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DIVERSITY OF VASCULAR EPIPHYTES IN URBAN ENVIRONMENT: A CASE STUDY IN A BIODIVERSITY HOTSPOT, THE BRAZILIAN ATLANTIC FOREST[√]

Samyra Gomes FURTADO[*]
Luiz Menini NETO[**]

ABSTRACT

Less is known about the epiphytes in the urban environment, a synusia that is extremely relevant in the Atlantic Domain, where the studied area is located, the *campus* of the Universidade Federal de Juiz de Fora, which possesses Semideciduous Seasonal Forest in a secondary stage of regeneration (FT), as well as green areas and cultivated trees within public areas (UT). The study was conducted between March 2012 and September 2013. We recorded 43 species, being Bromeliaceae the richest family (nine spp.). Among the ecological category it must be highlighted the accidental holoepiphytes (16 spp.), number probably attributed to the disturbed environment. The UT harbor 42 species, while 15 occur in the FT. The taxonomic distinctness was higher in UT (77.933 versus 76.762); however, the variation in taxonomic distinctness was higher in the FT than in UT (861.9 and 626.4, respectively). Therefore, the degree of disturbance is similar in both environments, although the unevenness is higher in the FT. Similarity analyses showed the importance of vegetation formation and distance of ocean in the recognition of relationships between the flora of vascular epiphytes in urban environment. The results suggest that such vegetation exhibits changes in the composition of species of vascular epiphytes, but highlights the relevance of cultivated trees in such environments for their occurrence.

Keywords: Disturbed Environment. Novel Ecosystems. Similarity Analysis. Taxonomic Distinctness. Urban vegetation.

1 INTRODUCTION

Nowadays, great efforts are dedicated to the conservation of natural areas, but as highlighted by Hietz (1999), it is unlikely that the intense anthropization of the natural environment will end in the near future, therefore, the study of disturbed areas can provide data concerning the composition of species and how anthropic changes affect biodiversity. The available data show that urbanization can enlarge or reduce

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[*] Bacharela em Ciências Biológicas pela Universidade Federal de Juiz de Fora. Mestranda em Ecologia pelo Programa de Pós-graduação em Ecologia (PGECOL-UFJF). @: furtadosg@gmail.com
[**] Doutor em Botânica pela Escola Nacional de Botânica Tropical do Instituto de Pesquisas Jardim Botânico do Rio de Janeiro. Docente do Centro de Ensino Superior de Juiz de Fora (CES/JF). @: menini.neto@gmail.com

the species richness, depending on several factors, such as the taxonomic group, the time scale of the analysis and the intensity of urbanization (MCKINNEY, 2008).

The vegetation in the urban environment, the novel ecosystems represented by the natural remnants and cultivated trees on the public roads or in parks and squares, is important both to human welfare as well as to the maintenance of biodiversity (BOLUND; HUNHAMMAR, 1999; ALVEY, 2006). Thus, as a result of a high level of urbanization and increase in the human population (BOLUND; HUNHAMMAR, 1999; MCKINNEY, 2008), 54% of which now live in cities (LUGO, 2010). The disturbed environment represents a field of study that cannot be ignored, although are few scientific studies concentrated on urban areas (MARRIS, 2009).

The use of land in Minas Gerais (MG) for the crops of coffee, sugarcane and for pastures, emphasizes the degraded status of its natural remnants, especially in the Zona da Mata region (MEIRA-NETO et al., 1997). This can be observed in the municipality of Juiz de Fora, where the scarce fragments of Seasonal Semideciduous Forest (SSF) are in an advanced or intermediary stage of secondary regeneration, often comprised of abandoned coffee crops (SCOLFORO; CARVALHO, 2006). This region is part of the Corredor Sudeste da Mata Atlântica (Southeastern Corridor of Atlantic Forest), and is of biological importance due to the potential of connectivity between the existing remnants (DRUMMOND et al., 2005). However, only 4.1% of the area is protected within conservation units (PMJF, 2008), and few floristic studies have been performed in the municipality, most of which have focused on the arboreal composition (ALMEIDA; SOUZA, 1997; FONSECA; CARVALHO, 2012; MOREIRA; CARVALHO, 2013) and only one dealt with the phanerogamic (PIFANO et al., 2007) or bryophytic flora (MACHADO; LUIZI-PONZO, 2011).

Epiphytes have important mutualistic relationships with fauna (BENZING, 1990), also acting as bioindicators of the conservation status of ecosystems (TRIANA-MORENO et al., 2003). Thus, the conservation of this synusia is relevant, considering its importance in the composition and richness of the tropical forests and its ecological relationships, as well as its ecosystem functions (HIETZ, 1999).

Although studies about the vascular epiphytic flora in urban trees are scarce in Brazil and other countries (FABRICANTE et al., 2006; BRYAN, 2011; D’CUNHA; GOWDA, 2013; ALVES et al., 2014), the analysis of Bromeliaceae species as biomonitors of the air quality are more common (GRACIANO et al., 2003; ALVES et al., 2008; BERMUDEZ et al., 2009, and references therein). Furthermore, studies conducted in urban forest fragments with different levels of anthropic disturbance are relatively common in Brazil (DISLICH; MANTOVANI, 1998; BORGO; SILVA, 2003; FRENEDOZO *et al.*, 2005; DETTKE *et al.*, 2008; BATAGHIN *et al.*, 2010).

