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DIVERSITY OF EXOTIC SPECIES IN TWO URBAN FOREST PATCHES IN CURITIBA, PARANÁ

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Resumo

Diversidade de espécies exóticas em dois fragmentos florestais urbanos de Curitiba, Paraná. Os fragmentos florestais urbanos (FFU) enfrentam desafios relacionados à mudança do clima e impactos antrópicos sobre os ecossistemas naturais e sua biodiversidade, sobretudo pela presença de espécies exóticas invasoras. O objetivo desta pesquisa foi caracterizar a flora invasora de dois fragmentos florestais urbanos localizados em Curitiba, Paraná. A pesquisa foi conduzida nos bosques Papa João Paulo II e Gutierrez, localizados em Curitiba, Paraná. Foram instaladas 10 parcelas amostrais de 20x30 m (600 m²), sendo amostrados todos os indivíduos com CAP >15 cm, sendo seis no Bosque João Paulo II, e quatro no Bosque Gutierrez. Foi realizada uma caracterização florística em cada parcela, com separação de espécies nativas e exóticas. Foram calculados os índices ecológicos de Diversidade de Shannon-Weaver, Equabilidade de Pielou, Simpson e Jaccard, para quantificar a diversidade da vegetação. As análises florísticas foram feitas em ambiente R. Foram mensurados 546 indivíduos arbóreos, pertencentes a 61 espécies de 31 famílias. Os valores médios dos índices de Shannon-Weaver e Pielou foram superiores no Bosque Gutierrez. Houve baixa similaridade na composição florística entre as parcelas amostrais. Ocorreram diferenças estatisticamente significativas entre as categorias de variáveis, em relação às espécies nativas e exóticas, e entre os FFU. A presença de espécies nativas ainda supera a de espécies exóticas e exóticas invasoras em ambos os FFU. A espécie exótica invasora *Ligustrum lucidum* já influencia de maneira preocupante a sustentabilidade ecológica dos FFU. Os FFU avaliados estão passando pelo processo de homogeneização biótica em sua composição florística.
Palavras-chave: Espécies invasoras, floresta urbana, índices ecológicos, serviços ecossistêmicos.

Abstract

Urban forest patches (UFP) face challenges related to climate change and anthropic impacts on natural ecosystems and their biodiversity, mainly due to the presence of invasive exotic species. The objective of this research was to characterize the invasive flora of two urban forest patches located in Curitiba, Paraná. The research was conducted in the Papa João Paulo II and Gutierrez woods, located in Curitiba, Paraná. Ten sample plots of 20x30 m (600 m²) were installed, all individuals with DBH >15 cm were sampled, six in Papa João Paulo II, and four in Gutierrez. A floristic characterization was carried out in each plot, separating native and exotic species. The ecological indices of Shannon-Weaver Diversity, Pielou, Simpson and Jaccard Equability were calculated to quantify vegetation diversity. Floristic analyzes were carried out in an R ambient. Altogether, 546 tree individuals were measured, belonging to 61 species of 31 families. The mean values of the Shannon-Weaver and Pielou indices were higher in Bosque Gutierrez. There was low similarity in floristic composition between sample plots. There were statistically significant differences between the categories of variables, in relation to native and exotic species, and between UFP. The presence of native species still exceeds that of exotic and invasive alien species in both UFP. The exotic invasive species *Ligustrum lucidum* already has a worrying influence on the ecological sustainability of UFP. The evaluated UFP are going through the process of biotic homogenization in their floristic composition.
Keywords: Ecological índices, ecosystem services, invasive species, urban forest.

INTRODUCTION

In the 21st century, cities have been facing numerous challenges related to climate change and anthropogenic impacts on natural ecosystems and biodiversity. Urbanization alters the landscape and leads to habitat fragmentation, affecting ecological processes and increasing their vulnerability and exposure to adverse effects of global climate change (ADLER; TANNER, 2015). As a result, natural ecosystems within urban areas have their ability to maintain ecological processes compromised, making them less resilient to changes caused by climate change.

Urban forests play a crucial role in this context, assisting in urban sustainability by providing ecosystem services. Within urban forests, there are Urban Forest Patches (UFPs), defined by Biondi (2015) as green areas composed of remnants of forests modified by urbanization, located within the urban or peri-urban perimeter. These areas are the most relevant for maintaining the supply of ecosystem services and biodiversity conservation since they are where ecological processes are less affected by urbanization.

