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Original Article

Floristic diversity and edaphic filters in an urban forest under Cerrado domain, in Cuiabá, Central Western Brazil

Diversidade florística e filtros edáficos em uma floresta urbana sob o domínio do Cerrado, em Cuiabá, no Centro Oeste do Brasil

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Abstract

We aimed to characterize the adult and regenerating tree components and their relationships with soil characteristics of a native vegetation remnant in Cuiabá, Mato Grosso, Brazil. The area of the fragment is stratified into "dry area" (lithic neosoil) and "damp area" (gleisoil). We conducted a forest inventory with a random distribution of 25 parcels. We analyzed the physical and chemical components of the soil. We evaluated the vegetation's horizontal structure, diversity, and sample sufficiency using the Bootstrap richness estimator. We classified the species according to dispersal syndrome and ecological group. Overall, we found 93 species in the adult layer and 70 species in the regenerating layer. The similarity dendrograms based on the two evaluated indices demonstrated the existence of the two initially stratified environments in both strata. The IndVal (%) indicated that the set of indicator species differed between the strata. Thereby, the fragment is in an intermediate stage of successional progression. PCA showed that plots in the wet area had higher pH values and Ca, Zn, and Fe levels, while plots in the dry area did not clearly distinguish, varying in terms of K, B, and organic matter content. In CCA, a set of species that occurred exclusively in the damp area showed a strong relationship with the analyzed variables. The area is a diverse ecosystem that efficiently provides ecosystem services to society and should be the subject of long-term conservation and research.

Keywords: urban forest, climate changes, conservation, urban ecology.

Resumo

Nós objetivamos caracterizar os componentes de arbóreos adultos e em regeneração, bem como suas relações com as características do solo de um remanescente de vegetação nativa em Cuiabá, Mato Grosso, Brasil. A área do fragmento foi estratificada em "área seca" (neossolo lítico) e "área úmida" (gleissolo). Realizamos um inventário florestal com uma distribuição aleatória de 25 parcelas. Analisamos os componentes físicos e químicos do solo. Avaliamos a estrutura horizontal da vegetação, além da diversidade e suficiência amostral por meio do estimador de riqueza Bootstrap. Classificamos as espécies de acordo com a síndrome de dispersão e o grupo ecológico. No geral, encontramos 93 espécies no extrato adulto e 70 espécies no extrato regenerante. Os dendrogramas de similaridade com base nos dois índices avaliados demonstraram a existência dos dois ambientes inicialmente estratificados em ambos os extratos. O Índice de Valor de Indicação (IndVal %) indicou que o conjunto de espécies indicadoras diferiu entre os extratos. Assim, o fragmento encontra-se em um estágio intermediário de progressão sucessional. A Análise de Componentes Principais (PCA) mostrou que as parcelas na área úmida apresentavam valores de pH mais elevados e níveis elevados de cálcio (Ca), zinco (Zn) e ferro (Fe), enquanto as parcelas na área seca não se distinguiram claramente, variando em termos de potássio (K), boro (B) e teor de matéria orgânica. Na Análise de Correspondência Canônica (CCA), um conjunto de espécies que ocorreu exclusivamente na área úmida mostrou uma forte relação com as variáveis analisadas. A área é um ecossistema diversificado que fornece eficientemente serviços ecossistêmicos à sociedade e deve ser objeto de conservação e pesquisa de longo prazo.

Palavras-chave: floresta urbana, mudanças climáticas, conservação, ecologia urbana.

1. Introduction

The report of the International Intergovernmental Panel on Climate Change warns that the frequency of heatwaves in urban areas is expected to increase, with greater intensity and duration (Rosenzweig et al., 2018). Urban centers are directly affected by the impacts caused by global climate change, leading to an increase in average temperatures

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worldwide due to the effects of climate change and heat islands (Rosenzweig et al., 2011).

These effects can be mitigated through the ecosystem services provided by urban forests. In this context, vegetation has proven to be an effective tool, significantly improving the urban microclimate (Dimoudi and Nikolopoulou, 2003; Cohen et al., 2013). Trees, in particular, provide enhanced thermal comfort through shading from their canopies and the effects of transpiration, alleviating the implications of high temperatures by reducing the thermal sensation in urban centers (Ferrini and Fini, 2011). Under this perspective, it is evident that the denser the tree cover, the greater the benefits in terms of temperature reduction and increased relative air humidity, highlighting forest remnants as the main tool for climate stability (Dacanal et al., 2010; Hoffmann et al., 2010).

Urban forest fragments are remnants of forests that are typically altered, representing what remains of the occupation process. In many cases, the isolation of these areas has diminished niches for pollinating fauna and seed dispersal, leading to a reduction in gene flow, resulting in the decline of some populations and, more rarely, local extinctions (Newbold et al., 2015; FAO, 2015; Hodges and Mckinney, 2018). Despite their fragility, these environments are important from an environmental, economic, landscape, and social standpoint, as they still maintain unique ecosystem characteristics, and they are desirable for maintaining human quality of life (Rodrigues and Primack, 2001).

These ecosystems provide a significant number of goods and services, and the quantity and quality of these ecosystem services are directly related to their conservation status, meaning the state of preservation (Haines-Young and Potschin, 2008; Luederitz et al., 2015; Decocq et al., 2016; Liang et al., 2016; Mori et al., 2017). It is important to understand these benefits and incorporate them into urban planning (Jansson, 2013). Urban forests, besides ensuring the protection and maintenance of biodiversity, also aid in the mitigation and adaptation to climate change due to their regulatory effects, such as microclimate control and the reduction of polluting gases, necessitating strategic conservation policies and the implementation of green spaces as a tool for controlling and improving quality of life (Molla, 2015).

The city of Cuiabá, in the northern region of Brazil, has experienced significant development encroaching upon rural areas, with densely packed low-rise housing complexes. The replacement of native vegetation with altered areas, such as city constructions, has significantly affected radiation and energy balances, demonstrating the reality of the urban heat island effect in the city of Cuiabá (Angelini, 2015).

Among the remaining vegetation in the city of Cuiabá, only a few are actually municipal or state protected areas, such as the Mãe Bonifácia Municipal Park, Massairo Okamura State Park, and Zé Bolo Flô Municipal Park, which are the largest recognized forest fragments acting as parks and serving as a refuge for numerous species of both fauna and flora (Guarim and Vilanova, 2008).

