.1 cm to 20.0 cm ($\chi^2 = 5.15$, $P < 0.05$) and from 20.1 cm to 40.0 cm ($\chi^2 = 5.12$, $P < 0.05$). For the height classes (Figure 1B), there was a significant difference only in the last class (>15.0 m), in which non-flooded gallery forests had higher abundance of taller trees than flooded gallery forests ($\chi^2 = 5.79$, $P < 0.05$). Generally, flooded gallery forests had higher density of thinner and shorter trees, while non-flooded gallery forests had higher density of larger trees.

Of all the species sampled, 43 species occurred in both physiognomies (Table 2). The qualitative and quantitative similarities between flooded gallery forests and non-flooded gallery forests were 56% and 62%, respectively. They showed floristic similarities and above all similarity in the species/abundance relationship between them. The greatest contribution to the high similarity came from species that were more abundant and with higher importance value in the total survey, especially *E. edulis* and *Tapirira guianensis.* Both were also the only ones that occurred in more than 80% of the plots in each physiognomy, thus culminating in high relative frequency.

The species with the highest importance value in flooded gallery forests were *E. edulis*, *T. guianensis*, *Cedrela odorata*, *Calophyllum brasiliense*, *Protium heptaphyllum*, *Magnolia ovata* and *Dendropanax cuneatus.* In general, all species had high relative density and relative dominance except the last one mentioned with smaller individuals (Table 2). In addition, all species are well known as indicators of these palustrine environments. In non-flooded gallery forests, the species with the highest importance value were *E. edulis*, *Guarea kunthiana*, *Garcinia gardneriana*, *Casearia gossypiosperma*, *Guarea guidonia*, *T. guianensis* and *Inga edulis.* The last three mentioned had high relative dominance values and were hence represented with larger individuals in the survey. The others had high importance value especially due to their densities.

Table 2 Tree species parameters in flooded (FLG) and non-flooded (NFG) gallery forests, south Goiás state