However, for UFP to efficiently provide ecosystem services, it is necessary for their natural characteristics, such as composition and floristic structure, and the abiotic environment, such as soil and water, to be capable of resisting and adapting to the impacts caused by urbanization. This can be achieved with higher levels of native biodiversity, considering that these environments may have numerous difficulties in returning to their original characteristics due to the anthropogenic context in which they are embedded.

Furthermore, in general, UFPs are exposed to various types of anthropogenic pressure, due to the surrounding urban matrix. Among the various pressures that UFPs are subject to is biological invasion, especially by plant species, which initiate a process of biotic homogenization (ADLER; TANNER, 2015).

From the process of biotic homogenization, profound effects occur on all ecological processes in that environment. This is because invasive exotic species compete for resources with native species, becoming dominant. As a result, UFPs often contain various stages of ecological succession in the same location, with different trajectories of vegetation dynamics (JOHNSON *et al*., 2020).

The city of Curitiba is recognized worldwide for its green areas, composed of different typologies, and the presence of UFPs in the categories of the largest green areas. However, not only the quantity of UFPs is important, but also the quality of these environments from an ecological perspective should be considered to assess their functionality in providing ecosystem services.

Therefore, in light of the above, this research tested the hypothesis that the urban forest patches represented by the Papa João Paulo II and Gutierrez woods are being affected by biological invasion by plant species. Thus, the objective was to analyze the influence of the presence of exotic and invasive exotic species on the composition and floristic structure of two urban forest patches located in Curitiba, Paraná.

MATERIAL AND METHODS

Study area

The research was conducted in two green areas, the Papa João Paulo II and Gutierrez woods, located in the municipality of Curitiba, the capital of the state of Paraná, located in the Southern region of Brazil (Figure 1). The zero milestone of the municipality is located in Tiradentes Square, in the central region of the city, at coordinates 25º25'40" South and 49º16'23" West, at an altitude of 934 meters (INSTITUTO DE PESQUISA E PLANEJAMENTO URBANO DE CURITIBA (IPPUC), 2021). The territory of Curitiba covers 435.27 km² (43.527 ha), with an extension from north to south of 33 km, and from east to west of 21 km (IPPUC, 2015).

According to IPPUC (2015), the average temperature in Curitiba during the summer is 21 °C, reaching up to 35 °C on the hottest days, while in winter, the average temperature is 13 °C, dropping to 2 °C on the coldest days.

According to Pregitzer et al. (2018), urban forest patches commonly have their flora composed of a high number of exotic species, making it distinct from forests in non-urban areas. Thus, the two selected UFPs represent a common characteristic of this type of urban green area – the presence of invasive exotic species.

The Papa João Paulo II forest is located in the Centro Cívico neighborhood, created in 1978 and inaugurated in 1980 (MACEDO; SAKATA, 2010). The forest is situated in the Belém River Basin, between 900 and 920 meters above sea level, 2.0 km north of Curitiba's zero mile marker (BORGO; SILVA, 2003). This green area has a total area of 46,337 m² (4.63 ha) and features a gentle relief due to its location along the Belém River (MACEDO; SAKATA, 2010).

The phytophysiognomy of the forest remnant is classified as Montane Mixed Ombrophilous Forest (Montane MOF), in an intermediate to advanced stage of ecological succession and with a moderate degree of environmental alteration (BORGO; SILVA, 2003). There are three forest strata: the canopy, which includes specimens of *Araucaria angustifolia* (Bertol.) Kuntze (araucaria), although not continuous; the understory; and the herbaceous-shrub (SOCIEDADE DE PESQUISA EM VIDA SELVAGEM E EDUCAÇÃO AMBIENTAL (SPVS), 2009).

The Gutierrez forest is located in the Vista Alegre neighborhood and was established through Decree 529, dated September 11. 1986, with the aim of preserving water sources and the forest remnant that covers most of the green area (MACEDO; SAKATA, 2010). The terrain is rugged (MACEDO; SAKATA, 2010). The green area pays tribute to the lawyer João Carlos Hartley Gutierrez, who owned a farm that occupied the forest's area (CURITIBA, 2015).

The Gutierrez forest is located in a region of Alluvial MOF, in an intermediate to advanced stage of regeneration and with a moderate level of alteration of the original environmental characteristics (BORGO; SILVA, 2003). The forest canopy is discontinuous and can be divided into two main tree strata (SPVS, 2009).