In addition to the high floristic diversity present among the urban fragments in Cuiabá, they also function as a refuge for fauna, with the presence of various mammal populations observed, alongside numerous studies on the avifauna in the capital, demonstrating the vital role that green areas, both forest fragments and urban trees, play in supporting the diverse bird populations of the region (Santos and Oliveira-Júnior 2019; Guarim and Vilanova, 2008).

Gaps need to be filled concerning the structure, composition, and functionality of urban ecosystems, as there are still relatively few studies on these ecosystems compared to those conducted in extensive forest areas. As a result, it is uncertain whether urban ecosystems fulfill the expected and known role in theory. Thus, making conclusions about the conservation status of vegetation solely based on observations of its edge makes it impossible to affirm that isolated areas of vegetation serve any ecological function without conducting a diagnosis of their components (Araújo and Moreira, 2020; Cardoso et al., 2020; Santos et al., 2018).

Aiming to expand the knowledge about urban forest fragments and establishing a reference ecosystem for future conservation practices in the city of Cuiabá and its surrounding areas, this study aimed to evaluate an urban forest fragment and characterize it in terms of the floristics and phytosociology of the adult and regenerating tree strata, as well as discuss the soil-vegetation patterns in the different observed environments (dry area and wet area).

Therefore, the study sought to answer the following questions: What diversity is present in the adult and regenerating strata? What is the floristic similarity between the present environments (dry area and wet area)? Does the urban fragment face invasion by exotic species? What are the risks? How do soil characteristics influence the distribution pattern of species in the study area, and how can this knowledge be applied?

2. Material and Methods

2.1. Characterization of the study area

The study area is located in the municipality of Cuiabá, the capital of the state of Mato Grosso, at the edge of the domain occidental of the Cerrado and nearby the east of the Pantanal, Brazil. It is in the geomorphological province called "Baixada cuiabana/Cuiabá fall", with highs between 146 m to 250m (Chiaranda et al., 2016). The studied forest fragment is located in the city center and corresponds to an area of approximately 14 hectares, situated at the headquarters of the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA), at coordinates 15°33'32.38"S, 56°3'36.60"W (Figure 1). Nearby is one of the springs of the Coxipó river basin, which gives rise to the Gumitá stream.

The weather is classified as Aw by the Köppen classification; in other words, tropical with dry winter (Alvares et al., 2013). Cuiabá rates temperature is 26.1°C, and the rainfall is 1454.4 mm between 1981 to 2010, according to the data from the Instituto Nacional de Meteorologia (INMET).

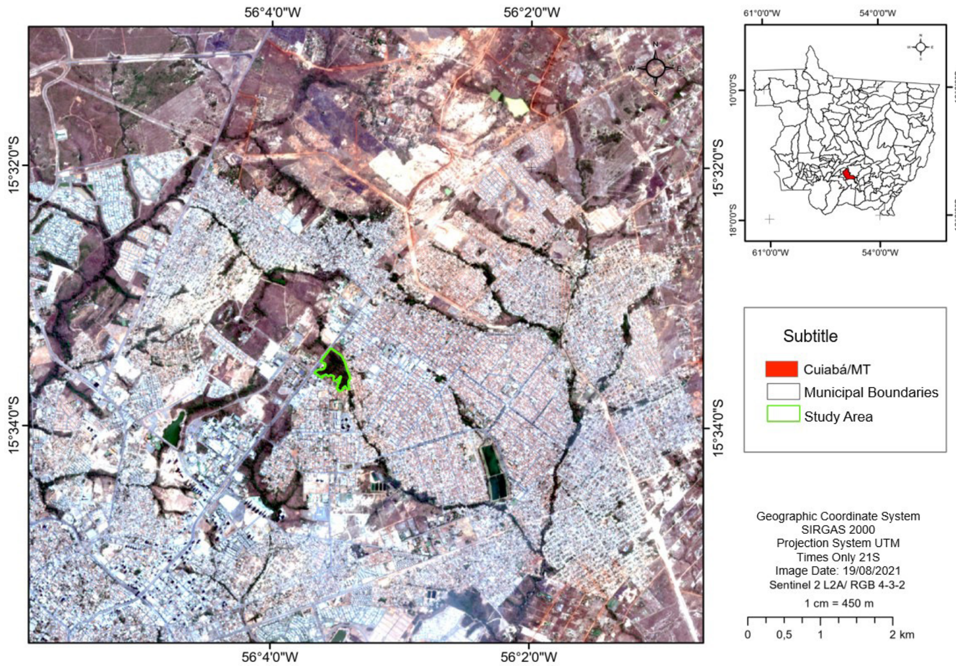

Figure 1. Localization of the forest urban area at Cuiabá City, Mato Grosso, Brazil.

The mulch is a piece of the forested savanna, with gallery woods (Brasil, 1982; IBGE, 2012), made by bigger or smaller deciduous spots in the winter, depending on the lithology, topography, or proximity of the river, which results in the vegetation mosaic deciduous and semideciduous (Figure 2).

2.2. Collecting data

2.2.1. Vegetation

We stratified the area into "dry area" (lithic neosoil) and "damp area" (gleisoil). It used the presence of macrophytes, which are plants from damp areas, as a criterion to delimit those two locations. The dry area has 13.05 ha, and the damp area has 0.95 ha (Figure 3).

We installed 5 samples in the "damp area" and 20 samples in the "dry area", with dimensions of 20m × 20m to show the adult tree layer (Felfili et al., 2005). The circumference at 1.30 m from the ground was measured with measuring tape for later diameter at breast height ($d_{1,3}$) calculations. The criteria of inclusion utilized was of trees with $d_{1,3}$ > 5 cm. The walking on this piece begins at the left lower vertex toward North-South (Phillips et al., 2021).

In all samples, we installed inside another two sub-plots, one with 5m × 5m to collect trees with $d_{1,3}$ < 5cm and high > 1m, and another with de 2m × 2m, with trees with $d_{1,3}$ < 5cm and high < 1m, calculating up to 0.075 ha, these sub-plots were used to measure the natural regeneration (Felfili et al., 2005).

We made the identification of the species in the field, together with the gathering of botanical material, the exsiccates are being kept at the Coordenação de Conservação e Restauração de Ecossistemas (CCRE), at the Secretaria do Estado do Meio Ambiente, Mato Grosso (SEMA/MT), located in Cuiabá. To the species unknown in the field, we collected samples for future identification

Figure 2. Characterization of the studied strata, with (a) the "dry area" located on lithic neosol, and (b) the gallery forest vegetation under moisture influence.