Species	Total survey			FLG			NFG		
	NI	BA	IV	RD	RDo	RF	RD	RDo	RF
Euterpe edulis Mart.	811	6.818	46.0	42.4	15.1	7.0	15.7	6.2	4.5
Tapirira guianensis Aubl.	220	10.336	29.5	11.5	23.0	6.8	4.3	9.1	4.3
Cedrela odorata L.	76	5.099	14.0	4.8	14.0	4.8	0.4	0.4	0.6
Calophyllum brasiliense Cambess.	84	3.673	12.5	5.0	10.0	5.6	0.9	0.4	1.3
Guarea guidonia (L.) Sleumer	62	3.268	10.6	0.8	0.2	2.3	4.4	13.8	3.9
Guarea kunthiana A. Juss.	107	1.738	10.6	2.0	0.5	3.7	6.8	6.7	4.7
Protium heptaphyllum (Aubl.) Marchand	76	2.357	9.8	3.4	5.4	4.2	2.3	1.9	2.4
Richeria grandis Vahl	61	2.637	9.4	2.0	5.5	3.4	2.7	2.9	1.7
Casearia gossypiosperma Briq.	103	0.640	8.3	3.2	0.6	5.1	4.8	1.8	4.1
Magnolia ovata (A.St.-Hil.) Spreng.	55	1.806	7.5	3.0	4.5	4.5	0.9	0.9	0.9
Dendropanax cuneatus (DC.) Decne. & Planch	63	0.810	7.1	3.6	2.1	6.2	0.8	0.3	0.9
Garcinia gardneriana (Planch. & Triana) Zappi	71	1.112	6.7	0.1	0.0	0.6	6.1	4.7	3.2
Tabebuia insignis (Miq.) Sandwith	34	1.817	6.4	2.3	5.1	3.9	-	-	-
Inga edulis Mart.	30	1.665	6.1	0.3	0.4	1.1	2.2	6.5	3.2
Nectandra cissiflora Nees	20	1.468	5.0	0.2	0.2	0.6	1.5	6.0	2.4
Unonopsis guatterioides (A.DC.) R.E.Fr.	46	0.291	5.0	-	-	-	4.0	1.3	4.1
Eugenia subterminalis DC.	61	0.239	4.9	0.6	0.1	1.1	4.6	0.9	2.4
Casearia commersoniana Cambess.	43	0.272	4.3	0.1	0.0	0.3	3.7	1.1	3.2
Allophylus edulis (A.St.-Hil. et al.) Hieron.	40	0.254	4.3	0.7	0.1	1.1	2.6	0.9	3.0
Miconia collatata Wurdack	47	0.255	4.2	1.3	0.3	1.1	2.5	0.7	2.1
Nectandra lanceolata Nees	31	0.774	3.9	0.7	0.4	0.8	1.8	2.7	1.9
Eugenia sp.	40	0.304	3.8	1.0	0.2	1.7	2.2	0.9	1.9
Eugenia florida DC.	25	0.266	3.4	0.3	0.0	1.1	1.8	1.1	2.4
Genipa americana L.	10	0.991	3.4	0.2	0.7	0.6	0.6	3.1	1.5
Geissanthus ambiguus (Mart.) G.Agostini	29	0.127	3.3	0.2	0.0	0.8	2.3	0.5	3.0
Alchornea triplinervia (Spreng.) Müll.Arg.	15	0.613	3.1	0.4	0.4	1.1	0.8	2.1	1.7
Eugenia acutata Miq.	25	0.245	3.0	-	-	-	2.2	1.1	2.4
Aspidosperma polyneuron Müll.Arg.	13	0.818	2.9	0.5	1.5	0.8	0.5	1.2	1.1
Inga marginata Willd.	16	0.151	2.7	0.6	0.2	2.3	0.6	0.4	1.3
Chrysophyllum gonocarpum (Mart. & Eichler) Engl.	17	0.248	2.7	0.3	0.3	0.8	1.1	0.6	2.1
Ficus enormis Mart. ex Miq.	8	0.748	2.4	0.5	2.1	1.7	-	-	-
Virola urbaniana Warb.	14	0.307	2.3	0.9	0.9	2.5	-	-	-
Croton urucurana Baill.	12	0.458	2.2	0.4	0.9	0.8	0.5	0.6	1.3
Cariniana estrellensis (Raddi) Kuntze	6	0.705	2.1	0.1	0.7	0.3	0.4	1.9	1.1
Hymenaea courbaril L.	2	1.041	2.1	-	-	-	0.2	4.5	0.4
Cecropia pachystachya Trécul	11	0.235	2.0	0.5	0.4	1.7	0.3	0.4	0.6
Trichilia casaretti C.DC.	16	0.087	1.9	0.4	0.1	0.8	0.9	0.2	1.5
Xylopia emarginata Mart.	14	0.189	1.9	0.9	0.5	2.0	-	-	-
Citronella gongonha (Mart.) R.A.Howard	9	0.133	1.7	0.6	0.4	2.3	-	-	-
Inga vera Willd.	7	0.392	1.7	0.3	0.8	0.8	0.3	0.4	0.4
Trichilia catigua A.Juss.	9	0.030	1.4	0.1	0.0	0.3	0.6	0.1	1.3
Aegiphila integrifólia (Jacq.) Moldenke	4	0.321	1.1	0.1	0.5	0.3	0.3	0.6	0.4
Cheiloclinium cognatum (Miers) A.C.Sm.	7	0.082	1.1	-	-	-	0.6	0.4	1.1
Aspidosperma cuspa (Kunth) S.F.Blake	5	0.268	1.1	-	-	-	0.4	1.2	0.6
Monteverdia aquifolia (Mart.) Biral	8	0.102	1.1	0.1	0.0	0.3	0.6	0.4	0.9