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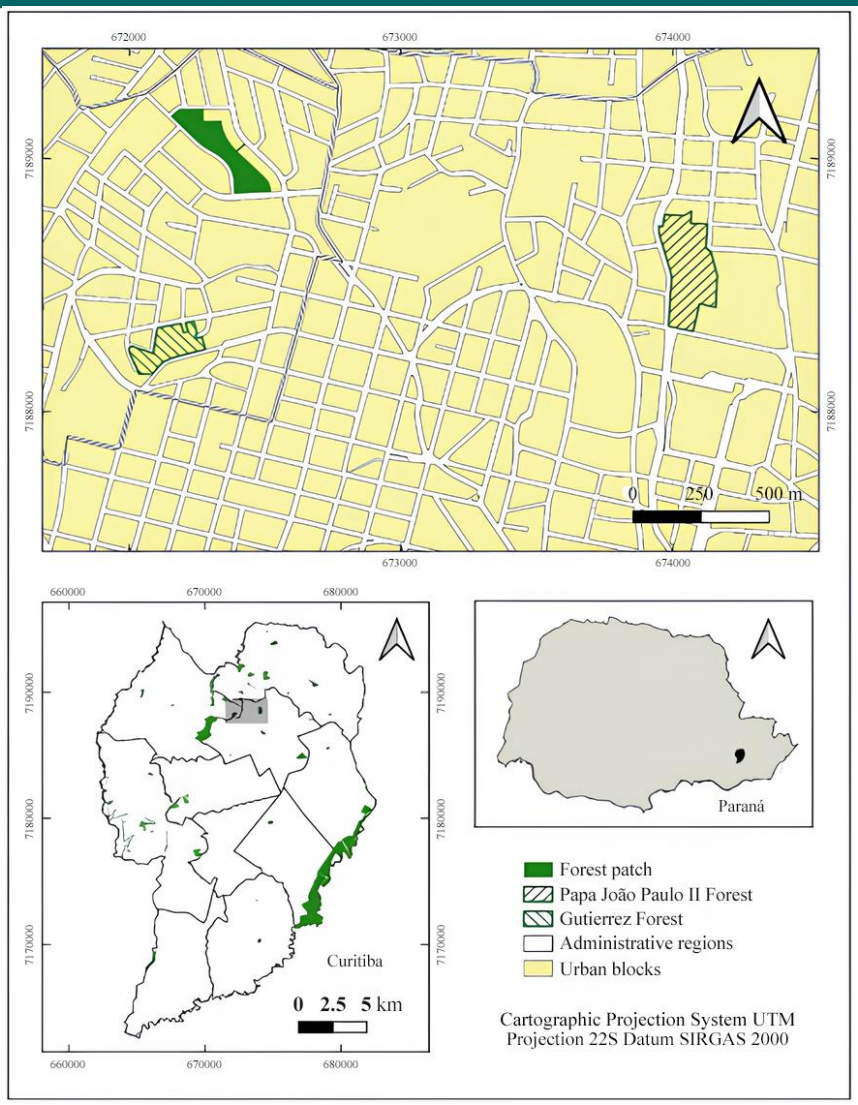

Figure 1. Location of the Papa João Paulo II and Gutierrez woods, in the municipality of Curitiba, Paraná.
Figura 1. Localização dos bosques Papa João Paulo II e Gutierrez, no município de Curitiba, Paraná.

Methodological Procedures
Installation of Sample Plots

The areas composed of remnants of tree vegetation were delimited in each forest, with 3.60 ha of tree vegetation in the Papa João Paulo II forest and 2.28 ha in the Gutierrez forest being counted. However, due to the presence of trails in these patches, their permeable areas relevant to this research are smaller than their total area. Rectangular shapes with dimensions of 20 x 30 meters (600 square meters) were chosen for the sample plots, as it was determined that these dimensions would be suitable for the conditions of both forests in relation to areas with forest vegetation.

Initially, 41 plots were delimited in the Papa João Paulo II forest and 18 in the Gutierrez forest, proportionally to the area of each tree vegetation patch in each forest. Six and four plots were randomly selected for data collection, respectively. The quantities selected aimed to represent at least 10% of the tree cover area in each UFP, following Kauai et al. (2019). Although the cited research was conducted in the Amazon, an adaptation of the methodology was used due to the lack of studies in UFPs, considering it to be consistent with the characteristics of the two forests evaluated.