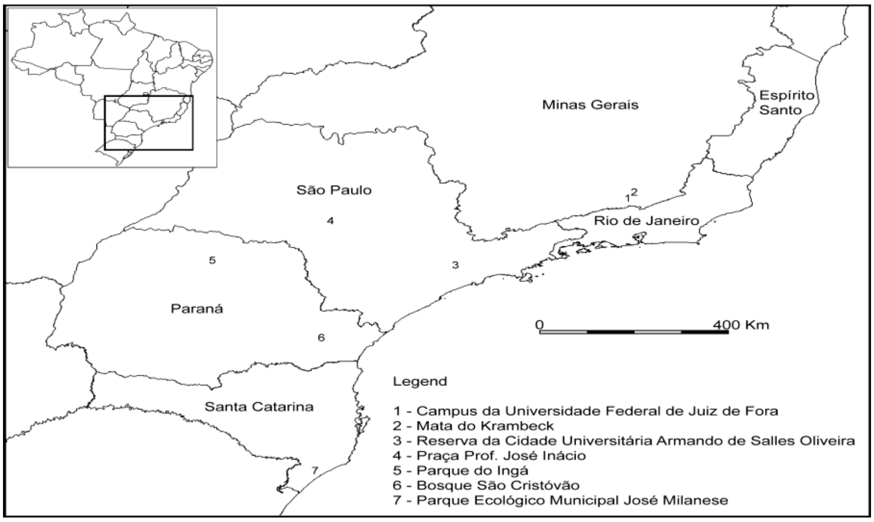
Due to the scarcity of specific studies on the epiphytic flora in urban areas, we aimed to: 1) survey the species of vascular epiphytes in the forest fragments and cultivated trees on the *campus* of the Universidade Federal de Juiz de Fora (UFJF), contributing to the knowledge of epiphytes in the urban environment; 2) analyze the floristic composition and patterns of geographic distribution of the epiphytes in such disturbed environments; 3) compare the diversity of the epiphytes in the urban trees and forest fragments of the *campus*; 4) test whether the assertion that urbanization increases biological homogenization (MCKINNEY, 2006) is also valid for epiphytic species, through similarity analyses of urban forests in the Atlantic Domain.

2 MATERIAL AND METHODS

2.1 STUDY AREA

The *campus* of the UFJF (hereafter referred as *campus*) occupies an area of ca. 83 ha in the municipality of Juiz de Fora (21°43'S, 43°22'W) (Fig. 1), comprising the Unidade Serrana da Zona da Mata, and belonging the Mantiqueira Setentrional (ALMEIDA; SOUZA, 1997; ROCHA et al., 2003). The area is between 800–900 m a.s.l. and the soils are classified as dystrophic red-yellow latosols (ROCHA et al., 2003). The climate of the region is Cwb (Köppen classification). The mean annual rainfall and temperature are 1,536 mm and 18.9°C, respectively (CESAMA, 2010).

Figure 1: Location of the *campus* and the areas used in similarity analyses.



The vegetation is part of the Atlantic Domain, which is composed predominantly of Montane Seasonal Semideciduous Forest (IBGE, 2012). Until the beginning of the 1960s, this area was occupied by pastures, belonging to an old farm owned by the municipal government, the Sítio Martelos, which ceded to the construction of the *campus* (ALMEIDA; SOUZA, 1997). Currently, the area is in an intermediate stage of secondary succession, with the presence of native arboreal and liana species in forest fragments (MOREIRA; CARVALHO, 2013).

The landscaping of the *campus* was responsible for the introduction and cultivation of several alien species used in afforestation (MOREIRA; CARVALHO, 2013), such as *Delonix regia* (Bojer ex Hook.) Raf. (Fabaceae), *Eriobotrya japonica* (Thunb.) Lindl. (Rosaceae), *Spathodea campanulata* Beauv. (Bignoniaceae), *Syzygium cumini* (L.) Skeels (Myrtaceae), and *Pinus elliottii* Engelm (Pinaceae), which is represented by a large number of cultivated and invasive specimens in the forest fragments. Native species are also present: *Ceiba speciosa* (St.-Hill.) Ravenna (Malvaceae), *Handroanthus chrysotrichus* (Mart. ex A.DC.) Mattos (Bignoniaceae), *Tibouchina estrellensis* (Raddi) Cogn., and *T. pulchra* (Melastomataceae).

2.2 FIELD AND LABORATORY WORK

We conducted the survey between March 2012 and September 2013, via the collection of fertile specimens in forest fragments and cultivated trees (urban trees) of the *campus*. The specimens were collected and identified according to usual methodology and were deposited in the Herbarium CESJ (THIERS, 2015).

The classification of ecological categories was according to Benzing (1990). The geographical distribution data were obtained from the Lista de Espécies da Flora do Brasil (2015) and the World Checklist of Selected Plant Families (2013) and were classified according to three distribution patterns: 1) endemic to the Atlantic Forest; 2) endemic to Brazil, occurring in two or more phytogeographic domains; or 3) having a wide distribution, occurring in Brazil and other South and Central American countries.

2.3 TAXONOMIC DISTINCTNESS

Clarke and Warwick (1998; 2001) proposed two indices of biodiversity that can be calculated from presence/absence data and capture the taxonomic relatedness of the species, independently of sample size and effort, taxonomic distinctness (Δ^+) and variation in taxonomic distinctness (Λ^+). Theoretical and methodological framework can be found in Clarke and Warwick (1998; 2001).

