Acta Botanica Brasilica, 2023, 37: e20230150
doi: https://doi.org/10.1590/1677-941X-ABB-2023-0150

Original article

Botanical structure of two urbansecondary forest and associations with meliponiculture in eastern Amazon

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Received: June 11, 2023
Accepted: July 05, 2023

ABSTRACT

The structure of urban secondary forests and their potential for meliponiculture in the eastern Amazon was studied in the municipality of Belterra, Pará. The sampling was carried out in 25 plots of 40 m2 in two areas (0.1 ha) of secondary forests (SF), in which three classes of DBH values were considered (C1:1 cm ≤ DBH ≤ 5 cm; C2: 5 cm < DBH ≤ 10 cm and C3: DBH ≥ 10 cm). a total of 230 individuals were registered in SF I, comprising 66 species and 27 botanical families and 185 individuals in SF II, comprising 43 species distributed in 24 botanical families. The highest richness and abundance were verified for C1, followed by C2 in both areas. In SF I, the basal area values (G=1.509) were higher than in SF II, while the total volume (V=20.21) was higher than SF I, the mean height for C3 was higher in SF II, and C1 and C2 were higher in SF I. The Shannon-Wiener diversity index was higher in SF I (H = 3.722) than in SF II (H=3.197). It was observed that 75% species have bee pollination systems (mellitophilous flora) and are thus considered sources of honey resources.

Keywords: Secondary succession; Biodiversity; Mellitophilous flora, bees, Meliponiculture.

Introduction

Brazil contains the largest remaining expanse of tropical forests on the planet, with more than 60% of the Amazon rainforest within its borders (FAO 2010). As in other tropical regions, the abandonment of agricultural areas and the increase in deforestation rates, mainly due to the occurrence of infrastructure works for urbanization, and expansion of agriculture for food and commodity production, have led to the growth of secondary forests throughout the country. These forests are the result of a natural process of vegetation regeneration in areas where previously there was ground-level cutting of the primary forest and are fundamental for the conservation of biodiversity and carbon sequestration, guarantee of water supply and pollination of plants (Vieira & Gardner 2012; Chazdon *et al*. 2016; Elias *et al*. 2017; Giannini *et al*. 2017; Lennox *et al*. 2018; Silva Junior *et al*. 2020).

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One of the ecosystem services that brings benefits to humans, since it is important for the maintenance of native and cultivated plant populations, is pollination, which aids genetic variability in a population through the transfer of pollen grains from the male parts of flowers to the female, thus resulting in the formation of fruits and seeds (Ollerton *et al*. 2011; Costanza *et al*. 2017; Roubik 2018). Considered to be the world's main pollinating agents, bees interact with approximately 80% of flowering plant species and with 73% of cultivated agricultural species (Ricketts *et al*. 2008; Potts *et al*. 2010; Ollerton *et al*. 2011; Rech *et al*. 2014). In Brazil, of 114 cultivated plants used directly or indirectly for food, about 66% are pollinated by bees (Wolowski *et al*. 2019).

In the interior of the Amazon, the breeding of stingless bees (meliponiculture) has been shown to be an activity that fits perfectly into the precepts of sustainable use of natural resources and has been shown to be an excellent alternative for income generation among traditional populations (Absy *et al*. 2018; Rezende *et al*.2021). In the west of the state of Pará, in the lower Amazon, the practice of keeping stingless bees (meliponiculture) has shown great potential as a sustainable activity (Pires *et al*. 2020). Plant recovery with native species in degraded areas favors meliponiculture by reintroducing those that meet the food needs of bees, based on the periods of nectar and pollen supply (Luz *et al*. 2014).

The survey of the flora around the bee hives can identify and recognize the plant species that are part of the diet of bees, and assists in studies of biodiversity, natural resource management and environmental recovery programs (Pierre *et al*. 2018). Plants that are attractive to bees can be classified into: plants that produce pollen in large quantities (pollinating flora), plants that provide nectar (nectariferous flora) and plants that simultaneously provide pollen and nectar (nectariferous-pollinating flora) (Barth 2004).

In this way, the knowledge of the mellitophilous flora provides a greater knowledge of the particularities of the ecosystems in which bee keeping activities are developed. This helps to establish productive potential and management possibilities since the variability of the flora allows a sustainable and profitable meliponiculture (Absy *et al*. 2018; Ferreira *et al*. 2021; Souza *et al*. 2020; 2021).

As such, the present study aims to reveal the floristic composition and apicultural potential of two areas of secondary forests in the eastern Amazon.

Materials and methods

Study Area

The study was conducted in the municipality of Belterra, western Pará (- 54°45'57" W; 02°33'32.39" S and 55°06'36.48" W; 02°54'49" S), in two areas that are at an altitude of approximately 152 m (Fig. 1). The climate of

