

ARTICLE

## Floristic Composition and Community Structure of Epiphytic Angiosperms in an Urban Forest Fragment in the Eastern Amazon

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ABSTRACT

Vascular epiphytes are one of the most important forest components, contributing to microclimatic maintenance. These plants find ideal conditions for development in the Amazon due to the spatial heterogeneity and high temperature and humidity typical of this biome. In recent years, the Brazilian Amazon has undergone dramatic changes in its landscape, mainly due to the increase in deforestation and fire rates. We present here the floristic composition and analyze the community structure of epiphytic angiosperms of an urban forest fragment in Eastern Amazon. A total of 71 epiphytic individuals were recorded belonging to eight species and four families. Orchidaceae was the most representative family, corroborating the pattern for surveys of epiphytic diversity in the Neotropical region. Epiphytic species were found on 24 individuals of 10 tree species. The epiphytic importance value (IVe) was low for all species, except for *Aechmea tocartina* and *Rhipsalis baccifera*. Cactaceae was the family with the highest IVe. Most epiphytes were found in the crown of trees (83.1%). The diversity index of the fragment was  $H' = 1.80$  and the equity index was  $J = 0.87$ , reflecting the absence of highly dominant species. Conservation of urban forest fragments is necessary for the maintenance of epiphytic flora and ecosystem services.

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## 1. Introduction

Epiphytes are plants that germinate and spend their entire life cycle on other plants, usually trees, without parasitizing them <sup>[1]</sup>. Among vascular plant species, approximately 10% are epiphytic, corresponding to more than 31,000 species distributed in 79 families, mostly angiosperms <sup>[2]</sup>. Vascular epiphytes are more abundant in the tropics, where they constitute one of the most important forest components, contributing to microclimatic maintenance and often constituting a source of moisture and nutrients (through the accumulation of organic matter), breeding sites and shelters for species of the fauna <sup>[1,3]</sup>. They can also be indicators of successional stages in forests, with greater specific richness being associated with more advanced stages of regeneration <sup>[4]</sup>.

The epiphytic habit interferes with the mechanisms for obtaining water and nutrients, but brings advantages in the competition for light, hinders predation, and minimizes the damage caused by natural disturbances such as fires or flooding <sup>[3]</sup>. Light, temperature and humidity vary across different strata and ecological zones of the phorophytes and are usually determinant for the establishment of epiphytes <sup>[1]</sup>. In addition, the degree of roughness of the bark, the diameter, and the height of phorophytes are also factors that frequently influence epiphytic richness and abundance <sup>[5-8]</sup>. Thus, understanding the influence of biotic and abiotic factors on the vertical distribution of epiphytes is fundamental in tropical forest environments.

The Brazilian Amazon is recognized for its high richness of plant species, including endemic ones <sup>[9]</sup>. This phytogeographic domain also stands out for its spatial heterogeneity and high temperature and humidity, ideal conditions for the development of vascular epiphytes <sup>[1]</sup>. However, the epiphytic synusia was little studied in the Brazilian Amazon until the beginning of the 21<sup>st</sup> century <sup>[10]</sup>, a scenario that has been gradually changing with the realization of several floristic-taxonomic <sup>[11]</sup> or ecological <sup>[12-15]</sup> studies.

In recent years, the Brazilian Amazon has undergone dramatic changes in its landscape, mainly due to the expansion of cattle farming and soybean production areas and the increase in deforestation and fire rates, especially in the eastern portion where the forest fragmentation process is alarming <sup>[16-18]</sup>. Thus, considering the importance of the epiphytic synusia and the significant loss of vegetation cover recently reported in this phytogeographic domain, in this work we present the floristic composition and analyze the community structure of epiphytic angiosperms of an urban forest fragment in the Eastern Amazon.

