DOI: 10.29298/rmcf.v15i83.1457

Research article

Estructura y diversidad florística en áreas verdes urbanas de la ciudad de Tapachula, Chiapas, México

Structure and floristic diversity of urban green areas in *Tapachula* city, *Chiapas*, Mexico

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Fecha de recepción/Reception date: 8 de diciembre de 2023.
Fecha de aceptación/Acceptance date: 28 de febrero de 2024.

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Abstract

Urban vegetation is a vital part of urban infrastructure due to the environmental services it provides and the benefits to the population; therefore, it is important to know its diversity and structure. The objective of this work was to assess the structure and floristic composition of trees, palms and shrubs located in public urban areas of the city of *Tapachula*, state of *Chiapas*. Mensuration information was collected from eight public parks; five public green areas, four medians and 38 streets, with a total area of 27.32 ha. Normal diameter (1.30 m base from the ground) and total height were recorded. The density of species per urban green area was calculated. Diversity was evaluated using the Shannon-Weiner and Margalef indexes. Taxonomically, 130 species, 109 genera and 44 families were identified. Of the 130 specific taxa recorded, 65 belong to native species and 65 exotic. The total number of individuals was 1 927 exotic and 550 native. *Ficus microcarpa* is the predominant exotic with 6.14 Importance Value Index (*IVI*). Of the native species, *Roseodendron donnell-smithii* stands out as the most representative (*IVI*=1.45). The Shannon-Weiner Index calculated for different green areas registered $2.7 \leq H' \leq 3.3$ and the Margalef Index $5.2 \leq D_{Mg} \leq 15.2$, showing that the streets have a great species diversity.

Key words: Urban trees, urban forestry, exotic species, native species, diversity index, landscaping.

Resumen

La vegetación es una parte vital de la infraestructura urbana por los servicios ambientales y los beneficios que provee a la población, por lo que es importante conocer su diversidad y estructura. El objetivo del presente trabajo fue evaluar la estructura y composición florística de árboles, palmas y arbustos ubicados en áreas urbanas públicas de la ciudad de Tapachula, en el estado de Chiapas. Se recabó información dasométrica de ocho parques públicos, cinco áreas verdes públicas, cuatro camellones o jardineras y 38 calles, con una superficie total de 27.32 ha. Se registró el diámetro normal (1.30 m de la base del suelo) y la altura total. Se calculó la densidad de especies por área verde. La diversidad fue evaluada mediante los índices de *Shannon-Weiner* y de *Margalef*. Taxonómicamente, se identificaron 130 especies, 109 géneros y 44 familias. De los taxa registrados, 65 pertenecen a especies nativas (550 individuos) y 65 a exóticas (1 927 individuos). *Ficus microcarpa* es el taxón exótico preponderante con un Índice de Valor de Importancia (*IVI*) de 6.14. De las especies nativas, *Roseodendron donnell-smithii* destaca como el elemento más representativo (*IVI*=1.45). El Índice de *Shannon-Weiner* calculado para diferentes áreas verdes registró $2.7 \leq H' \leq 3.3$ y el Índice de *Margalef* $5.2 \leq D_{Mg} \leq 15.2$, lo cual evidencia que las calles poseen una gran diversidad de especies.

Palabras clave: Arbolado urbano, dasonomía urbana, especies exóticas, especies nativas, índice de diversidad, paisajismo.

Introduction

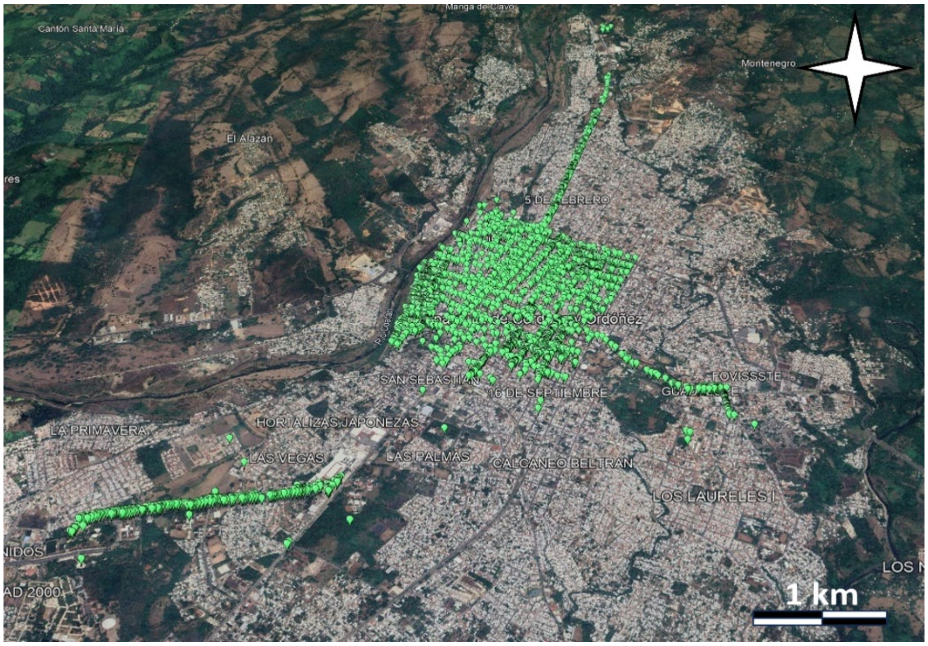
Rapid and uncontrolled urbanization causes the loss of biodiversity, soil degradation, high levels of fragmentation of green spaces and low connectivity between the city and the natural environment (Velasco *et al.*, 2014). In this sense, the importance of studying urban trees to have concrete data on what is happening at the present and provide solutions that can mitigate environmental problems at a local scale is indisputable (Martínez-Trinidad *et al.*, 2021). Green areas for public use can conserve and preserve biological variability within the city, being reservoirs of fauna and flora species from each region (Mexia *et al.*, 2018). The trees intercept and store rainwater to recharge the soil aquifers, absorb polluting particles and the canopy functions as a barrier against noise, and at the same time offers shelter for birds, squirrels, bats, insects, among other animals (Guillen-Cruz *et al.*, 2021).