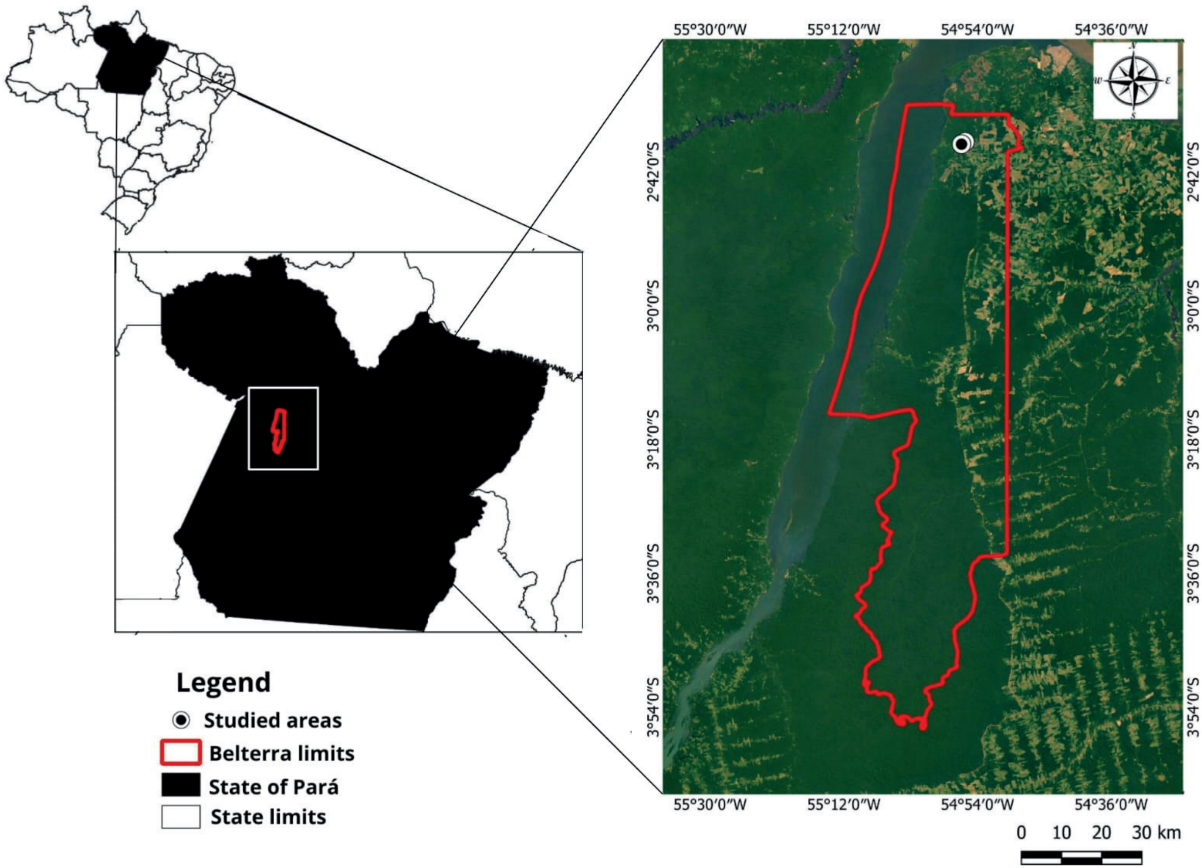


Figure 1. Areas of secondary forest in the municipality of Belterra, western Pará.

the region, according to the Köppen classification is of type Ami (megathermal, tropical humid), with the average temperature of the coldest month being above 18 °C. It also has an average annual temperature around 24.8 °C, average relative humidity of 90% and average annual precipitation of 2100 mm (Furtado-Neto *et al*. 2019) According to Espírito-Santo *et al.* (2005), the vegetation is classified as Dense Lowland Ombrophilous Forest, characterized by the dominance of large arboreal individuals and the abundance of woody lianas, palms and epiphytes. The relief is flat or dissected, the floodplains are periodically flooded rainy period (Andrade et *al*. 2015).

Characterization of sampled areas

Two areas of secondary forest where stingless bee keeping occurs were selected. These were named secondary forest I (SF I) and secondary forest II (SF II), which developed in areas that were deforested for agricultural activities. The vegetation of SF I is approximately 12 years old and that of SF II is approximately 18 years old. The plots were chosen due to them being areas favorable to bee foraging (Aleixo *et al*. 2014).

Analysis of floristic composition

Vegetation was evaluated by sampling 25 plots of 10 x 4 m (1,000 m2), which were systematically distributed in each area. The foraging radius of local bees (1,000 m2) was taken into account (Aleixo *et al*. 2014). Although SF I was larger in size, we opted for the same number of plots as SF II in order to facilitate the comparison between them regarding vegetation parameters. SF I and SF II present characteristics of an anthropized environment, and in these spaces a greater number of anthropic pressures are exerted such as deforestation of vegetation and agriculture.

Individual trees were grouped into three diameter classes: C1: 1 cm ≤ DBH ≤ 5 cm in the first 10 m (2 m x 5 m); C2: 5 cm < DBH ≤ 10 cm in the first 20 m (2 m x 10 m) and C3: DBH > 10 cm throughout the plot (10 m x 4 m) as illustrated in (Fig. 2). Any species that were not identified in the field were collected and identified with the help of the literature and consultation of exsiccates listed in the Herbarium of the Federal University of Western Pará (UFOPA). The botanical nomenclature was checked with the electronic database of the list of species of Flora of Brazil (Brazil Flora Group 2021).

To sample the vegetation, botanical expeditions were carried out in the areas in 2021 and plant specimens were collected. Only fertile samples (with flower, fruit or spores) were collected, as recommended by Mori *et al.* (1989). At the Plant Systematics Laboratory of the Federal University of Western Pará, the material was dehydrated in an oven at a temperature of 60 °C (for 2 to 3 days) and then sent for identification. After identification, the species were incorporated into the UFOPA herbarium collection.

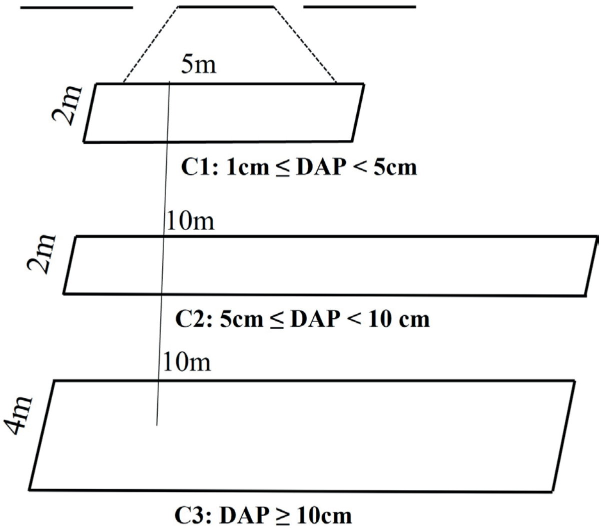


Figure 2. Representation of the sample units with the identification of the diameter classes of the inventoried plant species. Adapted from Andrade *et al.* (2015).

Each specimen received a registration number containing all the information regarding the place of collection, morphological characteristics, and the identification of the taxonomic group. For the latter, essential criteria for proper identification were met. Among them, (APG IV 2016) was adopted as the species classification system, while their names were verified in the databases of Flora do Brasil 2020 (Brazil Flora Group 2021; IPNI 2023). Subsequently, the species were listed and organized into botanical families, genera and also in terms of origin: exotic or native (Lorenzi 2010; Moro & Martins 2011) regarding the ecological group: pioneers, early secondary and late secondary (Gandolfi *et al*. 1995; Fonseca & Rodrigues 2000; Carvalho & Nodari 2007), as for the dispersion type: anemochory, autochory and zoochory (Van der Pijl 1982); as for the pollination system, this followed the classification proposed by Faegri and Van der Pijl (1979) and also specialized literature on pollination ecology, reproductive and floral biology, in addition to a specialized database (https://www.rcpol.org.br; RCPol 2021), so as to determine the types of pollinators of each plant species and the available resources.

Data analysis

For each area, four types of attributes were considered: floristic composition attribute, structural attributes (density of individuals per plot, average diameter at ground height); diversity attributes (species richness and diversity); functional attributes (successional category, frequency distribution of dispersal syndromes for species and individuals and pollination system). Using the analysis of the floristic composition, the Shannon diversity index (H'), the Pielou equability index and the Simpson dominance index were calculated.

To compare the areas, cluster analysis was performed, using an abundance matrix to calculate the similarity matrix with the Bray-Curtis index and the linkage method with unweighted pair group method with arithmetic mean (UPMGA) algorithm.

The mean species accumulation curve with an increase in the number of sampled individuals was calculated in the EstimateS 8.2.0 program (Colwell 2009), considering 100 randomizations of the data. In addition to the mean curve, the expected number of species was calculated using the nonparametric richness estimator bootstrap, which is a richness estimator based on the incidence of species, and allows one to standardize species richness comparisons to a common number of individuals (Freitas & Magalhães 2012).

The diametric structure of the areas was characterized by the frequency of the number of trees for each diameter class. The phytosociological parameters and the dendrogram were calculated in the FITOPAC 2.1 program (Shepherd 2009) and the parameters of the diametric structure were calculated in Excel 2010.