## 2. Material and Methods

### 2.1 Study Area

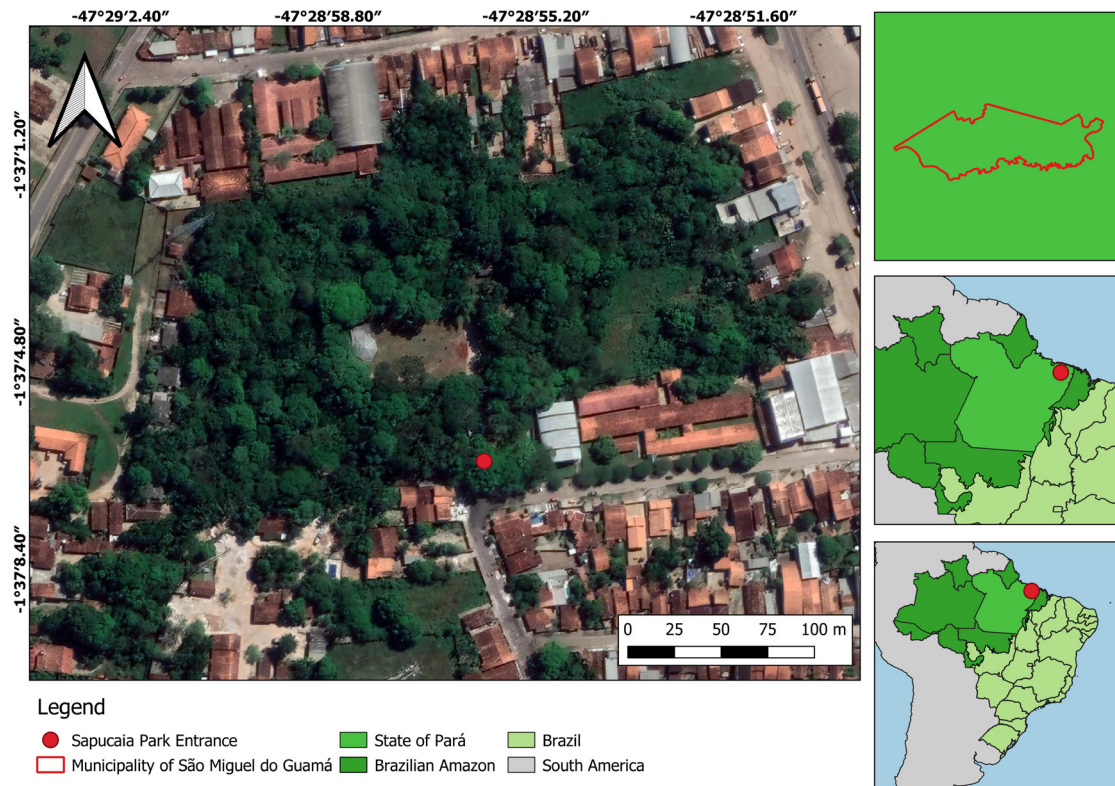
The study was carried out in the Engenheiro Agrônomo Edson Carlos Sodré Lopes Municipal Park, also known as Sapucaia Park, an urban park with 3.9 hectares in the municipality of São Miguel do Guamá (S 01°37' W 47°28' - 47°29'), in the northeast of the state of Pará, Brazil (Figure 1). The vegetation in the municipality was originally composed of Dense Alluvial Ombrophilous Forest and Lowland Ombrophilous Forest, however, currently there are only secondary forest fragments <sup>[19]</sup>. The climate of the region is of the "Am" type, according to the classification of Köppen, with average annual temperature of 25 °C and rainfall of 2.250 mm, more concentrated in the months from January to July, a relative humidity of around 85%, and near-sea level elevations <sup>[19,20]</sup>.

The Sapucaia Park is surrounded mainly by residential buildings and administrative public buildings. It has a sub-rectangular shape (Figure 1), with the entrance on one of the larger sides, to the south. A map of the area was elaborated using the QGIS software version 3.16.

The park has sparse medium-sized trees (about 10-15 meters) and a relatively open canopy except in its one third of the area, the furthest from the entrance, where the canopy is more closed. Some taxa are visually easy to recognize in the area: at the entrance, there are some individuals of *Mangifera indica* L. (mango tree), dozens of *Euterpe oleracea* Mart. (açai palm) in the central part, and *Musa* spp. (banana trees) to the east. The western portion of the park is periodically flooded, especially in the first months of the year, as a result of heavier rains that cause the overflow of a small stream nearby. The park is open to public visitation during the day (closed at night), with short trails throughout its interior, providing a leisure option for the local population.

