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Native vs introduced: a comparative study of structure and diversity of plants in urban green areas from San Pedro Garza Garcia, Mexico

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Abstract

Urban forests play a critical role as a source of environmental services for both human fitness and local fauna. Historically, urban planning activities have prioritized the use of introduced species for ornamental purposes and availability. However, the recent trend highlights the importance of using native species. Native species are better adapted and require less management. In this way, we compared the structure and diversity of native and introduced woody plants in the main urban green areas of San Pedro Garza Garcia, in the Mexican Northeastern. We conducted a census of urban trees between January and March 2024 across seven parks and two main sidewalks (total area: 59.1 ha). For each species, we determined the abundance, dominance, and frequency, as well as the Importance Value Index. We determined the effective species index by correcting the Shannon Entropy Index. To assess group differences, we generated confidence intervals using BOOTSTRAP simulations (10,000 samples) and conducted proportion tests. We also analyzed dominance and distribution patterns, using range-abundance curves and histograms of height and diameter. We recorded 11,318 individuals from 98 plant species (50 native and 48 introduced). Native species accounted for 69% of individuals and 68% of basal area, while introduced species contributed 31% and 32%, respectively. The introduced species have higher diversity, while the native ones were most abundant and had better structure. This highlights the importance of prioritizing native over introduced species in urban forest projects for complementary functions and better structure.

Keywords: species diversity, urban forest, urban forest structure, urban public parks, urban planning.

Introduction

Urban forests are plant communities composed mainly of woody plants in the public areas of the cities (Almas and Conway 2016). Despite their human modification, these green areas are recognized as providing essential environmental services that benefit both humans and associated wildlife (Berglihn and Gómez-Boggethun, 2021). Among the benefits that trees and shrubs provide to animal species are cover, food, and their function as resting and/or breeding areas (Orellana-Asenjo et al. 2023). Oxygen production, carbon dioxide capture, their role as wind and noise barriers, the shade provided by their canopies (which decreases the temperature), as well as their ornamental importance or landscape beauty, are just some of the positive contributions of forests present in urban areas (Ahumada et al. 2025; Alpaidze and Salukvadze 2023). Furthermore, urban inhabitants greatly value the

presence of plants in green areas as plants contribute to improving their living conditions (Addas 2023). Additionally, the set of plant species present in gardens and public avenues has an influence on the economic value of some sectors (Quispe et al. 2019). For this reason, green areas currently represent necessary components for the organization, development, and functioning of cities that have rapid population growth (Pulla-Morocho and Rodríguez-Ortega 2021).

In recent years, the role of some large urban areas as generators of biodiversity and cultural centers has been recognized worldwide, due to their integration and promotion of green areas in their comprehensive development (Borelli et al. 2023). An example of this is the municipal seat of San Pedro Garza Garcia, which is part of one of the most important metropolitan areas in northeastern Mexico due to its economy and environmental initiatives (García-Fuentes and Díaz de León 2024). In fact, a recent study found that San Pedro Garza García was the municipality with the highest availability of green areas per inhabitant within the metropolitan area of Monterrey, Nuevo León (Jiménez-Pérez et al. 2022). Northeastern Mexico, and in particular the Monterrey metropolitan area, has been the subject of various studies on the structure and floristic composition of green areas and/or urban forests (Alanís-Rodríguez et al. 2023a). In these studies, as in others carried out in other regions of the world, it is common for introduced species to be more prevalent than native species (Martínez-Trinidad et al. 2021). This situation has motivated researchers and public servants to promote the use of native plant species, considering that these are better adapted to local conditions and therefore do not require excessive spending on irrigation and nutrients (Almas and Conway 2016; Jiménez-Pérez et al. 2025).

Therefore, our main objective was to contrast the structure and diversity between native and introduced plant species in the main parks and avenues of the municipality of San Pedro Garza Garcia. Our specific objectives were: 1) to calculate and compare the ecological importance between native and introduced species, 2) to compare alpha diversity between native and introduced species, and 3) to characterize the distributions of total height and diameter using comparative histograms for native and introduced species. We predicted that introduced plant species would show higher ecological importance values and representation with respect to native species.

Methods

Study area

We included seven urban parks and two avenues (the most important and emblematic) from the San Pedro Garza Garcia municipality in Northeast Mexico. The total area assessed was 59.1 ha, of which 43.14 ha corresponds to parks and 15.96 ha to sidewalks (Fig. 1). The potential native plant community of the area is the submontane scrubland (Instituto Nacional de Estadística y Geografía (INEGI) 2017); this type of vegetation has been the subject of structural and floristic studies in the region (Canizales et al. 2009).

