Revista Mexicana de Ciencias Forestales Vol. 14 (80)
Noviembre - Diciembre (2023)

DOI: 10.29298/rmcf.v14i80.1397

Research article

Caracterización arbórea, evaluación de daños y su impacto en la infraestructura en un campus universitario

Tree characterization, damage assessment and its impact on infrastructure in a university campus

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Fecha de recepción/Reception date: 24 de mayo de 2023.
Fecha de aceptación/Acceptance date: 6 de octubre de 2023.

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Abstract

The description of the structure and the knowledge of the physical and structural damages of urban trees are essential for their maintenance and conservation as well for urban planning and public safety. The objective of this analysis was to characterize the tree structure, the physical damage of the trees and the obstruction of the buildings that influence the green areas of the *Facultad de Ciencias Agrícolas y Forestales de la Universidad Autónoma de Chihuahua* (Graduate School of Agricultural and Forest Sciences of the Autonomous University of *Chihuahua*) in the City of *Delicias*, state of *Chihuahua*. Indexes of richness (D_{Mg}) and diversity of species (H' and D) were determined and the horizontal structure was evaluated through the Importance Value Index (*IVI*). The morphology, the current state of the trees and the physical and structural damage present through direct observation were also analyzed. 48 species were identified, 21 were native and 27 were introduced, exhibiting a richness of 7.05 (D_{Mg}) and a diversity of 3.09 (H'). A density of 209 N ha^{-1} and a dominance of 2 318.67 m^2 ha^{-1} were obtained. According to the *IVI*, the most important species were: *Pinus halepensis*, *Thuja occidentalis*, *Fraxinus uhdei*, *Ligustrum lucidum*, *Sapindus drummondii*, *Platanus occidentalis* and *Morus alba*, representing 48.61 % of the total. 89.25 % of the trees have a desirable morphological structure, 92.92 % have a vigorous crown and most of them are without damage, where the main deterioration sign turned out to be mainly associated with the loss of bark pieces.

Key words: Urban green areas, urban forest, tree damage, horizontal structure, Importance Value Index (*IVI*), tree morphology.

Resumen

La descripción de la estructura y el conocimiento de los daños físicos y estructurales del arbolado urbano son fundamentales para su mantenimiento y conservación, así como para la planificación urbana y la seguridad pública. El objetivo de este análisis fue caracterizar la estructura arbórea, los daños físicos del arbolado y la obstrucción de las edificaciones que influyen en las áreas verdes de la Facultad de Ciencias Agrícolas y Forestales de la Universidad Autónoma de Chihuahua en la Ciudad de Delicias, Chihuahua. Se determinaron índices de riqueza (D_{Mg}) y diversidad de especies (H' y D) y se evaluó la estructura horizontal mediante el Índice de Valor de Importancia (*IVI*). También se analizó la estructura morfológica, el estado actual del arbolado y los daños físicos y estructurales presentes mediante observación directa. Se identificaron 48 especies, 21 nativas y 27 introducidas, con una riqueza de 7.05 (D_{Mg}) y una diversidad de 3.09 (H'). Se registró una densidad de 209 N ha^{-1} y una dominancia de 2 318.67 m^2 ha^{-1}. De acuerdo con el *IVI*, las especies más importantes fueron: *Pinus halepensis*, *Thuja occidentalis*, *Fraxinus uhdei*, *Ligustrum lucidum*, *Sapindus drummondii*, *Platanus occidentalis* y *Morus alba* que representaron 48.61 % del total. Una alta proporción de los árboles (89.25 %) tiene una estructura morfológica aérea deseable, y 92.92 % portan una copa vigorosa que prácticamente no tiene daños. El principal signo de deterioro está asociado a la pérdida de fragmentos de corteza.

Palabras clave: Áreas verdes urbanas, bosque urbano, daños del árbol, estructura horizontal, Índice de Valor de Importancia (*IVI*), morfología del arbolado.

Introduction

Trees in urban areas provide valuable ecological, economic and social benefits, and contribute to creating a more livable and comfortable city for its residents (Dwyer *et al.*, 2000; Allison *et al.*, 2020). Species diversity in urban forests can offer protection against pest and diseases attacks, climate change and provision of ecosystem services (Dallimer *et al.*, 2012; Nowak, 2012; Kendal *et al.*, 2014). Paradoxically, urban trees can cause different damages according to their location, growth phase and maintenance intensity (Lyytimäki, 2017).

In this sense, an urban forest is the sum of all vegetation in a city, including trees, shrubs, grass, and palms (Escobedo *et al.*, 2011). A point of interest in these factors is tree vegetation. According to Alanís *et al.* (2014), in some regions of the world, research has been initiated to understand the diversity and current state of these natural and artificial communities that influence urban areas. Likewise, several studies have been developed to determine the health and aesthetic status and the relationship of buildings with urban tree masses (Chau *et al.*, 2020; Coelho-Duarte *et al.*, 2021; Kim *et al.*, 2021; Mundher *et al.*, 2022). Additionally, few investigations refer to the wooded areas of university centers, aiming to describe ecological factors that represent the structure of the urban forest (Islas-Rodríguez *et al.*, 2012; Alanís *et al.*, 2014) and risk factors associated with trees (Pérez *et al.*, 2018).

