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Floristics, phytosociology and productivity in riparian areas of Cerrado

Florística, fitossociologia e produtividade em áreas ripárias do Cerrado

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Abstract

Having a water system free of deforestation and pollution around the city is a constant struggle since it often suffers from contamination, silting, loss of fauna and devastation of riparian forests. The studied area is a remnant of riparian forest that includes the streams of the urbanized microbasin of the municipality of Gurupi (Água Franca, Dois Irmãos, Mutuca, Pouso do Meio I and Pouso do Meio II). This research evaluates phytosociological and floristic indicators, volume, biomass and shoot carbon stock. The goal is to determine biodiversity, richness and productivity, aiming to maintain these resources and manage their continuous flow. The method used was a temporary systematic inventory, obtaining the following measures: total height (m); CBH (circumference at breast height), with values ≥ 15 cm being converted to DBH (diameter at breast height); stem quality; and sociological position. To determine productivity, we used equations established in the forest literature. The number of arboreal individuals, botanical species and families were respectively: 616, 66 and 40 for the Água Franca stream; 288, 46 and 22 for the Dois Irmãos stream; 560, 54 and 32 for the Mutuca stream; 307, 36 and 19 for the Pouso do Meio I stream; and 113, 15 and 11 for the Pouso do Meio II stream. The estimated values of shoot biomass, shoot carbon and total volume indicate that the areas are quite altered, with the need for recovery actions so that the water system is maintained, guaranteeing the quality of life of the population.

Additional keywords: floristic diversity; urbanized microbasin; vertical and horizontal structures.

Resumo

Ter um sistema hídrico, em torno da cidade, livre de desmatamento e poluição é luta constante, pois este frequentemente sofre com a contaminação, assoreamentos, perda da fauna e devastação das matas ripárias. A área estudada é de mata ripária remanescente que compreende os córregos da microbacia urbanizada do município de Gurupi (Água Franca, Dois Irmãos, Mutuca, Pouso do Meio I e Pouso do Meio II), com o objetivo de avaliar indicadores fitossociolóicos, florísticos,volume, biomassa e estoque de carbono aéreo, de forma a determinar a biodiversidade, riqueza e produtividade para viabilizar a manutenção, garantindo o fluxo contínuo desses recursos de forma manejada. O método utilizado foi o inventário sistemático temporário, onde foram medidas: altura total (m), CAP (circunferência à altura do peito) com valores ≥ 15 cm, sendo convertido em DAP (Diâmetro à altura do peito), qualidade do fuste e posição sociológica. Para determinar a produtividade, foram utilizadas equações consagradas na literatura florestal. O número de indivíduos arbóreos, espécies e famílias botânicas foi, respectivamente, de: 616; 66 e 40 para o córrego Água Franca; 288; 46 e 22 para o córrego Dois Irmãos; 560; 54 e 32 para o córrego Mutuca; 307; 36 e 19 para o córrego Pouso do Meio I e 113; 15 e 11 para o córrego Pouso do Meio II.Os valores estimados de biomassa aéreas, carbono aéreo e volume total indicam que as áreas se encontram bastante alteradas, tornando necessárias ações de recuperação para que o sistema hídrico seja mantido, garantindo a qualidade de vida da população.

Palavras-chave adicionais: diversidade florística; estruturas vertical e horizontal; microbacia urbanizada**.**

Introduction

The remaining riparian forests are forest compositions found along watercourses, whose function is to protect streams and rivers. Therefore, they influence water quality, preserving the hydrographic cycle in river basins, and preventing edge erosion and silting of streams and rivers (Primo; Vaz, 2006). Even under law, these forests have been destroyed by anthropic actions (especially for the establishment of economically viable activities) that cause degradation. The disordered use of plant biomass for energetic purposes (Vale et al., 2002) and the technique of removal and burning of vegetation for the sale of coal and cleaning of areas to be cultivated (Vale & Felfili 2005) are some of the examples of the appropriation of the Cerrado

biome by the production system.

Urbanized hydrographic basins are quite frequent in several cities of Brazil. Population growth has triggered actions contrary to the conservation of natural resources, consequently intensifying the degradation of water bodies. In this sense, the urbanization of basins is becoming more frequent, that is, sites where streets take the place of tributaries and the interaction of the urban environment with rivers is considered common. This is a conflict of use that requires caution given the damage as to the quality and quantity of available water, essential for the conservation of springs.

There is a need to ensure strategies that range from environmental diagnosis to the implementation of environmental management, guaranteeing the sustainability of systems. This is because when the landscape is modified, the reconstitution does not take place in an integral way. In other words, the landscape can not return to its original form, its perfect initial stage, no matter how much recovery measures are employed.

In view of the above, this research determines phytosociological indicators, volume, biomass and shoot carbon stock in riparian areas of the streams that comprise the urbanized microbasins of the municipality of Gurupi (TO). These parameters will serve to study the diversity, richness and productivity so that the exploitation of products, goods and/or services and the continuous flow of these resources can be managed.

Material and methods

The municipality of Gurupi is located in the western mesoregion of Central-South Tocantins State, between coordinates 11° 43' 45" S and 49° 04' 07" W, with an altitude of 287m. This municipality is the headquarters of the 10th Administrative Region of the State. It is located 245 km from the state capital of Tocantins (Palmas), and 742 km from Brasília-DF. The city lies where the rivers Araguaia and Tocantins meet, on the banks of BR-153, at kilometer 663 in the Brasilia-Belém direction; between parallels 11 and 12. The study area comprised the PPA^s (Permanent Preservation Areas) of the streams that constitute the urbanized microbasin of the municipality, namely: Água Franca, Dois Irmãos, Mutuca, Pouso do Meio I e Pouso do Meio II.