continued

Table 2 Continued

Trichilia clausseni C.DC.	7	0.036	1.0	0.1	0.0	0.6	0.4	0.1	0.6
Endlicheria paniculata (Spreng.) J.F.Macbr.	6	0.050	1.0	-	-	-	0.5	0.2	1.1
Casearia decandra Jacq.	5	0.061	1.0	0.1	0.1	0.6	0.3	0.2	0.6
Myrcia tomentosa (Aubl.) DC.	5	0.040	1.0	0.3	0.0	1.1	0.1	0.1	0.2
Maclura tinctoria (L.) D.Don ex Steud.	4	0.122	0.9	0.1	0.0	0.3	0.3	0.5	0.6
Pleradenophora membranifolia (Müll. Arg.) A.Melo	8	0.090	0.9	-	-	-	0.7	0.4	0.6
Syagrus oleracea (Mart.) Becc.	4	0.084	0.9	0.1	0.2	0.6	0.2	0.1	0.4
Myrsine guianensis (Aubl.) Kuntze	5	0.060	0.9	0.3	0.1	0.8	0.1	0.0	0.2
Sloanea guianensis (Aubl.) Benth.	5	0.048	0.8	-	-	-	0.4	0.2	0.9
Casearia sp.	6	0.023	0.8	0.2	0.0	0.8	0.3	0.0	0.2
Ormosia arborea (Vell.) Harms	4	0.059	0.8	-	-	-	0.4	0.3	0.9
Eugenia involucrata DC.	5	0.015	0.8	-	-	-	0.4	0.1	0.9
Sorocea bonplandii (Baill.) W.C.Burger et al.	4	0.026	0.8	-	-	-	0.4	0.1	0.9
Nectandra turbacensis (Kunth) Nees	4	0.086	0.7	-	-	-	0.4	0.4	0.6
Sweetia fruticosa Spreng.	3	0.108	0.7	-	-	-	0.3	0.5	0.6
Albizia niopoides (Spruce ex Benth.) Burkart	2	0.186	0.7	-	-	-	0.2	0.8	0.4
Myrciaria sp.	3	0.062	0.7	-	-	-	0.3	0.3	0.6
Aspidosperma sp.	3	0.135	0.6	-	-	-	0.3	0.6	0.4
Urera baccifera (L.) Gaudich. ex Wedd.	3	0.027	0.6	0.1	0.1	0.6	0.1	0.0	0.2
Chionanthus trichotomus (Vell.) P.S.Green	3	0.018	0.6	0.2	0.0	0.8	-	-	-
Trichilia pallida Sw.	3	0.014	0.6	-	-	-	0.3	0.1	0.6
Erythroxylum argentinum O.E.Schulz	6	0.031	0.6	0.4	0.1	0.6	-	-	-
Sapium haematospermum Müll.Arg.	3	0.097	0.6	0.1	0.1	0.3	0.2	0.3	0.4
Guazuma ulmifolia Lam.	2	0.118	0.6	0.1	0.3	0.6	-	-	-
Boehmeria caudata Sw.	5	0.050	0.6	-	-	-	0.4	0.2	0.4
Brosimum lactescens (S.Moore) C.C.Berg	3	0.071	0.5	0.2	0.2	0.6	-	-	-
Enterolobium contortisiliquum (Vell.) Morong	1	0.191	0.5	-	-	-	0.1	0.8	0.2
Handroanthus impetiginosus (Mart. ex DC.) Mattos	4	0.033	0.5	0.3	0.1	0.6	-	-	-
Ficus sp.	2	0.029	0.4	0.1	0.1	0.6	-	-	-
Myrsine umbellata Mart.	2	0.020	0.4	0.1	0.0	0.3	0.1	0.0	0.2
Ocotea corymbosa (Meisn.) Mez	4	0.060	0.4	-	-	-	0.4	0.3	0.2
Cupania vernalis Cambess.	2	0.019	0.4	-	-	-	0.2	0.1	0.4
Handroanthus umbellatus (Sond.) Mattos	2	0.007	0.4	0.1	0.0	0.6	-	-	-
Hyeronima alchorneoides Allemão	2	0.006	0.4	-	-	-	0.2	0.0	0.4
Myrcia sp.	1	0.113	0.4	-	-	-	0.1	0.5	0.2
Nectandra megapotamica (Spreng.) Mez	3	0.064	0.4	-	-	-	0.3	0.3	0.2
Citharexylum myrianthum Cham.	1	0.089	0.3	-	-	-	0.1	0.4	0.2
Nectandra cuspidata Nees	3	0.026	0.3	-	-	-	0.3	0.1	0.2
Piptadenia gonoacantha (Mart.) J.F.Macbr.	1	0.059	0.3	-	-	-	0.1	0.3	0.2
Trema micranta (L.) Blume	1	0.047	0.3	-	-	-	0.1	0.2	0.2
Jacaratia spinosa (Aubl.) A.DC.	1	0.045	0.3	-	-	-	0.1	0.2	0.2
Styrax pohlii A.DC.	2	0.012	0.2	0.1	0.0	0.3	-	-	-
Ficus obtusiuscula (Miq.) Miq.	1	0.034	0.2	0.1	0.1	0.3	-	-	-
Peltophorum dubium (Spreng.) Taub.	1	0.033	0.2	-	-	-	0.1	0.1	0.2
Randia armata (Sw.) DC.	2	0.006	0.2	-	-	-	0.2	0.0	0.2
Ocotea minarum (Nees & Mart.) Mez	1	0.022	0.2	-	-	-	0.1	0.1	0.2
Nectandra membranacea (Sw.) Griseb.	1	0.014	0.2	-	-	-	0.1	0.1	0.2
Astronium fraxinifolium Schott	1	0.014	0.2	-	-	-	0.1	0.1	0.2