### 2.2 Data Collection and Analysis

Field expeditions were carried out from September 2018 to March 2020 for collection of specimens and data. All trees with diameter at breast height greater than 30 cm were inspected for the presence of epiphytes, which were identified and quantified. Canopy species were observed with the aid of a photographic camera with close-up lenses and, more rarely, through free climbing of the phorophytes. Fertile epiphytic individuals were collected using a pruning shear with telescopic handle and later herborized according to usual taxonomic techniques <sup>[21]</sup>, and deposited in the HCP herbarium (acronym according



**Figure 1.** Map of the Engenheiro Agrônomo Edson Carlos Sodré Lopes Municipal Park, also known as Sapucaia Park, in the municipality of São Miguel do Guamã, Pará, Brazil. Map produced by José Antônio Lima Rocha Junior.

to <sup>[22]</sup>). Sterile epiphytic individuals were collected for *ex-situ* cultivation in the Nupéfita Orchidarium, at the Federal Rural University of Amazonia - *campus* Capitão Poço; when the specimens flowered, they were also herborized. Young epiphytic individuals whose identification was not possible either in the field or in a greenhouse were excluded from the analyses <sup>[23]</sup>.

Specimens were identified by consulting experts and the specialized literature on epiphytes and analyzing images of specimens deposited in Brazilian herbaria (<http://www.splink.org.br/>). Species names and geographic distribution data are in accordance with the main databases on the subject <sup>[24,25]</sup>. The epiphytic species were classified into ecological categories, according to their relationship with the phorophyte <sup>[3]</sup>.

Phorophytes were identified in the field to the lowest taxonomic level possible, but they were not collected. The phorophytic individuals were divided into three ecological zones: lower trunk (first 1.3 m close to the ground), upper trunk (from 1.3 m to the base of the crown), and crown (above the morphological inversion point) <sup>[26]</sup>. We quantitatively analyzed the structure of the community based on the number of epiphytic individuals (NI), number of phorophytic individuals occupied by epiphytic

species *i* (Np), number of phorophytic species occupied by epiphytic species *i* (Npsp), and ecological zones occupied by the epiphytes. We calculated several structural parameters: absolute frequency on phorophytic individuals (AFp), absolute frequency on phorophytic species (AFps), relative frequency on phorophytic individuals (RFp), relative frequency on phorophytic species (RFps), and the epiphytic importance value (IVE) of the species, in addition to absolute and relative frequencies by ecological zones of the phorophytes <sup>[27-28]</sup>. The IVE was obtained from the arithmetic mean of the sum of the RFp and RFps values <sup>[28]</sup>. Frequency values on phorophytic individuals < 20% <sup>[23]</sup> and epiphytic importance values < 15% were considered low <sup>[7]</sup>. Diversity and equitability parameters were also estimated for the epiphytes in the area based on the occurrence of species on phorophytic individuals using the Shannon ( $H'$ ) and Pielou ( $J$ ) indices, respectively.

### 3. Results

#### 3.1 Floristic Composition of Epiphytic Angiosperms

A total of 71 epiphytic individuals belonging to eight species, eight genera and four families were recorded in Sapucaia Park. Orchidaceae was the most representative family in the area, with four species,

followed by Cactaceae, with two species, and Araceae and Bromeliaceae, with one species each (Table 1). All species were found as obligatory holoparasites and have a wide geographic distribution. *Rhopsalis baccifera* (J.M.Muell.) Stearn is pantropical and the other species are neotropical. Among the neotropical species, *Anthurium gracile* (Rudge) Lindl., *Epiphyllum phyllanthus* (L.) Haw. and *Polystachya foliosa* (Hook.) Rchb.f. have a wider distribution, occurring from North America to South America; *Brassia caudata* (L.) Lindl. occurs in Central and South America; and *Aechmea tocontina* Baker, *Catasetum roseo-album* (Hook.) Lindl. and *Notylia peruviana* (Schltr.) C.Schweinf. occur only in South America. In Brazil, *A. tocontina* and *N. peruviana* are restricted to the Amazon, while the others have been found in at least one other phytogeographic domain besides the Amazon.

### 3.2 Structure of the Epiphytic Community

Epiphytic species were found on 24 phorophytic individuals, corresponding to 10 tree species. Each epiphytic species was found on 1-10 phorophytic individuals and on 1-4 phorophytic species. *Anthurium gracile* was the most abundant species (NI = 22), but was found growing on few phorophytes (Np = 3), resulting in low AFp and RFp (12.5% and 9.4%, respectively).