The climate of this region, according to Koppen (Koppen & Geiger, 1928), is hot and humid throughout the year, with a rainy period between October and April, and dry season between May and September. The annual average temperature varies between a minimum of 12 ^oC and a maximum of 30 ^oC; in the hottest months of the year, it reaches 42 ^oC in daylight.

The soils of the region are classified as argisols, which are usually of great agricultural significance. They are very deep, porous, permeable soils (even when very clayey), situated in flat relief, with slopes that rarely exceed 3% (Sano et al., 2008).

Data collection and Sampling

Data were obtained in the years 2015 and 2016 from a temporary systematic inventory, in riparian forest areas with a total size of 6,058.31 km² (sum of the PPA^s of the five streams). A sampling design with multiple plots was used, distributed from an initial plot placed at the margins of each stream near the spring. From this plot, the next plots were measured in a systematic way, where the total sample was regulated by the collector's curve (Oosting, 1951) for each stream. Sample plots were 10 m x 50 m (500 m^2) each, being allocated throughout each of the five streams.

Biometric characteristics for analysis were total height, measured in meters using a digital clinometer model EC2; CBH (circumference at breast height, considered at 1.30 m from the ground), with values ≥ 15 cm measured with a centimeter tape measure and converted to DBH (diameter at breast height).

The successional categories were determined by taking as reference the works of Franco et al. (2012) apud Gandolfi et al. (1995), who classify trees as pioneers (species clearly dependent on light), early secondary (species that occur under medium shade conditions), late secondary (species that develop in the sub-forest under slight or dense shade conditions) and without characterization (species that due to lack of information could not be included in any category). Species were systematically classified according to APG III (2009), and stem quality was based on criteria established by Yared et al. (1998) and Amaral et al. (1998).

Based on the values obtained for diameter at breast height and total height, frequency distribution was done, where data were grouped in fixed class intervals for total height (2 m) and diameter (5 cm) for further elaboration of the histograms. This methodology of fixing intervals for DBH and TH (total height in meters) classes is very used in forest research, as can be seen in the works developed by Watzlawick et al. (2011) and Silva et al. (2015).

Phytosociological sampling

The phytosociological survey described the horizontal structure of the studied area with the use of FITOPAC software version 2.1 (Shepherd, 2010). This software generates data on relative density, relative dominance, absolute and relative frequencies, importance value and cover value. The Shannon diversity index (H') and the equitability (J') (Pielou, 1975) were also calculated as parameters of heterogeneity.

Liocourt quotient ("q")

The Liocourt quotient was determined to identify the discrepancy between percentages of mortality and recruitment for each diameter class, according to Equation 1:

$$q = \frac{n2}{n1} \quad (1)$$

Wherein: $n1$ = number of trees of the previous diameter class; $n2$ = number of trees of the posterior diameter class.

Shoot woody biomass determination

The calculation was obtained from the formula described by Higuchi et al. (1998), aimed at dense forest with an ombrophilous characteristic in the Amazon region. The authors reached determination levels higher than 96% and a standard error of 2.56% using Excel software 2016. The same equation was used by Haidar et al. (2013) in the mapping of phytoecological regions for the forest inventory of Tocantins State. Biomass was defined by Equation 2:

$$SB = (0.0077+0.492\times DBH^2\times TH)\times 0.6 \quad (2)$$

Wherein: SB = shoot woody biomass (t ha^{-1}); *DBH* = diameter, considered at 1.30 m from the ground, in cm; *TH* = total height, measured in m.

Shoot carbon determination

Shoot carbon was evaluated from the formula for dry biomass described by Higuchi et al. (1998) and used by Haidar et al. (2013), which highlights the 2:1 ratio between dry biomass and carbon stock. Thus, the biomass estimation was multiplied by 0.5 for obtaining the carbon stock, determined by Equation 3:

$$SC = (0.0077+0.492\times DBH^2\times TH)\times 0.6\times 0.5 \quad (3)$$

Wherein: *SC* = shoot carbon stock (t ha^{-1}); *DBH* = diameter at 1.30 m from the ground, in cm; *TH* = total height, in m.

Volume determination

Total volume in m^3 was determined using the formula described by Haidar et al. (2013) in their studies on the mapping of phytoecological areas for the forest inventory of the southern region of Tocantins State. These areas comprise the watercourses of the Santo Antônio and Santa Tereza rivers towards riparian forests, dense forests of seasonal character and Cerradão.

Haidar et al. (2013) used this equation since it presents a coefficient of determination higher than 95% and a standard error of 1.16%, identifying appropriate accuracy and precision. Total volume was established by Equation 4:

$$Nl(TV) = -9.1892+1.9693\times Nl(DBH)+0.837\times Nl(TH) \quad (4)$$

Wherein: Nl = neperian or natural logarithm; TV = total volume (m³); *DBH* = diameter at 1.30 m from the ground, in centimeters; TH = total height, in meters.

Results and discussion

In the riparian forests of the urbanized microbasin of the municipality of Gurupi (TO), the measured variables DBH (cm) and total height (m) indicate that the streams have, on average, thin and low trees. Mean DBH values were: 5.3 cm; 6.5 cm; 24.3 cm; 27.4 cm and 27.4 cm for the riparian areas of Água Franca, Mutuca, Dois Irmãos, Pouso do Meio I and Pouso do Meio II, respectively. The mean total heights for the same areas, in the same order, were: 4.5 m; 6.9 m; 7.1 m; 7.4 m and 7.6 m.

CV ranged from 62.62%, with a standard deviation of 15.07 (Dois Irmãos), to 84.22%, with a standard deviation of 25.62 (Pouso do meio II) for the variable DBH. For the variable TH, in turn, CV ranged from 40.34%, with a standard deviation of 3.9 (Pouso do meio II), to 66.92%, with a standard deviation of 2.81 (Mutuca). These values are considered very high and classify the areas as heterogeneous. Santos et al. (2017), when studying the diameter structure for a Cerrado sensu stricto fragment in the municipality of Gurupi (TO), also found very high CV values for both variables: 51.81% for DBH and 44.87% for TH (m). Água Franca is the stream with the greatest extension within the municipality, and the one that presents the largest number of botanical species and families, followed by Mutuca, Dois Irmãos and Pouso do meio I (Table 1).