We discarded the accidental epiphytes and used five levels of taxonomic categories: species, genera, families, orders and the clades of vascular plants (Monilophyta and Spermatophyta). The indices were used to compare the diversity of epiphytes among the urban tree (UT) and forest fragment (FF) environments. To test the null hypothesis that a particular subsample was composed of a random set of the full list of vascular epiphytes, we generated the funnel-plot confidence interval (95%) for Δ^+ and Λ^+ (CLARKE; WARWICK, 1998).

2.4 FLORISTIC SIMILARITY ANALYSIS

To evaluate whether the hypothesis that urbanization increases the biological homogenization (MCKINNEY, 2006) is valid for the epiphytic synusia, we conducted two floristic similarity analyses, using the Jaccard index: a cluster analysis (with the algorithm unweighted pair-group method using the arithmetic means) and a Principal Coordinates Analysis (PCoA). The matrix of presence (1) or absence (0) comprised 155 species from seven urban forests located in the Atlantic Domain (Table 1; Figure 1). Infraspecific, unidentified taxa and accidental epiphytes were removed from the analyses. A Mantel test was performed to evaluate the correlation between similarity and geographic distance among areas. The analyses were performed using PAST v. 3 (HAMMER et al., 2001).

Table 1: List of the seven areas of urban vegetation used in the similarity analyses.

Acronyms	Elevation	Coordinates	N	Vegetation	Source
UFJF (MG)	900 m	21°46'S, 43°22'W	37	SSF	Present study
MK (MG)	750 m	21°43'S, 43°22'W	49	SSF	Menini Neto et al. (unpublished data)
CUASO (SP)	750 m	23°33'S, 46°43'W	40	DOF/SSF	Dislich and Mantovani (1998), Groppo and Pirani (2005)
JOSEINA (SP)	500 m	22°24'S, 49°08'W	9	SSF	Fabricante et al. (2006)
PINGA (PR)	550 m	23°25'S, 51°25'W	24	SSF	Dettke et al. (2008)
SCRIS (PR)	900 m	25°24'S, 49°19'W	15	MOF	Hefler and Faustioni (2004)
PEMJM (SC)	30 m	28°48'S, 49°25'W	65	DOF	Oliveira et al. (2013)

Acronyms (used in figures 1, 2 and 3), UFJF: Universidade Federal de Juiz de Fora; MK: Mata do Krambeck; CUASO: Cidade Universitária Armando de Salles Oliveira;

JOSEINA: Praça Professor José Inácio; PINGA: Parque do Ingá; SCRIS: Bosque São Cristóvão; PEMJM: Parque Ecológico Municipal José Milanese. MG: Minas Gerais; SP: São Paulo; PR: Paraná; SC: Santa Catarina. N: number of species used in the similarity analysis. Vegetation: vegetation type, DOF: Dense ombrophilous forest; MOF: Mixed ombrophilous forest; SSF: Seasonal semideciduous forest.

3 RESULTS

3.1 RICHNESS AND ECOLOGY

Forty-three species were recorded: 34 angiosperms and nine ferns, belonging to 16 families (Table 2). Forty-two species were found in the urban trees, of which 14 also occurred in the forest fragment.

Table 2: List of families and species of vascular epiphytes recorded on the *campus*.

Fam	Species	UT	FT	GD	DT	EC	Voucher
	Ferns						
Lom	*Nephrolepis exaltata* (L.) C.Presl	+	-	3	an	A	Furtado 83
Pol	*Microgramma squamulosa* (Kaulf.) de la Sota	+	+	1	an	C	Furtado 15
Pol	*Microgramma vacciniifolia* (Langsd. & Fisch.) Copel	+	+	3	an	C	Furtado 158
Pol	*Platycerium bifurcatum* (Cav.) C.Chr.	+	-	*	an	C	Not collected
Pol	*Pleopeltis astrolepis* (Liebm.) E.Fourn.	+	+	1	an	C	Furtado 13
Pol	*Pleopeltis hirsutissima* (Raddi) de la Sota	+	+	3	an	C	Furtado 14
Pol	*Pleopeltis minima* (Bory) J. Prado & R.Y. Hirai	+	-	1	an	C	Novelino s.n. (CESJ 29795)
Pol	*Pleopeltis pleopeltifolia* (Raddi) Alston	+	+	1	an	C	Furtado 12
The	*Thelypteris dentata* (G. Forst.) E.P.St. John	+	-	*	an	A	Furtado 78
	Angiosperms						
Ara	*Monstera deliciosa* Liebm.	+	-	*	zo	H	Krieger s.n. (CESJ 18660)
Ara	*Philodendron bipinnatifidum* Schott ex Endl.	+	+	3	zo	H	Krieger s.n. (CESJ 18658a)
Ara	*Philodendron* cf. *cordatum* Kunth ex Schott.	-	+	3	zo	H	Not collected
Ara	*Philodendron hederaceum* (Jacq.) Schott	+	-	#	zo	H	Furtado 156
Ara	*Syngonium angustatum* Schott	+	-	#	zo	H	Furtado 60
Ast	*Crepis japonica* (L.) Benth.	+	-	*	an	A	Furtado 58
Ast	*Emilia sonchifolia* (L.) DC ex Wight	+	-	3	an	A	Furtado 59
Bro	*Aechmea bambusoides* L.B.Sm. & Reitz	+	-	1	an	C	Furtado 76
Bro	*Billbergia zebrina* (Herb.) Lindl.	+	+	1	zo	C	Furtado 84
Bro	*Tillandsia gardneri* Lindl.	+	+	2	an	C	Furtado 262
Bro	*Tillandsia geminiflora* Brongn.	+	+	3	an	C	Furtado 21
Bro	*Tillandsia recurvata* (L.) L.	+	+	2	an	C	Furtado 17
Bro	*Tillandsia stricta* Sol.	+	+	2	an	C	Furtado 82
Bro	*Tillandsia tricholepis* Baker	+	+	2	an	C	Furtado 16
Bro	*Tillandsia usneoides* (L.) L.	+	-	3	an	C	Furtado 263
Bro	*Vriesea* aff. *procera* L.B.Sm.	+	-	-	an	C	Furtado 81
Cac	*Epiphyllum phyllanthus* (L.) Haw.	+	-	3	zo	C	Furtado 159
Cac	*Hylocereus setaceus* (Salm-Dyck) R. Bauer	+	-	3	zo	C	Brügger s.n. (CESJ 35809)
Car	*Drymaria cordata* (L.) Willd. ex Roem. & Schult.	+	-	*	an	A	Furtado 264
Com	*Tradescantia zebrina* Heynh. ex Bosse	+	-	*	au	A	Furtado 260
Cyp	*Scleria* sp.	+	-	-	zo	A	Furtado 261
Mor	*Ficus* cf. *citrifolia* Mill.	+	+	-	zo	H	Not collected