Thus, a total of 10 sample plots were randomly installed at a distance of at least 2 meters from the forest trails. The sampling covered 0.36 ha, equivalent to 10.71% of the vegetation area in the Papa João Paulo II forest, and 0.24 ha in the Gutierrez forest, representing 10.56% of the total area of this patch.

The procedures for selecting the locations for installing the sample plots were carried out using Google Earth® and QGIS 3.16® software, based on satellite images dated from September 2019. The random selection of the plots was conducted using Microsoft Excel® 2016.

Although the collections were carried out in two locations, the analyses treated the plots as a sequence from 1 to 10. aiming to facilitate comparisons between the plots and between the two evaluated forests.

Characterization of Floristic Composition

A floristic characterization was conducted, separating native species from the MOF (Mixed Ombrophylous Forest) and exotics, which included species not naturally occurring in MOF regions, including invasive exotics. Individuals of trees, shrubs, and palms with a Circumference at Breast Height (CAP) > 15 cm (≈ 4.78 cm Diameter at Breast Height (DBH)) were counted. This stage took place between November 2021 and March 2022.

The vertical structure of the forest was subdivided into three strata: (1) emergent, consisting of tree individuals that rise above the canopy; (2) canopy, represented by the average coverage of tree crowns; and (3) understory, including trees and shrubs over 1.5 meters in height but not part of the canopy.

The species were identified using accepted names from the Flora do Brasil database (www.floradobrasil.jbrj.gov.br) for native (autochthonous) species of the MOF, and The World Flora Online (http://www.worldfloraonline.org) for exotic species.

Exotic invasive species were considered both in arboreal and shrub forms, with the minimum DBH considered for trees as described in the Decree No. 473 of June 5, 2008, of the Municipality of Curitiba (CURITIBA, 2008), and in the Portaria IAP No. 59 of April 15, 2015, of the State of Paraná (PARANÁ, 2015). In the case of Portaria IAP No. 59, species with records of occurrence in MOF regions were selected.

Native species were characterized regarding their conservation status through consultations with the Ministry of the Environment's Decree No. 148, dated June 7, 2022 (MMA, 2022), which establishes the National List of Threatened Species in Brazil.

For each sample plot, ecological indices were also calculated, including Shannon-Weaver Diversity (H'), Pielou's Evenness (J'), Simpson's Diversity (D), and Jaccard's Similarity (J), to quantify the diversity of vegetation):

- Shannon-Weaver Diversity (H')

$$H' = (pi * lnpi)$$
$$pi = ni/N$$

Equation 1

Where: H' = Shannon-Weaver Diversity Index; pi = estimated proportion of individuals (i) of each species; ni = number of individuals of speciesi; N total number of individuals

- Pielou (J'):

$$J' = \frac{H'}{H'máx}$$

Equation 2

Where: J' = Pielou equability; H' = Shannon-Weaver Diversity Index; S = total number of species sampled; $H'máx$= ln (S).

- Simpson (D):

$$D = \sum(\frac{n}{N})^2$$

Equation 3

Where: D = Simpson's index; n = total number of organisms of a specific species; N = total number of organisms of all species.

- Jaccard (J):

$$J = \frac{a}{a+b+c}$$

Equation 4

Where: a = number of common species in both plots (a and b) b = number of unique species in plot a; c = number of unique species in plot b.

The statistical analyses related to phytosociological parameters were conducted in the R environment (R CORE TEAM, 2022).

RESULTS

The sample size sufficiency was deemed adequate, as increasing the sampling by 10% in terms of the number of individuals would result in an increase in the number of species of less than 5%, equivalent to 14 species (Figure 2).