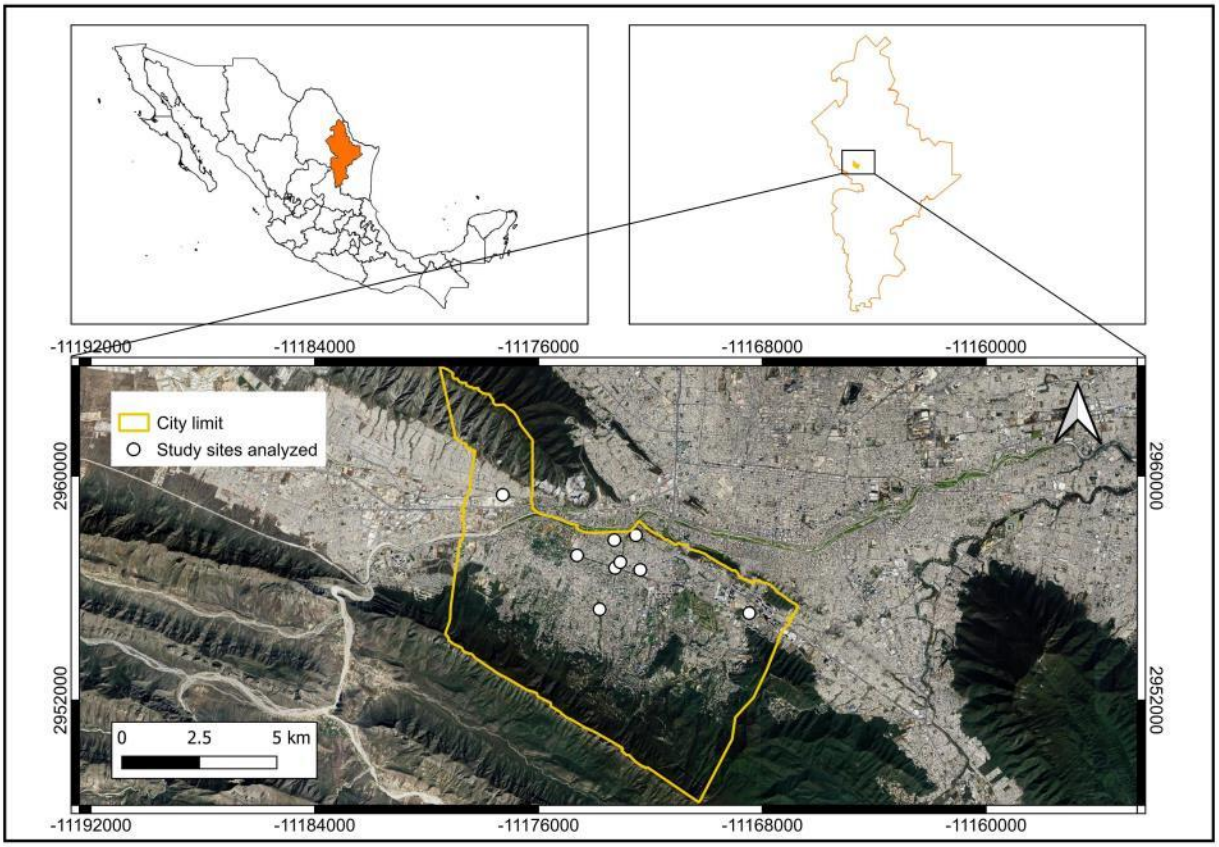


Fig. 1. Location of the seven urban parks and two tree-lined avenues evaluated in the municipality of San Pedro Garza Garcia, Nuevo Leon, northeast Mexico. The white dots show the spatial distribution of the analyzed sites within the city limits.

Fieldwork

Between January and March of 2024, we performed a census of tree, tree-like, and scrub woody species in the studied areas. For each individual, we recorded the species and measured the following variables: total height (h), using a SUUNTO PM-5 clinometer; diameter at breast height ($d_{1.30}$), using Mantax Blue calipers (100 cm Haglöf);

and crown diameter (*k*), using a Truper ODM-12 odometer with a 13" wheel, considering both the largest diameter and the diameter perpendicular to it. We verified the taxonomic nomenclature using the platform Tropicos (2025).

Ecological importance variables

For each individual, we determined the average diameter, basal area, and crown area. We calculated the average diameter using the following equation (Alanís-Rodríguez et al. 2020): $\bar{d} = \frac{d_1+d_2}{2}$

Where $\bar{d}$ is the average diameter, d_1 is the diameter measured from north to south, and d_2 is the diameter measured from east to west. We also estimate the basal area using the following formula (Alanís-Rodríguez et al. 2020): $A = \frac{\pi}{4} * d^2$ Where *A* is the area and *d* is the diameter.

Based on these variables, we estimated the absolute and relative values of abundance, dominance, and frequency for each species, considering its presence in the parks and roads analyzed (Alanís-Rodríguez et al. 2020).

Abundance

$$A_i = \frac{N_i}{S}$$

$$AR_i = \left[A_i / \sum_{i=1}^{n} A_i\right] x\ 100$$

Where A_i is the absolute abundance, N_i is the number of individuals of the species *i*, *S* is the sampled area (ha), and AR_i is the relative abundance.

Dominance

$$D_i = \frac{G_i}{S}$$

$$DR_i = \left[D_i / \sum_{i=1}^{n} D_i\right] x\ 100$$

Where D_i is absolute dominance, G_i is the basal area of the species *i*, *S* is the sampled area (ha), and DR_i is the relative dominance.

Frequency

$$F_i = \frac{P_i}{NS}$$

$$FR_i = \left[F_i / \sum_{i=1}^{n} F_i\right] x\ 100$$

Where F_i is the absolute frequency, P_i is the number of sites where the species i is present, NS is the total number of sampled sites, and FR_i is the relative dominance.

Finally, we obtained the Importance Value Index (IVI), using the following equation (Mostacedo and Fredericksen 2000):

$$IVI = \frac{\sum_{i=1}^{n}(AR_i, DR_i, FR_i)}{3}$$

Species diversity and proportion: native vs introduced

We calculated the Shannon-Wiener index (H') (according to Magurran 2004). With H', we performed the correction of the effective species index (^1D) proposed by Jost (2006), as follows: $^1D = \exp(H')$.

To estimate the uncertainty in comparisons of diversity and richness between native and introduced species, we used BOOTSTRAP simulations (Chernick and LaBudde 2014). We generated 10,000 samples of the differences in these comparisons to create confidence intervals based on percentiles (0.025 and 0.975) of the BOOTSTRAP distribution. The intervals used to test the statistical differences were 95% confidence intervals ($\alpha = 0.05$). We used the "prop.test" function in R software ver. 4.1.2 (R Core Team 2021) to compare the proportion of individuals between native and introduced species.

Patterns of dominance and distribution patterns per species

We elaborated Rank-abundance curves (Whittaker graphs), through a dual approach: 1) per individual park and (2) per origin (native vs introduced). First, we ranked the species according to their absolute abundance (number of individuals) in descending order, assigning rank 1 to the most abundant species in each group. Then, we generated graphs with logarithmic scales (base 10) on the abundance axis to better visualize the distribution of rare species. This analysis allowed us to identify differences in community structure, evenness, and dominance patterns among parks and origin groups, complemented by calculations of total richness and aggregate abundance by category. We segmented the visualizations using facets for spatial (parks) and taxonomic (native vs. introduced) comparisons. This methodology is consistent with Whittaker's (1965) work and with more recent explanations of general patterns of species abundance and distribution in biological communities (Verberk 2011).

Distribution of height and diameter classes

We generated comparative histograms for native and introduced species, representing individual frequencies at automatically generated intervals, segmented by origin. This representation allowed us to identify key structural patterns, including asymmetries and differences in size class distribution between groups, providing insights into the differential development of both assemblages in the urban forest.