Orc	*Capanemia thereziae* Barb. Rodr.	+	-	2	an	C	Menini Neto 184
Orc	*Catasetum cernuum* (Lindl.) Rchb.f.	+	+	2	an	C	Furtado 265
Orc	*Polystachya estrellensis* Rchb.f.	+	-	2	an	C	Furtado 57
Phy	*Phyllanthus niruri* L.	+	-	3	au	A	Furtado 61
Poa	*Dichanthelium sciurotoides* (Zuloaga & Morrone) Davidse	+		2	zo	A	Furtado 20
Poa	*Paspalum* cf. *nutans* Lam.	+	-	-	zo	A	Furtado 18
Poa	*Phyllostachys aurea* Carrière ex Rivière & C.Rivière	+	-	*	zo	A	Furtado 62
Poa	*Setaria parviflora* (Poir.) Kerguéle	+	-	3	zo	A	Furtado 56
Sol	*Solanum americanum* Mill.	+	-	3	zo	A	Furtado 63
Sol	*Solanum argenteum* Dunal ex Poir.	+	-	2	zo	A	Furtado 77
Sol	*Solanum hexandrum* Vell.	+	-	1	zo	A	Furtado 266
Urt	*Cecropia* cf. *glaziovii* Snethl.	+	-	-	zo	A	Not collected

Fam (Families), Ara: Araceae; Ast: Asteraceae; Bro: Bromeliaceae; Cac: Cactaceae; Com: Commelinaceae; Cyp: Cyperaceae; Lom: Lomariopsidaceae; Mor: Moraceae; Orc: Orchidaceae; Poa: Poaceae; Pol: Polypodiaceae; Phy: Phyllanthaceae; Sol: Solanaceae; The: Thelypteridaceae; Urt: Urticaceae; UT: species on the cultivated trees; FT: species on the forest fragment; GD: geographic distribution according to text; * Alien species, # Native of Brazil, but cultivated in the *campus*. DT (dispersal types), an: anemochoric; au: autochoric; zo: zoochoric. EC (ecological category), H: hemiepiphyte; A: accidental holoepiphyte; C: characteristic holoepiphyte. The vouchers are deposited in the Herbarium CESJ of UFJF.

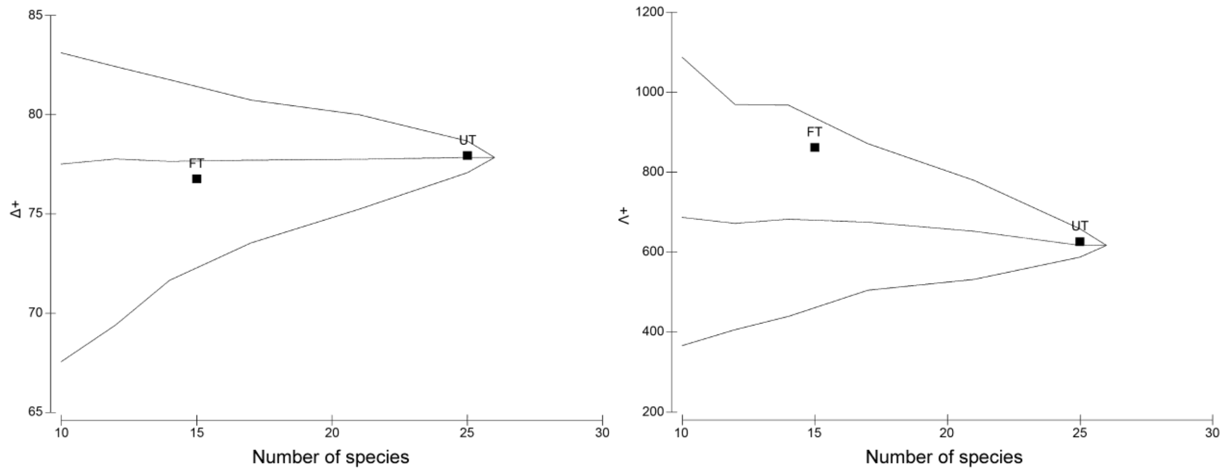
The richest family was Bromeliaceae (nine spp.), followed by Polypodiaceae (seven spp.) and Araceae (five spp.) (~46% of the total). The richest genera were *Tillandsia* (Bromeliaceae) (six spp.) and *Pleopeltis* (Polypodiaceae) (four spp.), that had a large number of individuals observed. Ten species were alien invasive or cultivated on the *campus* (Table 2).