Although the species was recorded on three phorophytic species, resulting in a RFps value of 15%, it presented an IVe value (12.2) that was only the third highest among all species and equal to that of *C. roseo-album*, which was represented by only three individuals (NI = 3), but had RFp and RFps values identical to those of *A. gracile*.

*Aechmea tocontina* was the second most abundant species (NI = 14) and was recorded growing on a greater number of individuals (Np = 10) and species (Npsp = 4) of phorophytes than *A. gracile*, thus reaching higher RFp (31.25%) and RFps (20%) values. The high RFps and especially RFp value explain the highest IVE (25.6) of *A. tocontina* in the area.

*Rhopsalis baccifera* was found growing on eight individuals of four species, resulting in RFp = 25%, RFps = 20%, and the second highest IVe (22.5). Together, *A. gracile*, *A. tocontina*, *C. roseo-album*, and *R. baccifera* were responsible for 72.5% of the IVE obtained. The other four epiphytic species presented NI = 2-10; NF = 1-4; RFp = 3.1-12.5; RFps = 5-10; and IVE = 4.05-11.3 (Table 1). Epiphytic importance values were low for all species except for *A. tocontina* and *R. baccifera*. Cactaceae was the family with the highest total importance value (IVE = 33.8), followed by Orchidaceae (IVE = 28.4), Bromeliaceae (IVE = 25.6), and Araceae (IVE = 12.2).

**Table 1.** Epiphytic angiosperms of the Engenheiro Agrônomo Edson Carlos Sodré Lopes Municipal Park, also known as Sapucaia Park, in the municipality of São Miguel do Guamá, Pará, Brazil.

Taxa	NI	Np	AFp	RFp	Npsp	AFps	RFps	IVE	Voucher
<b>Araceae</b>									
<i>Anthurium gracile</i>	22	3	12.5	9.4	3	30	15	12.2	J.R.V. Pacheco et al. 36
<b>Bromeliaceae</b>									
<i>Aechmea tocontina</i>	14	10	41.7	31.25	4	40	20	25.6	J.R.V. Pacheco & A. A. C. da Silva 72
<b>Cactaceae</b>									
<i>Epiphyllum phyllanthus</i>	10	4	16.7	12.5	2	20	10	11.3	J.R.V. Pacheco et al. 45
<i>Rhopsalis baccifera</i>	13	8	33.3	25	4	40	20	22.5	J.R.V. Pacheco et al. 46
<b>Orchidaceae</b>									
<i>Brassia caudata</i>	3	1	4.2	3.1	1	10	5	4.05	J.R.V. Pacheco et al. 48
<i>Catasetum roseo-album</i>	3	3	12.5	9.4	3	30	15	12.2	J.R.V. Pacheco et al. 39
<i>Notylia peruviana</i>	2	1	4.2	3.1	1	10	5	4.05	J.R.V. Pacheco & A. A. C. da Silva 71
<i>Polystachya foliosa</i>	4	2	8.3	6.25	2	20	10	8.1	J.R.V. Pacheco et al. 70
<b>Total</b>	71	32	133.4	100	20	200	100	100	

**AFp:** absolute frequency on phorophytic individuals; **AFps:** absolute frequency on phorophytic species; **IVE:** epiphytic importance value; **NI:** number of epiphytic individuals; **Np:** number of phorophytic individuals occupied by epiphytic species *i*; **Npsp:** number of phorophytic species occupied by epiphytic species *i*; **RFp:** relative frequency on phorophytic individuals; **RFps:** relative frequency on phorophytic species.

Regarding ecological zones, the crown was more occupied by epiphytes (83.1%), followed by the upper (14.1%) and lower (2.8%) portion of the trunk. All species were found in the crown except *Notylia peruviana*, which was found exclusively on the upper trunk. *Epiphyllum phyllanthus* and *B. caudata* were exclusive to the crown, whereas *A. tocantina*, *R. baccifera* and *P. foliosa* were predominantly observed in the crown, but also occurred on the upper trunk. Similarly, *A. gracile* predominated in the crown, but was also observed on the lower trunk. *Catasetum roseoalbum* was the only species to occur on the three zones (Table 2).