For this reason, the objective of this analysis was to characterize the tree structure, the physical damage to the trees and the obstruction of the buildings that influence the green areas of the *Facultad de Ciencias Agrícolas y Forestales de la Universidad Autónoma de Chihuahua* (Graduate School of Agricultural and Forest Sciences of the Autonomous University of *Chihuahua*) in the City of *Delicias*, state of *Chihuahua*.

Materials and Methods

Study area

The study was carried out in the wooded area of the *Facultad de Ciencias Agrícolas y Forestales de la Universidad Autónoma de Chihuahua* (FCAyF-UACH) (Graduate School of Agricultural and Forest Sciences of the Autonomous University of *Chihuahua*) in *Delicias*, *Chihuahua* (Figure 1). The planting of trees, both native and introduced, has gradually occurred since the school's founding in 1967 in car parks, esplanades and gardens, and in 2017 specimens of *Pinus eldarica* Medw. were established during the II National Congress of Students of Forest Sciences and Natural Resources (CONECIFORN).

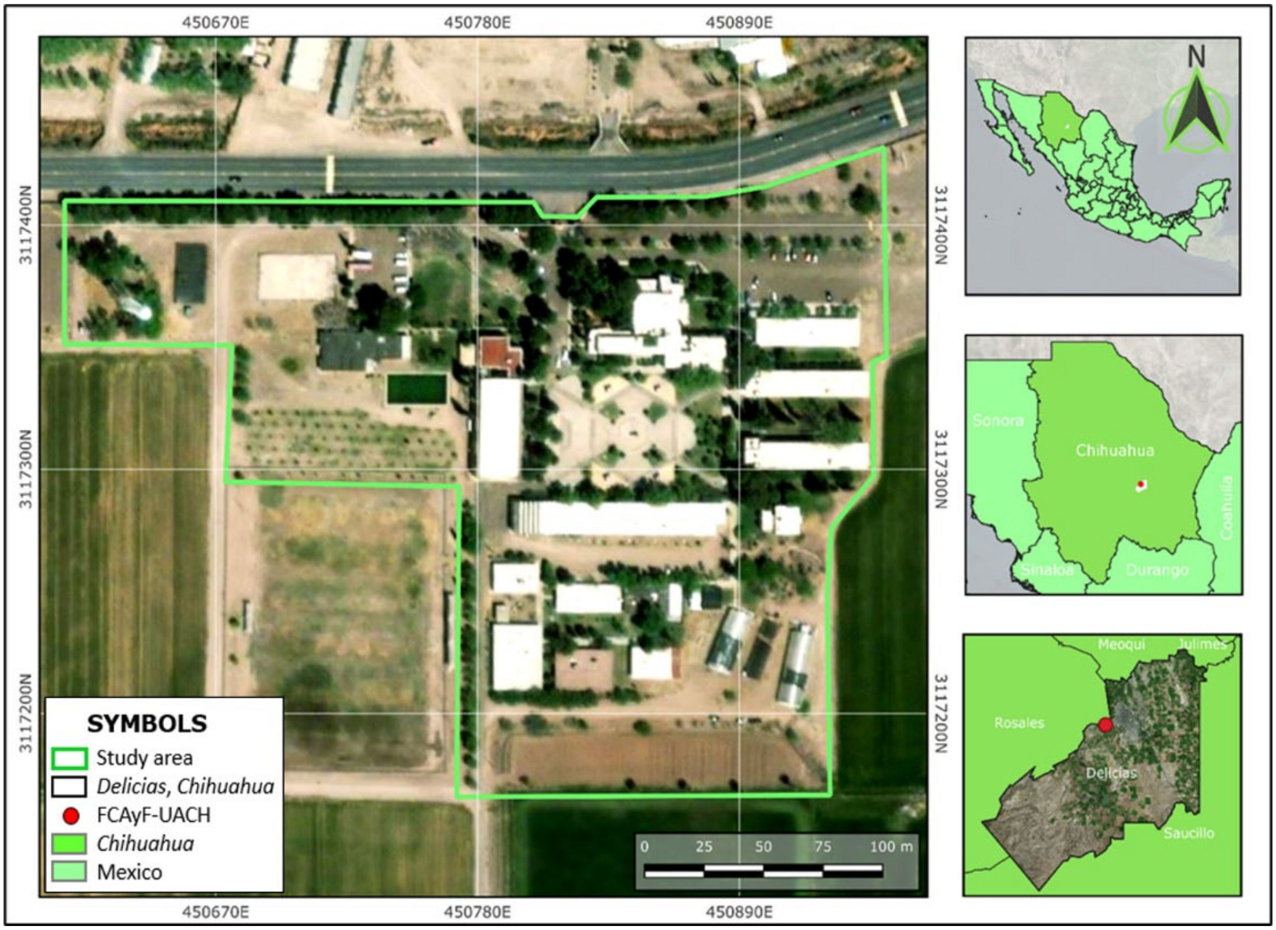


Figure 1. Location of the FCAyF-UACH.

Methods

The Margalef index (D_{Mg}) was used to calculate species richness, and diversity was assessed using the Shannon-Wiener index (H') (Magurran, 2021). Likewise, Shannon's true diversity index (D) was used, which considers the relative abundance of each species in the community and provides a more precise measure of diversity (Table 1).