The most representative ecological category was that of characteristic holoepiphytes (CHL) (21 spp.), followed by accidental holoepiphytes (AHL) (16 spp.) and hemiepiphytes (Hem) (six spp.). Anemochory was the most common dispersal form (23 spp.), followed by zoochory (18 spp.) and autochory (two species) (Table 2).

3.2 TAXONOMIC DISTINCTNESS

Values of Δ^+ and Λ^+ for urban trees and forest fragments are 77.933/626.4 and 76.762/861.9, respectively. Both values fell within the 95% probability limit (Figure 2).

Figure 2: Values of Δ^+ (left figure) and Λ^+ (right figure) of the vascular epiphytes in urban trees (UT) and fragment forest trees (FT).

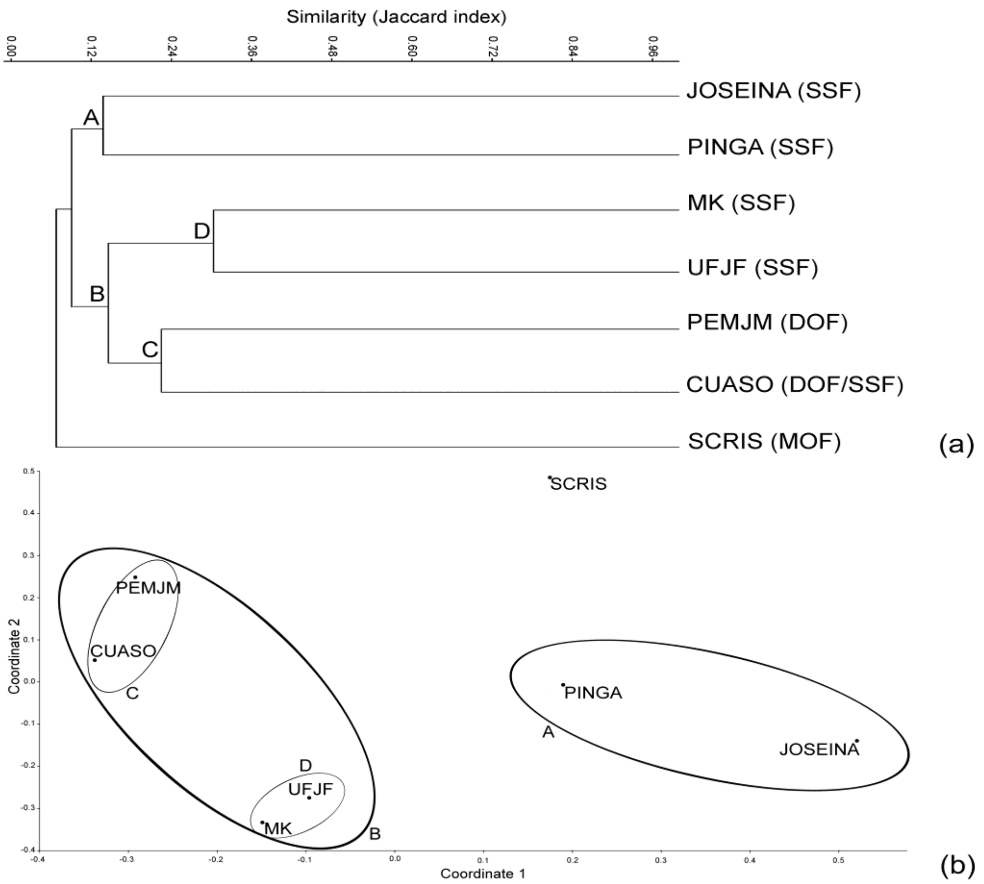


3.3 BIOGEOGRAPHY AND SIMILARITY ANALYSIS

Cluster analysis gave a cophenetic coefficient of 0.87, representing a good fit between the matrix of the species and the dendrogram. Figure 3a showed an initial segregation of the Bosque São Cristóvão (SCRIS) and a wide group composed of two subgroups (A and B), but with a low similarity index (SI) (about 0.09). The first branch (A) was composed of two areas; Praça José Inácio (JOSEINA) and Parque do Ingá (PINGA) (SI = 0.13), and the second branch (B) was divided into two groups; Parque José Milanese (PEMJM)/ Cidade Universitária (CUASO) (C) (SI = 0.22), and Mata do Krambeck (MK)/*campus* (UFJF) branch (D), which had the highest SI of 0.3, although a low value.

The percentage of the variance explained by the first two coordinates of the PCoA was 23.7% and 21.3%, respectively. Figure 3b shows that this analysis have a similar configuration to that of cluster analysis, with a strong separation of SCRIS (in the upper right quadrant) from the other areas. Furthermore, the branches A and B were separated into the coordinate 1, and branches C and D into the coordinate 2.

Figure 3: Dendrogram (a) and scatter plot (b) showing the relationships between seven areas of urban vegetation of Atlantic Forest.



The Mantel test showed a weak correlation between similarity and geographic distance (R = 0.168), but without statistical significance (p = 0.238).