Table 1 - Streams, length, number of plots, number of individuals, number of species, number of families, Shannon index (H') and Pielou equability (J') evaluated in the urbanized microbasin of the Santo Antônio and Santa Tereza rivers in municipality of Gurupi (TO)

Streams	Length (km)	Number of plots	Number of individuals	Number of species	Number of families	H'	J'
Água franca	12.0	24	616	66	40	3.33	0.80
Mutuca	5.0	11	560	54	32	3.44	0.86
Pouso do meio I	2.9	27	307	36	19	2.92	0.80
Dois irmãos	3.0	25	288	46	22	3.20	0.84
Pouso do meio II	0.9	8	113	15	11	2.02	0.74
TOTAL	23.8	95	1884	217	124		

The Mutuca stream was the one that indicated the highest value of Shannon Index (3.44), that is, presenting the greatest floristic diversity. This result is expected because, according to Odum (1988), the

diversity of plant species generally increases with succession and reaches a maximum at climax, where species of various successional stages coincide. In contrast, streams Pouso do Meio I and II were those that presented the lowest value of H'.

Values similar to this were determined by Venâncio et al. (2008) when studying the floristic composition of two floodplain areas in the Araguaia plain (TO), obtaining a Shannon-Weaver index of 3.44. Furthermore, Andrade et al. (2002) found a Shannon-Weaver index of 3.53 in a dense Cerrado area at RECOR-IBGE in Brasilia. Other values similar to this study were found by Medeiros et al. (2012) when evaluating the composition and structure of Cerrado stricto sensu tree communities in Filadélfia (TO): Shannon-Weaver diversity index of 3.32.

For the Pielou equitability index (J'), the stream with the highest value was also Mutuca: 0.862, indicating 86% diversity. The stream with less equitability was Pouso do meio II: 0.746, indicating 76% of the theoretical maximum diversity obtained by means of the sampling performed, showing the low total amplitude of this index (0.12). Data similar to these were found by Medeiros & Walter (2008): equitability of 0.77 and Shannon index of 3.04, calculated for Carolina city (MA). For Filadélfia city (TO), the values were 0.83 for equitability and 3.32 for Shannon's index. Pinto et al. (2009) found estimated equitability values between 0.71 and 0.91 for the riparian and gallery forests of Planalto Central.

Phytosociology

Phytosociology is described for all species but was shown for the first eight trees of highest importance value index for each evaluated riparian area (in descending order). There is repetition of species in the analyzed areas. An example is species buriti (*Mauritia flexuosa*), which appears in three of the five streams (Água Franca, Dois Irmãos and Mutuca). Angico (*Anadenanthera peregrina*) is not found only in the Pouso do Meio II stream, and can be indicated as a species of great importance value for the urbanized microbasin under study (Table 2).

Regarding botanical families, Fabacaea, Anacardiaceae, Annonaceae, Euphorbiaceae, Lecythidaceae and Moraceae appear in all riparian areas studied.

In the Água Franca stream, two species were highlighted regarding the importance value index: *Mauritia flexuosa* and *Anadenanthera peregrina*. These species accounted for 22.95% of the total value and 20.02% of the cover value, being both the most representative species of the streams. The studied forest had a total density of 513.3 trees/ha (low), where the ten most prominent individuals share the phytosociological position of pioneers. In the Dois Irmãos stream, *Mauritia flexuosa*, *Pachira aquatica* and *Mangifera indica* stood out for dominance, accounting for 38.36% of the IVI. The cover value index presented by these trees was 46.34%, reaching almost half of the total value. Among the main trees, only *Cariniana estrellensis* and *Inga vera* were in the ecological group late secondary, while the other trees were characterized as pioneers. The area had a total density of 519.6 trees/ha (low).

In the Mutuca stream, *Mauritia flexuosa*, *Anadenanthera peregrina* and *Pithecoctenium crucigerum* stood out for dominance, accounting for 24.58% of the importance value. The same species have the highest cover value, accounting for 30.9% of the CVI. The evaluated area had a total density of 1018.1 trees/ha.

In relation to the ecological group, only species *Cariniana estrellensis* and *Cedrela fissilis* presented late secondary characteristics; the other species, with higher importance values, were shown to be pioneers.

In Pouso do Meio I, *Ficus adhatodifolia* and *Inga vera* stood out for dominance, representing 36.93% of the importance value index; the cover value of both species was 43.63%. The remaining forest studied had a total density of 496.77 trees/ha (low). This stream had as late secondary species *Inga vera*, *Licania kunthiana* and *Cariniana estrellensis*. For the Pouso do Meio II stream, *Ficus adhatodifolia* and *Heliocarpus popayanensis* were highlighted, representing 64.18% of the IVI and 77.58% of the CVI. The studied forest had a total density of 282.50 trees/ha (low). Its sociological structure comprised late secondary species such as *Heliocarpus popayensis*, *Licania kunthiana* and *Cariniana estrellensis*, while the other species found were pioneers.

All studied areas had density values lower than those found for the riparian areas of the Santo Antonio and Santa Teresa river basins: 867 and 1089.58 trees/ha, respectively (Haidar et al., 2013), indicating alterations.