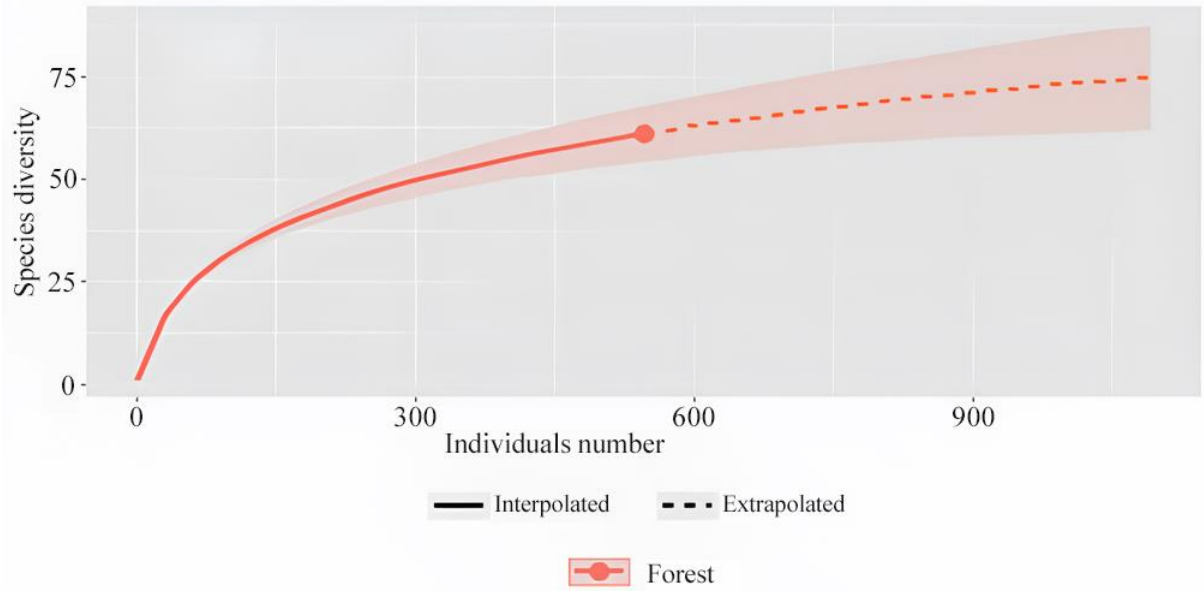

Figure 2. Sampling intensity curve for sample plots.
Figura 2. Curva de intensidade amostral para as parcelas amostrais.

In total, 546 tree individuals were measured, with 336 trees in the Papa João Paulo II forest and 210 in the Gutierrez forest. Among these, 456 individuals belong to native species (83.51% of the total), eight to non-invasive exotic species (1.47%), and 82 to Invasive Exotic Species (IES) (15.01%).

In the Papa João Paulo II forest, there were 257 tree individuals of native MOF species (76.49%), seven non-invasive exotic species (2.08%), and 72 IES individuals (2.14%). In the Gutierrez forest, there were 199 tree individuals of native MOF species (94.76%), one non-invasive exotic species (0.48%), and 10 IES individuals (4.76%).

The sampled tree individuals belong to a total of 61 species, all of which were identified. In the Papa João Paulo II forest, 41 species were recorded, and in the Gutierrez forest, 38 species were identified. There were 18 species occurring simultaneously in both forests. Individuals of the exotic species *Ligustrum lucidum* W.T. Aiton (chinese privet), *Persea americana* Mill. (avocado), and *Eriobotrya japonica* (Thunb.) Lindl. (Loquat) were found in both forests.

The identified species belong to 31 botanical families. Myrtaceae was the most representative family with nine species (14.76%), followed by Salicaceae with seven species (11.48%), Lauraceae with six species (9.83%), and Fabaceae with four species (6.56%). Together, these families represent 42.63% of the total sampled species.

Out of the total number of species found in both forests, 53 species (86.89%) are native to the MOF. Three species (4.91%) are non-invasive exotics in MOF regions: *Euterpe edulis* Mart. (juçara palm) with six individuals, *Ceiba speciosa* (A.St.-Hil.) Ravenna (silk floss tree) and *Platanus occidentalis* L. (american sycamore) with one individual each. Five species (8.2%) are invasive exotics: *Ligustrum lucidum* (51 individuals), *Hovenia dulcis* Thunb. (japanese raisin tree) with 18 individuals, *Persea americana* (avocado) with 10 individuals, *Eriobotrya japonica* (loquat) with two individuals, and *Pittosporum undulatum* Vent. (sweet pittosporum) with one individual.

Only one species, *A. angustifolia*, is considered endangered and classified as "EN" (Endangered).)

Table 1 presents the exotic and invasive exotic species found in each sample plot.

Table 1. Exotic and invasive alien species in each sample plot.
Tabela 1. Espécies exóticas e exóticas invasoras em cada parcela amostral.