Knowing the diversity and floristic structure contributes to properly managing trees in urban green areas to maximize environmental services (Morales-Gallegos *et al.*, 2023). Inside a city, the tree composition becomes an integral part of it; it positively interacts with the atmosphere and soil, and adapts to the difficult conditions dictated by the urban environment (Liu *et al.*, 2022). Based on the above, the objective of the present study was to evaluate the structure, composition of trees and shrubs, as well as compare the richness and diversity of species between avenues, streets, squares, parks and public medians of the city of *Tapachula*, state of *Chiapas*, in order to have a representative estimate of the tree heritage and set a guideline for better future planning.

Materials and Methods

Study area

The city is located within the *Soconusco* region, *Chiapas*, and is located between 14°53'28.34" N and 92°16'15.74" W (Martínez-Camilo *et al.*, 2019). Two types of climate prevail: Am (warm humid with intense rains in summer) with an annual precipitation greater than 2 500 mm and annual average temperature of 26 °C, and Aw_2 (warm subhumid with rains in summer) with a higher average annual temperature of 22 °C and an annual average precipitation of 500 to 2 500 mm (Murcia and Macías, 2009). The *Tapachula* municipality covers about 51.74 km^2 with an average elevation of 170 masl. Geomorphologically, the city is located between the low mountain range with steep slopes and the coastal plain with hills, which rest on Mesozoic metamorphic rocks (García-Palomo *et al.*, 2006). The sampling areas were located throughout the central part of the city with the aim of recording the oldest specimens (Figure 1). It was also decided to evaluate the south-west axis that coincides with the road to the airport and the exit to the east of the city, until reaching the *Bonanza* roundabout, which coincides with the end of the city before the highway to *Guatemala*. Field data were collected during 2018-2020.



Source: Prepared by the authors based on an image from https://www.google.com/intl/es-419/earth/.

Figure 1. Location of the sampling points inside the city of *Tapachula*, *Chiapas*, Mexico.

55 green areas were selected, all with free access to the public, and the typology of urban green spaces was described as: 38 streets, eight public parks, four planters or medians and five public green areas. In addition, the surface area of the types of urban green areas was determined and a database was generated in Microsoft Excel® in which the infrastructure of the urban typology was included (Alanís-Rodríguez *et al.,* 2022, Morales-Gallegos *et al.*, 2023).

Floristic inventory

A tree, palms and shrubs census established in the types of urban green areas was carried out. Individuals of interest were georeferenced using a GPS/GNSS navigator for Android® (Dangullaa *et al.*, 2020). All census individuals were measured in terms of total height (*h*) with a PM-5 Suunto® hypsometer, normal diameter at 1.30 m ($d_{1.30\ m}$) from the ground with a model TP30ME Truper® crosshead 30 m fiberglass measuring tape (Cruz-Salazar *et al.*, 2020; Holguín-Estrada *et al.*, 2021).

The species were identified by common and scientific name, using botanical keys (Macías *et al.*, 2015) and to verify the correct and updated nomenclature, the Tropicos® platform was used (Tropicos, 2023). The taxa that could not be identified in the field were collected for determination in the ECO-TA-H herbarium of *El Colegio de la Frontera Sur* (*Ecosur*). Their origin was determined (native or exotic) and the total number of trees, palms and shrubs per urban green area was counted (Alanís-Rodríguez *et al*., 2022, Morales-Gallegos *et al.*, 2023).

Structure and diversity

The abundance for each individual of each species was calculated, based on the number of individuals, its dominance according to its basimetric area and its frequency based on its presence in the sampling sites. The relative values of the structural attributes were combined into the Importance Value Index (*IVI*) (Holguín-

Estrada *et al.*, 2021). Richness and alpha diversity were estimated with the Shannon-Wiener entropy index, which is based on the proportional distribution of the abundance of each species, and the Margalef richness index, which considers the quantification of the number of species present and the Shannon true diversity index (^{1}D) (Moreno *et al.*, 2011); in addition, a Foreign index (*Sa*) was used that indicates the percentage of species not native to the geographical area based on the native species and species native to the region (Morales-Gallegos *et al.*, 2023) (Table 1).