Table 1. Indexes used to describe the horizontal structure, richness and diversity of the urban trees of the FCAyF-UACH.

Formula	Variables
$D_{MG} = \frac{S-1}{nl(N)}$	D_{MG} = Margalef index S = Number of species N = Total number of individuals
$H' = -\sum_{i=1}^{S} p_i \times nl(p_i)$	H' = Shannon-Wiener index S = Number of species pi = Individuals ratio of the *i* species
$p_i = {}^{n_i}/_{N}$	
$D = exp(H') = exp\left[-(\sum_{i=1}^{s} pi\; nl\; pi)\right]$	D = True diversity index pi = Relative abundance of the i^{eth} species S = Number of species
$IVI = \frac{\sum_{i=1}^{n}(AR_i, DR_i, FR_i)}{3}$	IVI = Importance Value Index ARi = Relative abundance per species with respect to total abundance DR_i = Relative dominance of species *i* with respect to total dominance FR_i = Relative frequency of species *i* with respect to the total frequency

On the other hand, the horizontal structure was evaluated by calculating abundance (N ha^{-1}), dominance (m^2 ha^{-1}) and frequency. Using this information, the Importance Value Index (*IVI*) was determined, which can be expressed in percentage values on a scale from 0 to 100 (Alanís *et al.*, 2020) (Table 1).

The morphological characterization of the trees was carried out by identifying variables in three sections of the tree (base, stem and crown). In determining the composition of the tree base, the categories of normal base, presence of adventitious shoots, exposed roots and pressed roots were considered. The stem of the tree was analyzed in relation to its shape, identified as a straight, inclined, curved or V-shaped bifurcation. Likewise, the type of crown was classified based on the categories hanging, columnar, conical, spherical, irregular, ovoid or palmiform (López, 2009).

In addition, a detailed description of the current state of the trees was made and they were classified as: trees with good vitality, weak or dead, as indicated by Sabrin *et al.* (2021). This way of cataloging the trees made it easier to evaluate the general condition of the trees and their ability to remain healthy and functional.

On the other hand, the characterization of physical and structural damage to the trees was recorded in the three sections of the tree: base, stem and branches. Also, the obstructions present in the crown caused by urban structures were noted. Three categories of physical damage were identified at the base of the tree: no damage, cracked concrete, and lifted concrete according to Schütt *et al.* (2022). At the trunk, the stem without damage, the simple lesion and the complex lesion described by Jim and Zhang (2013) were considered. In relation to the crown, different categories of damage or growth defects were evaluated, including low branching, co-dominant union, multiple stems, crossed branches and missing branches (Saaverdra-Romero *et al.*, 2019a).

Finally, the obstructions in the tree crown were described as unrestricted crowns (free crowns), crowns affected by tree competition, the obstruction of sidewalks or streets, due to electrical wiring or public lighting, and crowns in contact with buildings (Román-Guillén *et al.*, 2019). This form of analysis was developed to clearly and accurately identify the current condition of the trees, which allows defining the types of damage to the trees, the most frequent damages, growth defects and the species at highest risk. With this information, it is possible to make more effective management and maintenance decisions to ensure the health and safety of urban trees and citizens (Saavedra-Romero *et al.*, 2019b).

Results and Discussion

Diversity and richness of species

48 tree species were identified in the FCAyF-UACH, 21 (43.75 %) are native and 27 (56.25 %) are introduced; these species belong to 35 genera and 25 families. Alanis *et al.* (2014) recorded 39 species, of which 27 (69.23 %) were native and 12 (30.77 %) introduced on a university campus in *Linares*, *Nuevo León*. In this same city, the urban trees were evaluated, resulting in a total of 41 species, 14 (34.15 %) native and 27 (65.85 %) introduced (Leal *et al.*, 2018).

On the other hand, Saavedra-Romero *et al.* (2019a) studied the *San Juan de Aragón* Forest in Mexico City. They recorded 12 species, eight (66.67 %) native and four (33.33 %) introduced. Alanís-Rodríguez *et al.* (2022) analyzed the urban trees of *Hualahuises*, *Nuevo León*, and detected 46 species, 25 (55.26 %) native and 21 (44.74 %) introduced. Canizales *et al.* (2020) mention that the urban trees of the

City of *Montemorelos*, *Nuevo León*, have 13 species of which six are native (46.15 %) and seven introduced (53.85 %).

Although the number of species recorded was greater than that described in other urban areas of the country, the percentage of native species is lower in all the urban forests mentioned previously, except for what was stated by Leal *et al.* (2018) for the trees of *Linares*, *Nuevo León*. Based on the origin of trees in cities, Arriaga *et al.* (1994) maintain that it is preferable to use native species, since they give an authentic identity to the population in relation to its original distribution, they adapt to local conditions, protect genetic diversity, provide habitat for local fauna and present less vulnerability to diseases and pests. However, authors such as Sánchez and Artavia (2013) pointed out that the choice of exotic species is also important in urban tree planting, because they have significant characteristics such as resistance to pollution, small size, rapid growth and attractive flowering and foliage, in addition, they suggest that approximately 75.00 to 80.00 % of native species can be combined with exotic species.