Results

Ecological importance variables

We recorded 98 woody plant species, of which 50 were native and 48 introduced. We counted 11,318 individuals, of which 69% (7,779) corresponded to native species and 31% (3,539) to introduced species (Table 1; $\chi^2 = 220$, GL = 8, $p < 0.001$).

Total basal area was 636 m^2, of which 68% (435 m^2) corresponded to native species and 32% (201 m^2) to introduced species (Table 1). These differences were also significant; the BOOTSTRAP distribution yielded an average difference of 232.8 m^2 with a 95% confidence interval of [7.98, 470.73].

The native species that showed the highest relative abundance were *Leucophyllum frutescens* (Berland.) I.M. Johnst. (33.1%) and *Fraxinus uhdei* (Wenz.) Lingelsh. (21.5%). While among the introduced species, *Quercus virginiana* Mill. (32.1%) and *Leucaena leucocephala* (Lam.) de Wit. (17%) were the most abundant. *Fraxinus uhdei* showed the highest relative dominance among native species (63.4%), while *Q. virginiana* (33.9%) was the most dominant introduced species. Regarding relative frequency, the native species with the highest distribution (4.7%) was *F. uhdei*, *Ehretia anacua* (Terán & Berland.) I.M. Johnst. and *Carya illinoinensis* (Wangenh.) K. Koch., while the introduced species with the highest distribution (5.7%) were *Q. virginiana* and *Pinus eldarica* Medw.

Regarding the Importance Value Index (IVI), the native species *F. uhdei*, *L. frutescens*, and *E. anacua* were the most ecologically important, together accounting for 47.7% of the IVI. Among the introduced species, the most important were *Q. virginiana*, *P. eldarica*, and *L. leucocephala*, which together accounted for 42.1% of the IVI (Table 1).

Table 1. Structure and ecological importance of native and introduced urban trees in parks and roads of San Pedro Garza García, northeast Mexico. N = number of individuals; G = basal area (m^2); F = absolute frequency; Rabu =

relative abundance (%); Rdom = relative dominance (%); Rfre = relative frequency (%); IVI = Importance Value Index. Study sites: BV = Bosques del Valle; CV = Calzada del Valle; CSP = Calzada San Pedro; CL = Clouthier; EC = El Capitán; EE = El Edén; HU = Hundido; MI = Mississippi; RT = Rufino Tamayo.

Family	Species	Plant origin	Park	N	G	F	Rabu	Rdom	Rfre	IVI
Apocynaceae	*Nerium oleander* L.	Introduced	CV, CL, EC, HU	17	0.434	4	0.5	0.2	2.5	1.1
Arecaceae	*Phoenix dactylifera* L.	Introduced	BV, CSP, EC	24	3.44	3	0.7	1.7	1.9	1.4
Arecaceae	*Phoenix sylvestris* (L.) Roxb.	Introduced	CSP, EC	5	0.643	2	0.1	0.3	1.3	0.6
Arecaceae	*Syagrus romanzoffiana* (Cham.) Glassman	Introduced	BV, CV, EC, HU	22	1.401	4	0.6	0.7	2.5	1.3
Arecaceae	*Washingtonia filifera* (T.Moore & Mast.) H. Wendl. ex de Bary	Introduced	BV, CL, EC, EE, MI, RT	66	5.938	6	1.9	3	3.8	2.9
Arecaceae	*Washingtonia robusta* H. Wendl.	Introduced	BV, CSP, CL, EC, HU, RT	27	3.366	6	0.8	1.7	3.8	2.1
Asparagaceae	*Agave salmiana* Otto ex Salm-Dyck	Native	CSP, EE	70	1.437	2	0.9	0.3	1.1	0.8
Asparagaceae	*Beaucarnea recurvata* Lem.	Introduced	BV, HU	2	0.08	2	0.1	0	1.3	0.5
Asparagaceae	*Dasylirion berlandieri* S. Watson	Native	EE	19	0.918	1	0.2	0.2	0.5	0.3
Asparagaceae	*Yucca aloifolia* L.	Introduced	RT	29	0.102	1	0.8	0.1	0.6	0.5
Asparagaceae	*Yucca filifera* Chabaud	Native	BV, EC	9	1.268	2	0.1	0.3	1.1	0.5
Asparagaceae	*Yucca gigantea* Lem.	Introduced	BV, CSP, CL, EC, EE	85	0.173	5	2.4	0.1	3.2	1.9
Bignoniaceae	*Jacaranda mimosifolia* D. Don	Introduced	CL	1	0.351	1	0	0.2	0.6	0.3
Bignoniaceae	*Tecoma stans* (L.) Juss. ex Kunth	Native	CSP, CL, RT	13	0.104	3	0.2	0	1.6	0.6
Boraginaceae	*Cordia alliodora* (Ruiz & Pav.) Oken	Introduced	HU	1	0.105	1	0	0.1	0.6	0.2
Boraginaceae	*Cordia boissieri* A. DC.	Native	BV, CL, EC, EE, HU, MI, RT	221	3.564	7	2.8	0.8	3.7	2.4
Boraginaceae	*Ehretia anacua* (Terán & Berland.) I.M. Johnst.	Native	BV, CV, CSP, CL, EC, EE, HU, MI, RT	465	23.723	9	6	5.5	4.7	5.4
Boraginaceae	*Ehretia latifolia* Loisel.	Native	CL	1	0.005	1	0	0	0.5	0.2
Cannabaceae	*Celtis laevigata* Willd.	Native	BV, CV, CSP, CL, EC, HU, MI, RT	260	14.443	8	3.3	3.3	4.2	3.6
Cannabaceae	*Celtis pallida* Torr.	Native	BV, CL, EC, RT	33	0.265	4	0.4	0.1	2.1	0.9
Cupressaceae	*Cupressus lusitanica* Mill	Native	CV, CSP	165	0.667	2	2.1	0.2	1.1	1.1