Results

Floristic composition

In both areas, considering the 2,000 m2, 415 individuals belonging to 40 families, 66 genera and 99 species were sampled. In SF I, 230 individuals were sampled, which belong to 66 species distributed in 27 botanical families; C1 with 49 species distributed in 22 families. Meliaceae had the highest number of individuals (15) and Fabaceae had the highest number of species (7); C2 with 19 species distributed in 10 families, Apocynaceae with the highest number of individuals (12) and Meliaceae with the highest number of species (7) and, in C3, 15 botanical families, 26 species were sampled, Meliaceae with 12 individuals and Apocynaceae with the highest number of species (9). While, in SF II, 43 species were sampled, which were distributed in 24 botanical families; C1, 29 species and 18 families, Hypericaceae presented the largest number of individuals (26) and Meliaceae presented the largest number of species (5); in C2 18 species and 15 families were sampled, with emphasis on Myrtaceae (8) and Hypericaceae (3), which had the greatest number of species, and C3, in which 20 species were sampled that belonged to 15 families, with emphasis on Anacardiaceae with 12 individuals and Fabaceae with the greatest number of species (3). SF II presented higher values for volume and height for class C3, characterizing it as "capoeira" or advanced stage of regeneration, with trees that reach an average height of greater than 13 meters and the average diameter was greater than 10 cm. The areas SF I and SF II presented higher species richness and abundance of individuals for the diameter classes C1, followed by C2 in both areas.

Horizontal structure attributes

The structural parameters of the vegetation sampled in the two areas show that there is no significant difference in the number of species and botanical families sampled per plot, which reinforces the fact that, from the floristic point of view, the areas are similar. There was also no significant difference between the areas regarding the number of individuals when using the one-way ANOVA test, followed by the Tukey-Kramer "t" test calculation in the PAST program (Hammer *et al.* 2001), considering a significance level of 5% (p-value < 0.05), obtaining as a result p = 0.3862.

In SF I for C1, 22 families, 49 species and 130 individuals, with a basal area (G) 0.069 m2/ha, total volume of 0.29 m3, with mean height 3.6 m were identified; and, for C2, 10 families, 19 species and 49 individuals were identified. The basal area (G) was 0.16 m2/ha with a total volume of 1.04 m3 with an average height of 6.2 m. For C3, 15 families and 26 species were identified, totaling 55 individuals. The basal area (G) was 1.28 m2/ha with a total volume of 14.25 m3, with an average height of 8.4 m.

The most ecologically important species, according to the importance value index (IVI) for SF I (C1), were *Fusaea longifolia* (Aubl.) Saff. (6.8%), *Hancornia speciosa* Gomes (6.4%), *Doliocarpus glomeratus* Eichler (6.2%), *Vismia guianensis* (Aubl.) Choisy (5.9%), *Guarea kunthiana* A.Juss. (5.4%), *Guarea guidona* (L.) Sleumer (5.1%), *Vismia baccifera* (L.) Triana & Planch. (4.9%), (C2), *Hancornia speciosa* Gomes (19.2%), *Trichilia pallida* SW. (13.2%), *Talisia mollis* (9.5%), *Fusaea longifolia* (Aubl.) Saff. (7.6%), *Vismia baccifera* (L.) Triana & Planch. (5.5%), *Guarea kunthiana* A.Juss. (4.9%) and *Vismia guianensis* (Aubl.) Choisy (4.4%), and for (C3), these were *Trichilia pallida* SW. (16.2%), *Hancornia speciosa* Gomes (12.16%), *Caryocar brasilienses* Cambess. (8.50%), *Jacaranda copaia* (Aubl.) D.Don (7.67%), *Talisia carinata* Radlk. (7.01%), and *Vismia guianensis* (Aubl.) Choisy (5.66%).

In SF II, for C1, there were 18 families, 29 species and 100 individuals. The basal area (G) 0.06 m2/ha, total volume of 0.23 m3, with mean height 3.3 m. For C2, 15 families, 18 species and 40 individuals were identified. The basal area (G) was 0.15 m2/ha, with a total volume of 1.08 m3, with an average height of 6.2 m. For C3, 15 families and 20 species were identified, totaling 55 individuals, basal area (G) was 1,135 m2/ha, with a total volume of 18.9 m3, and an average height of 13.3 m

The dominant species in this area were *Vismia baccifera* (L.) Triana & Planch. of the family Hypericaceae, which presented 23 individuals, followed by *Byrsonima sericea* DC. of the family Malpighiaceae with 21, *Tapirira guianensis* Aubl. of the family Anacardiaceae with 21 individuals, the genus *Myrcia* of the family Myrtaceae with 19 individuals distributed in two species *Myrcia sylvatica* DC. (13) and *Myrcia splendens* DC. with 6 individuals respectively.

In SF II, for C1, *Vismia baccifera* (L.) Triana & Planch (16.3%), *Byrsonima sericea* DC. (10.8%), *Guarea guidonia* (L.) Sleumer (9.8%), *Myrcia sylvatica* DC. (7.9%), *Lacistema aggregatum* (P.J. Bergius) Rusby (7.3%) and *Vismia guianensis* (Aubl.) Choisy (7.0%) were present; and, in C2, the species *Tapirira guianensis* Aubl. (17.9%), *Byrsonima sericea* DC. (14%), *Myrcia sylvatica* DC. (11%), *Myrcia splendens* DC. (8.8%), *Casearia javitensis* Kunth (6.9%) and *Cecropia palmata* (6.0%) and C3, *Tapirira guianensis* Aubl. (27%), *Cecropia palmata* Willd. (7.1%), Inga Alba (Sw.) Willd. (6.6%) and *Inga thibaudiana* DC. (6.4%), *Myrcia splendens* DC. (5.9%), *Theobroma grandiflorum* (Willd. ex Spreng.) K.Schum. (5.2%), and *Trichilia pallida* Sw. (5.0%) were present.

The result obtained for the frequency distribution in the diameter classes and presented in the graph in the form of an inverted "J" is the pattern presented for secondary forests with a large concentration of individuals in the smaller diameter classes and a drastic reduction in the number of individuals occupying the larger diameter classes (Fig. 3). The mean curve of species accumulation in SF I and SF II (Fig. 4) shows that, in SF I, there was a higher accumulation rate, since 66 species were sampled in this