Plot	Exotic/Invasive Species	Total Number of Individuals	Total Number of Species
1	*Ligustrum lucidum* (2), *Platanus occidentalis* (1)	3	2
2	*Hovenia dulcis* (14), *Ligustrum lucidum* (7), *Persea americana* (6)	27	3
3	*Hovenia dulcis* (2), *Ligustrum lucidum* (2), *Euterpe edulis* (1)	5	3
4	*Ligustrum lucidum* (34), *Hovenia dulcis* (1)	35	2
5	*Hovenia dulcis* (1), *Euterpe edulis* (1)	2	2
6	*Euterpe edulis* (3), *Ligustrum lucidum* (2), *Eriobotrya japonica* (1), *Pittosporum undulatum* (1)	7	4
7	*Ligustrum lucidum* (5), *Persea americana* (3), *Ceiba speciosa* (1)	9	3
8	Only native species	0	0
9	*Eriobotrya japonica* (1), *Persea americana* (1)	2	2
10	Only native species	0	0

Ecological Indices

Table 2 presents the results of diversity indices calculated for the sample plots. It can be observed that plots 7, 9, and 1. respectively, exhibited the highest floristic diversities, with the species present in equal abundance, as indicated by the results of the first three indices (Shannon-Weaver, Pielou, and Simpson).

Conversely, plot 4 in the Papa João Paulo II forest showed lower floristic diversity due to the dominance of individuals of the species *L. lucidum*, attributed to its ability to establish in disturbed environments. In the case of the Gutierrez forest, the highest dominance and, consequently, lower diversity, were observed in plot 8, due to the presence of trees of the native species *Matayba elaeagnoides* Radlk. (miguel-pintado).

Table 2. Ecological indices calculated for the sample plots.
Tabela 2. Índices ecológicos calculados para as parcelas amostrais.

Forest	Sample plot	Shannon-Weaver (H')	Pielou (J')	Simpson (D)
Para João Paulo II	1	2.5760	0.9092	0.9075
	2	2.0755	0.8352	0.8416
	3	2.0780	0.7874	0.8148
	4	1.8648	0.7504	0.7738
	5	2.2633	0.8358	0.8574
	6	2.5393	0.8099	0.8565
Mean		**2.2328**	**0.8213**	**0.8419**
Gutierrez	7	3.1772	0.9435	0.9502
	8	2.1638	0.7637	0.7997
	9	2.6287	0.9278	0.9083
	10	2.5438	0.8801	0.8964
Mean		**2.6284**	**0.8788**	**0.8887**

Regarding the forests, the average values of the Shannon-Weaver and Pielou indices were higher in the Gutierrez forest, supporting the higher species diversity in this UFP.

The results of the Jaccard Index indicated that, in general, there is low similarity in floristic composition between the sample plots (Table 3). The most similar plots in this regard were plots 2 and 4, and 2 and 3 in the

Papa João Paulo II forest, with similarity values of 0.6000 and 0.5294, respectively. In the Gutierrez forest, plots 8 and 10 had a similarity value of 0.5217.

In the case of plot 2 Individuals of the species *Hovenia dulcis* predominate, while in plot 3. *Casearia sylvestris* Sw. (wild coffee) is more common. However, in plots 8 and 10. there were more individuals of *M. elaeagnoide*s (miguel-pintado).

Table 3. Jaccard index for sample plots.
Tabela 3. Índice de Jaccard para as parcelas amostrais.

Plot	1	2	3	4	5	6	7	8	9	10
1	1.0000									
2	0.3182	1.0000								
3	0.2917	0.5294	1.0000							
4	0.3182	0.6000	0.4444	1.0000						
5	0.1429	0.4211	0.3810	0.4211	1.0000					
6	0.2500	0.3462	0.3704	0.2963	0.3571	1.0000				
7	0.1500	0.1714	0.1622	0.1714	0.1892	0.2381	1.0000			
8	0.2143	0.2083	0.1923	0.2609	0.2308	0.1765	0.3529	1.0000		
9	0.1724	0.2083	0.0690	0.2083	0.1852	0.1765	0.3529	0.3600	1.0000	
10	0.2069	0.2000	0.1034	0.2500	0.1786	0.1389	0.3429	0.5217	0.4000	1.0000

The lowest floristic similarities occurred between plots 1 and 5 in the Papa João Paulo II forest, with a similarity of 0.1429, and between plots 7 and 10 in the Gutierrez forest, with a similarity of 0.3429. Although these two pairs are close to each other, the species compositions differ, with few com