For the ecological group classification, the majority of species are classified as secondary: 44.8%; 45.8%; 51.0%; 57.6% and 47.7% in the riparian areas of Água Franca, Dois Irmãos, Mutuca, Pouso do Meio I and Pouso do Meio II, respectively. For pioneer species and without characterization, such values were 53.0%; 23.9%; 34.6%; 26.1% and 28.3% and 2.1%; 30.2%; 14.2%; 16.2% and 23.8% for the same areas mentioned above. In the total of the five areas, 13.5%, 37.7% and 48.6% of species were classified as without characterization, pioneers and secondary (early and late), respectively. At the same time, all streams had 50% of living individuals having diameters smaller than 35 cm and belonging to the ecological group of pioneers.

Of these species, the ones with the highest importance value index and cover value index are mostly pioneers, however a significant amount (33% of the total species of the five streams) are late secondary species, which evidences the transition process of the studied area.

The number of pioneer and secondary species in the studied areas was expected, since this group has the ability to colonize, mainly due to high seed

production and efficient dispersion mechanisms, factors that explain the predominance of these species in disturbed areas (Putz, 1983). According to Rodrigues and Gandolfi (2001), pioneer species facilitate the succession, maintaining great interaction with the fauna that visits the canopies as a place for feeding and shelter, acting as pollinators and/or dispersers. The results demonstrate the importance of these species to the microbasin as a function of their greater or lesser contribution to community structuring.

Table 2 - Phytosociological parameters and determination of the ecological groups for the five riparian areas evaluated from the urbanized microbasin of the Santo Antônio and Santa Tereza rivers in the municipality of Gurupi (TO).in ecreasing order of IVI.

Stream	Scientific name	NI	AD	ADo	AF	ADo	RDe	RF	IVI	CVI	EG
Água Franca	*Mauritia flexuosa*	36	30.0	5.6	20.8	33.3	5.8	2.1	41.2	39.1	P
	Anadenanthera macrocarpa	29	24.2	1.42	54.1	8.3	4.7	5.51	18.6	13.0	P
	Schinus terebinthifolius	39	32.5	0.61	50.0	3.6	6.3	5.08	15.0	9.9	P
	Curatella americana	35	29.2	0.56	37.5	3.3	5.6	3.81	12.8	9.0	P
	Cecropia pachystachya	30	25.0	0.34	50.0	1.9	4.8	5.08	11.9	6.8	P
	Simarouba versicolor	25	20.8	0.54	37.5	3.1	4.0	3.81	11.0	7.2	P
	Inga vera	25	20.8	0.54	29.2	3.1	4.0	2.97	10.2	7.2	P
	Physocalymma sacaberrimum	27	22.5	0.30	33.3	2.0	4.3	3.39	9.8	6.4	P
Dois irmãos	*Mauritia flexuosa*	45	80.4	13.5	42.8	41.2	15.4	10	66.7	56.7	P
	Pachira aquatica	28	50.0	1.90	21.4	5.7	9.6	5	20.4	15.4	P
	Mangifera indica	12	21.4	3.61	17.8	10.9	4.1	4.17	19.2	15.1	P
	Anadenanthera macrocarpa	15	26.8	1.12	32.1	3.4	5.1	7.5	16.0	8.5	P
	Cecropia Glaziovi	18	32.1	0.80	28.5	2.4	6.1	6.67	15.2	8.6	P
	Inga vera	14	25.0	1.05	14.2	3.1	4.8	3.33	11.3	8.0	ST
	Croton urucurana	16	28.6	0.55	14.2	1.6	5.5	3.33	10.4	7.1	P
	Anacardium Occidentale	9	16.1	0.42	10.7	1.2	3.0	2.5	6.8	4.3	P
Mutuca	*Mauritia flexuosa*	34	61.8	0.81	36.3	16.1	6.0	2.6	24.8	22.1	P
	Anadenanthera macrocarpa	40	72.7	0.62	63.6	12.3	7.1	4.6	24.1	19.5	P
	Pithecoctenium crucigerum	42	76.4	0.42	63.6	8.3	7.5	4.6	20.5	15.8	P
	Schinus terebinthifolius	35	63.6	0.31	72.7	6.1	6.2	5.3	17.7	12.3	P
	Cecropia pachystachya	39	70.9	0.11	100.0	2.1	6.9	7.3	16.4	9.0	P
	Xylopia brasiliensis	32	58.2	0.13	45.4	2.6	5.7	3.3	11.6	8.3	P
	Curatella americana	29	52.7	0.11	54.5	2.1	5.1	4.0	11.2	7.2	P
	Physocalymma sacaberrimum	22	40.0	0.07	54.5	1.3	3.9	4.0	9.2	5.2	P
Pouso do meio I	*Ficus adhatodifolia*	38	61.3	151.9	51.61	41.1	12.3	11.9	65.4	53.4	P
	Inga vera	33	53.2	30.28	38.71	8.1	10.7	8.96	27.8	18.9	ST
	Cariniana estrellensis	24	38.7	31.13	19.35	8.4	7.79	4.48	20.7	16.2	ST
	Tapirira Marchandii	17	27.4	9.30	29.03	2.5	5.52	6.72	14.7	8.0	P
	Croton Urucurana	17	27.4	4.60	25.81	1.2	5.52	5.97	12.7	6.7	P
	Xylopia brasiliensis	13	21.0	5.16	22.58	1.4	4.22	5.22	10.8	5.6	P
	Mauritia flexuosa	5	8.1	15.96	12.90	4.3	1.62	2.99	8.9	5.9	P
	Licania kunthiana	9	14.5	3.72	16.13	1.0	2.92	3.73	7.6	3.9	ST
Pouso do meio I	*Ficus adhatodifolia*	43	268.8	7.39	100.00	83.4	38.0	23.5	145.1	121.5	P
	Heliocarpus popayensis	10	62.5	0.20	37.5	2.2	8.85	8.8	19.9	11.1	P
	Licania kunthiana	5	31.3	0.08	37.5	0.8	4.42	8.8	14.1	5.2	ST
	Croton urucurana	8	50.0	0.06	25.0	0.7	7.08	5.8	13.6	7.8	P
	Tabernaemontana laeta	6	37.5	0.03	25.0	0.3	5.31	5.8	11.4	5.6	ST
	Anadenanthera Colubrina	6	37.5	0.06	12.5	0.6	5.31	2.9	8.9	5.9	P
	Cariniana estrellensis	2	12.5	0.05	25.0	0.5	1.77	5.8	8.1	2.3	ST
	Tapirira marchandii	2	12.5	0.03	25.0	0.3	1.77	5.8	8.0	2.1	P