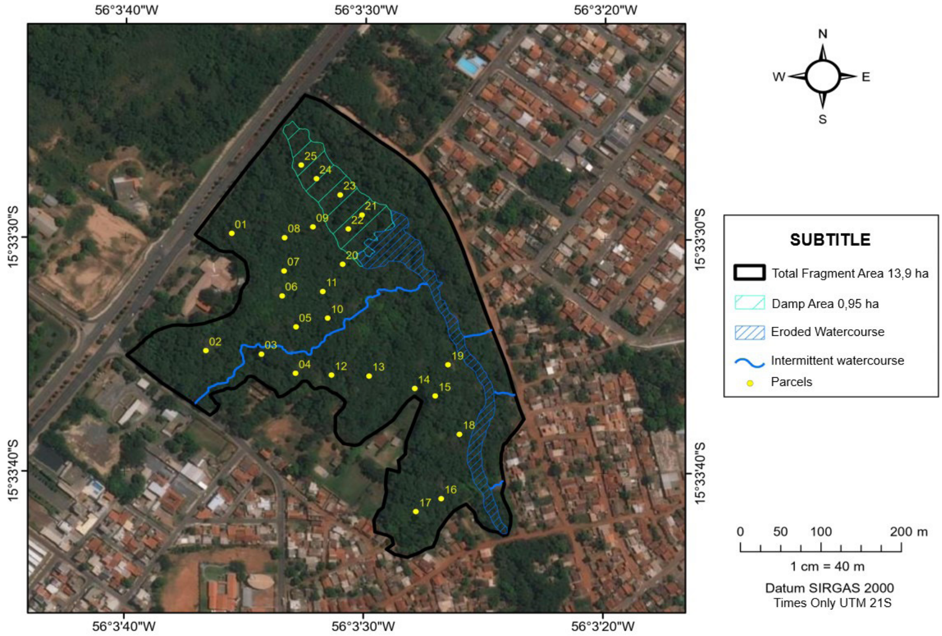

Figure 3. The study area's map indicates the areas' stratification and distribution of parcels.

based on morphological characters, floral and vegetative, assisted with specialized literature, digital herbarium, and specialist in the area. The classification system adopted for the families was the APG IV (Byng et al., 2016). The spelling and updating of the species were confirmed on the online platform Flora e Fungo do Brasil (JBRJ, 2024).

The species were identified according to the families recognized by APG IV (Byng et al., 2016). We checked the scientific names with their respective authors on the website REFLORA, Jardim Botânico do Rio de Janeiro (JBRJ, 2024).

2.2.2. Soil

We collected a composite sample in each plot from 5 points, according to the Manual of Soil Description and Collection in the Field (Santos et al., 2015). In soils with rocky materials, the collection was done with a shovel, and later the material was separated using a sieve.

We performed physical and chemical analyses of the soil, including micronutrients, following the methods: pH (H_2O) - in water at a ratio of 1:2.5 (soil:water). pH ($CaCl_2$) - in a 0.01M chloride solution at a ratio of 1:2.5 (soil: $CaCl_2$). P and K - extracted with 0.05N HCl and 0.0125N H_2SO_4 solutions. Ca, Mg, and Al - extracted with a 1N potassium chloride solution. H - extracted with calcium acetate at pH 7. M.O. (Organic Matter) - Oxidation with potassium dichromate and colorimetric determination. SAND, SILT, and CLAY - dispersed with NaOH and determined using a densimeter. For the extraction of micronutrients, it was used the following extractors: Zn, Cu, Fe, Mn - (0.025N H_2SO_4 + 0.05N HCl). S - Calcium phosphate. B - Hot water (Teixeira et al., 2017).

2.3. Data analyses

We checked the sample sufficiency by curve species-area, using 1000 aleatory simulations with the rich estimator Bootstrap (Colwell and Coddington, 1994), the software used was EstimateS 9.0 (Colwell 2005). We also estimated the Shannon-Wiener index (H') (Shannon and Wiener, 1964).

We made the structural characterization and floristic with the data bank, generating diametric distribution graphics (class interval = 10 cm) and families with more dominance as a number of species and a number of trees.

We classified the species, with specialized literature, according to the ecological group, following Gandolfi et al. (1995) classification, which categorizes the species into pioneers, early secondary, and late. We also classified the species accordingly to the seed dispersal syndrome, consonant van der Pijl (1982), being split in zoochory when dispersed by animals; anemochory, when dispersed by the wind; and autochory, when they somehow have their own dispersion mechanism (Gressler et al., 2006; Stefanello et al., 2009; Ishara and Maimoni-Rodella, 2011; Jacobi and Carmo, 2011; Reis et al., 2014; Pilon et al., 2015).

To analyze the horizontal structure, we calculated phytosociological parameters (density, frequency, dominance, coverage amount, and importance), aiming to characterize the separated community (dry and damp area) using the software Microsoft Excel (Felfili et al., 2005). We included the classification of the regenerating, and it was established with the relative density in descending order once that component does not show the valor of the diameter, making it impossible to calculate de dominance and, consequently, the coverage amount and importance.

We made the similarity and clustering analysis with the adult regenerative layer using the software Past 4.03. For every layer, two matrixes were boulted; the first one has the data of the presence and absence of the species; the second inserted the number of trees by specie in each parcel. The matrix of the presence and absence of the species was used to calculate Jaccard's similarity rates. By the matrix of the number of individuals by specie, it was calculated the similarity indices of Morisita (Gotelli and Ellison, 2011). The results of the indices were transcribed to two new matrices, one to each index containing the similarities between the parcels.

With the similarity matrix between the parcels, grouping analyses were made into two dendrograms of similarity, one to each index, using the group average as a grouping technique (Gotelli and Ellison, 2011). To find out the capacity of the dendrogram to reproduce the matrices of similarity, it was used the coefficient to cophenetic correlation (Cargnelutti Filho et al., 2010).

The indices of the indicator species (IndVal) were calculated to grow up and regenerated using the matrix of the number of the individual by parcel and the groups made by the grouping. The IndVal is expressed from 0 to 100%, and it is possible to imply a probability of occurrence in that environment through permutation (Dufrêne and Legendre, 1997).

The multiple physio-chemical of the ground collected by parcel was submitted to analyze of correlation of Pearson to verify those with the correlations are strong (valor above 0.8), which indicate multicollinearity between the data (Shrestha, 2020). In this case, only one of the variations was maintained, and the rest was removed from the ordination analysis once it was difficult to evaluate the importance of each.