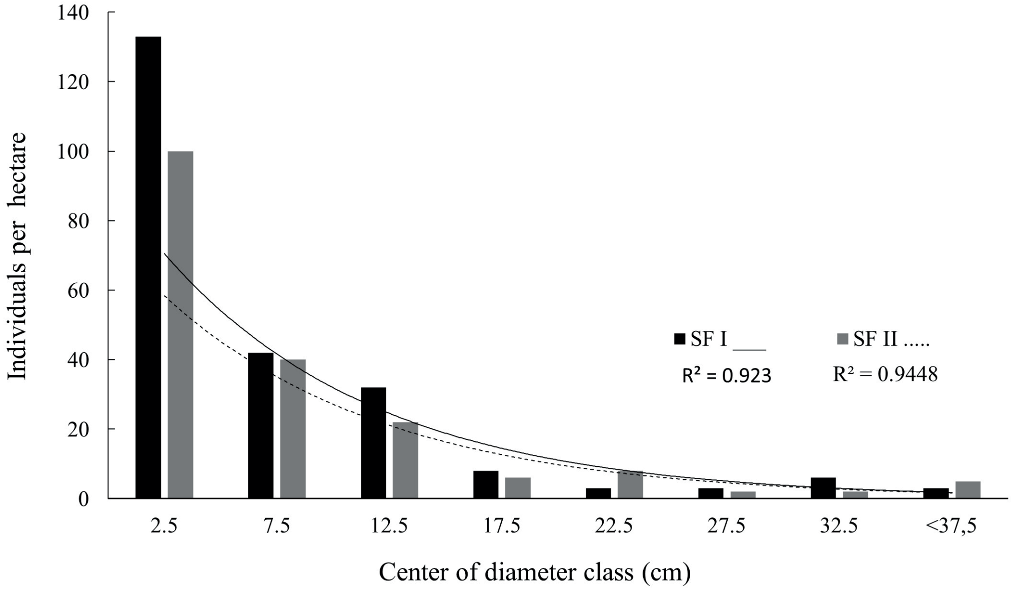


Figure 3. Absolute and cumulative frequency of the diameter distribution (cm) of the individuals sampled in two areas of secondary forests in Belterra, Pará.

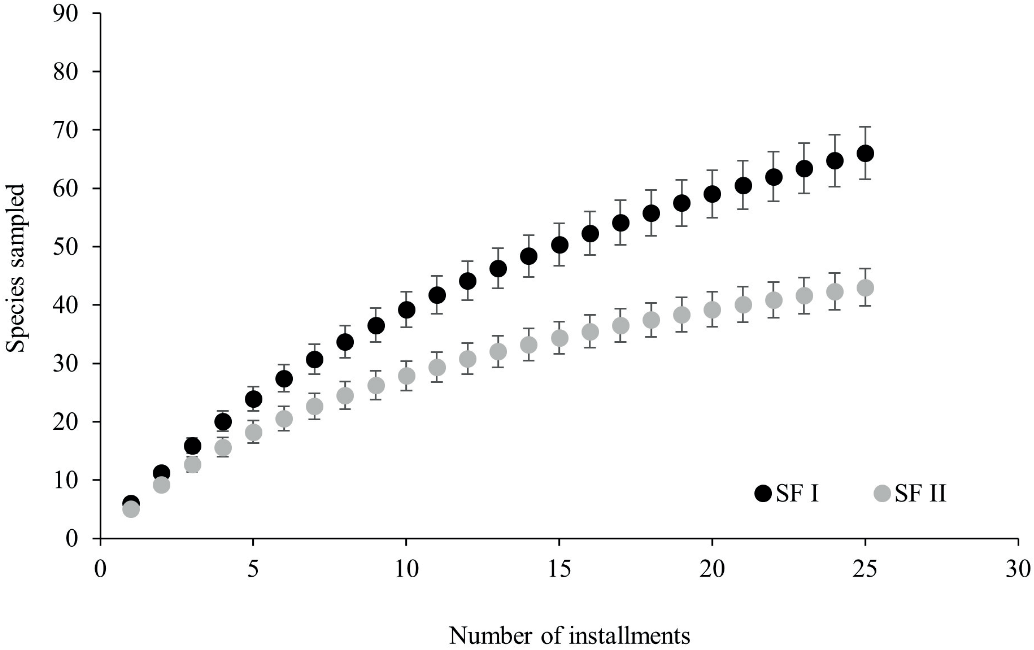


Figure 4. Mean species accumulation curve in two stingless-bee beekeeping areas in Belterra, Pará.

area, compared to the 43 species sampled in SF II. The number of individuals sampled in SF I was also higher (230) when compared to SF II (185). Regarding the expected number of species calculated via the bootstrap estimator, in SF I, 80 species were estimated; while, in SF II, 50 species were estimated, which indicates that about 83% and 86% of the species, respectively, were effectively sampled in the two areas (Fig. 5).

Based on the rarefaction curve, it is inferred that the sample sufficiency for the richness at the site is close to being reached (Fig. 5). It is worth mentioning that it was not possible to install more sampling units in the areas, due to the foraging radius of the bees raised in the hives, which is estimated at 1 km (Aleixo *et al*. 2014).

The Shannon-Wiener index found for SF I was H' = 3.722, and for SF II this was H' = 3.197. The Pielou index was 0.088 (SF I) and 0.849 (SF II). The Simpson index showed values of 0.962 (SF I) and 0.938 (SF II), with the value of SF I being slightly higher.

The cluster analysis of the floristic similarity of the two areas showed a differentiation in three groups. The first being formed by most of the plots of SF II, while the second was formed by the plots of SF I, the third was formed by plots of SF II with plots of SF I. Thus, it is noticed that the closer plots are more related to each other than the distant ones, and present a higher value of floristic similarity than the more distant plots (Fig. 6).

Functional attributes

As for the successional category, the largest number of species were the pioneers (46 species) followed by early secondary (23 species), late secondary (20 species), climax (4 species) and unidentified (2 species) (Fig. 7). Regarding dispersion type, in SF I, 22.5% of species and 55% of individuals are of dispersion via anemochory, 2.5% of species and 0.5% of individuals are of dispersion via autochory, while 75% of species and 44.5% of individuals are of dispersion via zoochory. In SF II, 28.1% of species and 29.8% of individuals are of dispersion via anemochory, 1.8% of species and 1.3% of individuals are of dispersion via autochory and 70.2% of species and 68.8% of individuals are of dispersion via zoochory (Fig. 8).

The vegetation of the two study areas presented a higher proportion of individuals of species that employ zoochory (Fig. 8). In the comparison between the frequency distributions of dispersal syndromes for species, 84% of the species in SF I employ zoochory; while, in SF II, the proportion is 91% (Fig. 9). The comparison shows that there was no statistically significant difference between the frequency distributions of dispersal syndromes for the species of the two areas.

Mellitophilous flora

Of the 66 species in SF I and of the 43 species in SF II, 72.7% (n=48 spp.) and 79.1% (n=34), respectively, are considered melliferous (Fig. 10).