The FCAyF-UACH trees exhibit a moderately high richness index (D_{Mg}=7.05). This result is similar to that obtained by Alanís *et al.* (2014), who recorded a value of 7.62 for the urban trees of a university campus in *Linares*, *Nuevo León*. Other areas with urban trees evaluated in northern Mexico have shown a lower richness than that calculated here. For example, Leal *et al.* (2018) in *Linares*, *Nuevo León* (D_{Mg}=5.24) and Canizales *et al.* (2020) in *Montemorelos*, *Nuevo León* (D_{Mg}=1.19). The species diversity was H'=3.09 (D=21.98), which is similar to what was reported (H'=3.05) by Alanís *et al.* (2014), and Ortiz and Luna (2019) (H'=3.15) in urban areas in *Linares*, *Nuevo León* and the City of *Resistencia*, *Chaco*, Argentina. This information indicates that the evaluated campus has moderately high richness and diversity, similar to other green areas in northern Mexico.

Importance Value Index

A total measurement of 808 trees was carried out corresponding to a density of 139 N ha^{-1} and a dominance of 2 318.67 m2 ha^{-1} (Table 2), which corresponds to 4 % of tree cover of the total area evaluated. The frequency of species was the same in all, since the population in said space was censused and not sampling sites were used. *Thuja occidentalis* L. is the species with the highest abundance with 15 N ha^{-1} (10.89 %), followed by *Pinus halepensis* Mill. with 14 (10.27 %). The most dominant species were *Pinus halepensis* and *Fraxinus uhdei* (Wenz.) Lingelsh. with 584.66 m^2 ha^{-1} and 293.00 m^2 ha^{-1}, respectively. According to the *IVI* calculated for the 48 species present, there are seven outstanding species: *Pinus halepensis*, *Thuja occidentalis*, *Fraxinus uhdei*, *Ligustrum lucidum* W. T. Aiton, *Sapindus drummondii* Hook. & Arn., *Platanus occidentalis* L. and *Morus alba* L. These species together represent 48.61 % of the total and the remaining 41 species 51.39 %, however, 21 of these had an *IVI* less than 4.00 % and 20 more obtained less than 1.00 %. Similar to the above, various authors mention species of the genera *Fraxinus* and *Thuja* among the most representative of urban forests in northern Mexico (Leal *et al.*, 2018; Canizales *et al.*, 2020; Alanís-Rodríguez *et al.*, 2022). The recurrent presence of these species suggests that they are well adapted to the specific conditions of the northern region of the country, particularly those of the *Fraxinus* genus, that has native species in the place, which demonstrates their ability to adapt to the environment.

Table 2. Importance Value Index (*IVI*) of urban trees from the FCAyF-UACH.

Species	**Common name**	**Origin**		**Density**		**Dominance**		**Frequency**		***IVI***
			Abs	**(*N* ha)**	**(%)**	**(m^2 ha^{-1})**	**(%)**	**(ha)**	**(%)**	**(%)**
Pinus halepensis Mill.	*Pino turco*	In	83	14	10.27	584.66	25.22	0.17	2.08	12.52
Thuja occidentalis L.	*Tuya occidental*	In	67	15	10.89	272.12	11.74	0.17	2.08	8.24
Fraxinus uhdei (Wenz.) Lingelsh.	*Fresno*	Na	88	12	8.29	293.00	12.64	0.17	2.08	7.67
Ligustrum lucidum W. T. Aiton	*Trueno chino*	In	64	13	9.41	117.60	5.07	0.17	2.08	5.52
Sapindus drummondii Hook. & Arn.	*Jaboncillo*	Na	54	11	7.92	132.94	5.73	0.17	2.08	5.25
Platanus occidentalis L.	*Sicómoro americano*	Na	76	5	3.59	209.50	9.04	0.17	2.08	4.90
Morus alba L.	*Morera asiática*	In	42	9	6.68	110.46	4.76	0.17	2.08	4.51
Vachellia farnesiana (L.) Wight & Arn.	*Huizache*	Na	29	7	5.20	103.35	4.46	0.17	2.08	3.91
Pinus eldarica Medw.	*Pino de Chipre*	In	15	9	6.68	41.38	1.78	0.17	2.08	3.52
Melia azedarach L.	*Árbol del paraíso*	In	54	7	4.95	48.82	2.11	0.17	2.08	3.05
Prosopis glandulosa Torr.	*Mezquite dulce*	Na	23	3	2.35	24.31	1.05	0.17	2.08	1.83
Cupressus sempervirens L.	*Ciprés mediterráneo*	In	40	4	2.85	11.80	0.51	0.17	2.08	1.81
Morus nigra L.	*Morera negra asiática*	In	7	1	0.62	62.83	2.71	0.17	2.08	1.80
Washingtonia filifera (Gloner *ex* Kerch., Burv., Pynaert, Rodigas & Hull) de Bary	*Palma abanico*	Na	10	3	1.86	32.59	1.41	0.17	2.08	1.78
Populus deltoides W. Bartram *ex* Marshall	*Chopo americano*	Na	19	1	0.87	51.19	2.21	0.17	2.08	1.72
Parkinsonia aculeata L.	*Retama*	Na	16	3	1.98	20.33	0.88	0.17	2.08	1.65
Cupressus arizonica Greene	*Cedro blanco*	Na	10	2	1.24	25.90	1.12	0.17	2.08	1.48
Eucalyptus globulus Labill.	*Eucalipto azul*	In	5	2	1.24	13.46	0.58	0.17	2.08	1.30
Jacaranda mimosifolia D. Don	*Jacaranda*	In	8	2	1.49	6.43	0.28	0.17	2.08	1.28
Acer pseudoplatanus L.	*Arce sicómoro*	In	9	1	0.99	15.34	0.66	0.17	2.08	1.24