Cupressaceae	*Cupressus macrocarpa* Hartw. ex Gordon	Introduced	CV, RT	43	6.316	2	1.2	3.1	1.3	1.9
Cupressaceae	*Cupressus sempervirens* L.	Introduced	BV, MI	41	0.226	2	1.2	0.1	1.3	0.8
Cupressaceae	*Juniperus deppeana* Steud.	Native	BV	1	0.015	1	0	0	0.5	0.2
Cupressaceae	*Thuja orientalis* L.	Introduced	CL, EC, HU	3	0.176	3	0.1	0.1	1.9	0.7
Cycadaceae	*Cycas revoluta* Thunb.	Introduced	BV	3	0.19	1	0.1	0.1	0.6	0.3
Ebenaceae	*Diospyros palmeri* Eastw.	Native	EC	1	0.019	1	0	0	0.5	0.2
Ebenaceae	*Diospyros texana* Scheele	Native	BV, CL	2	0.015	2	0	0	1.1	0.4
Euphorbiaceae	*Ricinus communis* L.	Introduced	CL	1	0.002	1	0	0	0.6	0.2
Fabaceae	*Bauhinia variegata* L.	Introduced	BV, CV, EC	5	0.262	3	0.1	0.1	1.9	0.7
Fabaceae	*Delonix regia* (Bojer ex Hook.) Raf.	Introduced	EC	2	0.38	1	0.1	0.2	0.6	0.3
Fabaceae	*Ebenopsis ebano* (Berland.) Barneby & J.W. Grimes	Native	BV, CV, CSP, CL, EC, EE, MI, RT	197	3.793	8	2.5	0.9	4.2	2.5
Fabaceae	*Erythrina americana* Mill.	Native	BV, CSP, CL, HU, RT	16	0.075	5	0.2	0	2.6	1
Fabaceae	*Erythrostemon mexicanus* (Rose) Gagnon & G.P.Lewis	Native	BV, CV, CL, EC, RT	155	2.713	5	2	0.6	2.6	1.7
Fabaceae	*Eysenhardtia polystachya* (Ortega) Sarg.	Native	CL, EC	2	0.002	2	0	0	1.1	0.4
Fabaceae	*Havardia pallens* (Benth.) Britton & Rose	Native	RT	16	0.234	1	0.2	0.1	0.5	0.3
Fabaceae	*Leucaena leucocephala* (Lam.) de Wit	Introduced	BV, CV, CL, EC, RT	603	13.166	5	17	6.5	3.2	8.9
Fabaceae	*Neltuma laevigata* (Humb. & Bonpl. ex Willd.) Britton & Rose	Native	BV, CL, EC, RT	169	11.815	4	2.2	2.7	2.1	2.3
Fabaceae	*Parkinsonia aculeata* L.	Native	BV, CL, EC, HU, RT	303	7.311	5	3.9	1.7	2.6	2.7
Fabaceae	*Senegalia wrightii* (Benth.) Britton & Rose	Native	CL, EC, RT	15	0.16	3	0.2	0	1.6	0.6
Fabaceae	*Vachellia constricta* (Benth.) Seigler & Ebinger	Native	BV, RT	10	0.099	2	0.1	0	1.1	0.4
Fabaceae	*Vachellia farnesiana* (L.) Wight & Arn.	Native	BV, CV, CL, EC, EE, MI, RT	138	5.685	7	1.8	1.3	3.7	2.3
Fabaceae	*Vachellia rigidula* (Benth.) Seigler & Ebinger	Native	CL, RT	47	0.3	2	0.6	0.1	1.1	0.6
Fabaceae	*Vachellia schaffneri* (S.Watson) Seigler & Ebinger	Native	RT	1	0.006	1	0	0	0.5	0.2

Fagaceae	*Quercus canbyi* Trel.	Native	BV, CSP, CL, RT	55	4.628	4	0.7	1.1	2.1	1.3
Fagaceae	*Quercus fusiformis* Small	Native	BV, CV, CSP, CL, EC, RT	91	5.972	6	1.2	1.4	3.2	1.9
Fagaceae	*Quercus grisea* Liebm.	Native	BV	1	0.41	1	0	0.1	0.5	0.2
Fagaceae	*Quercus muehlenbergii* Engelm.	Native	CSP	2	0.029	1	0	0	0.5	0.2
Fagaceae	*Quercus polymorpha* Schltdl. & Cham.	Native	BV, CV, CSP, CL, EC, EE, MI, RT	252	9.137	8	3.2	2.1	4.2	3.2
Fagaceae	*Quercus robur* L.	Introduced	BV, CV, CSP, CL, EC, MI, RT	143	6.503	7	4	3.2	4.5	3.9
Fagaceae	*Quercus rubra* L.	Introduced	BV, CV, CSP, CL, EC, MI, RT	141	13.129	7	4	6.5	4.5	5
Fagaceae	*Quercus texana* Buckley	Introduced	CV, CL	3	0.432	2	0.1	0.2	1.3	0.5
Fagaceae	*Quercus virginiana* Mill.	Introduced	BV, CV, CSP, CL, EC, EE, HU, MI, RT	1135	68.139	9	32.1	33.9	5.7	23.9
Juglandaceae	*Carya illinoinensis* (Wangenh.) K. Koch	Native	BV, CV, CSP, CL, EC, EE, HU, MI, RT	153	17.75	9	2	4.1	4.7	3.6
Lauraceae	*Persea americana* Mill.	Introduced	BV, CV, EC	5	0.018	3	0.1	0	1.9	0.7
Lythraceae	*Lagerstroemia indica* L.	Introduced	CV, CSP, EC, HU, MI	129	0.823	5	3.6	0.4	3.2	2.4
Magnoliaceae	*Magnolia grandiflora* L.	Introduced	EC	2	0.022	1	0.1	0	0.6	0.2
Malvaceae	*Ceiba pentandra* (L.) Gaertn.	Introduced	CV, CL	5	0.428	2	0.1	0.2	1.3	0.5
Meliaceae	*Cedrela odorata* L.	Introduced	BV, CV, CSP	57	0.342	3	1.6	0.2	1.9	1.2
Meliaceae	*Melia azedarach* L.	Introduced	BV, CV, CL, EC, HU, RT	169	6.462	6	4.8	3.2	3.8	3.9
Moraceae	*Ficus carica* L.	Introduced	CL	1	0.003	1	0	0	0.6	0.2
Moraceae	*Morus nigra* L.	Introduced	BV, CV, CSP, EC, HU, RT	23	1.681	6	0.6	0.8	3.8	1.8
Moraceae	*Neltuma glandulosa* (Torr.) Britton & Rose	Native	BV, HU	5	0.623	2	0.1	0.1	1.1	0.4
Moringaceae	*Moringa oleifera* Lam.	Introduced	CL, EC	3	0.144	2	0.1	0.1	1.3	0.5
Myrtaceae	*Eucalyptus globulus* Labill.	Introduced	BV, CV, EC	15	3.466	3	0.4	1.7	1.9	1.4
Nyctaginaceae	*Bougainvillea glabra* Choisy	Introduced	BV, CL, HU, RT	18	0.087	4	0.5	0	2.5	1
Oleaceae	*Forestiera angustifolia* Torr.	Native	BV, CL, EC, RT	8	0.016	4	0.1	0	2.1	0.7