Discussion

The results of this study fit within the proposal of Salomão *et al*. (2012) for a classification system of successional stages of secondary forests for the state of Pará (initial, intermediate and advanced). This suggests

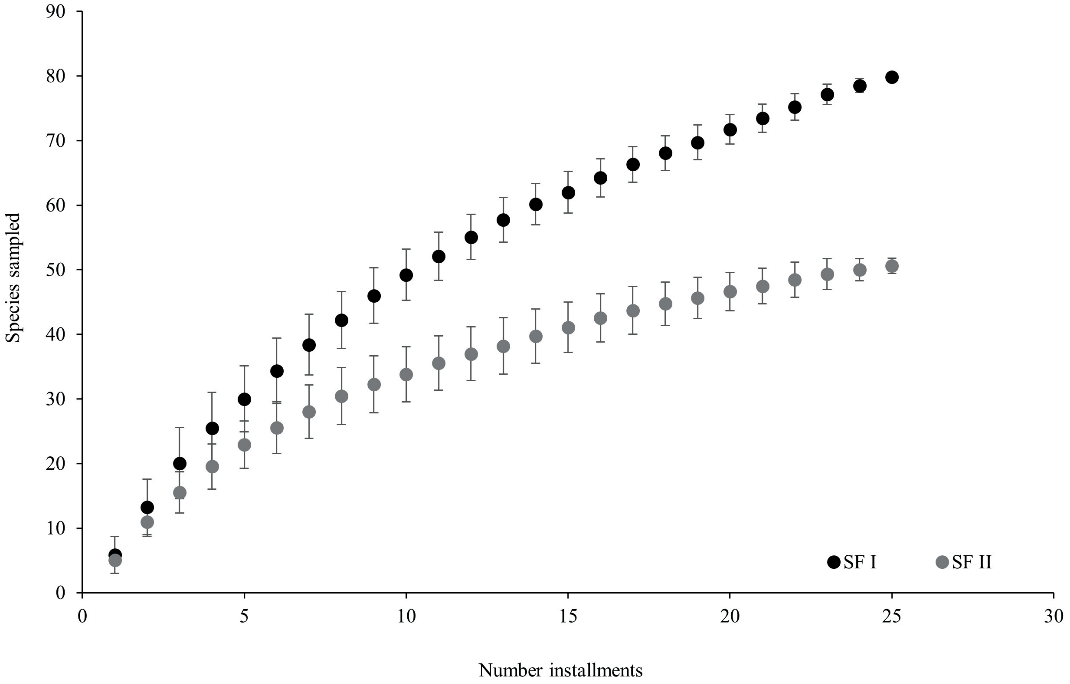


Figure 5. Non-parametric bootstrap method in two stingless-bee beekeeping areas in Belterra, Pará.

that they may have arisen from the abandonment of agricultural areas or abandoned pastures. There is presence of pioneer trees of few species of the genera *Vismia* Vand., *Cecropia* Loefl. and *Solanum* L., thus characterizing the initial stage of succession. In addition, there is a mixture of medium-sized species, which are characterized as shrub-tree, with a predominance of pioneer tree species, such as *Tapirira guianensis* and species of the genera *Vismia* Vand., *Inga* Mill. and *Cecropia* Loefl. and trees with an average height greater than 10 m and an average DBH greater than 11 cm (Vieira *et al*. 2003; Vieira & Proctor 2007)

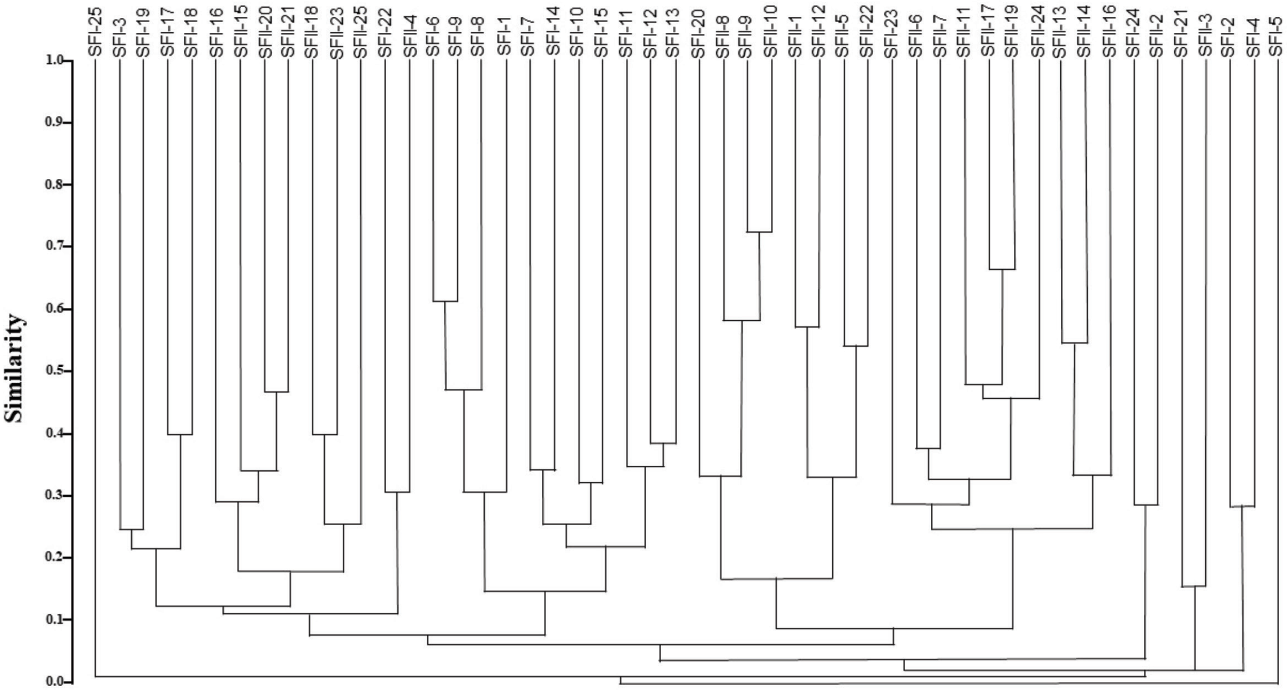


Figure 6. Dendrogram of floristic similarity (Bray-Curtis index) between the sampled plots in two areas in Belterra, Pará.