Table 1. Formulas used to calculate the richness, diversity, foreign species and Importance Value Index in the types of urban green areas within the city of *Tapachula*, *Chiapas*, Mexico.

Formulas	Where
Basimetric area	
$Ab = \left(\frac{\pi}{4}\right) \times d^2$	Ab = Basimetric area (m²) π = 3.1416 d = Diameter
Absolute and relative abundance	
$A_i = \frac{N_i}{S}$	A_i = Absolute abundance N_i = Number of invididuals of the *i* species S = Sampled area (ha)
$AR_i = \left[\frac{A_i}{\sum_{i=1}^{n} A_i}\right] \times 100$	AR_i = Relative abundance per species
Absolute and relative dominance	
$D_i = \frac{G_i}{S}$	D_i = Absolute dominance G_i = Basimetric area of the *i* species S = Sampled area (ha)
$DR_i = \left[\frac{D_i}{\sum_{i=1}^{n} D_i}\right] \times 100$	DR_i = Relative dominance of the *i* species with regard to total dominance
Absolute and relative frequency	

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

F_i = Absolute frequency

P_i = Number of sites in which the *i* species is present

NS = Total number of sampling sites

FR_i = Relative frequency of the *i* species with regard to total frequency

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

Importance Value Index

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

IVI = Importance Value Index

AR_i = Relative abundance of the *i* species with regard to total

DR_i = Relative dominance of the *i* species with regard to total

FR_i = Relative frequency of the *i* species with regard to total

Margalef richness index (D_{Mg})

$$D_{Mg} = \frac{S-1}{ln(N)}$$

D_{Mg} = Margalef's index

S = Species number

N = Total number of invididuals

ln = Natural logarithm

Shannon–Weiner entropy index (H')

$$H' = -\sum_{i-1}^{S} pi \times ln(pi)$$

$$pi = \frac{ni}{N}$$

H' = Shannon-Weiner entropy index

S = Number of present species

pi = Species proportion

ln = Natural logarithm

ni = Number of invididuals of the *i* species

N = Total number of invididuals

Shannon true diversity index (${}^{1}D$)

$${}^{1}D = exp(H')$$

${}^{1}D$ = Shannon true diversity index

H' = Shannon entropy index

Foreign index (*Sa*)

$$Sa = \left(\frac{Snn}{(Snn + Sn)}\right) \times 100$$	*Sa* = Foreign index *Snn* = Number of non-native species *Sn* = Number of native species

The 10-20-30 rule was also used, which assumes that a tree species should not exceed 10 %, a genus 20 % and a family no more than 30 % as an indicator of diversity (Dangulla *et al.*, 2020; Martínez-Trinidad *et al.*, 2021). The calculations were performed in a Microsoft Excel® spreadsheet (Morales-Gallegos *et al.*, 2023).

Results

The total area explored was 27.32 ha. The total number of individuals (2 477) grouped into 130 species, 109 genera and 44 families. The most representative families in number of species were Fabaceae with 19 taxa, Arecaceae with 12, Bignoniaceae with 10, Rutaceae with eight, Moraceae with seven and Malvaceae with six. Angiosperms represented 96.92 %, while gymnosperms represented 3.08 %. Due to their origin, of the 130 taxa recorded in the study, 65 were native and 65 exotic. *Cedrela odorata* L. and *Roystonea regia* (Kunth) O. F. Cook are declared as species subject to special protection (Pr) in the NOM-059-SEMARNAT-2010 Mexican regulation (Semarnat, 2010) (Table 2).

Table 2. Tree species, palms and shrubs, and average dasometric variables found in 55 green areas of the city of *Tapachula*, *Chiapas*, Mexico.

Species	Family	No. Ind.	Origin	***Dn*** (cm)	***At*** (m)	***Ab*** (cm^2)