Oleaceae	*Fraxinus americana* L.	Introduced	BV	74	10.494	1	2.1	5.2	0.6	2.6
Oleaceae	*Fraxinus uhdei* (Wenz.) Lingelsh.	Native	BV, CV, CSP, CL, EC, EE, HU, MI, RT	1672	275.66	9	21.5	63.4	4.7	29.9
Oleaceae	*Ligustrum japonicum* Thunb.	Introduced	BV, CSP, CL, EC	35	2.045	4	1	1	2.5	1.5
Pinaceae	*Abies guatemalensis* Rehder	Native	CSP	12	0.027	1	0.2	0	0.5	0.2
Pinaceae	*Pinus cembroides* Zucc.	Native	HU, MI	2	0.006	2	0	0	1.1	0.4
Pinaceae	*Pinus eldarica* Medw.	Introduced	BV, CV, CSP, CL, EC, EE, HU, MI, RT	220	32.285	9	6.2	16.1	5.7	9.3
Pinaceae	*Pinus greggii* Engelm. ex Parl.	Native	CV, HU	2	0.276	2	0	0.1	1.1	0.4
Pinaceae	*Pinus halepensis* Mill.	Introduced	BV, CV	36	5.61	2	1	2.8	1.3	1.7
Pinaceae	*Pinus ponderosa* P. Lawson & C. Lawson	Native	EC	2	0.052	1	0	0	0.5	0.2
Pinaceae	*Pinus pseudostrobus* Lindl.	Native	BV, CSP, EC, EE, MI, RT	24	0.814	6	0.3	0.2	3.2	1.2
Pinaceae	*Pinus taeda* L.	Introduced	CV	1	0.249	1	0	0.1	0.6	0.3
Pinaceae	*Pinus uncinata* Ramond ex DC.	Introduced	BV	1	0.004	1	0	0	0.6	0.2
Pittosporaceae	*Pittosporum tobira* (Thunb.) W.T. Aiton	Introduced	BV, CV, CSP. EC, HU	138	3.894	5	3.9	1.9	3.2	3
Platanaceae	*Platanus rzedowskii* Nixon & J.M. Poole	Native	BV, CV, CSP, CL, EC, HU, MI, RT	276	5.423	8	3.5	1.2	4.2	3
Rhamnaceae	*Condalia hookeri* M.C. Johnst.	Native	CL, RT	2	0.019	2	0	0	1.1	0.4
Rosaceae	*Eriobotrya japonica* (Thunb.) Lindl.	Introduced	BV, CSP, CL, EC	8	0.257	4	0.2	0.1	2.5	1
Rosaceae	*Prunus persica* (L.) Batsch	Introduced	BV, CL, EC	3	0.2	3	0.1	0.1	1.9	0.7
Rutaceae	*Casimiroa edulis* La Llave	Introduced	BV, MI, RT	15	0.096	3	0.4	0	1.9	0.8
Rutaceae	*Casimiroa greggii* (S. Watson) F. Chiang	Native	EC	6	0.179	1	0.1	0	0.5	0.2
Rutaceae	*Citrus* x *limon* (L.) Osbeck	Introduced	CL, EC	4	0.008	2	0.1	0	1.3	0.5
Rutaceae	*Citrus* x *sinensis* (L.) Osbeck	Introduced	EC	7	0.063	1	0.2	0	0.6	0.3
Rutaceae	*Zanthoxylum fagara* (L.) Sarg.	Native	RT	7	0.147	1	0.1	0	0.5	0.2
Salicaceae	*Populus mexicana* Wesm.	Native	BV, CV, CSP, CL, EC, HU, MI, RT	74	21.33	8	1	4.9	4.2	3.4
Salicaceae	*Salix nigra* Marshall	Native	BV, CV, CL, EC, RT	135	7.005	5	1.7	1.6	2.6	2
Sapindaceae	*Koelreuteria paniculata* Laxm.	Introduced	BV, CL, RT	104	6.286	3	2.9	3.1	1.9	2.7
Sapindaceae	*Sapindus saponaria* L.	Native	BV	1	0.163	1	0	0	0.5	0.2

Sapotaceae	*Sideroxylon lanuginosum* Michx.	Native	BV, CL, EC, HU, RT	24	0.399	5	0.3	0.1	2.6	1
Scrophulariaceae	*Leucophyllum frutescens* (Berlamnd.) I.M. Johnst.	Native	BV, CV, CSP, CL, EC, MI, RT	2578	2.104	7	33.1	0.5	3.7	12.4
Taxodiaceae	*Taxodium mucronatum* Ten.	Native	BV, CV, CSP, EC, RT	48	3.76	5	0.6	0.9	2.6	1.4
Ulmaceae	*Ulmus crassifolia* Nutt	Native	EC, HU, RT	18	0.359	3	0.2	0.1	1.6	0.6
Ulmaceae	*Ulmus minor* Mill.	Introduced	CL, EC, MI, RT	64	1.172	4	1.8	0.6	2.5	1.6

Diversity and proportion of species: native vs introduced

The number of effective species was lower for native species (^1D = 11.41) and ^1D = 13.14 for introduced species. The mean difference between the two groups was 1.68, $CI_{95\%}$: -2.38, -1.01.