4 DISCUSSION

Concerning remnants of SSF in Minas Gerais (MENINI NETO et al., 2009), the flora of the *campus* showed a lower richness than Reserva Biológica da Represa do Grama (59 spp.), but was similar to Mata do Baú (41 spp.). However, the conservation level and size (ca. 264 and 10 ha, respectively) of these two fragments are larger than those on the *campus*. In comparison with a primary remnant of SSF in the region, the vascular flora of the *campus* is much poorer in species; Barbosa et al. (2015) found 91 species, in the Fazenda Fortaleza de Sant'Anna, in an area of only 1 ha, ca. 40 km from the UFJF. In this case, the higher conservation of the area was responsible for the observed difference.

Pifano et al. (2007) recorded only six species of epiphytic angiosperms in the Morro do Imperador, a neighboring area to the *campus*, composed of about 78 ha of SSF and granitic inselberg. The discrepancy in the richness of two close areas might be because the cited study did not focus on the epiphytic flora, as Morro do

Imperador contains larger fragments and suffers less anthropic impact than the *campus*. Only the occurrence of *Tillandsia gardneri* is common to both areas and the absence on the *campus* of two abundant species that are present both in Morro do Imperador and in other remnants of municipality is notable: *Portea petropolitana* (Wawra) Mez (Bromeliaceae) and *Rhipsalis lindbergiana* K. Schum. (Cactaceae).

Compared to the studies of vascular epiphytic flora, performed exclusively on urban trees in Brazil (FABRICANTE et al., 2006; ALVES et al., 2014) the number of species found in the *campus* of UFJF is around three- to four-fold richer. The list presented here is also richer than others obtained in disturbed urban fragments of SSF in Southeastern and Southern Brazil (DISLICH; MANTOVANI, 1998; FRENEDOZO et al., 2005; DETTKE et al., 2008; BATAGHIN et al., 2010).

The richest families and genera in this study are among the largest of epiphytes (GENTRY; DODSON, 1987; BENZING, 1990) and are commonly found among the richest in studies performed in the neotropics (*e.g.*, SUGDEN; ROBINS, 1979; CATLING; LEFKOVICH, 1989; KERSTEN; SILVA, 2001; MENINI NETO et al., 2009; BATAGHIN et al., 2010; CEJA-ROMERO et al., 2010), except for *Solanum*, whose species are accidental epiphytes, and lack adaptations to epiphytism.

Bromeliaceae, Polypodiaceae and Araceae are usually poorer than Orchidaceae in the majority of studies on vascular epiphytes conducted in the neotropics (CATLING; LEFKOVITCH, 1989; BENZING, 1990; KERSTEN; SILVA, 2001; MENINI NETO et al.; 2009; CEJA-ROMERO et al., 2010; ALVES; MENINI NETO, 2014; BARBOSA et al., 2014, FURTADO; MENINI NETO, 2015). In contrast, Orchidaceae commonly has a low richness among the epiphytes in disturbed forest environments and/or urban environments as corroborated by the present study (DISLICH; MANTOVANI, 1998; FRENEDOZO et al., 2005; FABRICANTE et al. 2006; DETTKE et al. 2008; BATAGHIN et al. 2010). Several factors in the disturbed areas might be responsible for this result and corroborate other surveys in similar environments, such as: low humidity, competition with tolerant species in the adverse conditions caused by the urban environment, a reduction or even the absence of specific pollinators, the absence of mycorhizal fungi that are obligatory symbionts during the germination process and/or predatory collection of the ornamental species.

Tillandsia is frequently the most representative genus amongst the vascular epiphytes in several surveys conducted in the Southern Region of Brazil, although this prominence is uncommon in the Southeastern Region (MENINI NETO et al., 2009). However, *Tillandsia* has a high richness and abundance in the SSF, and is frequently responsible for the expressivity of the Bromeliaceae in these vegetation physiognomies (KERSTEN, 2010). The recorded species of *Tillandsia* on the *campus* are widely distributed (occur in some cases throughout the Neotropical Region), and are capable of tolerating several types of environments, such as *T. recurvata* and *T. usneoides* (SMITH; DOWNS, 1977). This low specificity of habitat allows several species of *Tillandsia*, known as atmospheric plants, to adapt to diverse environments, due to the presence of numerous scales on the leaf surface, which are capable of obtaining all the necessary water and nutrients for the survival of the individuals, as well as reflecting part of the sunlight in open environments. This feature also permits many species to attach themselves to electric and telephone wires, forming dense clumps (BENZING 2000) and tolerating environments with a high level of anthropic disturbance, since they do not need a tree as a phorophyte. Several *Tillandsia* species are also tolerant to the pollution present in urban environments, especially heavy metals from vehicle exhaust, and these species are often used in air biomonitoring, such as *T. recurvata*, *T. tricholepis* and *T. usneoides* (GRACIANO et al., 2003; ALVES et al., 2008; BERMUDEZ et al., 2009), justifying this richness.

The existence of poikilohydry in other prominent genus, *Pleopeltis*, might be responsible for its richness, both in the forest fragments and on cultivated trees in the streets and green areas. Poikilohydry allows the reduction in plant metabolism when water is unavailable (BENZING, 1990), so that the low humidity of the urban environment is not a barrier to its establishment and maintenance.