continued

Table 2 Continued

Machaerium hirtum (Vell.) Stellfeld	1	0.012	0.2	-	-	-	0.1	0.1	0.2
Guapira opposita (Vell.) Reitz	1	0.010	0.2	-	-	-	0.1	0.0	0.2
Ficus gomelleira Kunth	1	0.007	0.2	0.1	0.0	0.3	-	-	-
Hirtella gracilipes (Hook.f.) Prance	1	0.006	0.2	-	-	-	0.1	0.0	0.2
Myrsine leuconeura Mart.	1	0.005	0.2	0.1	0.0	0.3	-	-	-
Senna sp.	1	0.004	0.2	0.1	0.0	0.3	-	-	-
Pleradenophora sp.	1	0.004	0.2	-	-	-	0.1	0.0	0.2
Nectandra gardneri Meisn.	1	0.003	0.2	0.1	0.0	0.3	-	-	-
Virola sebifera Aubl.	1	0.003	0.2	-	-	-	0.1	0.0	0.2
Pouteria gardneri (Mart. & Miq.) Baehni	1	0.003	0.2	0.1	0.0	0.3	-	-	-
Rhamnidium elaeocarpum Reissek	1	0.003	0.2	0.1	0.0	0.3	-	-	-
Ficus luschnathiana (Miq.) Miq.	1	0.003	0.2	0.1	0.0	0.3	-	-	-
Zanthoxylum riedelianum Engl.	1	0.003	0.2	-	-	-	0.1	0.0	0.2
Cordiera sessilis (Vell.) Kuntze	1	0.002	0.2	-	-	-	0.1	0.0	0.2
Piper arboreum Aubl.	1	0.002	0.2	-	-	-	0.1	0.0	0.2

NI = number of individuals, BA = basal area, IV = importance value, RD = relative density, RDo = relative dominance, RF = relative frequency; species are listed in total IV descending order