Secondly, we ware made a preliminary principal components analysis (PCA) to detect which variance shows low representation on both principal components; angles formed between the different axis from 90° means the correlation between the variants and lower to (<45°) or bigger than (>135°) this stronger angle will be the correlation (Yan and Kang 2002). This way, the variants with valor under 0.3 to both principal components were removed, and those kept at the end of the PCA, being pH in water, Ca (cmolc/dm^3), K (mg/dm^3), organic material (g/dm^3), Zn, Fe and B (mg/dm^3).

Thus, we proceed with analyzing the canonical correspondence (CCA) with the ground variations chosen with the PCA using the software Past 4.03. We used the test of permutation of Mount Carlo to check the meaningfulness of the axis of the CCA.

3. Results

3.1. Diversity

We found 93 species on the adult tree layer, the abundance Bootstrap estimates 106 species. The curve shows a weak tendency to a stabilization next to the 0.6 hectares. For the gathering of the natural regeneration, we found 70 species, with an estimation by the Bootstrap of 82 species. Equal to the adults, there was a weak stabilization at 500 m^2 of sampling (Figure 4).

Though the diametric distribution in classes (Figure 5), the graphic shows the exponential distribution with the form of "J upside down", with the most significant number of trees focused in the first class, reducing gradually to the subsequent classes.

Accordingly with the floristic point of view, 40 botanic families, 81 genres, and 99 species of tree were identified as reflected in the calculated index. The diversity index of Shannon (H') was 3.45 nats.ind^{-1}, and the equality of Pielou (J'), 0.76, indicates high diversity and low ecological dominance.

Concerning the number of species (Figure 6), the most richness family was Fabaceae (21), Rubiaceae (7), Anacardiaceae (6), Bignoniaceae (5), Malvaceae (5), Vochysiaceae (4), Annonaceae (3), Myrtaceae (3), Sapindaceae (3), Chrysobalanaceae (2) e Meliaceae (2), that together add more than 60% of the total number of species found in this piece of forest studied.

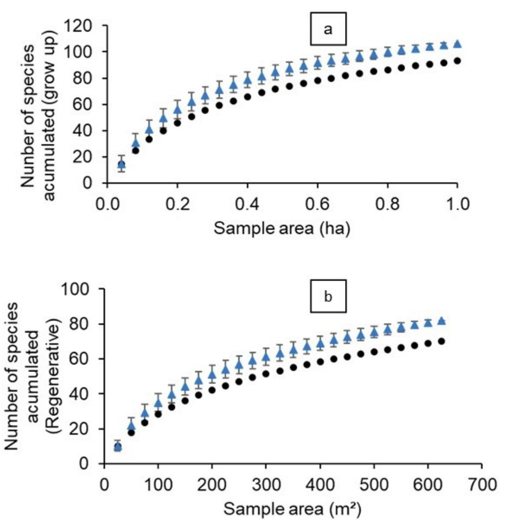

Figure 4. Number of species accumulated and estimated by the estimator Bootstrap on the two layers evaluated in this urban forest, at Cuiabá, Mato Grosso, Brazil. (a) Grow up layer; and (b) Layer regenerative. Black dots = accumulated valor; blue triangle = estimated valor; and bars indicates standard deviation to the abundancy estimator.

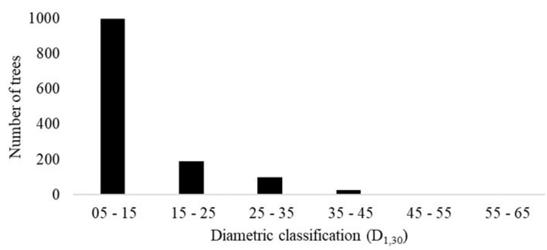

Figure 5. Diametric distribution of the trees sampled in the piece of urban forest in Cuiabá, Mato Grosso, Brazil.

Relate the number of trees (Figure 7), the families more abundant were Fabaceae (229), Bignoniaceae (208), Burseraceae (147), Anacardiaceae (125), Lecythidaceae (101), Sapindaceae (89), Calophyllaceae (65), Rubiaceae (49), Dilleniaceae (45) e Euphorbiaceae (26), that together add more than 80% of the trees in the study.

The zoochory syndrome got more richness, followed by the anemochory syndrome, both in the grown-up layer as in the regenerative (Figure 8). The distribution in ecological groups, on both layers, the pattern repeats itself, and the most significant concentration of the species are in the secondly initial group, followed by late secondary and, by last, with less proportion, by the pioneers (Figure 9).

3.2. Dry area

Among the 90 species found in 962 trees measured of grown-ups in the dry area, the specie with the higher index of importance value (IVI) was *Anadenanthera peregrina* (L.) Speg., with an equal index of 15.17, it has a highlighted place, especially by its dominance and the more extensive basal area among the species (4,86m^2). The second specie with high value is *Protium heptaphyllum* (Aubl.) Marchand, due to its relative density, it is the specie that most occurred in the dry area (147 trees). Those two species, plus the species *Tapirira guianensis* Aubl., *Matayba guianensis* Aubl., *Astronium fraxinifolium* Schott, *Copaifera langsdorffii* Desf., *Curatella americana* L. e *Dipteryx alata* Vogel, add 51.2% of the IVI, and 66.96% of the relative dominance, being the species, which represented the most in this piece of dry area.

In the natural regeneration of the dry area, we found 62 species in 536 trees measured. Regarding the species that compose the adult layer in this area, 38 were not found in the bank of regeneration. The only specie with a density bigger than one among the adult layer that was not found in the natural regeneration was *Hevea brasiliensis* (Willd. ex A. Juss.) Müll.Arg.

Among the species of the regeneration dry area, nine were found between the adult trees: *Albizia lebbeck*, *Albizia niopoides*, *Brosimum gaudichaudii*, *Copaifera malmei*, *Croton* sp., *Eugenia florida*, *Moquilia tomentosa, Psidium guajava,* and *Tocoyena formosa*. Three are exotic: *M. tomentosa*, *A. lebbeck,* and *P. guajava*.

For the species considered more important to the adult element, only *Protium heptaphyllum* is among those who are 55.9% of the relative density of the regenerative, together with *Cordiera macrophylla, Ouratea castaneifolia, Senegalia polyphylla, Antonia ovata, Cardiopetalum calophyllum, Erythroxylum deciduum,* and *Duguetia marcgraviana,* who was most representative only in regeneration.