NI: Number of individuals; AD: Absolute Density; ADo: Absolute Dominance; AF: Absolute Frequency; RDo: Relative Dominance; RDe: Relative Density; RF: Relative Frequency; IVI: Import Value Index; CVI: Coverage Value Index; EG: ecological group

Regarding stem quality (Table 3), the Mutuca stream is the one that presents greater number of trees with crooked stems, followed by Pouso do Meio I, Água Franca, Dois Irmãos and Pouso do Meio II. Of the total area evaluated, 15.7%; 44.8% and 39.4% presented stem quality equal to 1, 2 and 3, respectively. These values were expected because this stem characteristic is known for the Cerrado region. Similar values were found by Haidar et al. (2013), indicating 41.6% and 50% of individuals with stem quality 3 for the riparian areas of the Santo Antônio and Santa Tereza river basins, respecively.

Table 3 - Determination of the bole quality in percentage values for the five riparian areas evaluated in the streams of the urbanized microbasin of the Santo Antônio and Santa Tereza rivers in the municipality of Gurupi (TO).

Stream	SQ 1 (%)	SQ 2 (%)	SQ 3 (%)
Água franca	15.25	39.77	25.97
Dois irmãos	22.91	38.88	38.19
Mutuca	14.28	57.14	28.57
Pouso do meio I	12.16	43.24	45.04
Pouso do meio II	15.03	32.33	52.63

SQ: stem quality

Volume, Carbon Stock, Biomass and Basal Area

The species with the highest volume, biomass and shoot carbon stock was *Ficus adhatodifolia* in streams Pouso do Meio I and Pouso do Meio II, with 95.74 m^3 ha^{-1}; 49.94 t ha^{-1} and 24.97 t ha^{-1} and 100.30 m^3 ha^{-1}, 22.08 t ha^{-1} and 44.16 t ha^{-1}, respectively. Species *Mauritia flexuosa*, in turn, had the highest volume, biomass and shoot carbon stock for the Mutuca stream, with values of 29.63 m^3 ha^{-1}, 15.20 t ha^{-1} and 7.60 t ha^{-1}; for the Água Franca stream, with values of 49.58 m^3 ha^{-1}, 25.52 t ha^{-1} and 12.76 t ha^{-1}; and for the Dois Irmãos stream, with values of 45.16 m^3 ha^{-1}, 22.92 t ha^{-1} and 11.46 t ha^{-1}, respectively.In the Água Franca stream, the total volume of the woody material was 107.4 m^3 ha^{-1}, having the highest volume concentration within the diameter class of 42-50 cm DBH (9.40 m^3 ha^{-1}). The Dois Irmãos stream had a total volume of 110.9 m^3 ha^{-1}, with the largest volume in the diameter class of 46-54 cm (12.18 m^3 ha^{-1}). the Mutuca stream showed similar volumes between the diameter classes of 14-22 cm and 70+ cm, with a large number of individuals in the class of 14-22 cm. The number of individuals in this class was so great that the volume of the woody material could be compared with the volume presented by the accumulation of individuals with more than 70 cm DBH. Pouso do Meio I showed a higher volume (112.9 m^3 ha^{-1}) in the diameter class of 70+ cm, indicating that there are individuals with a high DBH value. Pouso do Meio II also showed a higher volume in its last diameter class, therefore, large individuals are present in this stream.

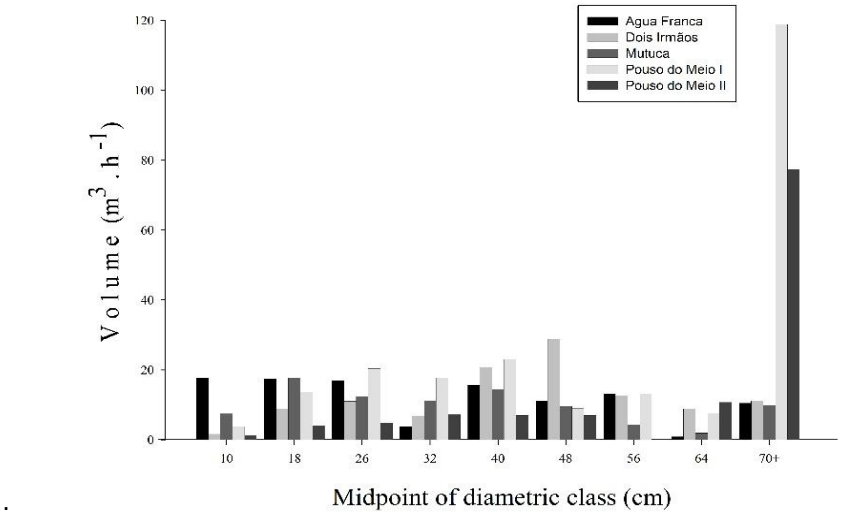
The maximum total volume obtained (226.3 m^3 ha^{-1}) was in Pouso do Meio I, which is among the average values found by Haidar et al. (2013) in the mapping of phytoecological regions for the forest inventory of Tocantins State (southern region). These authors found a variation ranging from 159.6 to 380.7 m^3 ha^{-1} in the riparian forests.