Capanemia thereziae (Orchidaceae) must be highlighted, since occur as epiphyte only upon *Eriobotrya japonica* (loquat), an Asian species introduced into Brazil (ZAPPI; TURNER, 2001) and cultivated in the *campus*. Careful analysis of the arboreal individuals belonging to other species, neighbors to the loquats, as well as in the forest fragments, confirms this exclusivity. Buzatto et al. (2010) states that it is very common as an epiphyte on *E. japonica* in Paraná. This orchid was also recorded on the same phorophyte in the Serra do Caraça, Minas Gerais (MOTA, 2006) and near to Pedra Selada, Rio de Janeiro (MEDEIROS et al., 2013). This preference for an alien species of phorophyte needs evaluation, since the architecture of crown and trunk, as well as the rhytidome shows no particular features.

The data from ecological category agree in part with those in the literature, where CHL are more frequent, however, the second category commonly is FHL and/or Hem (KERSTEN, 2010). The proportion of AHL (more than one third of species) is due to the presence of Poaceae and Solanaceae (four and three species, respectively), besides the Asteraceae (two spp.), Asparagaceae, Caryophyllaceae, Commelinaceae, Cyperaceae, Phyllanthaceae and Urticaceae (one species each). Also, the occurrence of many AHLs is one reason for the great richness of epiphytes on the *campus* in comparison with other urban areas (DISLICH; MANTOVANI, 1998; FRENEDOZO et al., 2005; DETTKE et al., 2008; BATAGHIN et al., 2010).

The environmental changes caused by degradation, such as an increase in light incidence and reduction in air humidity, as well as the collection of ornamental plants, cause a disequilibrium of the community, reducing and impeding the establishment of CHL, resulting in an environment without competition for the presence of accidental epiphytes (BARTHLOTT et al., 2001; BATAGHIN et al., 2008; DETTKE et al., 2008). In general, urbanization results in an increase in the number of alien species due to changes in the process of natural selection (BYERS, 2002; MCKINNEY, 2006). Therefore, this disturbance might be the reason for the occurrence of typically terricolous species as epiphytes, both aliens and natives.

The architecture of some species used for afforestation *campus* creates conditions of greater humidity and nutrient retention, due to the accumulation of organic matter in the base bifurcation of phorophytes, especially in *Clitoria fairchildiana* R.A. Howard and *D. regia* which provide a substratum probably similar to soil conditions, allowing the adaptation of accidental epiphytes, a fact observed especially in species of the Cyperaceae, Phyllanthaceae, Poaceae (including the bamboo *Phyllostachys aurea*), Solanaceae (except *S. hexandrum*). This argument is strengthened by the absence of accidental epiphytes within the forest fragment.

This feature of the stem allowed the germination of seeds of some trees, but due to their adult size, they will probably never attain maturity and have not been considered in the list: *Melia azedarach* L. (Meliaceae), *P. elliottii*, *Piper* sp. (Piperaceae), *Senna macranthera* (DC. ex Collad.) H.S.Irwin & Barneby (Fabaceae), and *Tecoma stans* (L.) Juss ex. Kenth (Bignoniaceae).

Other studies have identified wind as the most common dispersal agent of vascular epiphytes (KERSTEN, 2010). However, the proportion of zoochoric species is superior to that commonly found (MENINI NETO et al., 2009), reflecting the great number of AHL that show this type of dispersal. Dettke et al. (2008), found more zoochoric than anemochoric species in disturbed remnants, reinforcing the influence of anthropic changes in the species composition. However, as stressed by these authors, this greater proportion of zoochoric species is important to maintain animals in an urban environment and facilitates the dispersal of species to closer fragments.

Although urban trees were richer than forest fragments, the average taxonomic distinctness (Δ^+) and variation in taxonomic distinctness (Λ^+) of both environments were within the 95% funnel-plot probability limit and were therefore not different from a random distribution of values (CLARKE; WARWICK, 1998) and conformed to the expected diversity of the community of vascular epiphytes in both environments, suggesting that anthropic pressure is similar in both environments.

However, the value of Δ^+ for UT is close to the expected mean, but is slightly higher than the Δ^+ value in the FF. This is an unexpected result, since the UT are in a much more disturbed environment than the FF, due to for example, more severe pollution and periodic pruning of the trees. However, for the *campus*, it is possible that the occurrence of the surveyed urban trees around a lake is responsible for the observed diversity, due to the higher humidity than in the forest fragment or to the more intense luminosity available to the epiphytes in urban trees.

The higher value of Λ^+ in the FF than in UT shows that the fragments were uneven in the composition of vascular epiphytes, due to a lower taxonomic spread: 15 species, 11 of which were concentrated in only two families; Bromeliaceae and Polypodiaceae. According to Clarke and Warwick (2001) and Warwick et al. (2002), a high Λ^+ is typical for degraded environments. Again, this is an unexpected result, since theoretically the FF is more conserved than the UT environment, so more data concerning epiphytes in the urban environment can inform about the diversity of this synusia in such disturbed areas.

The wide geographic distribution of the majority of recorded species indicates the presence of several generalists, which tolerate large environmental amplitude, adapted to this disturbed environment. *Polystachya estrellensis*, *Tillandsia recurvata* and *T*. *usneoides* have the widest distribution, and occur throughout the Neotropical Region, whereas at least 26 species occur in two or more phytogeographical domains in Brazil (more frequently in the Atlantic and Amazonian forests, and

Cerrado), several of which are present in other countries of South and Central America. Seven species are endemic to the Atlantic Forest, only two of which are endemic to Brazil (LISTA DE ESPÉCIES DA FLORA DO BRASIL, 2014).