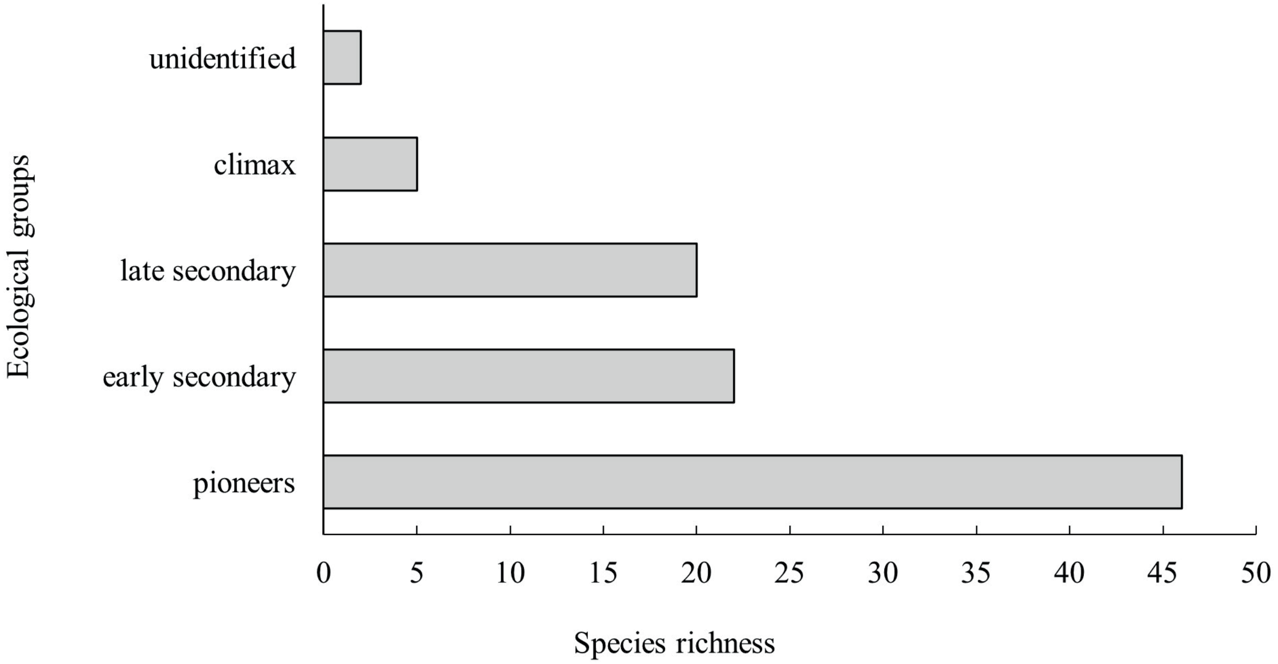


Figure 7. Most important ecological groups in species observed in two areas of secondary forest near the hives of stingless bees in Belterra, Pará.

Attributes of the horizontal structure

Larger basal area in more advanced successional stages is common in forest environments, while density does not always follow this trend. The lower density of SF II compared to SF I is the result of a vertically stratified environment, in which larger trees compete with smaller ones and inhibit their development. Thus, it must be emphasized that SF I presented a higher density due to being in a more initial successional stage when compared to SF II, in which species and individuals compete more equitably with each other for the existing resources.

According to Alves and Metzger (2006), secondary forest formations generally have a lower density of larger trees and a significant reduction in canopy cover. This can enable greater entry of light and faster growth of plants of the regeneration that, in general, belong to pioneer species. Pioneer species are characterized by their higher relative growth rate (Puig 2008). The most important species in the structure of SF I and SF II are predominantly early pioneer and secondary species, which are common in areas at an early stage of secondary succession.

The species *Fusaea longifolia* (Aubl.) Saff. composes the natural vegetation of hygrophilous forest and normally

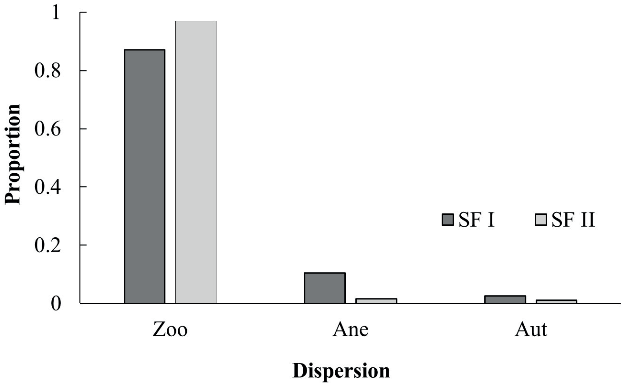


Figure 8. Frequency distribution of dispersal types for individuals in two areas of secondary forest near stingless-bee hives in Belterra, Pará.

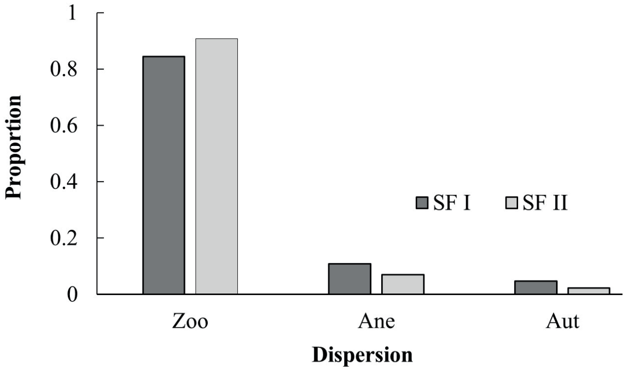
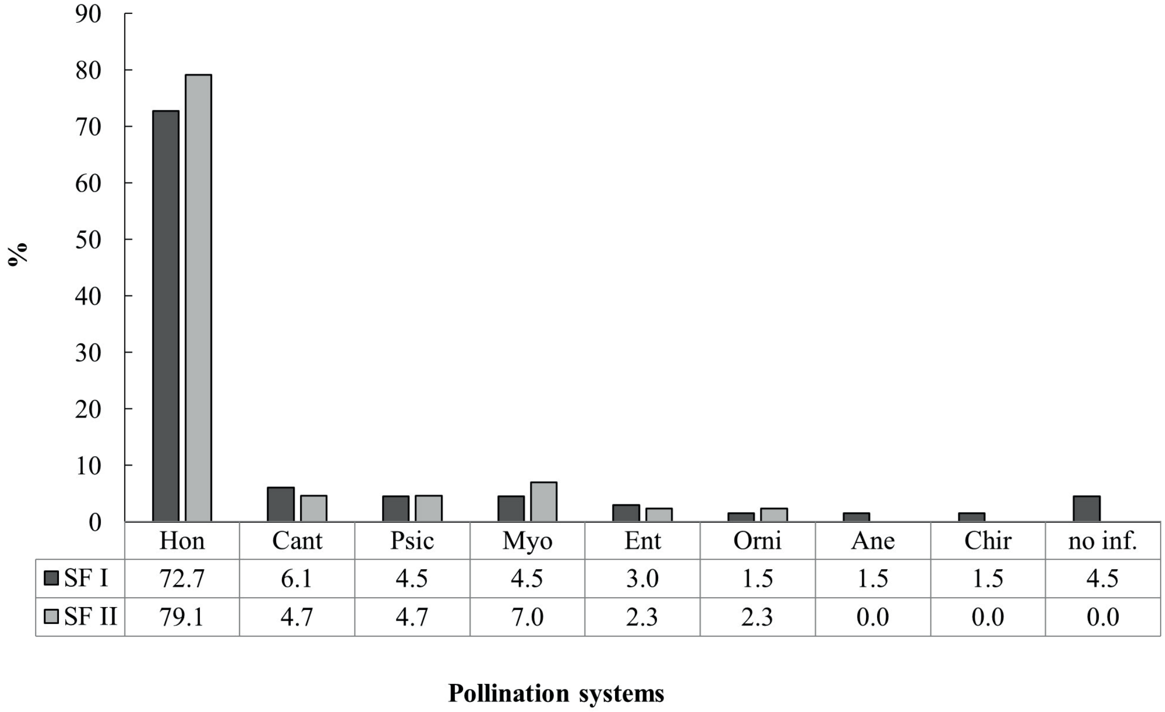


Figure 9. Frequency distribution of dispersal types for species in two areas of secondary forest near stingless-bee hives in Belterra, Pará.