As for the relative frequency (RF) of species by ecological zones, we found that *A. gracile* and *C. roseoalbum* were each responsible for 50% of the occupation on the lower trunk of the phorophytes. In the upper trunk, *R. baccifera* presented the highest RF value (42.8%), and the other four species that occurred in this ecological zone had equal RF (14.3%). In the crown, where the greatest richness of species was found, *A. tocantina* had the highest relative frequency (38.4%), followed by *R. baccifera* (19.2%) and *E. phyllanthus* (15.4%). The other species that occurred in the crown showed low RF values (3.9-11.5).

There was a spatial separation of the epiphytes in the park; *A. tocantina*, *B. caudata*, *C. roseoalbum*, *E.*

*phyllanthus*, *R. baccifera*, and *P. foliosa* grew in areas with a more open canopy, where the luminosity was more intense, while *A. gracile* and *N. peruviana* were found in periodically flooded and thus more humid areas with a more closed canopy. The Shannon diversity index ( $H'$ ) for the fragment was 1.80 and the equity ( $J$ ) was 0.87.

#### 4. Discussion

The floristic richness of Sapucaia Park can be considered low when compared to other subtropical and tropical areas in southern and southeastern Brazil [29] and also in the Brazilian Amazon [13,30]. However, it is important to note that the Sapucaia Park is an urban and relatively small fragment with secondary vegetation where anthropogenic disturbances are frequent, while the areas surveyed in other studies were little disturbed forest fragments, conservation units, or much larger areas.

It is known that the abundance and richness of epiphytes is lower in forests at early successional stages in relation to those at intermediary stages [4], and in disturbed or secondary vegetation in relation to primary forests [31]. The opening and maintenance of trails and the pruning of lower and weaker tree branches are anthropogenic disturbances that may have negatively affected the findings of our study in the Sapucaia Park.

**Table 2.** Epiphytic angiosperms of the Engenheiro Agrônomo Edson Carlos Sodré Lopes Municipal Park, also known as Sapucaia Park, in the municipality of São Miguel do Guamá, Pará, Brazil.

Taxa	Nlt	Nlto	AFlt	RFIt	Nupt	Nupto	AFupt	RFupt	Nc	Nco	AFc	RFc
<b>Araceae</b>												
<i>Anthurium gracile</i>	1	1	4.2	50	0	0	0	0	21	2	8.3	7.7
<b>Bromeliaceae</b>												
<i>Aechmea tocantina</i>	0	0	0	0	2	1	4.2	14.3	12	10	41.7	38.4
<b>Cactaceae</b>												
<i>Epiphyllum phyllanthus</i>	0	0	0	0	0	0	0	0	10	4	16.7	15.4
<i>Rhipsalis baccifera</i>	0	0	0	0	4	3	12.5	42.8	9	5	20.8	19.2
<b>Orchidaceae</b>												
<i>Brassia caudata</i>	0	0	0	0	0	0	0	0	3	1	4.2	3.9
<i>Catasetum roseo-album</i>	1	1	4.2	50	1	1	4.2	14.3	1	1	4.2	3.9
<i>Notylia peruviana</i>	0	0	0	0	2	1	4.2	14.3	0	0	0	0
<i>Polystachya foliosa</i>	0	0	0	0	1	1	4.2	14.3	3	3	12.5	11.5
<b>Total</b>	2	2	8.4	100	10	7	29.3	100	59	26	108.4	100

**AFc:** absolute frequency on crowns; **AFupt:** absolute frequency on upper trunks; **AFlt:** absolute frequency on lower trunks; **Nc:** number of individuals on crowns; **Nco:** number of crowns occupied by epiphytic species *i*; **Nupt:** number of individuals on upper trunks; **Nupto:** number of upper trunks occupied by epiphytic species *i*; **Nlt:** number of individuals on lower trunks; **Nlto:** number of lower trunks occupied by epiphytic species *i*; **RFc:** relative frequency of epiphytes on crowns; **RFIt:** relative frequency of epiphytes on lower trunks; **RFupt:** relative frequency of epiphytes on upper trunks.

In addition, the vegetation of the park includes species with morphological characteristics that do not favor the establishment of epiphytes, as in the case of açai palm trees that have smooth stipes and unbranched canopies<sup>[32]</sup>. The low abundance and specific richness of epiphytes found in this study may also be associated with the edge effect, which promotes unfavorable conditions for the occurrence of epiphytes such as higher luminosity and lower humidity<sup>[33]</sup>. The near-sea level elevation of the park is another important aspect. In the Amazon, greater species richness is found at elevations of 400-600 m, with a significant reduction at lower elevations<sup>[34]</sup>.