Thank you for providing the missing species name. In the first two plots, the species *Casearia decandra* occurs together. mon species in both plots (1 and 5, and 7 and 10). Species occur together in the first two plots *Casearia decandra* Jacq., *C. sylvestris*, *Eugenia uniflora* L. (pitangueira) e *Ocotea puberula* (Rich.) Nees (canela-guaicá). In plots 7 and 10, the following species were observed *Alchornea triplinervia* (Spreng.) Müll.Arg. (tapiá), *C. sylvestris*, *E. uniflora*, *M. elaeagnoides*, *Monteverdia gonoclada* (Mart.) Biral (café-de-jacu), *Palicourea sessilis* (Vell.) C.M.Taylor (café-de-bugre), *Picrasma crenata* (Vell.) Engl. (pau-amargo), *Sapium glandulosum* (L.) Morong (pau-de-leite), *Schinus terebinthifolia* Raddi (aroeira-vermelha) and *Solanum compressum* L.B.Sm. & Downs (fumeiro).

The highest similarity between the two forests was observed for plots 4 (Papa João Paulo II forest) and 8 (Gutierrez forest), with a value of 0.2609, which is still considered low because it is less than 0.5.

DISCUSSION

Floristic survey

The most frequent plant families found in the Papa João Paulo II and Gutierrez forests were also identified by Santos et al. (2023) in other Urban Forest Patches (UFPs) in Curitiba. It can be inferred that other threatened species, like *A. angustifolia*, may face resistance in establishing themselves in these UFPs due to their specific environmental requirements. Santos et al. (2023) suggest that in such cases, there is potential for conserving tree diversity, with a focus on species that are more sensitive to environmental changes and therefore at risk of extinction.

The high percentage of native species, almost 87%, was unexpected considering the anthropogenic alterations that Urban Forest Patches (UFPs) typically undergo. For example, a study conducted by Osako, Brito, and Silva (2022) in 10 UFPs in Presidente Prudente, SP, indicated a presence of 61.30% of tree individuals from native species. However, it's important to note that the quantity of species alone does not necessarily reflect the level of environmental alteration in UFPs. Other characteristics of the floristic component in each location should also be considered, such as the origin of species, the number of strata, and phytosociological parameters (Density, Frequency, Dominance, and Importance Value). These additional factors provide a more comprehensive understanding of the ecological dynamics within these forested areas.

All of the Invasive Exotic Species (IES) found have already been documented in UFPs in Curitiba, with *L. lucidum* being the most common in these environments (SANTOS et al., 2023). Fernandez et al. (2020)

conducted a review on the occurrence of *L. lucidum* and found records of its invasion in all continents, with Southern Brazil being one of the regions most affected by this species' invasion.

According to Paraná (2015), the species *L. lucidum*, *H. dulcis*, and *P. undulatum* are classified in Invasion Class I, where their transportation, cultivation, propagation, trade, donation, or intentional acquisition are prohibited. Meanwhile, *E. japonica* falls into Invasion Class II, allowing for the use of the species under controlled conditions, in accordance with specific regulations (PARANÁ, 2015).

The risk of invasion by *L. lucidum* in Brazil is considered high (INSTITUTO HÓRUS, 2022). In forest environments, *L. lucidum* has a high potential for seed dispersal, and once established, it can accelerate the rate of litter decomposition and nutrient cycling, disrupting natural dynamics, among other ecological impacts (FERNANDEZ et al., 2020).

H. dulcis has a high risk of invasion in Brazil, and in MOF areas, the species occupies the upper stratum, gradually taking over the space of native tree species (INSTITUTO HÓRUS, 2022). Reis et al. (2021) found that the UFPs in Curitiba are highly vulnerable to invasion by *H. dulcis*, especially in more urbanized regions, such as the northern part, with the Papa João Paulo II forest being moderately vulnerable to invasion by the species.

Although *P. americana* is not listed in official Invasive Exotic Species (IES) lists, the species was considered invasive due to the high number of seedlings, seedlings, and trees found in some sample plots.

The presence of invasive exotic species *L. lucidum*, *H. dulcis*, and *P. americana* already affects the ecological sustainability of the evaluated UFPs due to their influence on native flora and ecological processes, especially in the Papa João Paulo II forest, where the invasion by *L. lucidum* is more pronounced.

Nevertheless, the number of Invasive Exotic Species (IES) individuals was lower than expected, possibly due to the fact that the installation of the sample plots considered a distance from the internal trails. This statement is confirmed by the presence of several adult individuals of species such as *H. dulcis* and *L. lucidum* along the internal trails in both forests.