The analysis of proportions showed a predominance of native species (69% of individuals, 68% of basal area) over introduced species (31% of individuals, 32% of basal area) ($\chi^2 = 220$, df = 8, $p < 0.001$).

Distribution of height and diameter classes

Rank-abundance analysis per site showed that a few species accounted for a large proportion of the individuals, while most species were present in low abundance. The consistently dominant species in most of the evaluated sites was *F. uhdei* (native) in six of the nine sites and *Q. virginiana* (introduced) was dominant in five of them (Fig. 2).

According to the origin of woody plant species (native vs introduced), *Leucophyllum frutescens*, *F. uhdei*, and *E. anacua* were the most dominant for native species, while *Q. virginiana*, *L. leucocephala*, and *P. eldarica* had the highest dominance within introduced species (Fig. 3a).

In the height classes, we observed that the highest concentration of native species was between 0.8 and 1.7 m, while introduced species was between 5 and 7.5 m (Fig. 3b). Regarding diameter classes, native species showed a marked concentration in the 4.5 cm category, while introduced species presented a slightly inverted “j” distribution (Fig. 3c).

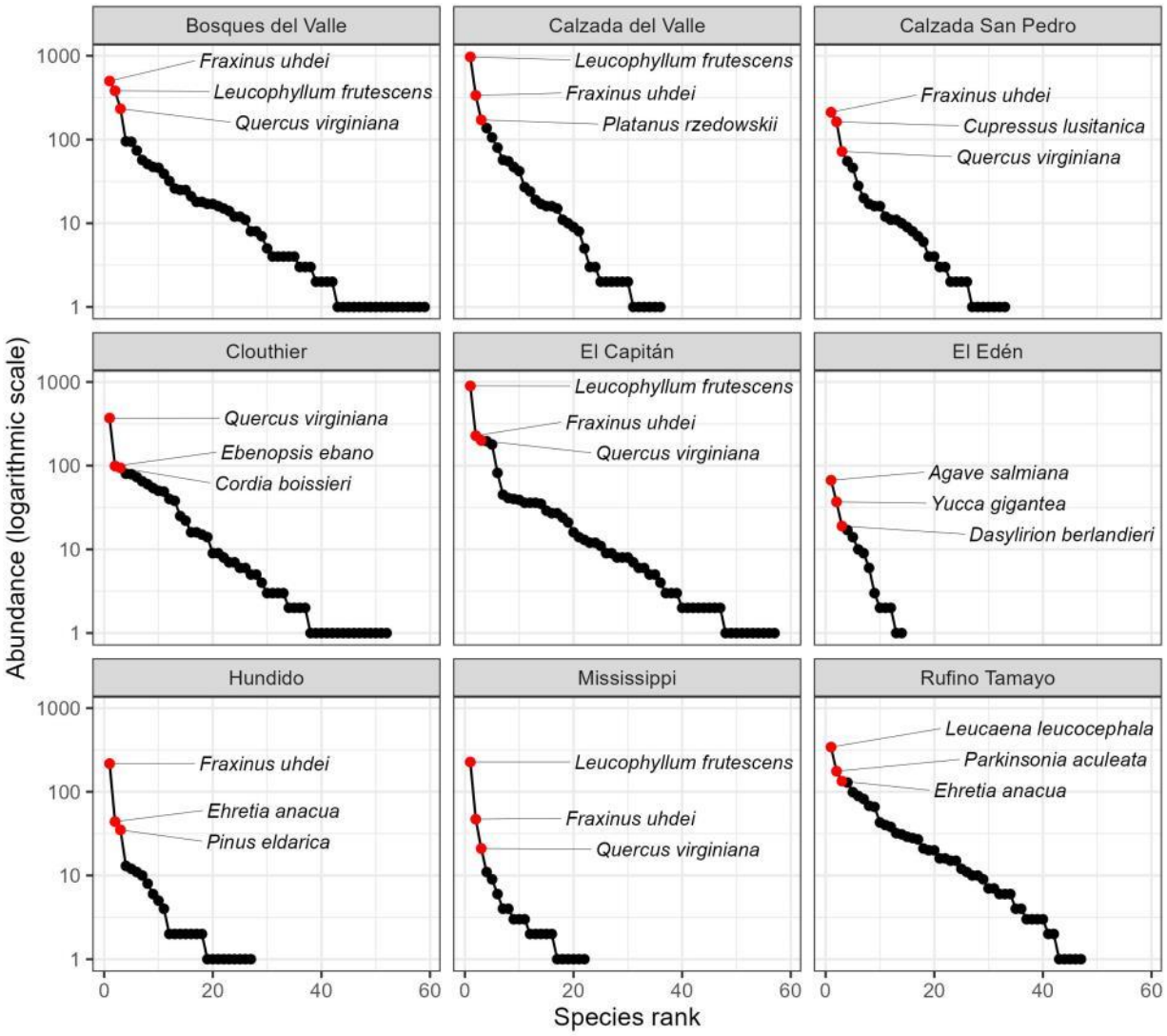


Fig. 2. Range-abundance curves for urban tree species in San Pedro Garza García. The curves include all woody plant species. The three most abundant species are highlighted for each site.