Despite the predominance of the generalist species on the *campus*, it appears that the hypothesis of biological homogenization in urban areas (MCKINNEY, 2006), is not confirmed by low similarity between the areas. Among 155 species used for the similarity analysis, only 15 were found in more than four areas: *Billbergia zebrina*, *Epiphyllum phyllanthus*, *Microgramma squamulosa*, *M. vaccinifolia*, *Oncidium pumilum*, *Philodendron bipinnatifidum*, *Pleopeltis hirsutissima*, *P. pleopeltifolia*, *Polystachya estrellensis*, *Tillandsia geminiflora*, *T. recurvata*, *T. stricta*, and *T. tricholepis*. *Microgramma squamulosa* and *T. recurvata* occurred in six areas.

Of these species, a wide study about the historical biogeography of angiosperm epiphytes in the Atlantic Domain showed that three are among the commonest species recorded: *O. pumilum*, *T. recurvata*, and *T. stricta* (L. MENINI NETO et al., unpublished data). However, these species are also frequently found in surveys along the Atlantic Forest, independent of vegetation formation and/or degree of conservation of the area (e.g., KERSTEN; SILVA, 2001; BORGO; SILVA, 2003; MENINI NETO et al., 2009; BATAGHIN et al., 2008; ALVES et al., 2014). Therefore, these species can neither be used as indicators of degraded environments nor of biological homogenization of disturbed areas.

The cluster and ordination analyses showed a similar configuration; however, the values of the Jaccard similarity index in the cluster analysis are substantially low, with the highest value of 0.3 between UFJF and MK, areas that lie in the municipality of Juiz de Fora, Minas Gerais. However, the observed general relationship is not explained by the geographical distance, as shown by the result of the Mantel test. Thus, the MENINI NETO et al. (2009) hypothesis, that vegetation formation is one of the most important factors to explain the similarity between the areas of Southeastern and Southern Brazil based on Angiosperm epiphytes, appears to be valid for vascular epiphytes, even when only considering disturbed areas.

The segregation of the only area with Mixed Ombrophilous Forest, Bosque São Cristóvão (SCRIS) is clear. The flora of vascular epiphytes associated with this formation is very characteristic and is influenced little by the surrounding vegetation (S.G. FURTADO et al., unpublished data), explaining this segregation.

The importance of seasonality in relationships of the areas was clearly shown by PCoA, that separates the areas composed of ombrophilous forests (SCRIS, PEMJM, and CUASO), in the upper half along coordinate 2, from the seasonal forests in the lower half of the scatter plot (JOSEINA, PINGA, MK and UFJF). This segregation also occurs in the dendrogram, in the separation of branches C and D. In addition, the cluster analysis also tends to separate the areas based on an interiorization gradient: branch A is composed of two areas that are over 300 km from the ocean, whereas in branch D, this distance decreases to about 100 km and the areas of branch C are within 60 km of the ocean.

5 FINAL REMARKS

Urban afforestation, green areas and urban forests are prominent, because they are responsible for a mild temperature and better air quality, as well as providing contact of humans with plants, which is indispensable to a better quality of life in an urban environment. The existence of areas with these features is even more relevant in a municipality such as Juiz de Fora, where there are few natural remnants and even the green areas are insufficient, as highlighted by Costa and Ferreira (2011).

Although urban environments are highly altered by anthropic action, the existing vegetation, both natural and cultivated, can be responsible for harboring a fraction of the biodiversity that is being lost globally over time. Despite this, little is known about the composition and ecology of these novel ecosystems and less is known regarding epiphytic plants and their adaptations to anthropic changes.

This study provides some data on this subject, showing that considerable modifications in specific composition, representativeness of ecological category and dispersal type occur, compared to areas that are more or less impacted. Furthermore, anthropic change did not fully impede the presence of these species, which can occupy cultivated trees in the public spaces to enrich the regional flora.

DIVERSIDADE DE EPÍFITAS VASCULARES EM AMBIENTE URBANO:
ESTUDO DE CASO EM UM *HOTSPOT* DE BIODIVERSIDADE,
A FLORESTA ATLÂNTICA BRASILEIRA

RESUMO

Pouco é conhecido sobre as epífitas em ambiente urbano, sinúsia extremamente relevante no Domínio Atlântico, onde a área estudada está localizada, o *campus* da Universidade Federal de Juiz de Fora, composto por Floresta Estacional

Semidecidual em estágio secundário de regeneração (FF), além de áreas verdes e árvores cultivadas nas vias públicas (AC). O estudo foi conduzido entre março de 2012 e setembro de 2013. Foram registradas 43 espécies, sendo Bromeliaceae a família mais rica (nove spp.). Dentre as categorias ecológicas destacam-se as holoepífitas acidentais (16 spp.), número provavelmente atribuído ao ambiente perturbado. As AC abrigam 42 espécies, enquanto 15 espécies ocorrem nos FF. A distinção taxonômica foi superior nas AC (77,933 *versus* 76,762), no entanto, a variação na distinção taxonômica foi maior nos FF do que nas árvores urbanas (861,9 e 626,4, respectivamente). Assim, o grau de perturbação é similar nos dois ambientes, embora a desigualdade seja maior nos FF. Análises de similaridade mostraram a importância da formação vegetacional e distância do oceano no reconhecimento das relações entre a flora de epífitas em ambiente urbano. Os resultados sugerem que tal vegetação exibe alterações na composição das espécies epifíticas, mas destaca a relevância das árvores cultivadas para sua ocorrência.

Palavras-chave: Ambiente perturbado. Análise de Similaridade. Distinção taxonômica. *Novel Ecosystems.* Vegetação urbana.

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