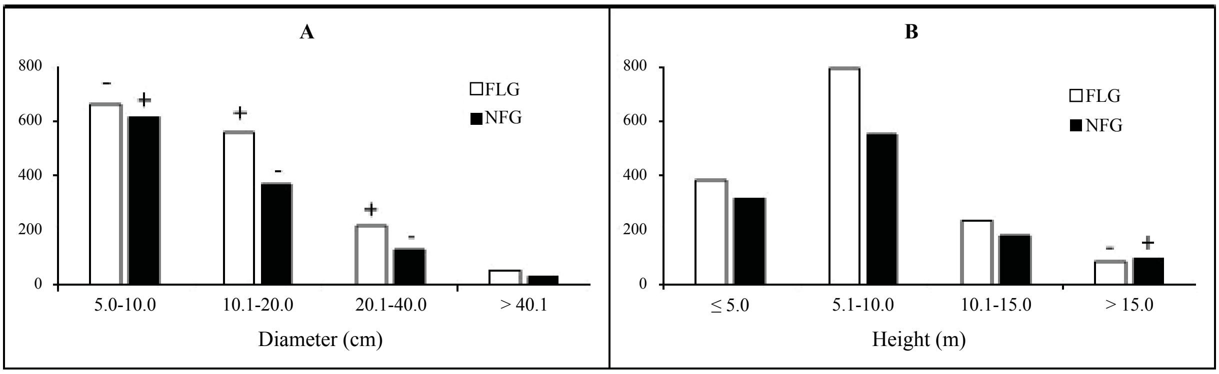

Figure 1 Tree density distribution in diameter (A) and height (B) classes in flooded (FLG) and non-flooded (NFG) gallery forests, south Goiás state

Positive (+) and negative (-) signals designated observed densities significantly above and below those expected, respectively

Notably, the species with the most prominence in the study was the palm tree *E. edulis*. In both physiognomies, it had the highest importance value which comprised about 42% of the individuals sampled in flooded gallery forests and 16% in non-flooded gallery forests. *T. guianensis* was also quite abundant, encompassing approximately 13% of individuals in flooded gallery forests, although it stood out due to the high relative dominance in both physiognomies. Variations in species ranking with respect to importance value between flooded gallery forests and non-flooded gallery forests were evident. For the five species with highest importance value of each survey, in addition to *E. edulis*, only *T. guianensis* was present as one of the most important species in both physiognomies. Other species had very distinct importance value, such as *C. brasiliense*, which ranked 4th in flooded gallery forests and only 27th in non-flooded gallery forests. *M. ovata* followed the same trend, occupying the 6th place in flooded gallery forests and 28th place in non-flooded gallery forests, and also *P. heptaphyllum*, which was the 5th species with the highest importance value in flooded gallery forests and 13th in non-flooded gallery forests. Finally, there was a significant number of species with only one individual in the total survey, 15 in flooded gallery forests and 22 in non-flooded gallery forests, representing 22.7% and 25.3% of the total species for each physiognomy, respectively.

DISCUSSION

Differences recorded for density and basal area corroborated the hypothesis, provided evidence that gallery forests had distinct structures, despite being geographically close. Basal area values in flooded gallery forests in the study were closer to those recorded in gallery forests in southeastern Brazil, which ranged from 31.0 to 33.0 m^2 ha^{-1} (Toniato et al. 1998, Guilherme et al. 2013). In the Midwest region, Guarino and Walter (2005) observed values above 40.0 m^2 ha^{-1}. The value seemed to be related to geographical location where the gallery forests with higher biomass seemed to occur in the west-north along dendritic networks of humid forests in the Brazilian Central Plateau and connected with the Amazon and Atlantic biomes (Oliveira-Filho & Ratter 1995). On the other hand, the humid forests in south-central Brazil had a greater floristic link with the Atlantic Forest (Oliveira-Filho & Fontes 2000), suggesting greater similarity in the basal area of the gallery forests of southern Goiás with the forests phytogeographically located at the Atlantic biome in southeastern Brazil.