Shoot carbon stock values were estimated to be 37.7 t ha^{-1}, 31.2 t ha^{-1}, 31.4 t ha^{-1}, 62.9 t ha^{-1} and 31.5 t ha^{-1}, and shoot biomass was estimated to be 75.4 t ha^{-1}, 62.4 t ha^{-1}, 62.9 t ha^{-1}, 125.9 t ha^{-1} and 119.0 t ha^{-1} in streams Água Franca, Dois Irmãos, Mutuca, Pouso do Meio I and Pouso do Meio II, respectively (Figure 1). For carbon and biomass, the values found are lower than those determined by Haidar et al. (2013), who estimated a variation from 73.5 t ha^{-1} to 116.7 t ha^{-1} for shoot carbon, and from 67,4 t ha^{-1} to 142.6 t ha^{-1} for shoot biomass in riparian forests. In turn, Nascimento et al. (2002) reached 397.7 ± 30 t ha^{-1} shoot biomass in central Amazonia, with 81.9% of the total biomass represented by trees with DBH $\geq$ 10 cm.

For basal area, values of 27.4 m^2 ha^{-1}, 20.2 m^2 ha^{-1}, 18.2 m^2 ha^{-1}, 24.4m^2 ha^{-1} and 13.9 m^2 ha^{-1} were found for Mutuca, Água Franca, Dois Irmãos, Pouso do Meio I and Pouso do Meio II, respectively. The mean basal area between the 5 streams is 20.8m^2 ha^{-1}. Lower values were determined by Coelho et al. (2017), who found estimated basal area values of 9.4 m^2 ha^{-1} in a riparian area in the municipality of Peixe (TO). Values within the estimates were determined by Felfili et al. (2007), ranging from 12.8 m^2 ha^{-1} to 25.8 m^2 ha^{-1}, estimated for the gallery forests of Chapada dos Veadeiros (GO), and of 13.8 m^2 ha^{-1}, estimated for an open ombrophilous forest in Rondônia (Silva; Bentes-Gama, 2008). Sillva (2011), when characterizing trees in the seasonal savanna-forest contact area, found a density of 1,518 ind.h^{-1}, corresponding to the basal area of 19.03 m^2 ha^{-1}. This value was lower than that of 29.15 m^2 ha^{-1} found in the Santo Antônio and Santa Tereza river microbasins (TO) (Haidar et al., 2013).

Diameter and height distribution

The highest percentage of individuals is present in the first three diameter classes, being: 90.2% (Água Franca); 81.4%; (Dois Irmãos); 76.5% (Mutuca); 69.2% % (Pouso do Meio I) and 67.8% (Pouso do Meio II). The Pouso do Meio II stream presented a lower percentage value in its first three classes, showing a more homogeneous distribution in relation to the number of individuals in all diameter classes. Because it is an area that still has its original vegetation, the first and second diameter classes presented the largest number of individuals, accounting, respectively, for 56.0% and 24.18% of the individuals in Água Franca; 29.4% and 25.9% in Dois Irmãos; 34.9% and 35.5% in Mutuca; 28.3% and 29.9% in Pouso do Meio I; and 24.1% and 29.4% in Pouso do Meio II (Figure 2).



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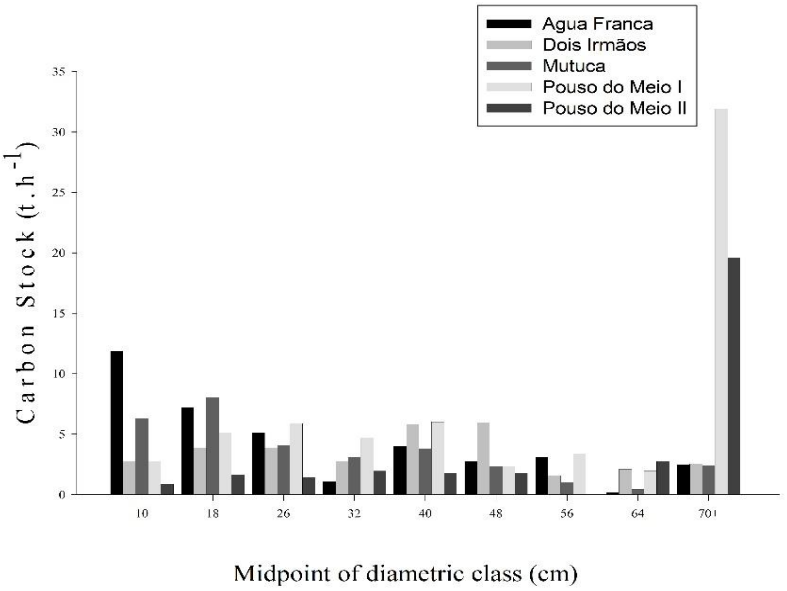

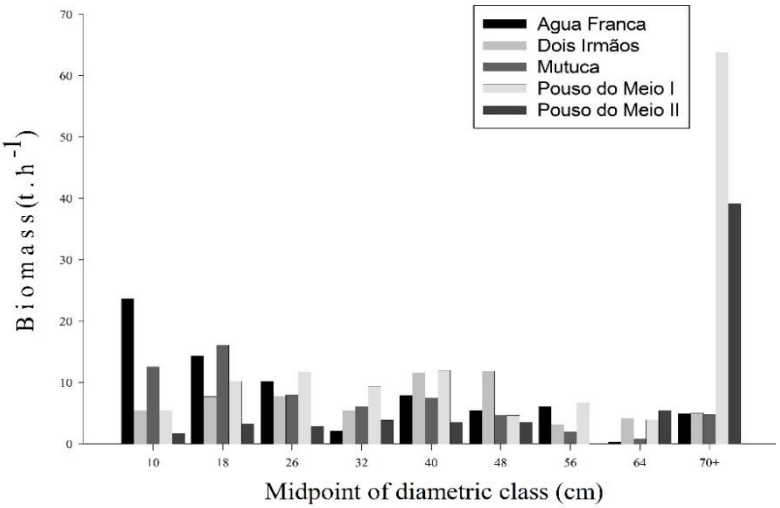

Figure 1 - Estimations of aerial biomass (t ha^{-1}), volume (m^3 ha^{-1}) and carbon stock (t ha^{-1}) of five riparian areas evaluated from the urbanized microbasin of the Santo Antônio and Santa Tereza rivers in the municipality of Gurupi (TO).