Acacia cornigera (L.) Willd.	Fabaceae	1	Na	11.10	2.53	0.01
Adonidia merrillii (Becc.) Becc.	Arecaceae	65	Ex	22.04	4.64	2.65
Anacardium occidentale L.	Anacardiaceae	6	Ex	48.83	8.08	1.29
Annona macroprophyllata Donn. Sm.	Annonaceae	11	Na	29.45	5.82	0.94
Annona muricata L.	Annonaceae	21	Na	21.90	5.59	0.94
Artocarpus altilis (Parkinson) Fosberg	Moraceae	7	Ex	65.86	11.29	2.58
Artocarpus heterophyllus Lam.	Moraceae	2	Ex	30.00	5.00	0.15
Averrhoa carambola L.	Oxalidaceae	11	Ex	41.91	7.27	1.64
Bauhinia forficata Link	Fabaceae	10	Ex	26.33	4.33	0.80
Beaucarnea recurvata Lem.	Asparagaceae	2	Na	25.00	4.75	0.10
Bismarckia nobilis Hildebrandt & H. Wendl.	Arecaceae	2	Ex	22.01	7.52	0.08
Bonellia macrocarpa (Cav.) B. Ståhl & Källersjö	Primulaceae	3	Na	26.67	4.33	0.18
Bougainvillea glabra Choisy	Nyctaginaceae	5	Ex	14.40	4.80	0.09
Bougainvillea spectabilis Willd.	Nyctaginaceae	5	Ex	35.40	4.40	0.62
Bursera simaruba (L.) Sarg.	Burseraceae	1	Na	20.00	4.00	0.03
Byrsonima crassifolia (L.) Kunth	Malpighiaceae	50	Na	38.29	6.23	7.23
Caesalpinia pulcherrima (L.) Sw.	Fabaceae	4	Na	18.75	4.54	0.11
Calliandra magdalenae (Bertero *ex* DC.) Benth. var. *colombiana* (Britton & Rose) Barneby	Fabaceae	5	Na	40.61	5.41	0.65
Calophyllum brasiliense Cambess.	Calophyllaceae	2	Na	45.00	4.00	0.32
Camellia japonica L.	Theaceae	1	Ex	15.00	4.00	0.02
Carica papaya L.	Caricaceae	2	Na	26.50	6.53	0.11
Caryota urens L.	Arecaceae	2	Ex	24.00	8.00	0.09
Cascabela thevetia (L.) Lippold	Apocynaceae	8	Na	26.88	5.69	0.47
Cassia fistula L.	Fabaceae	6	Ex	38.67	5.67	0.77
Casuarina equisetifolia L.	Casuarinaceae	6	Ex	62.67	20.33	1.86
Cecropia obtusifolia Bertol.	Urticaceae	1	Na	15.00	2.00	0.02
Cedrela odorata L.*	Meliaceae	1	Na	50.00	12.00	0.20
Ceiba pentandra (L.) Gaertn.	Malvaceae	7	Na	67.14	14.71	2.59
Chrysobalanus icaco L.	Chrysobalanaceae	3	Na	26.00	4.83	0.20
Chrysophyllum cainito L.	Sapotaceae	1	Na	65.00	15.00	0.33
Cinnamomum verum J. Presl	Lauraceae	1	Ex	60.00	6.00	0.28
Citrus × aurantium L.	Rutaceae	6	Ex	22.08	4.83	0.39
Citrus × limetta Risso	Rutaceae	2	Ex	21.53	5.51	0.09

Citrus × limon (L.) Osbeck	Rutaceae	52	Ex	22.11	4.43	2.36
Citrus × limonia (L.) Osbeck	Rutaceae	1	Ex	40.00	6.00	0.13
Citrus × paradisi Macfad.	Rutaceae	1	Ex	40.00	9.00	0.13
Citrus × sinensis (L.) Osbeck	Rutaceae	15	Ex	27.93	6.37	1.24
Citrus reticulata Blanco	Rutaceae	2	Ex	27.00	4.52	0.12
Cnidoscolus chayamansa McVaugh	Euphorbiaceae	3	Na	17.00	4.00	0.07
Coccoloba escuintlensis Lundell	Polygonaceae	1	Na	60.10	6.00	0.28
Cocos nucifera L.	Arecaceae	22	Ex	36.45	8.50	2.54
Codiaeum variegatum (L.) Rumph. *ex* A. Juss.	Euphorbiaceae	11	Ex	13.75	3.05	0.20
Coffea arabica L.	Rubiaceae	3	Ex	12.27	2.00	0.05
Cordia alliodora (Ruiz & Pav.) Oken	Cordiaceae	3	Na	55.00	7.00	0.72
Cordia dodecandra DC.	Cordiaceae	4	Na	29.52	6.52	0.28
Crescentia alata Kunth	Bignoniaceae	4	Na	11.51	3.38	0.05
Crescentia cujete L.	Bignoniaceae	11	Na	30.62	4.49	1.23
Cupressus sempervirens L.	Cupressaceae	7	Ex	33.86	5.11	0.80
Delonix regia (Bojer *ex* Hook.) Raf.	Fabaceae	10	Ex	60.90	11.00	3.11
Diphysa americana (Mill.) M. Sousa	Fabaceae	2	Na	21.00	6.00	0.09
Dracaena fragrans (L.) Ker Gawl.	Asparagaceae	1	Ex	15.00	5.00	0.02
Dypsis lutescens (H. Wendl.) Beentje & J. Dransf.	Arecaceae	155	Ex	22.14	5.41	6.41
Ehretia tinifolia L.	Ehretiaceae	1	Na	36.00	4.51	0.10
Elaeis guineensis Jacq.	Arecaceae	202	Ex	65.01	14.52	67.93
Enterolobium cyclocarpum (Jacq.) Griseb.	Fabaceae	7	Na	64.57	21.14	2.60
Eriobotrya japonica (Thunb.) Lindl.	Rosaceae	1	Ex	60.00	5.00	0.28
Erythrina folkersii Krukoff & Moldenke	Fabaceae	1	Na	40.00	3.00	0.13
Erythrina variegata L.	Fabaceae	1	Ex	24.00	5.00	0.05
Eucalyptus sp.	Myrtaceae	5	Ex	18.80	5.83	0.14
Ficus insipida Willd.	Moraceae	1	Na	75.00	16.00	0.44
Ficus microcarpa L. f	Moraceae	406	Ex	51.93	6.32	97.61
Ficus sp.	Moraceae	4	Na	64.00	13.00	1.33
Ficus benjamina L.	Moraceae	189	Ex	57.74	6.18	52.67
Ficus elastica Roxb. *ex* Hornem.	Moraceae	2	Ex	16.25	11.50	0.04
Garcinia mangostana L.	Clusiaceae	1	Ex	12.00	5.00	0.01
Gardenia jasminoides J. Ellis	Rubiaceae	2	Ex	21.50	4.00	0.07
Gmelina arborea Roxb. *ex* Sm.	Lamiaceae	2	Ex	58.00	11.50	0.53