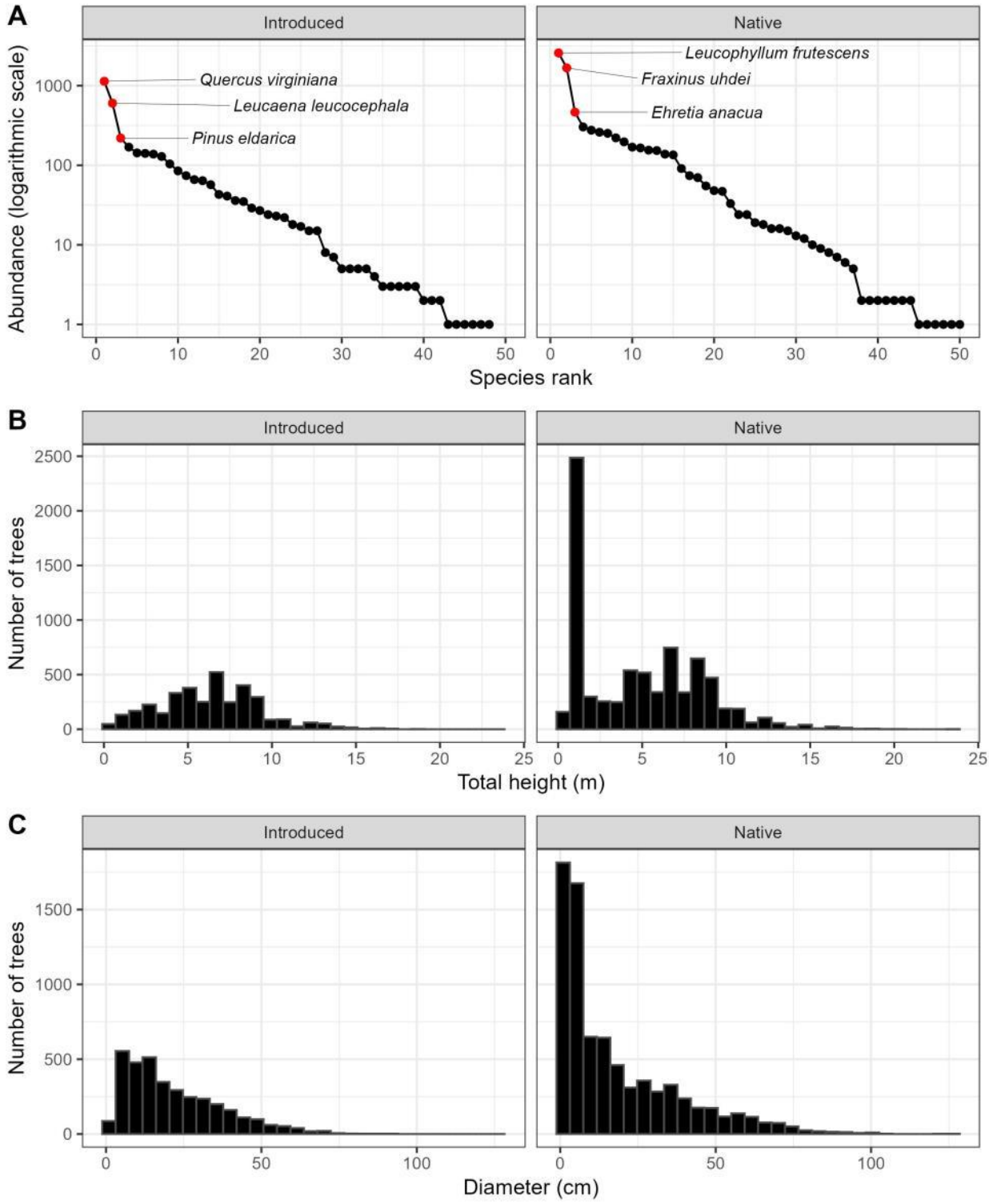


Fig. 3 Comparison of ecological variables between native and introduced species of urban trees in San Pedro Garza García. A) Rank-abundance curves by origin, highlighting the three most abundant species for each group. B) Distribution of total height classes of individuals. C) Distribution of diameter classes of individuals.

Discussion

Ecological importance variables

In our study, we found a slightly higher proportion of native species (50 versus 48), a result consistent with what was observed by Alanís et al. (2014) in the urban trees of the university campus of the Faculty of Forest Sciences at UANL and in the Contry neighborhood in Monterrey (Hernández-Cavazos et al. 2024). However, these findings contrast with other locations in Mexico, where the number of introduced species is usually higher, such as the studies performed in urban environments by Leal-Elizondo et al. (2018), Martínez-Trinidad et al. (2021), Alanís-Rodríguez et al. (2022), and Alanís-Rodríguez et al. (2023a). We also observed a predominance of native individuals (69% versus 31%), a pattern also documented in other locations in northeastern Mexico (Molina-Guerra et al. 2023).

The predominance of native species (68%) over introduced species (32%) in the basal area reflects a recent trend in urban planning, which favors the use of native species over introduced ones (Bernal-Grijalva et al. 2019; Alanís-Rodríguez et al. 2023a; Hardberger et al. 2025; Russo et al. 2025). Similar results have been documented in six rural areas of Hualahuises, Nuevo León (northeast Mexico), where native species represented 91.69% of the basal area (Molina-Guerra et al. 2023). These findings highlight the importance of conserving and promoting native species, not only for their contribution to diversity, but also for their ability to meet the specific requirements for the growth, resilience, and maintenance of urban trees in the face of climate change (Jiménez-Pérez et al. 2025; Russo et al. 2025).

The high relative abundance of native species such as *L. frutescens* and *F. uhdei* reflects their good ornamental potential. In particular, *F. uhdei* is one of the native species with the highest number of individuals in the urban forests of northeastern Mexico (Alanís-Rodríguez et al. 2023a). Among the introduced species, the high abundance of *Q. virginiana* and *L. leucocephala*, Alanís-Rodríguez et al. (2023a) mention that the use of these species is mainly due to their ornamental use and the wide availability in nurseries and greenhouses. The second reason for the presence of these species in these urban parks could be due to their invasive capacity and high dispersal capacity, allowing them to colonize diverse areas, even those areas not planned for this purpose (Richardson and Rejmánek 2011; Simberloff et al. 2013).

The high relative dominance, relative frequency, and importance value index of *Fraxinus uhdei* (native species) and of *Quercus virginiana* (introduced species) coincide with what has been reported in other municipalities in northeastern Mexico, where the genus *Fraxinus* has been identified as the most ecologically relevant and *Q. virginiana* as the second most structurally prevalent species (Leal-Elizondo et al. 2018; Canizales-Velázquez et al. 2020; Alanís-Rodríguez et al. 2022; Hernández-Cavazos et al. 2024). These patterns suggest that the availability of specific species in nurseries and the influence exerted on local authorities regarding the composition of urban green spaces have favored their predominance in several locations in the region (Avolio et al. 2020; Beaury et al. 2021).