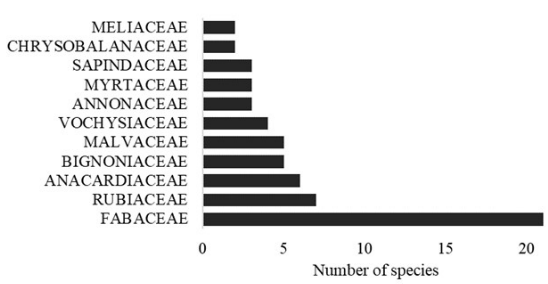

Figure 6. Relation with the families with a greater diversity of species in that piece of study in Cuiabá, Mato Grosso, Brazil.

3.3. Damp area

Within the damp area, we found 11 species in 357 adult trees measured. We observed that 79.8% of the IVI are among only three species: *Tabebuia insignis*, *Cariniana*

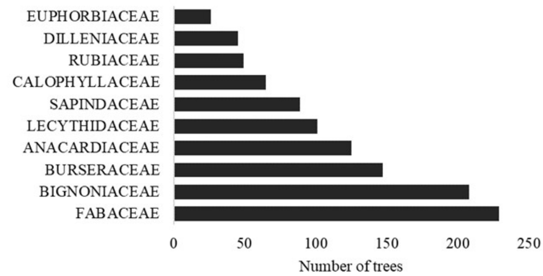

Figure 7. Relation of the families with a bigger number of individuals in that area of the study, in Cuiabá, Mato Grosso, Brazil.

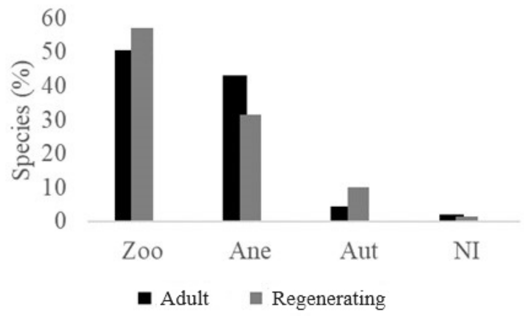

Figure 8. Distribution of the species according to the dispersion syndrome on the layer grown-up and regenerative of the piece of urban forest, at Cuiabá, Mato Grosso, Brazil. Black = grown up; grey = regenerating; Zoo = zoocoric; Ane = anemochoric; Aut = autocoric; NI = unidentified.

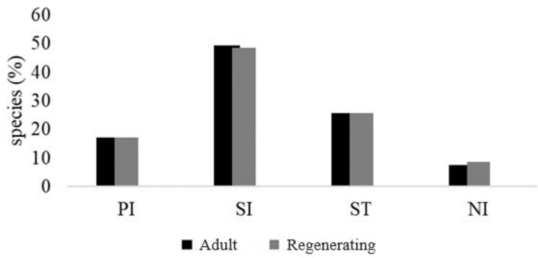

Figure 9. Distribution of the species according to the ecological groups in the grown-up layer and regenerative of the piece of the urban forest, at Cuiabá, Mato Grosso, Brazil. Black = grown up; grey = regenerating; NI = unidentified, PI = first species, SI = early secondary, ST = late secondary.

rubra, and *Calophyllum brasiliense*. The highlight also includes that those species only take place in the dry area in the parcels nearby the damp area, i.e., parcels 19 and 20 (Figure 3), which are parcels in a region of transition between the two areas, holding species of the dry and damp area eventually. Another species that occurs in less density but shows the same preference is *Dendropanax cuneatus*. Yet, *Inga vera* was the only native species occurring in the damp area. We observe, as well, the preference of the species *Cedrela fissilis,* which occurred in both areas but with the highest density in the damp area, being six and two trees, respectively. Two exotic species was found in the damp area: *Clitoria fairchildiana* and *Mangifera indica*. The rest (*Tapirira guianensis* e *Ficus insipida)* also occurred in both areas.

In the recovery of the damp area, we found 18 species on 100 trees (more species than the grown-up layer). Of those species, five are exotic, knowing that *Moquilea tomentosa* is not native to the biome, *Mangifera indica* is exotic but not invasive, and the species *Albizia lebbeck*, *Clitoria fairchildiana*, *Leucaena leucocephala, Syzygium jambos,* and *Ricinus communi* are exotic and invasive. In the adult inventory, we found individuals of *Cedrela fissilis*, *Tapirira guianensis*, *Inga vera,* and *Dendropanax cuneatus*, but some natives as *Platymiscium floribundum*, *Genipa americana*, and *Leptobalanus sclerophyllus* was not encountered.

3.4. Indicator species

The IndVal for adult individuals has shown that *Anadenanthera peregrina* (95%), *Astronium fraxinifolium* (75%), *Curatella americana* (55%), *Matayba guianensis* (80%), and *Protium heptaphyllum* (90%) were indicators of the parcels located in the dry area. *Calophyllum brasiliense* (99%), *Cariniana rubra* (99%), and *Tabebuia insignis* (99%) are species of the damp area (all of them with $p < 0.05$).

IndVal to regenerating shows that the species *Cardiopetalum calophyllum* (55%), *Cordiera macrophylla* (70%), *Ouratea castaneifolia* (70%) and *Protium heptaphyllum* (84%) were indicative of the parcels located in the dry area, and *Calophyllum brasiliense* (99%), *Cariniana rubra* (64%), *Ficus insipida* (60%), *Leucaena leucocephala* (40%), *Moquilea tomentosa* (68%), *Syzygium jambos* (40%) and *Tabebuia insignis* (40%), were indicative of the parcels located in the damp area.

3.5. Similarity

All dendrograms of similarity, both adults as the regenerating to presence data, absence, and number of specimens, shows patterns equally grouping, especially with relation with the parcel located in the damp area of the piece, of the parcel 21 to 25 (Figures 10 and 11). For the regenerative, parcel 19 was grouped with the damp parcels in the index of Jaccard (Figure 11a), and parcel 1 was isolated in the analysis with the index of Morisita (Figure 11b). To all grouping, the coefficient of the phonetics correlation was satisfactory, superior to 0.90 to the adults and the 0.85 to the regenerates.

3.6. Soil analysis

In the PCA, the two first components explain 47.0% and 32.4% of the data variation (79.5%) (Figure 12). The variant water pH, Ca, Zn, and Fe shows a better connection with component 1; organic material, B and K both posses' good connection with the component 2, and Fe negative with the component 2.