	Hon	Cant	Psic	Myo	Ent	Orni	Ane	Chir	no inf.
■ SF I	72.7	6.1	4.5	4.5	3.0	1.5	1.5	1.5	4.5
□ SF II	79.1	4.7	4.7	7.0	2.3	2.3	0.0	0.0	0.0

Figure 10. Pollination systems preponderant in the species observed in two areas of secondary forest near the hives of stingless bees in Belterra, Pará. Ane: anemophilous, Cant: cantharophilous, Ent: Entomophilous, Phale: phalenophilous, Hon: mellitophilous, Myo: myophilous, Orni: ornithophilous, Psic: psicophilous, Chir: chiropterophilous and no inf: no information.

inhabits sub-forests in lands that are not periodically flooded (Rios & Pastore Junior 2011). In SF I, the dominance of the genus *Vismia* Vand. (Hypericaceae) was observed, which often dominates the “capoeiras” in the region of Manaus, Brazil (Mesquita *et al*. 2001; Mônaco *et al*. 2003). The species *Hancornia speciosa* Gomes (mangaba rubber tree), of the family Apocynaceae, which is a native forest species, is normally located in fragmented areas, due to the reduction in areas of its natural occurrence either due to forest fragmentation, real estate expansion, tourism and/or an increase in cultivated areas. Fertilization success and fruit production are dependent on floral visitors such as bees and moths (Darrault & Schlindwein 2005; Reis *et al*. 2009). The species *Trichilia pallida* Sw., family Meliaceae, is a late secondary or climax plant, semideciduous, heliophilous, selective hygrophytic, and characteristic of gallery thickets and humid forests. It is found throughout the southeastern and midwestern regions of Brazil, as well as in Paraná, Bahia, Acre, Pará, Roraima and Rondônia. It has a wide dispersion, but is discontinuous and sparse throughout its distribution area, with a low frequency (Lorenzi 2010). Species of the genus *Vismia* Vand. (Hypericaceae) are often pioneers in the successional processes of secondary forests and dominate extensive areas (Martins *et al*. 2018). Carvalho and Costa (2001) studied the ecological and socioeconomic importance of *Tapirira guianensis* Aubl. in a secondary forest in the municipality of Belterra in the Brazilian Amazon and identified the species as being arboreal, pioneer and very abundant in the secondary forests (capoeiras) of the Amazon.

Regarding the trend of the diametric distribution, the “inverted J” shape is observed, as is expected in secondary forests that presented a greater number of representatives in the smaller diameter classes and fewer individuals in the larger diameter classes (Figure 3). Regarding the trend of the diameter distribution, the “inverted J” shape of the histograms is observed, as is expected in secondary forests, and SF I and SF II presented a greater number of representatives in the smaller diameter classes and fewer individuals in the larger diameter classes (Fig. 3).

Due to the potential replacement of senescent individuals by young individuals, it is possible to infer that the forest community is developing towards more advanced successional stages (Lopes *et al*. 2002) and shows potential for self-regeneration (Callegaro *et al*. 2015). However, it is important that forest management measures are carried out in the area in order to ensure the maintenance of the ecosystem, since forest fragments are subject to species loss due to factors that are inherent to the isolation of populations and the influences of anthropogenic activities (Vieira *et al*. 2003; Vieira & Proctor 2007; Salomão *et al*. 2012; Lennox *et al*. 2018; Silva Junior *et al*. 2020; Pinheiro *et al*. 2021).

Attribute diversity

Although the average curve of species accumulation has not stabilized, it can be considered that the sampling was significant, since it covered a large part of the species expected for the area. In addition, for tropical forests, it is practically impossible to achieve the stability of the mean species accumulation curve by sampling. This is because the asymptote of the species accumulation curve is only reached if the spatial distribution of the species is random, which does not happen in natural forests, in which aggregation is an intrinsic characteristic (Schilling *et al*. 2012).

The values of the Shannon-Wiener index found in our study were similar to those found in Gama *et al*. (2002), (H’)= 3,05 who studied the floristic composition and structure of the natural regeneration of a lowland secondary forest in the Amazon estuary. The values found by Pinheiro *et al*. (2021), who studied the floristic and structural analysis of a secondary forest in two successional phases in the municipality of Capitão Poço in northeastern Pará, ranged from 0.914 to 0.910.

According to Uhl and Murphy (1981), equability is directly proportional to diversity and, therefore, presents high or low values according to the diversity found in the area. These same authors cite that all species contribute a different number of individuals in the community and that the values found may indicate greater dominance of one or more species. The diversity index reveals aspects of a community’s structure and can show general patterns when comparing communities that differ in species composition (Bulla 1994). A low value in the diversity index indicates that one or a few species are highly abundant, and a high value indicates that many species are equally abundant in the community (Wilson *et al*. 1996). However, as the age of the forests increases, vertical stratification becomes more evident, which increases the structural complexity and floristic heterogeneity of the community (Liebsch *et al*. 2008) and, consequently, implies an increase in species diversity (Puig 2008).

The cluster analysis of the floristic similarity of the two areas showed the division into three groupings; the first being formed by most of the plots of SF II, while the second was formed by the plots of SF I, the third was formed by plots of SF II with plots of SF I. Thus, it is noticed that the closer plots are more related to each other than the distant ones and present a higher value of floristic similarity than the more distant plots (Fig. 6).

Functional attributes

Secondary forest formations generally have a lower density of larger trees and a significant reduction in canopy cover. This can enable greater entry of light and faster growth of plants of the regeneration that, in general, belong to pioneer species. Pioneer species are characterized by a greater relative growth rate (Alves & Metzger 2006).

Rayol *et al*. (2006b) studied the dynamics of the natural regeneration of a secondary forest in Bragança in the state of Pará and observed that the pioneers were dominant. In a secondary forest in Capitão Poço, in the state of Pará, Rayol *et al*. (2006a) noted that the group of pioneers was also significantly superior to the climax species. According to the authors, this fact was due to the forest still being in primary phase of succession and, consequently, the canopy still allowed the entry of light. Similar results were found by Muniz *et al*. (2007) in a secondary forest in the municipality of Bragança, Pará, in which the presence of fast-growing pioneer species belonging to early stages of succession were superior to the tolerant species.

According to Santana (2000), secondary vegetation is usually composed of pioneer individuals, that are little tolerant to shading and that are adapted to conditions of low fertility or are not very demanding in regard to nutrients. These extremely aggressive plants in terms of occupying physical space allow the formation of a less hostile space that is suitable for smaller species that need conditions of better shade in order to establish and reproduce. With the continuation of this cycle, depending on the quality of the soil's seed bank and/or dispersal capacity, among other factors, the forest may again exhibit a structure that is similar to the previous one.

The highest proportion of individuals with zoochoric dispersion was also found by Rodrigues *et al*. (2012) who studied secondary forests in Tomé-açu, Pará, Brazil. The large number of species with zoochoric dispersion indicates that dispersing animal species are present in SF I and SF II. According to Oliveira *et al*. (2011) the high relative frequency of zoochory is an indication that the diversity of animal species and possibly their interaction with plants is being maintained, which is fundamental for the maintenance of these ecosystems.