Diversity of native vs introduced species

The effective species index was higher for introduced species than for native species. However, the values observed in this study were higher than those recorded in previous studies on urban trees, such as in the city of Montemorelos with $^{1}D = 3.22$ (Canizales-Velázquez et al. 2020), in the Parque Hundido of San Pedro Garza García with $^{1}D = 7.24$ (Alanís-Rodríguez et al. 2023b), and in the Colonia Contry of Monterrey with $^{1}D = 4.71$ (Hernández-Cavazos et al. 2024). However, as noted by Raupp et al. (2006), even in communities with high diversity, the structure of urban trees is usually dominated by a few species, which we also observed in the evaluated sites, where the species *F. uhdei*, *L. frutescens*, and *Q. virginiana* concentrated the majority of the individuals.

Proportion of native vs introduced species

Our results regarding proportions of native vs introduced woody species show a marked contrast in relation to other studies carried out in other urban areas in the country, where a higher predominance of introduced species is observed (Leal-Elizondo et al. 2018; Martínez-Trinidad et al. 2021; Alanís-Rodríguez et al. 2022). In the municipality of San Pedro Garza García, the first efforts to incorporate native species into urban tree planting have been documented since the 1980s, driven by collaboration between academics and municipal authorities, which could explain the differentiated current patterns observed in the composition of the trees in the urban green spaces in San Pedro Garza García (Alanís-Rodríguez et al. 2023a).

In this sense, the municipality of San Pedro Garza García reflects a positive trend toward the integration of native species into urban planning. In this context, the municipality of San Pedro Garza García shows evidence of a process of integrating native species into urban planning, aimed at strengthening the ecological integrity of urban

trees (Almas and Conway 2016). This incorporation not only involves changes in the floristic composition, but it can also help maintain local ecological processes, including biodiversity, habitat provision, and functional support for associated animal communities (Alanís-Flores and González-Alanís 2003; Avolio et al. 2020). Aspects that are particularly relevant in urban contexts subject to increasing environmental pressures, where the composition of the tree population influences the adaptation, resilience, and sustainability of urban green spaces.

Patterns of dominance and distribution of species

In general terms, the range-abundance curves per park showed us a pattern characterized by the dominance of a few species and the presence of many species with low abundance, which coincides with the general ecological principles described by Verberk (2011). This pattern has also been documented in urban environments; for example, Raupp et al. (2006) reported in the urban woodland of 12 cities in eastern North America a marked concentration of individuals in a few genera, particularly *Acer* and *Fraxinus*, evidencing a composition dominated by a small number of taxa. However, when analyzing the parks individually, we observed differences in the uniformity of the communities. In parks such as El Edén and Hundido, the abrupt slope of the rank-abundance curves indicates low species uniformity, while in Bosques del Valle and Rufino Tamayo, a more gradual slope reflects more equitable distribution among species. This variation between sites has been previously reported in urban forestry studies, where uniformity depends on the planting history and the degree of tree diversification (Raupp et al. 2006).

In northeastern Mexico, during the 1980s and 1990s, monospecific plantings were common, particularly in parks and along sidewalks of new housing developments, which favored the structural dominance of a small number of species (Alanís-Rodríguez et al. 2023a). Likewise, *F. uhdei* remained the dominant species in most of the evaluated sites, consistent with reports from other urban forests in northeastern Mexico. In fact, in Mexico City, *F. uhdei* has been designated an urban landmark due to its historical and landscape importance (Meza-Aguilar 2015).

In the range-abundance analysis by provenance, the shrub *L. frutescens* stands out as the best-represented native species, as it has been used as a hedge in the evaluated sites (Jiménez-Pérez et al. 2025), while *Q. virginiana*, among the introduced species, highlights its widespread structural presence in the urban green areas due to the evergreen foliage and dense canopies that provide shade (Alanís-Flores 2005). The curve for introduced species shows a steeper slope, indicating low uniformity, while the curve for native species descends more gradually, reflecting greater uniformity; that is, abundance is more evenly distributed among several species.

Distribution of height and diameter classes

The distribution of height classes reveals structural differences between both groups. In native species, the higher concentration in the 0.8–1.7 m range is mainly explained by the high prevalence of the shrub *L. frutescens*. In contrast, introduced species are mostly concentrated in the intermediate 5–7.5 m range, reflecting an older community. These results are consistent with those reported for the urban trees of Parque Hundido in San Pedro Garza García (Alanís-Rodríguez et al. 2023b) and suggest that, in recent years, urban planning in the municipality of San Pedro Garza García has favored the use of native species over introduced ones.

Regarding diameter classes, the evident concentration of native individuals in the 4.5 cm category indicates to us that a large part of this group corresponds to specimens of the shrub *L. frutescens* and/or trees in early stages of growth. This pattern could favor the future stability of the tree stand if adequate management plans are maintained. It also reflects that reforestation efforts have been carried out in the analyzed sites in recent years (Jiménez-Pérez et al. 2025). On the other hand, the inverted "J" distribution observed in the introduced species reflects populations with a proportion of young individuals and a progressive decrease in the larger diameter categories, a pattern also documented in the tree stand of Hualahuises downtown (Alanís-Rodríguez et al. 2022).

Conclusions

We partially rejected our main hypothesis, since although introduced species showed higher alpha diversity and average height, native species exhibited a higher number of individuals, species richness, as well as larger crown area and average diameter values. Our results demonstrate that both native and introduced species contribute in a complementary way to the structuration of urban green forests. Based on the observed patterns, we recommend promoting the use of native species in urban tree planting programs, due to the benefits they offer in terms of adaptation to local conditions, ecological resilience, and sustainable management. In this regard, we recommend that other municipalities in northeastern Mexico adopt similar practices to those implemented in San Pedro Garza García, where the integration of native species into urban planning has been preferred.

Statements & Declarations

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Competing Interests

The authors have no relevant financial or non-financial interests to disclose.

Authors contributions

All authors contributed to the conception and design of the study. Fieldwork and data collection were carried out by Javier Jiménez-Pérez, Eduardo Alanís-Rodríguez, and Arturo Mora-Olivo. Statistical analyses were performed by Ernesto Rubio-Camacho and Cristian Adrian Martínez-Adriano. The first draft of the manuscript was written by María Cecilia Hernández-Cavazos, and all authors commented on and improved previous versions. All authors reviewed and approved the final version of the manuscript.

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