Although with distinct physical characteristics, the geographical proximity between the two gallery forests studied might explain the high floristic similarity and similarity in the species/abundance relationship recorded between them, thus refuting the initial hypothesis. This was also being recorded in other studies of the same forest formations in the Federal District (Sampaio et al. 2000, Guarino & Walter 2005). The greater quantitative than qualitative similarity found could be explained by the occurrence of xeric species, characteristic of better drained soils and absent under swampy conditions such as in flooded gallery forests. Non-flooded gallery forests might have transition zones with other better-drained forest physiognomies of the Cerrado such as the seasonal forests (Guilherme et al. 2013). There were more individuals of the larger classes in diameter and height in non-flooded gallery forests than in non-flooded gallery forests. The unstable soils in a typical palustrine or swamp forests could hamper the establishment of trees with thicker and taller trunks. In general, the observations might also explain the differences in structure between the gallery forests particularly in the lower floristic similarity as compared to the similarity in the species/abundance relationship. The differences were due to the segregation of some species caused by the environmental heterogeneity between the studied physiognomies. Therefore, the forest structure seemed more sensitive to the environmental changes than the floristic composition. Other study on the Atlantic Forest (Cirne-Silva et al. 2020) reported that the same species group might employ different strategies when faced with the limitations of the environment

Fabaceae was the richest family in terms of species in the total survey. It wascommon to find predominance of species for this family in tree vegetation surveys in the various forest physiognomies, including in the in riparian forest of central and southern regions of Goiás (Ferreira et al. 2020), Cerradão (Guilherme et al. 2020) and the ecotones between decidual seasonal forest and rocky Cerrado (Andriani et al. 2020). Therefore, the influence of the Cerrado biome seemed to be significant on the wide occurrence of species not only for Fabaceae, but also in other families such as Myrtaceae, Lauraceae and Meliaceae. However, studies of tree structure in gallery forests in Brazil had shown that these families were generally not among the most important species (Toniato et al. 1998, Marques et al. 2003). The reason might be intrinsically related to the mechanisms of establishment for each species as adaptive advantages of one or a few species in certain families and might promote selectivity in these hostile environments.

Factor of environmental hostility was the determinant in the strong ecological dominance recorded in flooded gallery forests and resulted in significantly low plant diversity. Soil water saturation created anoxia conditions and promoted the selection of few species in flooded gallery forests. Therefore, the differences recorded for richness and diversity between the physiognomies studied corroborated with the study hypothesis. The present study also reported low levels of diversity in flooded gallery forests in Minas Gerais and São Paulo with values ranging from 2.10 to 2.75 (Toniato et al. 1998, Nogueira & Schiavini 2003, Guilherme et al. 2013). In general, the highest values of diversity were recorded in non-flooded gallery forest and a previous study conducted in the Federal District (Sampaio et al. 2000) showed values ranging from 4.15 to 4.33. *G. gardneriana*, *C. gossypiosperma* and *Unonopsis guatterioides* were good species examples of abundant species in non-flooded gallery forest, but absent or weakly recorded in flooded gallery forests. All of them were abundant in a survey of riparian forest near the study area (Ferreira et al. 2020), indicating their preference for more humid and not water-saturated forest environments.

Abundant of species recorded in this study was also commonly reported in other studies of gallery forests in the Southeast and Midwest of Brazil (Marques et al. 2003, Guarino & Walter 2005). *T. guianensis* showed wide occurrence and distribution in neotropical forests (Oliveira-Filho & Ratter 1995, Maçaneiro et al. 2015) with preference for wetter soils, although they also occurred in better-drained soils. The preference might explain their high density and dominance in both studied physiognomies. Other studies on gallery forests conducted for both southeastern Brazil and Central Brazil reported high importance value for *T. guianensis* (Nogueira & Schiavini 2002, Kurtz et al. 2014). *C. brasiliense* and *M. ovata* were also well adapted to environments with soils of high-water saturation They were found even in mangroves and lowland forests of the Amazon (Oliveira-Filho & Ratter 1995) as well as also in the tropical forests of the Atlantic and the Brazilian Central Plateau (Flora do Brasil 2020). *P. heptaphyllum* was also a species which occurred under various soil moisture conditions and being treated as cosmopolitan (Oliveira-Filho & Ratter 1995), which explained its occurrence in both gallery forests studied. *D. cuneatus*, *C. odorata*, *G. guidonea*, *G. kunthiana*, *I. edulis* and *Richeria grandis* were all well represented and important in the current study. They were species of wide occurrence in humid forest formations not only in the Cerrado, but also in the Atlantic and Amazonian biomes (Flora do Brasil 2020). Therefore, they were treated as indicators of riparian forest environments.