Gossypium hirsutum L.	Malvaceae	1	Na	21.00	2.51	0.03
Guazuma ulmifolia Lam.	Malvaceae	2	Na	48.50	7.51	0.44
Hamelia patens Jacq.	Rubiaceae	1	Na	20.00	3.00	0.03
Handroanthus chrysanthus (Jacq.) S. O. Grose	Bignoniaceae	8	Na	51.63	14.63	1.78
Hibiscus rosa-sinensis L.	Malvaceae	5	Ex	27.60	4.11	0.34
Hymenaea courbaril L.	Fabaceae	1	Na	75.00	14.00	0.44
Inga spuria Humb. & Bonpl. *ex* Willd.	Fabaceae	1	Na	35.00	5.00	0.10
Inga edulis Mart.	Fabaceae	1	Na	46.00	8.00	0.17
Inga inicuil G. Don	Fabaceae	1	Na	46.00	5.00	0.10
Inga laurina (Sw.) Willd.	Fabaceae	1	Ex	65.00	12.00	0.33
Ixora coccinea L.	Rubiaceae	6	Ex	18.92	3.08	0.24
Jacaranda mimosifolia D. Don	Bignoniaceae	1	Ex	38.00	5.00	0.11
Jatropha curcas L.	Euphorbiaceae	1	Na	30.00	8.00	0.07
Lagerstroemia speciosa (L.) Pers.	Lythraceae	9	Ex	57.89	7.56	2.51
Leucaena leucocephala (Lam.) de Wit	Fabaceae	2	Na	17.00	7.00	0.03
Mangifera indica L.	Anacardiaceae	24	Ex	59.88	11.67	7.28
Manilkara zapota (L.) P. Royen	Sapotaceae	1	Na	30.00	6.00	0.07
Melia azedarach L.	Meliaceae	13	Ex	33.23	6.77	1.29
Morinda citrifolia L.	Rubiaceae	2	Ex	25.54	7.00	0.10
Moringa oleifera Lam.	Moringaceae	5	Ex	29.60	5.42	0.39
Muntingia calabura L.	Muntingiaceae	20	Na	30.40	4.85	1.96
Murraya paniculata (L.) Jack	Rutaceae	112	Ex	31.84	4.64	10.75
Mussaenda erythrophylla Schumach. & Thonn.	Rubiaceae	3	Ex	22.67	4.33	0.12
Nephelium lappaceum L.	Sapindaceae	6	Ex	26.17	3.17	0.40
Parmentiera aculeata (Kunth) Seem.	Bignoniaceae	65	Na	43.47	6.36	11.38
Persea americana Mill.	Lauraceae	8	Na	49.38	9.69	1.93
Phoenix roebelenii O'Brien	Arecaceae	29	Ex	20.48	3.31	1.13
Phyllanthus acidus (L.) Skeels	Phyllanthaceae	2	Ex	16.52	2.51	0.04
Pinus patula Schltdl. & Cham.	Pinaceae	1	Na	56.00	16.00	0.25
Platycladus orientalis (L.) Franco	Cupressaceae	10	Ex	29.10	4.33	0.70
Plumeria rubra L.	Apocynaceae	4	Na	16.10	3.38	0.09
Polyalthia longifolia (Sonn.) Thwaites	Annonaceae	199	Ex	17.98	7.39	5.38
Pouteria sapota (Jacq.) H. E. Moore & Stearn	Sapotaceae	1	Na	20.00	12.00	0.03
Psidium guajava L.	Myrtaceae	39	Na	27.69	5.49	2.76