Salix alba L.	*Sauce blanco*	In	12	2	1.11	11.10	0.48	0.17	2.08	1.23
Vachellia constricta (Benth.) Seigler & Ebinger	*Chaparro prieto*	Na	8	1	0.99	8.67	0.37	0.17	2.08	1.15
Carya illinoinensis (Wangenh.) K. Koch	*Pecán*	Na	8	1	0.74	13.68	0.59	0.17	2.08	1.14
Pinus pinceana Gordon & Glend.	*Piñonero llorón*	Na	6	1	0.62	15.47	0.67	0.17	2.08	1.12
Lagerstroemia indica L.	*Árbol de Júpiter*	In	5	1	0.99	5.60	0.24	0.17	2.08	1.10
Pinus montezumae Lamb.	*Pino chamaite*	Na	4	1	0.50	13.28	0.57	0.17	2.08	1.05
Taxodium mucronatum Ten.	*Ahuehuete*	Na	3	0	0.25	18.42	0.79	0.17	2.08	1.04
Quercus rubra L.	*Roble rojo americano*	In	4	1	0.50	11.29	0.49	0.17	2.08	1.02
Prunus armeniaca L.	*Chabacano*	In	4	1	0.50	8.97	0.39	0.17	2.08	0.99
Celtis pallida Torr.	*Granjeno*	Na	2	1	0.37	3.66	0.16	0.17	2.08	0.87
Casuarina equisetifolia L.	*Casuarina*	In	2	0	0.25	5.55	0.24	0.17	2.08	0.86
Punica granatum L.	*Granada cordelina*	In	3	1	0.37	2.30	0.10	0.17	2.08	0.85
Thuja orientalis L.	*Tuya asiática*	In	2	1	0.37	2.00	0.09	0.17	2.08	0.85
Morus alba L. var. *pendula* Dippel	*Péndula*	In	3	0	0.25	4.33	0.19	0.17	2.08	0.84
Yucca elata (Engelm.) Engelm.	*Cortadillo*	Na	3	1	0.37	0.58	0.02	0.17	2.08	0.83
Salix babylonica L.	*Sauce llorón*	In	2	0	0.25	2.71	0.12	0.17	2.08	0.82
Chilopsis linearis (Cav.) Sweet	*Mimbre*	Na	2	0	0.25	2.44	0.11	0.17	2.08	0.81
Juglans major (Torr.) A. Heller	*Nogal cimarrón*	Na	2	0	0.25	2.07	0.09	0.17	2.08	0.81
Citrus × sinensis (L.) Osbeck	*Naranjo dulce*	In	2	0	0.25	1.76	0.08	0.17	2.08	0.80
Yucca carnerosana (Trel.) McKelvey	*Palma samadoca*	Na	2	0	0.25	0.55	0.02	0.17	2.08	0.78
Yucca gloriosa L.	*Yuca brillante*	Na	2	0	0.25	0.53	0.02	0.17	2.08	0.78
Rosa chinensis Jacq.	*Rosa de castilla*	In	2	0	0.25	0.27	0.01	0.17	2.08	0.78
Pyracantha coccinea M. Roem.	*Piracanto eurasiático*	In	1	0	0.12	2.17	0.09	0.17	2.08	0.77
Ziziphus jujuba Mill.	*Jujube*	In	1	0	0.12	1.66	0.07	0.17	2.08	0.76

Schinus molle L.	*Pirul*	In	1	0	0.12	1.22	0.05	0.17	2.08	0.75
Yucca rostrata Engelm. *ex* Trel.	*Amole del Noreste*	Na	1	0	0.12	0.14	0.01	0.17	2.08	0.74
Prunus persica (L.) Batsch	*Durazno*	In	1	0	0.12	0.14	0.01	0.17	2.08	0.74
Couma macrocarpa Barb. Rodr.	*Juansoco*	In	1	0	0.12	0.14	0.01	0.17	2.08	0.74
Total			808	139	100.00	2 318.67	100.00	12.73	100.00	100.00

Abs = Absolute; In = Introduced; Na = Native.