Orchidaceae was the family that presented the greatest specific richness in Sapucaia Park, corroborating the results of studies conducted in the Amazon<sup>[13,34]</sup> and the pattern for epiphytic surveys in the neotropical region<sup>[23]</sup>. However, Cactaceae, represented by *E. phyllanthus* and *R. baccifera*, was the family with greater epiphytic importance value (IVe = 33.8), differing from what is frequently reported in the literature<sup>[10,23]</sup>, which indicates Orchidaceae, Bromeliaceae or Polypodiaceae as the most relevant families. Although Cactaceae ranks in the fifteenth position in terms of global number of vascular epiphytes<sup>[10]</sup>, *R. baccifera* is a widely distributed species adapted to heterogeneous habitats, with records even in regions with regular frost<sup>[35]</sup> and *Epiphyllum phyllanthus* is an extremely drought-resistant species and has a generalist behavior as to the choice of phorophytic species, often growing on forks in branches of tree crowns<sup>[36]</sup>.

*Anthurium gracile*, *A. tocantina* and *R. baccifera* were responsible for 69% of the recorded abundance of epiphytes, and also stood out in relation to the epiphytic importance index. The successful colonization of phorophytes by these species in the area may be partially related to their morphophysiological adaptations for obtaining and storing water<sup>[1,3]</sup>, such as the arrangement of the leaves in rosettes and the presence of absorbent epidermal scales in *A. tocantina*, the velame in *A. gracile* or the succulent stem in *R. baccifera*.

The greater abundance and specific richness found in the crown (87% of species) in Sapucaia Park is in agreement with the findings of several authors in subtropical or tropical forests<sup>[6]</sup>, including Amazonian areas<sup>[30,37]</sup>. This is because the crown constitutes a more branched zone, providing a larger surface area for the establishment of epiphytes, and greater luminosity than lower strata, which also allows for greater accumulation of organic matter<sup>[3]</sup>. In turn, the occurrence of *N. peruviana* exclusively in the upper portion of the trunk may indicate a preference of the species for more humid, shaded environments and with milder temperatures. In the

vertical gradient, the humidity is higher at the lower trunk and decreases towards the crown, while the luminosity and temperature show opposite trends<sup>[3]</sup>. In this scenario, *C. roseo-album* seems to be a less demanding species regarding vertical environmental variation, as it was the only species found in all ecological zones.

Distinct microhabitats also influence the occurrence of vascular epiphytes at the local scale<sup>[38]</sup>. This may explain the spatial separation of the species in the Sapucaia Park, with some of them growing in periodically flooded areas with lower luminosity and higher humidity (e.g. *A. gracile*) and others in areas with greater luminosity and lower humidity (e.g. *A. tocantina*). As the climate of the region is hot, the rainfall is high, and the soil is periodically flooded, water acquisition may not be a crucial factor for the occurrence of epiphytes in the area. Thus, attributes of the phorophytes should be the focus of future studies with angiosperm epiphytes in the Amazon region.

The epiphytic diversity in Sapucaia Park was  $H' = 1.80$ , lower than values found in areas sampled in southern Brazil ( $H' = 2.61-4.07$ )<sup>[38]</sup>, possibly reflecting the local habitat loss and fragmentation. Another important bias in our study was the non-inclusion of pteridophytes sensu lato, because these plants generally constitute an extremely representative group in the surveys of epiphytic synusia<sup>[10]</sup>. However, the equity ( $J = 0.87$ ) of the forest fragment of Sapucaia Park was similar to that found in epiphytic surveys in Brazil ( $J = 0.76-0.85$ )<sup>[6,26,38]</sup> and reflects the absence of highly dominant species.

## 5. Conclusions

Little is known about the diversity and structure of the Amazonian epiphytic flora. This scenario is worrying, considering that the epiphytes are of great ecological relevance and contribute to the maintenance of biological diversity, besides acting as indicators of environmental disturbances. Given the increasing deforestation rates in the Amazon, the conservation of urban forest fragments is even more necessary for the maintenance of the epiphytic flora and ecosystem services, including leisure and ecotourism. Thus, information about the floristic composition and vertical distribution of vascular epiphytes is fundamental for establishing strategies for the conservation of this group, especially in disturbed and urbanized areas.

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