Ravenala madagascariensis Sonn.	Strelitziaceae	1	Ex	32.00	4.00	0.08
Roseodendron donnell-smithii (Rose) Miranda	Bignoniaceae	64	Na	67.05	15.72	23.29
Roystonea regia (Kunth) O. F. Cook*	Arecaceae	27	Na	45.70	13.19	4.52
Sabal mexicana Mart.	Arecaceae	8	Na	59.38	8.13	2.36
Schizolobium parahyba (Vell.) S. F. Blake	Fabaceae	3	Na	74.33	14.67	1.31
Senna alata (L.) Roxb.	Fabaceae	1	Na	21.00	3.00	0.03
Simarouba amara Aubl.	Simaroubaceae	2	Na	39.00	5.00	0.24
Spathodea campanulata P. Beauv.	Bignoniaceae	1	Ex	75.00	17.00	0.44
Spondias mombin L.	Anacardiaceae	3	Na	69.33	9.00	1.15
Spondias purpurea L.	Anacardiaceae	1	Na	38.00	7.00	0.11
Sterculia mexicana R. Br.	Malvaceae	2	Na	30.00	11.00	0.16
Swietenia macrophylla King	Meliaceae	1	Na	65.00	8.00	0.33
Syagrus romanzoffiana (Cham.) Glassman	Arecaceae	5	Ex	25.81	6.00	0.27
Syzygium jambos (L.) Alston	Myrtaceae	2	Ex	62.52	8.00	0.64
Tabebuia guayacan (Seem.) Hemsl.	Bignoniaceae	3	Na	58.67	14.67	0.82
Tabebuia rosea (Bertol.) DC.	Bignoniaceae	63	Na	57.32	12.83	17.48
Tabernaemontana divaricata (L.) R. Br. *ex* Roem. & Schult.	Apocynaceae	3	Ex	18.67	2.03	0.08
Talisia oliviformis (Kunth) Radlk.	Sapindaceae	13	Na	32.92	6.77	1.22
Tamarindus indica L.	Fabaceae	1	Ex	60.00	9.00	0.28
Tecoma stans (L.) Juss. *ex* Kunth	Bignoniaceae	28	Na	32.13	6.25	2.92
Tectona grandis L. f.	Lamiaceae	4	Ex	32.52	7.75	0.35
Terminalia catappa L.	Combretaceae	233	Ex	36.73	7.48	28.81
Theobroma cacao L.	Malvaceae	1	Na	20.00	5.00	0.03
Thrinax sp.	Arecaceae	5	Na	36.22	7.41	0.66
Thuja occidentalis L.	Cupressaceae	18	Ex	34.05	4.78	2.06
Triplaris melaenodendron (Bertol.) Standl. & Steyerm.	Polygonaceae	1	Na	38.00	4.53	0.11
Vaccinium myrtillus L.	Ericaceae	1	Ex	20.00	5.00	0.03
Washingtonia sp.	Arecaceae	3	Ex	56.00	8.33	0.77
Yucca guatemalensis Baker	Asparagaceae	1	Na	18.00	4.51	0.03

No. Ind. = Number of individuals; *Dn* = Normal diameter (cm); *At* = Total height (m); *Ab* = Basimetric area (cm^2); Na = Native; Ex = Exotic. *Specie in NOM-059-SEMARNAT-2010 (Semarnat, 2010) in status subject to special protection.

In relation to the height class, the greatest presence of trees, shrubs and palms was recorded in the 5.04-7.31 m category with 904 individuals, followed by the 2.77-5.04 m category in which 593 individuals and 31 individuals with a height greater than 18.65 m. The distribution of individuals in height classes had an asymmetric distribution (Figure 2). Most urban trees are made up of young specimens and few mature and long-lived individuals.

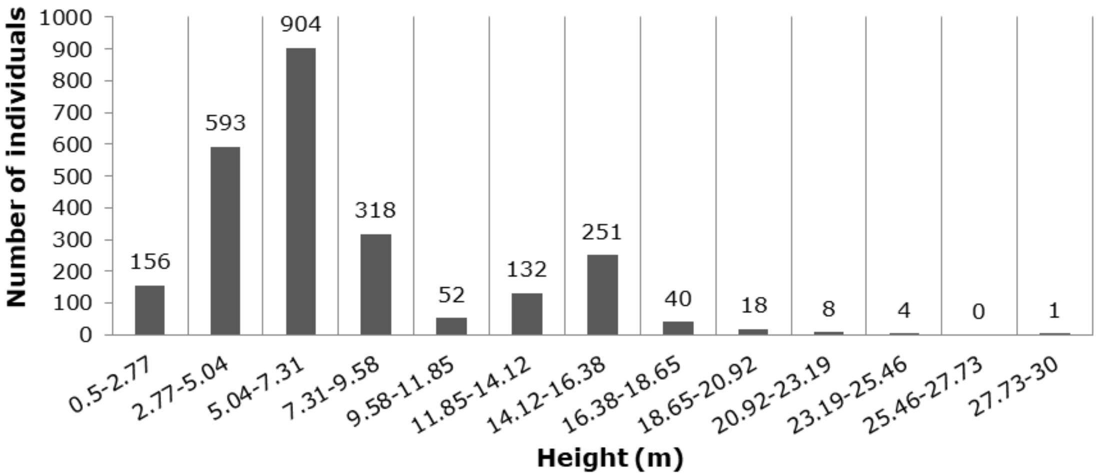


Figure 2. Number of individuals of trees, shrubs and palms according to total height class (m).

With regard to the diametric classes, it is observed that a low number of individuals with small diameters and a greater number of specimens with large diameters (>21 cm) prevail; there is heterogeneity in its distribution, which means that it is not strictly normal. In total, 555 individuals smaller than 21 cm in normal diameter and 1 922 individuals larger than 21 cm were counted; however, the highest abundance was recorded in the diameter classes of 13.5-20.0, 59.0-65.5 and 72.0-78.5 cm with 407, 344 and 305 individuals, respectively. The distribution of individuals in diametric classes was asymmetric, probably due to the wide diversity of present species (Figure 3).