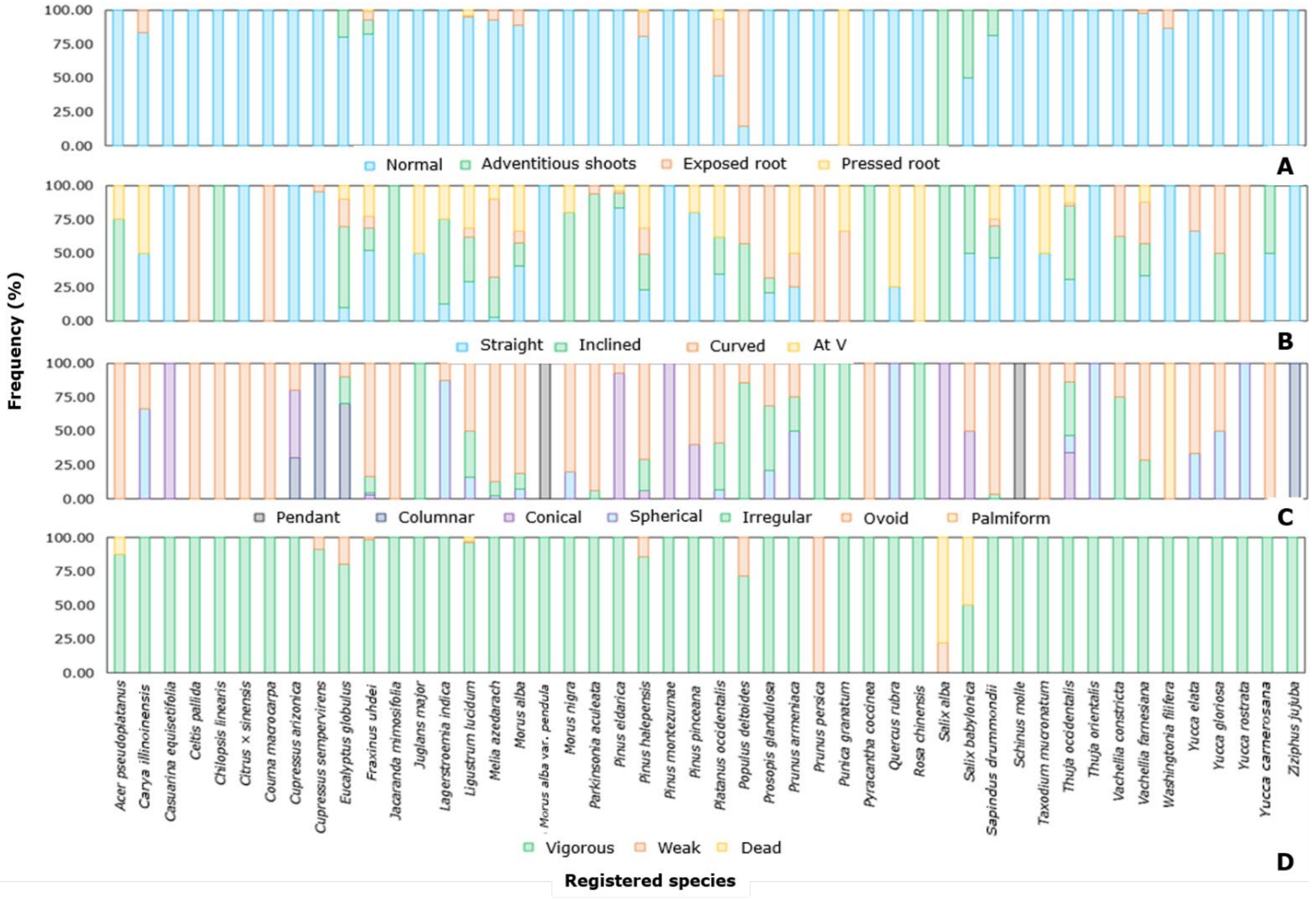
Vegetation morphology

The base of the recorded individuals was recognized as being in a normal condition (89.25 %), which is mainly related to soils covered with grass or native vegetation; exposed roots accounted for 4.24 % of the total trees considered in the study, a result that is associated with compacted soils. Martins *et al.* (2018) carried out a study in Brazil in which they related the presence of healthy roots to soils covered with grass, with an infiltration of up to 98.00 % humidity; in regard to bare soils, the authors indicate an approximate infiltration of 35.00 %, compaction that causes exposed roots and low vigor in the individuals.

The shape of the tree stem was practically straight (38.79 %), followed by the inclined stem shape (27.38 %), which can be explained by the low density at the FCAyF-UACH (139 *N* ha^{-1}); the inclined stem configuration is associated to trees that compete for light or that were planted near buildings. Moser-Reischl *et al.* (2021) mention that the dimension and shape of the stems responds to the surface and underground space available for the development of trees in cities in southern Germany.

The ovoid crown was the most representative in the sampled trees (43.62 %), but the least abundant crown shape turned out to be palm-shaped (2.08 %) due to a low frequency of palms within the campus. Species with an ovoid crown are usually the most common in urban areas, because the spaces where these types of trees grow tend to be open; which is preferred given the need to provide ample shadows that regulate the radiation and temperature of the spaces. In this sense, Zaki *et al.* (2020) mention that on a university campus in Malaysia it is highlighted that tree cover plays an important role in providing the cooling effect, which reduces the soil surface temperature.

Figure 2 shows that 92.92 % of the trees in the FCAyF-UACH -under a visual evaluation- show high vitality, which suggests that these specimens have a good capacity to assimilate nutrients, resist drought and strength to withstand the attack of pests and diseases. Likewise, with this analysis it was identified that there is high adaptability and resilience on the part of the introduced species.



A = Condition of the base of the tree; B = Condition of the tree stem; C = Crown formation; D = Foliage vigor.

Figure 2. Characterization of the morphology and foliage vigor of the species registered in the FCAyF-UACH.

On the other hand, the species with low vitality values are *Prunus persica* (L.) Batsch, *Salix alba* L. and *Salix babylonica* L., since these species have not successfully adapted to the semi-desert conditions of the region. The first one it is related to temperate climates and the following are species typical of flows or terrain with high humidity levels.