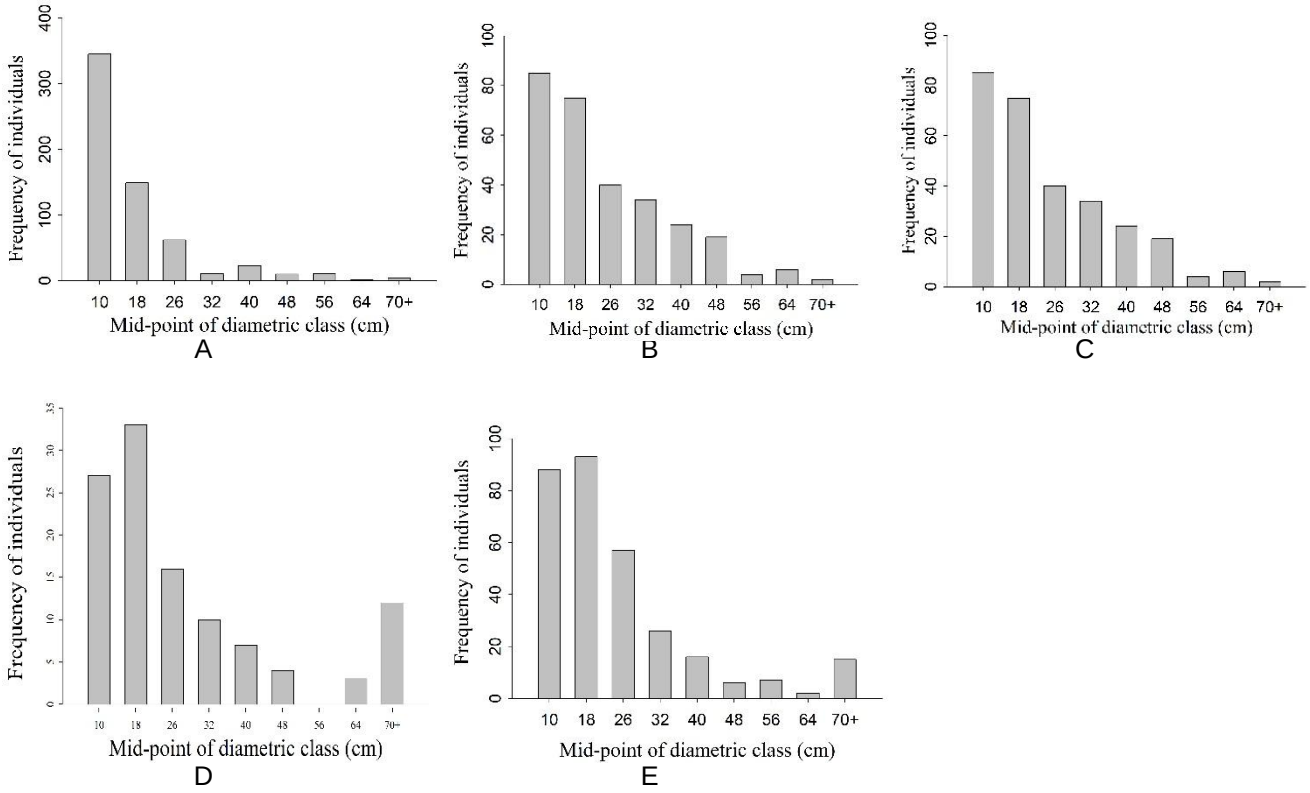

Figure 2 - Horizontal structure of the riparian areas evaluated from the urbanized microbasin of the Santo Antônio and Santa Tereza rivers in the municipality of Gurupi (TO): Água Franca (A), Dois Irmãos (B), Mutuca (C),Pouso do Meio I (D), and Pouso do Meio II (E).

Although the diameter distribution resembles an inverted J-shape (the higher the number of classes, the lower the absolute frequency) where most species are concentrated in the first three diameter classes, there is no equilibrium, that is, the observed constant "q" does not remain the same in the diameter classes of the population. According to Almeida Jr. and Zickel (2012), the high density of small individuals indicates the occurrence of austere disturbances in the past. The greater amount of small individuals does not provide absence of area revitalization.

The greatest variation of the "q" ratio (0.28 to 7.5) occurred in Pouso do Meio I between classes 54-62 cm and 70+ cm. For the initial intervals (<22cm), "q" variation had a maximum amplitude of 0.74 in the Pouso do Meio II stream. For the other streams, Liocourt quotient variability presented low values (Table 4). Haidar et al. (2013) found values lower than these in their studies in the riparian area of the Santa Tereza river basin, with variations of the "q" ratio (0.33 to 2) occurring between intervals above 35 cm; for the initial intervals (<35 cm), "q" ranged from from 0.42 to 0.81.

For the initial interval <30 cm DBH, "q" ranged between 0.17 and 0.43 (Água Franca); 0.53 and 0.88 (Dois Irmãos); 0.32 and 1.03 (Mutuca); 0.46 and 1.05 (Pouso do Meio I); and 0.48 and 1.22 (Pouso do Meio II). This finding indicates that mortality is being compensated for by recruitment among the first class intervals in all evaluated areas.

Table 4. Values of the Liocurt Quotient per diametric class for the five riparian areas evaluated in the urbanized microbial streams of the Santo Antônio and Santa Tereza rivers in the municipality of Gurupi (TO).