The high specific richness of the genera *Nectandra*, *Eugenia*, *Ficus* and *Trichilia* with 21 species in total recorded in the present study also reinforced the floristic link of the riparian forest formations in the southern region of the state of Goiás with the other gallery forests in southern and southeastern Brazil. Generally, these genera were well represented in surveys of tree vegetation of gallery forests located in Atlantic biome (Toniato et al. 1998, Kurtz et al. 2014, Maçaneiro et al. 2015).

However, the widely abundant and most prominent species in the study was *E. edulis*. There was a strong link between the palm tree and the Atlantic Forest, where it usually occurred with high density in conserved forest ecosystems and preferably in environments with high organic matter and higher soil moisture (Maçaneiro et al. 2015). In the study it was also found in the flooded gallery forests. The abundance of the species recorded in the present study was compared with those from other surveys of woody vegetation structure in remnants of hillside Atlantic Forest near the Atlantic Ocean (Kurtz et al. 2014). On the other hand, surveys of vegetation in gallery forests in Central Brazil showed very low densities of *E. edulis* (Guarino & Walter 2005) or absence in the records (Sampaio et al. 2000, Guilherme et al. 2013). The observation indicated that the gallery forests of south Goiás had a strong connection with the Atlantic biome. In addition, it reinforced that relicts of Atlantic vegetation were present in forest remnants in the Brazilian Central Plateau, especially in the Cerrado core area where climatic seasonality was quite accentuated. Oliveira-Filho & Ratter (1995) stated that these remnants were the result from processes of expansion and retraction of humid forests during climatic fluctuations in the Holocene and Pleistocene periods. Therefore, the current findings reinforced the strong connection of the gallery forests, especially the flooded gallery forests with the Atlantic biome.

Due to the indiscriminate and clandestine exploitation to obtain the apical meristems of *E. edulis* as a product widely appreciated both fresh or preserves, the palm tree had become endangered. Its fruits were a source of food for a wide variety of birds and mammals, therefore had great economic importance and ecological relevance (Santos et al. 2016). Its most significant populations were found in the protected areas of coastal Atlantic Forest, along the states of São Paulo, Paraná and Santa Catarina (Elias et al. 2019). The good conservation status of the studied gallery forests might explain the high palm tree density found here. It reinforced the importance of maintaining these humid forests in the midst of facing recurrent habitat loss, fire and forest fragmentation (Armenteras et al. 2021, Chiminazzo et al. 2021, Dias et al. 2021).

These forests were important not only for the preservation of biological diversity, genetic diversity and network of biological interactions, but also related to the provision of ecosystem services, relative to land use, maintenance of water springs and ecological corridors and aiming at the conservation of gene flow. Finally, considering the high environmental vulnerability of remnant native vegetation of the studied gallery forests (Carneiro et al. 2020), the current study provided important relevant information and good basis for the creation and establishment of a Conservation Unit in the region.

CONCLUSIONS

The two gallery forests differed in density and basal area. Higher density and basal area were found in flooded gallery forests, while larger trees were found in non-flooded gallery forests. Richness and diversity were higher in the non-flooded gallery forest than in flooded gallery forest, although both physiognomies showed floristic similarity qualitatively and similarity in the species/abundance relationship quantitatively. The floristic representativeness pointed to some more important genera in terms of species. The great abundance of the *E. edulis* palm tree reinforced the importance of these gallery forests connection in south Goiás to form the floristic link between Cerrado-Atlantic Forest biomes.

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