The PCA indicates that the parcels in the damp area have a more significant connection with Ca, Zn, and Fe and pH alkaline. However, the parcels located in the dry present different contents, some of the concentrations higher of K, organic material, and B (parcels 17, 1, 13, 8, and 10); intermediate values of the other variables; another with

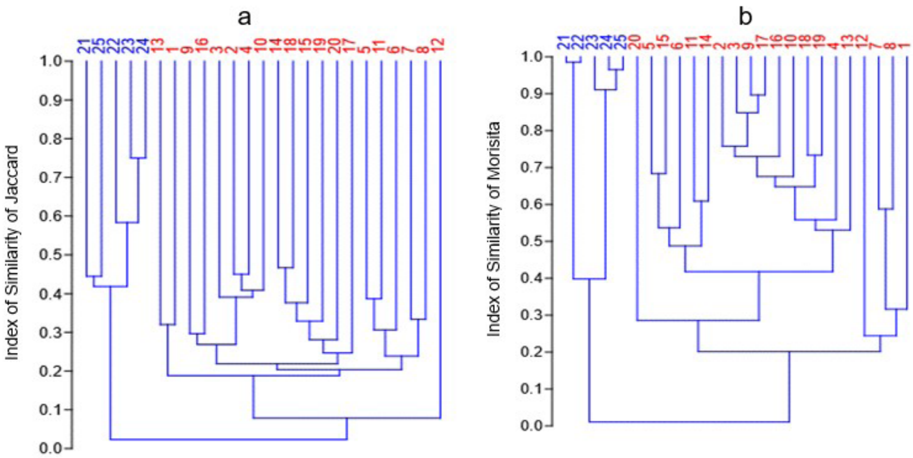

Figure 10. Dendrograms of similarity to the adult layer, using the index of Jaccard (a) and Morisita (b) by the technique of grouping of the media of the group in the piece of urban forest, located at Cuiabá, Mato Grosso, Brazil. Phonetics correlation (CC) A = 0.92 and B = 0.93. In blue, highlighted the parcels located in the damp area and, in red, the rest of the parcels located in the dry area.

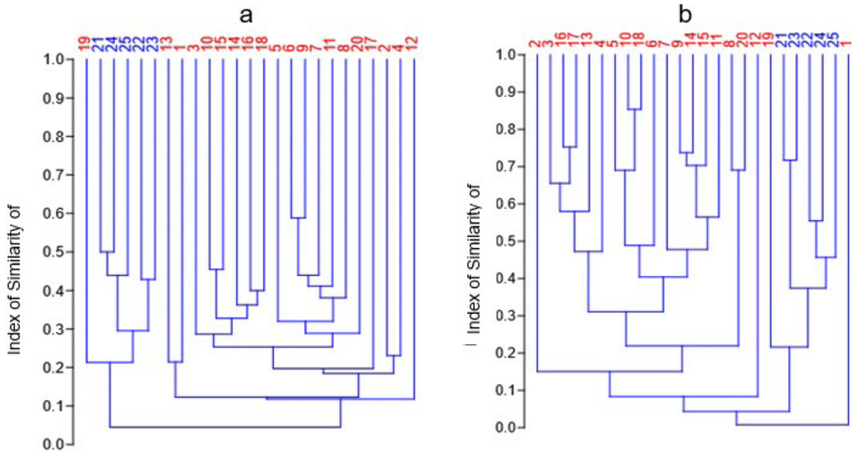

Figure 11. Dendrograms of similarity to the regenerating layer, using the index of Jaccard (a) and Morisita (b) by the technique of grouping of the media of the group in the piece of urban forest, located at Cuiabá, Mato Grosso, Brazil. Phonetics correlation (CC) A = 0.87 and B = 0.90. In blue, highlighted the parcels located in the damp area and, in red, the rest of the parcels located in the dry area.

low valor of K, organic material, B, Ca, water pH, Zn, and Fe, without any clear special distinction.

In Canonical Correspondences Analysis (CCA), the three first axles made explain 48.6%, 16.9%, and 15.3% of the total data variation (Figure 13). However, the permutation of the Monte Carlo test does not show importance to the axle 2, in this case, the figure only shows the axles 1 and 3, together explain 63.9% of the data variation (Figure 13).

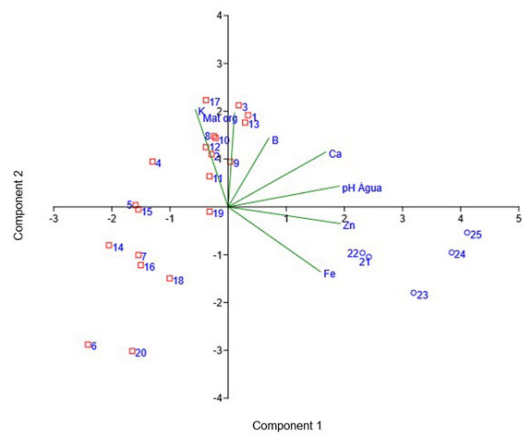

Figure 12. The principal component analysis (PCA) to the others parcels located in the piece of the urban forest, in Cuiaba city, Mato Grosso, Brazil. Green arrows indicate the vectors of the variants. Percentage of the variation explained about the component 1 = 47.0% and the component 2 = 32.5%. Blue circle is about the parcels located in the damp area, and the red square, to the others parcels. Green arrows are the eigenvector of each variation.

4. Discussion

The values obtained of index of Shannon (H'), and the equality of Pielou (J') allows us to deduce that the size of the population is not discrepant. Those values may be compared to the same physiognomy ecosystem and outside the urban area, as disputed by Marimon Junior and Haridasan (2005), studying a surrounding area in the savanna of Nova Xavantina – MT, which reported a diversity of 3.67 nats.ind^{-1}, and the equality of 0.84. Araujo et al. (2009), when evaluating a savanna in Sinop – MT, showed diversity and equality of 3.55 and 0.88, respectively. This way could understand that the fragment of vegetation has existed since the beginning of Cuiabá city, kept with high diversity without a predominant population, equally to the other savannas in different regions in Mato Grosso state. Reflecting that under the same entropic pressure, the area kept, until then, in terms of diversity and equilibrium between species.

Fabaceae was the richest family and abundant in the fragment (Figures 6 and 7). This family possess wide distribution in the tropics, and it is considered one of the most evolved lines, either from morphological side as for its richness and abundance, being the third biggest in number of species in the world (Azani et al., 2017), it is also named as one family that have always been present in Brazil (Souza et al., 2018), especially in phytophysionomy of the savanna, as in the *stricto sensu* (Silva et al., 2016; Gama et al., 2018), Gallery forest (Matos and Felfili, 2010; Loschi et al., 2013) and savanna (Gomes et al., 2004; Bueno et al., 2013; Otoni et al., 2013; Giácomo et al., 2015). The evolutive success of the family gave, especially by the species' capacity to fix nitrogen by symbiosis, a crucial element in the adaptation of this kind in the savanna (Bustamante et al., 2004). This interaction propitiates competitive vantage and allows different phytophysionomies colonization, an essential element in the succession of the savanna (Gama et al., 2018).