Class	Água franca	Dois irmãos	Mutuca	Pouso do meio I	Pouso do meio II
6-14	0.43	0.88	1.03	1.05	1.22
14-22	0.41	0.53	0.32	0.60	0.48
22-30	0.17	0.85	0.46	0.46	0.62
30-38	2.09	0.70	1.20	0.61	0.70
38-46	0.43	0.79	0.57	0.37	0.57
46-54	1.10	0.21	0.30	1.16	0.00
54-62	0.09	1.50	0.33	0.28	0.00
62-70	4.00	0.33	4.00	7.50	4.00
70+	0.43	0.88	1.03	1.05	1.22

The normal distribution trend for the variable total height was closer only in streams Água Franca and Dois Irmãos. In all streams, there is a greater amount of individuals recorded in the first three height classes, highlighting the Mutuca stream, which presents 44.64% of individuals in the second height class (3.5 to 7.5 m). In addition, riparian forests have few trees with a height greater than 15 meters. Only Água Franca and Pouso do Meio I have a considerable number of individuals in the height class of 19.5 to 23.5 m, respectively 8 and 7 individuals (Figure 3). The vertical structure model, where most individuals are concentrated in median height classes, is appropriate for this type of vegetation, being described in research conducted in the southern region of Tocantins State (Silva Neto et al., 2016).

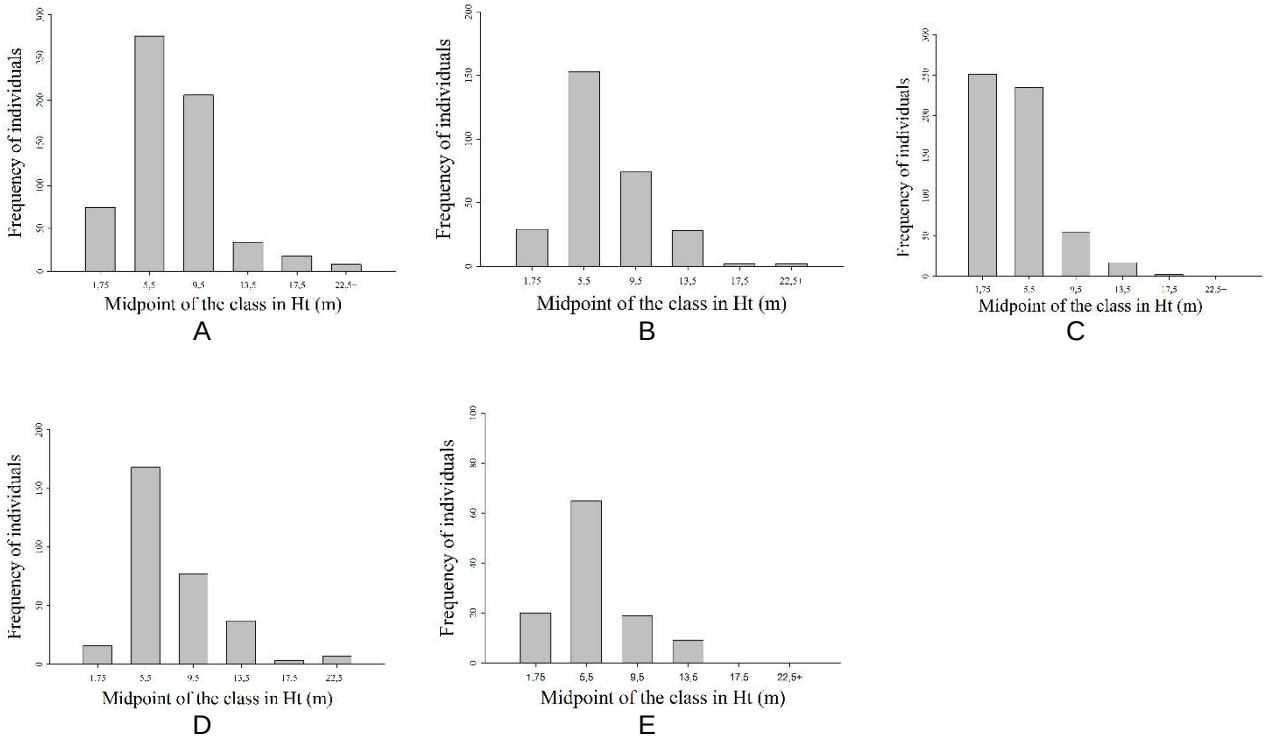

Figure 3 - Vertical structure of the riparian areas evaluated in the urbanized microbasin of the Santo Antônio and Santa Tereza rivers in the municipality of Gurupi (TO): Água Franca (A), Dois Irmãos (B), Mutuca (C),Pouso do Meio I (D), and Pouso do Meio II (E).

Conclusions

The riparian areas evaluated have an autoregenerative potential from the ecological point of view. Phytosociological indicators highlight the families Fabacea (185), Anacardiaceae (151), Leguminosa-mimosoideae (81) and Annonaceae (77) with higher species richness, being indicated for the recovery of the studied areas. In total, there are 1,884 trees, mostly thin (higher percentage in the first three diameter classes), low (total height with higher percentage in the first four classes) and with crooked stems (quality 2 and 3).

The values of diversity and equitability, diameter and total height structures are similar to those found in other studies described for the vegetation in riparian areas of Cerrado. As for shoot carbon stock, biomass, basal area and volume (with the exception of Pouso do Meio I), the values are lower than those found in riparian areas of the same biome and in the same geographical location. Along with the values of constant “q”, such finding indicates that these fragments of riparian forests are altered. These parameters are important for the characterization and typology of the basin, being eligible in the determination of the ecological ICMS, an essential instrument of environmental management, although still little used in municipal environmental evaluations.

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