Silva Júnior *et al*. (2020) considered the analysis of species dispersion types by vegetation type in a conservation unit in the Amazon and showed that, in the three forests studied – secondary forest (SF), flooded forest (FF) and terra firme forest (TFF), there was a predominance of zoochory followed by autochory (Fig. 4). In a fragment of secondary forest in Campinas, São Paulo, Kinoshita *et al*. (2006) found 63% of species to be zoochoric; Ferreira *et al*. (2010), in an evaluation of natural regeneration in an area under restoration, under the domain of Semideciduous Seasonal Forest, also found the predominance of zoochoric species (62.5%), and Leyser *et al*. (2012), in a study in the Alto Uruguay region, found 72% of species to be zoochoric in the regenerating stratum of Semideciduous Seasonal Forest. The predominance of zoochoric dispersion among forest formation species, followed by anemochoric species and finally autochoric species, has been demonstrated in studies by Melo & Durigan (2007), Daronco *et al*. (2013), Liebsch *et al*. (2008) and Kinoshita *et al*. (2006), and this hierarchical scale was observed in both areas of our study.

A study by Lennox *et al*. (2018), which was carried out in two regions of Pará, in the municipalities of Santarém, in the western region of the state, and Paragominas, in north-eastern Pará, measured carbon and researched more than 1,600 species of plants, birds and beetles in 59 secondary forests under natural regeneration and 30 primary undisturbed forests, identified that the analyzed areas correspond to young "capoeiras" (up to ten years), intermediate "capoeiras" (from 11 to 20 years) and old "capoeiras" (from 20 years).

Mellitophilous flora

The survey carried out in the secondary forests revealed that there is a diversity of tree, shrub and herbaceous species with potential for meliponiculture, and these can be used by the family farmers of the Belterra region. Mellitophilous floras, considered suitable for apiculture or meliponiculture, are composed of plant species that attract bees to collect floral resources such as pollen, nectar and oil, these being the basis of the nutrition of these insects in all their stages of development (Almeida *et al*. 2003).

Oliveira *et al*. (2009), in their study of the pollen resources collected by stingless bees in a fragment of urban secondary forest in Manaus, identified 90 pollen types distributed in 32 families, 67 genera, 81 species and nine indeterminate types. The type of habit of plants for pollen collection by bees included trees (68%), herbs (10.9%), shrubs (9.5%), palms (9.5%) and lianas (1.3%). Some sources were potential suppliers of pollen to bees and most were occasional and/or complementary sources. Also, in the study by Oliveira *et al*. (2009), the most visited plant families in terms of the number of pollen types were Fabaceae (25%), Myrtaceae (8%) and Arecaceae (8%) and in terms of monthly frequency were Fabaceae (21.23%), Melastomataceae (14.28%), Myrtaceae (11.86%), Anacardiaceae (6.45%), Arecaceae (6.23%), Malpighiaceae (6.11%) and Burseraceae (6.1%). The ten most important pollen types totaled 62.2% of the pollen frequency collected for the bee species, in which the main ones were *Miconia myriantha* Benth.,

Leucaena leucocephala (Lam.) de Wit, *Tapirira guianensis* Aubl., *Eugenia stipitata* McVaugh, *Protium heptaphyllum* (Aubl.) Marchand and *Vismia guianensis* DC. These are botanical species with potential as sources of trophic resources for stingless bees in areas of urban secondary forest.

The species *Tapirira guianensis* Aubl. is an arboreal, dioecious species that is abundant in the secondary forests of the eastern Amazon and has been indicated as a potential resource for bees since it has a high supply of flowers (Oliveira *et al*. 2009). This species was presented as primarily mellitophilous, with resources available to attract a great diversity of small and generalist visitors, which may contribute to pollination (Fernandes *et al*. 2012). The great abundance and diversity of floral visitors to *Tapirira guianensis* flowers occurs due to the high potential of this species, which offers pollen and nectar in volume and concentration of solutes that attract small insects. Families, such as Anarcadiaceae, Fabaceae, Oxalidaceae, Rutaceae and Sapotaceae, provide nectar and pollen in abundance (Costa *et al*. 2014).

In most species of Anacardiaceae, the floral reward offered to visitors, is nectar. In these species, the flowers have rimose anthers and their pollen is fully exposed, which favors opportunistic collections. Pollen grains of *Tapirira guianensis* Aubl. were found in honey samples of *Apis mellifera* (Linnaeus, 1758)., in a secondary forest area in Igarapé-Açu (Pará) and showed values that indicated it to be the dominant pollen in the months of high rainfall, a fact that makes it an important food source for colony maintenance (Oliveira *et al*. 1998). In two municipalities in the state of Pará, Carreira *et al*. (1986) observed that this species occurred in honey with pollen frequency of over 90%, a fact that indicates that it is monofloral honey.

Tapirira guianensis Aubl. is a tree that reaches a large size in the secondary forest and can be successfully used in heterogeneous reforestation of degraded areas. Due to its characteristics, this species can be used by bee keepers in the formation and/or management of beekeeping pasture. Other important families in the contribution of pollen to bees are Burseraceae (with the species Protium heptaphyllum), Hypericaceae (*Vismia guianensis* DC.), Salicaceae (*Casearia grandiflora* Cambess.) and Bixaceae (*Bixa orellana* L.).

Pollen grains from *Vismia* were found in pollen samples of *Melipona* (*Michmelia*) *seminigra merrillae* Cockerell, 1919, in Manaus (Amazonas) by Absy and Kerr (1977). *Vismia* Vand. genera, popularly known in the region as "lacre", have been considered indicators of altered areas, and are abundant in "capoeiras" and small, natural clearings in the forest (Oliveira *et al*. 1998; Ribeiro *et al*. 1999). Absy and Kerr (1977) cite that the workers of *Melipona seminigra merrillae* extract a red latex from its fruit, which is transported in the corbiculas of bees and that, when mixed with the seeds, is used to caulk the joints and cracks of the hives.

The resources to be used by bees depend on their availability in the collection area. In gardens and in small forests, where the floristic richness is lower, bees have a smaller pollen niche. However, in the same area, different bee species have variable niche extensions, which suggests that their preferences for a particular type of pollen may determine the extent of the pollen niche.

Conclusion

Secondary forests show high diversity in terms of plant species. Since a great diversity of species and botanical families with potential for beekeeping was observed, this study proposes the conservation of tree and shrub species for pollination and the conservation of bees, thus ensuring their food and honey production.

Although anthropized, the secondary forests contain a flora that is rich in mellitophilous plants that can contribute to the development of meliponiculture and, consequently, to the maintenance of floristic diversity via the services of pollination. We thus suggest the valorization of urban secondary forests for the keeping and rational management of native stingless bees.

Acknowledgments

We would like to thank the Federal University of West Pará (UFOPA) for providing equipment and technical support for experiments at the Laboratory of Botany and Palynology. This work was funded through a research grant from the National Council for Scientific and Technological Development – CNPq (140195/2020-3).

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