In general, the registered tree species have appropriate characteristics to provide ecosystem services, such as temperature regulation and urban air purification. In this sense, Martins *et al.* (2018) and Sabrin *et al.* (2021) indicate that a tree with good vitality is a specimen with a greater probability of remaining in the urban environment for a longer period, and will be able to generate environmental benefits and temperature regulation in urban centers for a longer period of time. Kokkonen *et al.* (2021) and Rodríguez-Santamaría *et al.* (2022) highlight that the inclusion of trees in any type of urban planning or modeling related to air quality is crucial, because trees with broad canopies planted in open areas improve air quality and reduce the mobilization of soil particles.

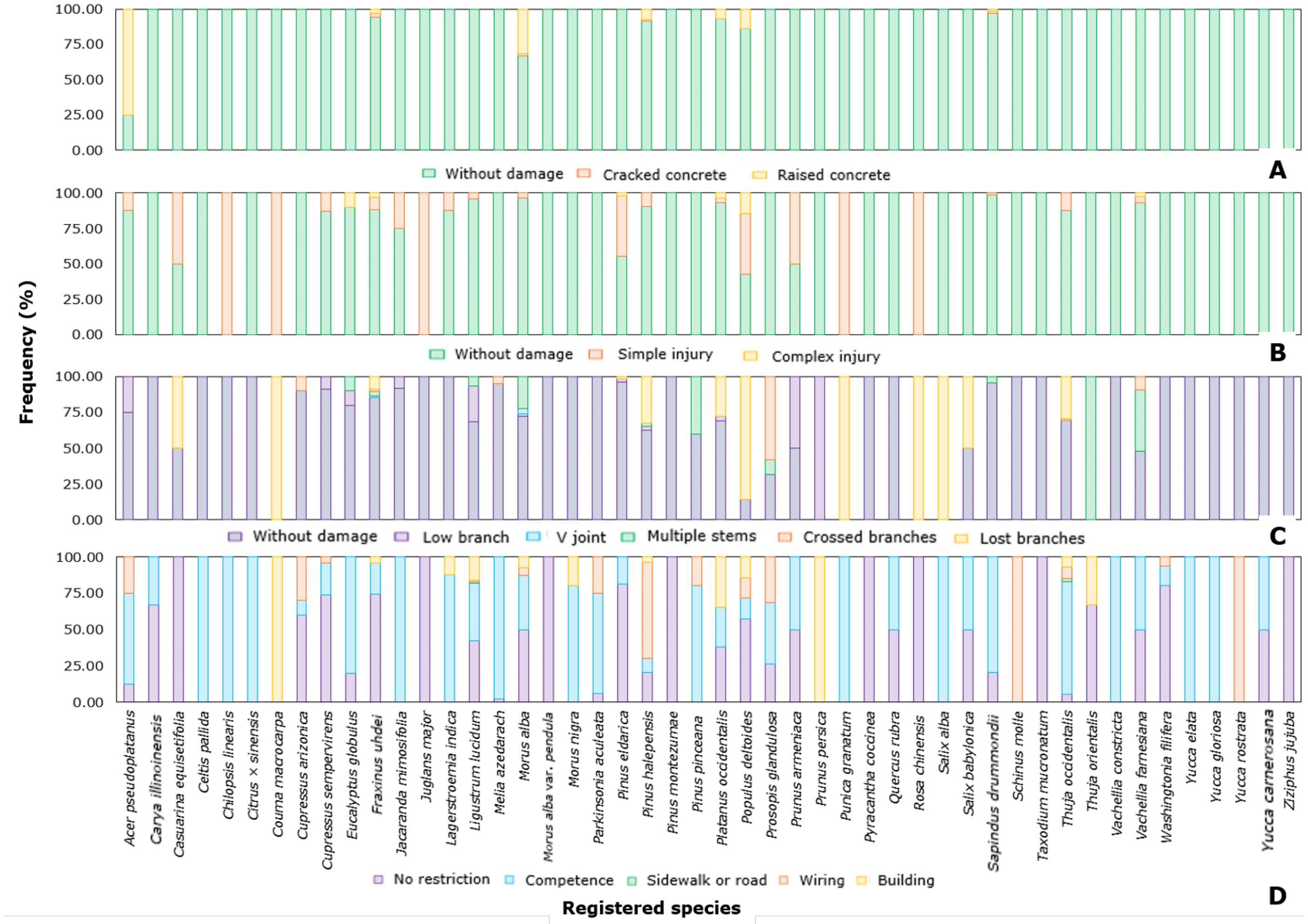
Physical and structural damage

According to the analysis carried out on the root-structure relationship, the majority of the FCAyF-UACH trees do not present damage (96.94 %), however, raised concrete was verified in 2.91 % of cases. Jim and Zhang (2013) conducted a study in Hong Kong and defined that for soil-root relationships, the common problems were lifted paving and cracked paving. These root damages are mainly related to the proximity of the planted trees to the buildings. In this same sense, Jim (2023) attributes some defects of the tree base to narrow and sealed sites, because they limit tree growth and cause multiple physical restrictions. In contrast, Östberg *et al.* (2012) and Schütt *et al.* (2022) indicate that this type of impact is associated with planted species and the limited availability of water by some species.