According to Lima (2022), there are currently no specific actions and programs for the management of Invasive Exotic Species (IES) in green areas carried out by the Municipal Environmental Secretariat of Curitiba (SMMA), with only some occasional removals. In 2012, a survey of IES was conducted in parks and forests, including Papa João Paulo II and Gutierrez woods, when partial management of these species was carried out as part of the Urban Biodiversity Program - Biocidade (LIMA, 2022). Thus, the actions taken in 2012 were likely responsible for a reasonable decrease in the number of invasive trees in certain areas within the forests, leading to the results obtained in this research.

Ecological indexes

As shown in Table 2, the Shannon-Wiener Diversity Index and Pielou's Evenness Index in the Gutierrez forest were higher, with values of 2.62 and 2.23, respectively, compared to those in the Papa João Paulo II forest. Kanieski et al. (2012) obtained a Shannon-Wiener value of 2.13 in a MOF patch in the São Francisco de Paula National Forest, RS.

On the other hand, Santos et al. (2023) found diversity values exceeding 3.06 in other UFPs in Curitiba, which were observed to be less affected by the presence of IESs. This reinforces the observation that the Papa João Paulo II and Gutierrez forests are undergoing a process of biotic homogenization in their floristic composition.

The values of the Pielou's Evenness Index in the Papa João Paulo II and Gutierrez forests, respectively, indicate a high evenness in the forest community, suggesting that individuals of each species are relatively evenly distributed in the area. According to Biondi and Bobrowski (2014), this shows a high equitability in the forest community.

Kanieski et al. (2012) found an average value of 0.76 for the Pielou's Evenness Index, indicating, according to the authors, high uniformity in species composition in their study plots. Osako, Brito, and Silva (2022) found an even higher average evenness for UFPs located in Presidente Prudente, SP, with a value of 0.81.

Therefore, it can be inferred that the obtained result represents a lower alteration in the species occupancy pattern in the UFPs evaluated in Curitiba compared to those assessed in the mentioned studies, possibly due to the size of the UFPs and the autoecological characteristics of each species.

The Simpson's Diversity Index indicated a higher average dominance of species in the Papa João Paulo II forest, with a value of 0.8419, and the plot 4 had the highest dominance (0.7738) due to the larger numbers of *L. lucidum* individuals. On the other hand, in the Gutierrez forest, the highest species dominance occurred in plot 8, with a value of 0.7997, due to the presence of *M. elaeagnoides* individuals. It is known that the dominance of *L. lucidum* affects the richness, diversity, and evenness of species in native forests (FERNANDEZ et al., 2020).

Regarding the Jaccard Index, Biondi and Bobrowski (2014) explain that although the floristic composition between plots may be close, there can still be different dominances. Indeed, both native and exotic species were found to dominate certain plots, with *M. elaeagnoides* and *L. lucidum* being notable examples. The highest similarity found among UFPs in Presidente Prudente, SP, by Osako, Brito, and Silva (2022) was 0.3600. The

authors attributed this to the high incidence of the invasive exotic species *Leucaena leucocephala* (Lam.) de Wit (leucena), whose presence can alter natural environments in terms of ecological processes.

As a result, there is a significant floristic distinction between the two UFPs, even though the sites are relatively close and have the same original forest physiognomy. This difference may be due to the method of exploitation or intervention applied in these UFPs over time, with different purposes, either for timber extraction or for the installation of infrastructure built within and around them.

Another explanation is the location and use of each forest for tourism purposes. In the case of Papa João Paulo II forest, it is located in a region with tourist attractions, such as the Oscar Niemeyer Museum, situated at the back of the forest, in addition to cultural activities that take place within it. Visitors to both the museum and the forest have a more significant impact on its natural resources than in the Gutierrez forest, which is less frequented, as it is located on terrain with steeper slopes and has fewer tourist attractions.

CONCLUSIONS

The analyses conducted allow us to conclude that:

- The presence of native autochthonous species still outweighss tha of exotic e and invasive exotic species in both UFPs. However, the biologial invasion of tree soecies has already begun to affect their forest structures, poisina a problem tha needs to e adressed in the management of both UFPs.
- The invasive exotic species *L. lucidum* is already significantly impacting the ecological sustainbility of the UFPs, especially in the Papa João Paulo II forest.
- The evaluated UFPs are undergoing the process of biotic homogenization in their floristic composition, due to biological invasion by plant species
- It is recommended to remove individuals of invasive exotic species and engage in enrichment planting of native MOF species, to restore the original ecological conditions of the two evaluated forests.

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