Another characteristic related to the high richness and abundance is the succession stage, being common in areas

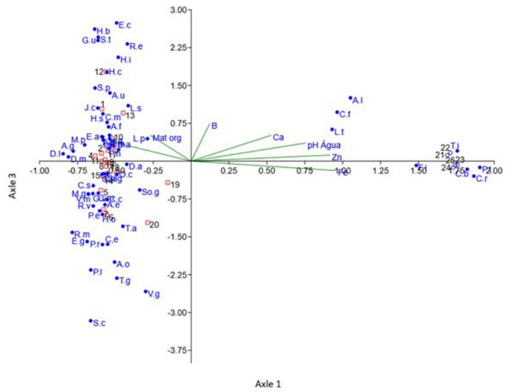

Figure 13. Canonical Correspondences Analysis (CCA) in a urban forest area, in Cuiabá city, Mato Grosso, Brazil. Explained variant percentage: Axle 1 = 48.6% and axle 3 = 15.3%. Blue circle is about the parcels located in damp area, and the red square to the others parcels. Green arrow are the eigenvectors of each variation. Only the first letter of the genre and specific epithet was added in the image.

that are in the process of the second succession (Deus and Oliveira, 2016; Sabino et al., 2016). In the fragment, we observed the predominancy of the specie *Anadenanthera peregrina,* classified as a secondary initial. This specie rules in the fragment of the area that corresponds the parcels 01 and 08 (Figure 3), where there are indications of occurring disruptions in the past, thus the natural pressure developed through the edge effect delaying the natural processes of succession.

Highlight the richness of the botanic family, Myrtaceae are among the richest but not among the most abundant, in other words, there are many species, but low individuals by species (Figures 6 and 7).

This family is registered as one of the richest families in the savanna because the species' adaptation function developed to the dispersion with several animals (Camilotti et al., 2011; Gomes et al., 2004; Casella and Silva Júnior, 2014), which is the primary interaction responsible for the evolution of angiosperms, and it is the most common syndrome in tropical forests, both in savanna areas and in forests (Corrêa et al., 2007; Vieira et al., 2002; Saravy et al., 2003).

Gomes et al. (2020) highlighted the demand for species of Myrtaceae in determinate soil characteristic as acid soil or the availability of replaceable aluminum, making those populations show an aggregate pattern of space distribution. Hence, eventually, this area of vegetation, by its size, could not cover the specific niche where those populations are predominant.

The sample sufficiency is based on the species-area curve. The adult tree layer, as in the regenerative (Figure 4), shows a weak tendency of stabilization. Otherwise, both with more than 80% of the waited maximum diversity based on the estimator Bootstrap allowed us to realize that the floristic piece of the parcel was the sampling representative accomplished majority. Consequently, the data shown in this study match entirely with the local flora.

The diametric distribution allowed us to perceive the decreased tendency, with more individuals concentrating on the first classes and gradually reducing to the following classes. This is a distribution pattern usual in natural forests and a good indicator from a structural perspective of the fragment once the concentration in individual concentration on the first class indicates high tree density in the initial development, and they take place in other classes in the natural process of succession (Meyer, 1952; Higman et al., 1999). This aspect is interesting to the area's dynamic once the natural replacement of the individual that died is assured and shown a regenerative potential.

There is an increase in the proportion of zoochory species compared to the anemochory species when comparing the two layers (Figure 8). The significant decrease in the proportion of anemochory species may indicate an intermediate stage of succession. According to Vieira et al. (2002), seed dispersal through anemochory is more efficient in open areas. Since the studied fragment consists of a forested savanna phytophisionomy (with canopy), it is possible that the group of anemochory species, which is the predominant syndrome among early-stage species (van der Pijl, 1982), has already fulfilled its ecological function and permanent species are replacing it with a longer life cycle and a more complex dispersion syndrome.

Regarding the species classification in ecological groups (Figure 9), on both layers, the percentage of each group is almost equal, with low florist representation of the first species and late secondary species, which also indicates that the forest remains are found in a stage between the succession to the major proportion of the early secondary.

Both areas stratified (dry and damp area) are floristically different and reflect how the vegetation answers the environmental stimulus, different by the occurrence of lithic neosols in the parcels classified as belonging to the dry area and gleisoil on the damp area. The x factor is the hydromorphism, which works as an environmental filter for some species, because it creates the specific condition to the plant development, making the group of species that occurs in that area distinct from the common species in soil not hydromorphic (Azevedo et al., 2014; Veloso et al., 2014).

Observing the Jaccard and Morisita similarity dendrograms (Figures 10 and 11), we observed that this pattern of clustering of parcels is repeated, creating two major groups: the parcels from the dry area and parcels from the damp area. This information was visually confirmed and supported by the analyses.

The regenerating layer of Morisita grouped parcel 1 as the same group of the parcels from the damp area. This occurred because the index also considers the number of trees per species, which was high in parcel 1 of the regenerating layer, which was akin to the layer in the damp area. However, as observed in Figure 3, this parcel is located far from the damp area of the fragment, in the region under the influence of the lithic neosols, which is an interesting aspect to highlight due to the interpretation of the indices based on field observations.

According to the Jaccard index, among the regenerating layer, 19 was grouped with the parcels from the damp area, which is understandable since it is located near the damp area of the fragment and is influenced by hydromorphism in the pedogenetic process. However, inferring whether these species will establish themselves over time is impossible. On the other hand, the dendrograms of the adult component, which use data from the already established trees, are more dependable for concluding the clustering patterns based on similarity.

In the dry area of the fragment, there is a substitution of species, as observed in the regeneration classification, which shows that the most important species in the adult stratum are not the densest in regeneration, except for *Protium heptaphyllum*, which had high density in both layers. This fact can be confirmed through the indicator species index (IndVal), which demonstrated that the species *Anadenanthera peregrina*, *Astronium fraxinifolium*, *Curatella americana*, *Matayba guianensis,* and *Protium heptaphyllum* are indicators in the adult layer of the dry area, and *Cardiopetalum calophyllum*, *Cordiera macrophylla*, *Ouratea castaneifolia,* and *Protium heptaphyllum,* are indicators in the regenerating layer of the dry area. This distinct composition between the layers is essential since species substitution is a natural process through the stages, as Egler (1954) described and observed in tropical forests (Rech et al., 2015; Longhi et al., 2000; Garcia et al., 2011).