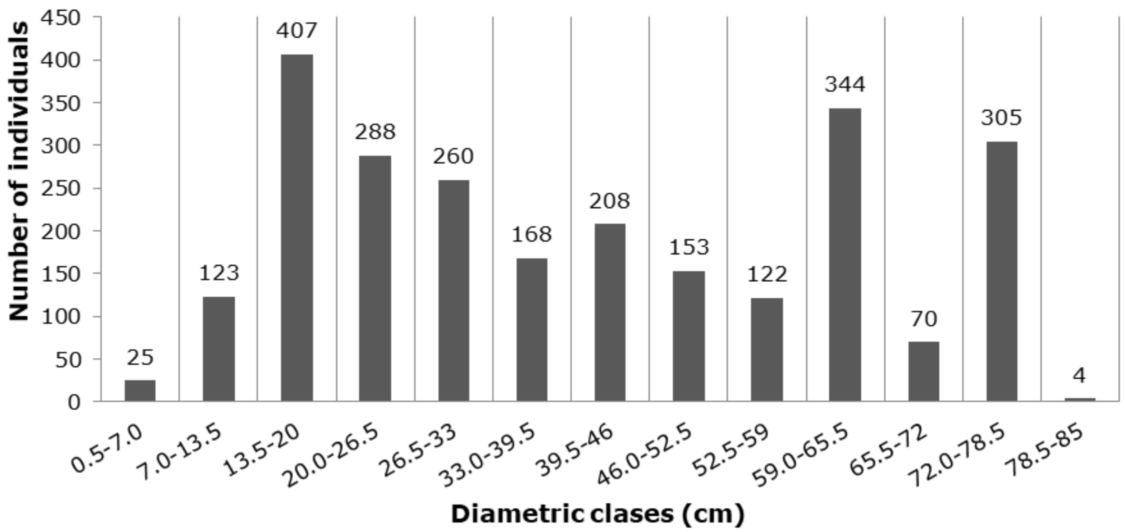


Figure 3. Number of individuals of trees, shrubs and palms according to the normal diameter class (cm).

The most abundant species were: *Ficus microcarpa* L. f. (16.39 %), *Terminalia catappa* L. (9.41 %), *Elaeis guineensis* Jacq. (8.16 %), *Polyalthia longifolia* (Sonn.) Thwaites (8.03 %), *Ficus benjamina* L. (7.63 %), *Dypsis lutescens* (H. Wendl.) Beentje & J. Dransf. (6.26 %) and *Murraya paniculata* (L.) Jack (4.52 %) (Table 3). Those with the highest Importance Value Index were: *Ficus microcarpa* (exotic), *Elaeis guineensis* (exotic), *Ficus benjamina* (exotic) and *Terminalia catappa* (exotic) (Table 3).

Table 3. Ecological parameters of abundance, dominance, frequency and Importance Value Index of the most frequent tree species, palms and shrubs in the green areas of the city of *Tapachula*, *Chiapas*, Mexico.

Species	Abundance		Dominance		Frequency		Importance Value
	***N* ha^{-1}**	**%**	**m^2 ha^{-1}**	**%**	***N* site^{-1}**	**%**	***IVI***
Ficus microcarpa L. f.	14.87	16.39	3.58	0.86	0.75	1.18	6.14
Terminalia catappa L.	8.53	9.41	1.06	0.25	1.00	1.57	3.74
Elaeis guineensis Jacq.	7.40	8.16	2.49	0.60	0.75	1.18	3.31
Ficus benjamina L.	6.92	7.63	1.93	0.46	1.00	1.57	3.22
Polyalthia longifolia (Sonn.) Thwaites	7.29	8.03	0.20	0.05	1.00	1.57	3.22
Dypsis lutescens (H. Wendl.) Beentje & J. Dransf.	5.68	6.26	0.23	0.06	1.00	1.57	2.63
Murraya paniculata (L.) Jack	4.10	4.52	0.39	0.09	0.50	0.78	1.80
Roseodendron donnell-smithii (Rose) Miranda*	2.34	2.58	0.85	0.21	1.00	1.57	1.45
Parmentiera aculeata (Kunth) Seem.*	2.38	2.62	0.42	0.10	1.00	1.57	1.43
Tabebuia rosea (Bertol.) DC.*	2.31	2.54	0.64	0.15	1.00	1.57	1.42
Adonidia merrillii (Becc.) Becc.	2.38	2.62	0.10	0.02	1.00	1.57	1.41
Byrsonima crassifolia (L.) Kunth*	1.83	2.02	0.26	0.06	0.75	1.18	1.09

*Native species

According to the richness and diversity indexes, the city of *Tapachula* has a greater richness of species in alignment trees (streets) and in public green areas, while in the flower beds or medians the results were lower (Table 4).

Table 4. Diversity indexes obtained by type of green area in the city of *Tapachula*, *Chiapas*, Mexico.