The FCAyF-UACH trees have a healthy or undamaged stem for the most part (82.67 %), which can be explained by the regulated management aimed at the existing individuals on the campus. The main damage turned out to be the loss of bark, wood rot and mechanical shock, which refers to significant disturbances that require monitoring.

The results are similar to those of Velasco *et al.* (2013), who identified that the physical condition of the stem is good in 46.08 % of the individuals and the health status is healthy in 80.95 % of the cases registered in Mexico City. In *Sancti Spíritus* City in Cuba, Delgado *et al.* (2021) referred that the tree mass studied exhibits good conditions, since 85.28 % of the specimens have no visible damage to their external constitution; damage to the trunks was the most frequent (8.67 %). For their part, Zevgolis *et al.* (2022) recommend that trees that develop severe structural defects in the trunk should be frequently inspected and evaluated for removal for reasons of human safety and risk of damage to property and infrastructure.

Figure 3 shows that on the university campus evaluated in the City of *Delicias*, most of the trees have a healthy and undamaged crown (73.85 %), however, the most common physical damage was the loss of branches (14.30 %), a symptom that is mainly due to strong gusts of wind and the partial elimination of healthy branches that obstruct buildings, electrification service lines and existing trails in the area. The canopy quality data turn out to be greater than those described by Velasco *et al.* (2013) who determined 19.00 % of the analyzed trees had a crown in good physical condition, while up to 20.31 %, required total elimination.



A = Damage to the base of the tree; B = Damage to the tree trunk; C = Damage and growth disorder in branches; D = Restriction of the tree crown.

Figure 3. Characterization of physical and structural damage of the species registered in the FCAyF-UACH.

On the other hand, Román-Guillén *et al.* (2019) confirmed that the trees sampled in the state of *Chiapas* had a bad structure (31.00 %), followed by regular (28.00 %), terrible (26.00 %) and good (15.00 %), which suggests that most of them have forks, dead branches and other defects.

Additionally, FCAyF-UACH tree growth disorders are a response to poor pruning and management practices (crossed branches and multiple stems). In this same sense, Muñoz *et al.* (2022) mentions that applying incorrect pruning to urban trees is a factor that can cause harm and reduce their vitality, since it favors the appearance of epicormic shoots and potential damage from decomposition or other disorders.

Individuals from the FCAyF-UACH without crown restrictions account for 38.64 % of the total stock, which means that the majority have some type of restriction in said structure. Competition was calculated in 44.82 % of cases, followed by the presence of electrification and communications cables (9.12 %) and building restriction (7.35 %). In this sense, competition between individuals is related to the selection of species with multiple stem development (mainly trees of the *Vachellia* and *Celtis* genera). Likewise, the restriction related to infrastructure is due to the poor choice of planting sites and the development of electrification infrastructure without adequate planning or total elimination of individuals.

Román-Guillén *et al.* (2019) concluded that in the capital city of the state of *Chiapas*, 24.00 % of individuals interfere with electrical wiring. For their part, Jim and Zhang (2013) estimated that 7.95 % of the individuals recorded in a study in Hong Kong have development problems in the canopy, which is associated, essencially, with buildings that caused growth unbalanced or a partial removal of the cup.

Conclusions

The FCAyF-UACH trees have a moderately high species richness and diversity, similar to other areas with urban trees in northern Mexico, with 48 identified species, 21 native and 27 introduced. The most representative species are *Pinus halepensis*, *Thuja occidentalis*, *Fraxinus uhdei*, *Ligustrum lucidum*, *Sapindus drummondii*, *Platanus occidentalis* and *Morus alba*, which influences the structure, function and ecosystem services. The morphological structure of the trees is aesthetic and is related to the typical formation in natural conditions with a high percentage of strong tree bases, straight trunks and oval crowns. The appearance of the foliage of most of the trees is of good vitality, which can be explained by the fact that they are native species and the adaptation of the introduced ones to the climatic conditions of the area. In terms of physical and structural damage, most tree bases do not show significant damage. Among the damages to the infrastructure, cracked and lifted concrete is observed in a small percentage. Some trees have injuries to the trunk and loss of branches in the crown, which may well be due to strong winds. Growth disorders and crown restriction due to competition are frequent problems, which are associated with poorly executed pruning and lack of planning in the plantation.

Acknowledgements

A sincere recognition to the esteemed professors-researchers and students of the *Universidad Autónoma de Chihuahua-Facultad de Ciencias Agrícolas y Forestales* (Graduate School of Agricultural and Forest Sciences of the Autonomous University of *Chihuahua*) for their generous support in data collection and impeccable logistical management during the development of this research.

Conflict of interests

The authors declare no conflict of interest. Dr. Eduardo Alanís Rodríguez, Section Editor of the Revista Mexicana de Ciencias Forestales, declares that he has not participated in the editorial process of this article.

Contribution by author

Samuel Alberto García García, Joel Rascón Solano and Ana Karen Vargas Flores: study idea, data recording, interpretation of results and writing of the manuscript; Eduardo Alanís Rodríguez and Oscar Alberto Aguirre Calderón: review and analysis of data and writing of the Discussion of Results; Víctor Manuel Molina Guerra and Rufino Sandoval García: drafting Conclusions and general review of the manuscript.

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