On the damp area, the species indicator on the adult layer was *Calophyllum brasiliense*, *Cariniana rubra,* and *Tabebyua insignis*, and on the layer regenerative, beyond those three species, *Ficus insipida*, *Leucaena leucocephala*, *Moquilea tomentosa,* and *Syzygium jambos* also considered by the index, being the three last ones exotic, that is, there is some similarity with the species indicator on the adult layer; but, exotic species are appearing by this layer, and the characteristics of some of them will be discussed on the following paragraph.

In the sampling of the regenerating layer of the damp area, it was checked that there are more species in the natural regeneration than in the floristic composition of the adult vegetation. This can be explained by the fact that propagules arrive through the watercourse in the fragment, which results in propagules of exotic species, such as the three mentioned above, plus *Albizia lebbeck*, *Clitoria fairchildiana*, *Mangifera indica,* and *Ricinus communis*, what, from the exotic found only *M. tomentosa*, which is exotic to the biome but occurs naturally in the Brazilian Northeast, in the states of Alagoas, Bahia, Ceará, Paraíba, Pernambuco, Piauí, Rio Grande do Norte e Sergipe (Sothers and Prance, 2024), in the Atlantic forest, is the only one that is not considered invasive. In the regenerating layer of the dry area of the fragment were found three exotic species, being them *M. tomentosa*, *A. lebbeck*, and *P. guajava,* which these last two are invasives.

The colonization of these exotic species occurred primarily due to their introduction by humans in their widespread use for urban afforestation. Before addressing eradication techniques, it is important to encourage the use of native species that have ornamental potential, as well as to develop research on their silviculture.

The invasion by exotic species of natural vegetation areas can present risks, being necessary for evaluating the possible impacts that may occur on the composition, structure, and ecological relations that already exist in the ecosystem (Miyamura et al., 2019). Usually, the success of a plant in a new environment to become invasive is given by the characteristics that are competitive advantages with the native species, such as high efficiency photosynthetic on the use of the nutrients, fast cycle, fast grow-upping and multiplication, regrown capacity, intensive production and seed distribution, allopathic effects, beyond that might not be any natural predators (Everett, 2000; Rejmánek, 1996; Williamson and Fitter, 1996; Matos and Pivello, 2009).

Among the exotic species that were found in the study area, *L. leucocephala*, which until this moment does not do part of the adult layer on the fragment, was located on the regeneration of the damp area of the fragment, and its occurrence shows some ricks of ecological unbalance on the ecosystem. According to the Global Program of invasive species (Matthews and Brand, 2005), *L. leucocephala* is considered one of the world's 100 worst exotic invasive species. Each can produce 2000 seeds in a year (Instituto Hórus, 2022).

Studies proved the aggressivity and the capability invasive of species, together with the allopathic effect (Eleutério, 2021; Ribeiro et al., 2019; Pires et al., 2001). The *L. leucocephala* can compete and exclude native species, with high potation to invade the surrounding areas very quickly (Instituto Hórus, 2022). Studies point out the aggressivity of this species to urban ecosystems in all territories of Brazil (Nigro and Moreira, 2021; Martelli et al., 2020; Baloque and Capoane, 2021; Mamede and Benites, 2020).

Two exotic species were found in the adult component of the dry area of the fragment. *Hevea brasiliensis,* with all of 26 trees in parcel 12 that is located near a region constructed of the fragment, which is due to cultivation made in the area. Distinctively, *Swietenia macrophylla* (Mohogany), the other exotic species found in the dry areas, with two individuals sampled in parcel 3, probably regenerated itself by the dispersal seed by the trees nearby the head office of IBAMA, since that parcel, beyond being located near the head office, it is near to a water course intermittent at a lower elevation on the land (Figure 3), rising, that way, the possibility of deposition of these seeds. Another obvious evidence of this exemplar is from a plantation is that the species is not native to the biome beyond the diameter of that is near to 10 cm (first diameter class, Figure 5), being in initial growth mode.

We observed that the parcels located near the damp area possess higher levels of Ca, Zn, and Fe and an alkaline pH, being possible to check the CCA the close relation of those variables with a group of species of the damp area on both layers sampled and studied (Figure 12). The species *A. lebbeck* and *M. tomentosa* was associated with those variables; soever, also occurred in the dry area in small scale. Thus, it is inaccurate to affirm that a pattern of aggregation of those species is a function of the variables analysis since high density occurs in the damp area, influencing the index. A justification is the effortless way they arrive propagated by the water, as was established previously, beyond not being species exclusively of the damp area. The following species *C. rubra, C. brasiliensis,* and *T. insignis,* physiologically can develop, at least in predominant populations, in wet forests, such as riparian forests and the savanna gallery, inundated forests, and Pantanal (Santos, 2020; Oliveira, 2018; Costa Neto et al., 2018; Pinheiro et al., 2018; Pott et al., 2011).

The parcels in the dry area showed quite different tenors, concentrations bigger of K, organic material, and B, and another with low levels of K, organic material, B, Ca, pH water, Zn, and Fe. So, there is no obvious space distinction or relationship between any specific species group, those patterns were impossible to observe because of the total fragmentation, which is considered small to this specific analysis. Those relations were established in the damp area because the variability associated with there is a close relationship with the soil class and works as an environmental filter to the selected species.

5. Conclusions

Although the effects of this fragmentation, the ecosystem kept itself in structure and composition. Shown a heterogeneous environment, with the presence of two different ranches in order of different pedogenic processes (hydromorphic soil and drained soil), and that condition the manifestation of distinct forest community with low floristic similarity and high diversity.

Studying the natural regeneration, we observed the substitution of species regarding the adult layer as a positive point of view, because there is no predominant population and are advanced succession species. On the other hand, it is worrisome that the incidence of exotic species from the urban forest in the damp area threatens the balance between the population because of the competition, which may cause a loss of diversity.

The colonization of those exotic species happened, especially through the introduction by men on a large scale to urban forests, and even before dealing with eradication techniques, it is essential to encourage the use and develop research with forestry of the native species that shows us ornamental potential. Therefore, with preventive measures, it is necessary to remove the exotic species from the area that presents a risk of invasion to the natural environment. We even suggest no to use them to recover areas nor as an ornamental tree.

The urban fragment studied is important from the point of view economic and social regarding biodiversity conservation; besides allocating different native species regarding both flora and fauna, it still has a significant role in the city and is beneficial, frequently direct, about the population quality of life.

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