Site	Sampled area (ha)	Species	%	No. Ind.	%	Indexes		
						Shannon *H'*	**Margalef D_{Mg}**	**Foreign *Sa***
Flower beds or ridges	0.79	30	23.1	258	10.4	2.7	5.2	66.67
Streets	10.92	113	86.9	1551	62.6	3.3	15.2	50.44

Public parks	3.1	52	40	302	12.2	3.1	8.9	50
Public green areas	12.51	60	46.2	366	14.8	3.1	10.00	48.33

No. Ind. = Number of individuals.

Discussion

The city streets presented a greater diversity of species: this is probably due to the fact that this type of surface shown, along with the green areas, were the largest. However, the diversity of the former had double the records compared to green areas. It is considered that this data reflects the probable renewal of the road's own trees, which are more susceptible to intervention by the city council, because the conditions of the sidewalks cause more stress on the vegetation than larger spaces. 130 species were recorded in the city of *Tapachula*, a figure much higher than the 38 defined by Alanís-Rodríguez *et al.* (2022) in the center of *Hualahuises*, *Nuevo León*, and at 33 by Molina *et al.* (2023) in urban forests of six rural areas of said town, northeast of Mexico. It is worth mentioning that the ecological situation of *Tapachula* offers more favorable conditions for biological diversity than those of *Nuevo León*, since it is a humid tropical environment.

The Fabaceae family was the most representative with 19 species. Equal numbers of native and exotic species were recorded (65 and 65, respectively). Generally, for other Mexican cities, more exotic than native species have been recorded (Alanís-Rodríguez *et al.*, 2022; Molina *et al.*, 2023; Morales-Gallegos *et al.*, 2023). This pattern can be observed in much of the world and is related to the increase in the production of ornamental trees introduced in nurseries (Alanís-Rodríguez *et al.*, 2022). The high presence of exotic species in the city of *Tapachula* is related to the increase in their use in the green areas of the cities of southern Mexico in the 80s and 90s, due to their attractiveness and the low availability of species native (Morales-Gallegos *et al.*, 2023).

On the other hand, under the aim of protection and conservation against exotic or native pests and diseases, Santamour (1990) proposed the 10-20-30 rule to promote the diversity of urban forests (10% abundance at the specie level, 20% abundance at the generic level and 30% abundance at the plant family level). In addition, a range of ages should be maintained to rationally plan the removal and replacement of dead specimens and pruning (Flores *et al.*, 2018). In the case of the city of *Tapachula*, *Ficus microcarpa* exceeds 10 % presence, *Citrus* 20 % in terms of the genus, and the Fabaceae family exceeded 30 % in accordance with what was recommended by Santamour (1990).

In a diagnosis of the urban trees of "*El Vedado*" in Havana, Cuba, 33 tree species were counted, of which *Ficus* sp., *Calophyllum antillanum* Britton and *Terminalia catappa* represent 42 % of the total; 34 % of urban trees showed serious health problems, mainly in the crowns (Castillo and Pastrana, 2015), data similar to those identified in the present study. In 17 urban green spaces in the city of *Recife*, *Pernambuco*, Brazil, 49.1 % native species and 50.9 % exotic species were calculated, similar to the proportion in the study of interest (De Souza e Silva *et al.*, 2020). In contrast, Dangullaa *et al.* (2020) evaluated the composition, diversity, structural characteristics and provenance of trees in two cities in northwestern Nigeria, and concluded the predominance of native species over exotic ones, as well as the highest populations of exotic origin.

In Mexico, the structure, diversity and ecosystem services of trees were evaluated in four parks in the city of *Texcoco*, State of Mexico (Martínez-Trinidad *et al.*, 2021), and in a similar way to the study described here, *Ficus benjamina* it was an abundant species with 23 % of the total. For the state of *Chiapas*, specifically for the city of *Tuxtla Gutiérrez*, Román-Guillén *et al.* (2019) reported a total of 7 539 trees, distributed in 38 families, 88 genera and 114 species; 74 % were introduced individuals. Although the urban trees of *Tapachula* have a lower percentage of exotic species, due to its climatic regime and geographical position, it is important to promote tree diversity to reduce phytosanitary problems, mainly due to the lack of planning in the selection of species and their relationship with ecosystem benefits.

Conclusions

Angiosperm tree species are the most numerous in the city. Unlike other cities in Mexico and the world, the percentage of exotic and native species is similar. The alignment trees and in public green areas gather the greatest richness of species. *Ficus microcarpa* is a species that does not comply with the 10-20-30 rule, so its presence should be reduced, while the *Citrus* genus is also overrepresented. This study is the first approach and historical record published about the trees of the city of *Tapachula*, and provides information for better management of the trees in the selection and replacement of tree species.

Acknowledgements

The authors thank the people who participated in the field activities as practitioners.

Conflict of interests

The authors declare no conflict of interest.

Contribution by author

Carlos Mario Almeida-Cerino: field work, preparation of the manuscript, information collection and data analysis; Vincenzo Bertolini: preparation and review of data and manuscript; Tomás Martínez-Trinidad: preparation and review of the manuscript.

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