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# Woody neotropical streetscapes: a case study of tree and shrub species richness and composition in Xalapa

## Paisajes urbanos leñosos en el Neotrópico: Riqueza y composición de especies de árboles y arbustos en Xalapa

Ina Falfán[1] and Ian MacGregor-Fors[1*]

1 Red de Ambiente y Sustentabilidad. Instituto de Ecología, A.C., Veracruz, México.

* Corresponding author. ian.macgregor@inecol.mx

## Abstract

The urbanization process goes far beyond the replacement of preexisting non-urban systems, transforming the land in such way that represents worrisome ecological threats. In the novel urban systems, original vegetation is removed and/or replaced with a combination of native and exotic species. In this study, our aim was to generate an updated species list of the trees and shrubs that thrive in the streetscape of Xalapa (Veracruz, Mexico), describing their native/exotic ratio. For this, we followed a city-wide approach comprised by a grid of 106 sampling sites. We recorded a total of 140 tree and shrub species, of which 32 had not been previously reported for the city. Exotics represented more than half of the recorded species, which together with native ones were distributed unevenly throughout the city. Most frequent species include: Weeping Fig (*Ficus benjamina*), Chinese Hibiscus (*Hibiscus rosa-sinensis*), Paperflower (*Bougainvillea glabra*), Rhododendron (*Rhododendron* sp.), Mexican Cypress (*Cupressus lusitanica*), and Little-leaf Boxwood (*Buxus microphylla*). It is noticeable that sites at which we recorded no trees or shrubs were located near downtown and peripheral areas of the city. Our findings should be considered carefully, as the unequal distribution of plant diversity in urban areas can compromise the benefits that vegetation provides to citizens, as well as their ecological functions.

Keywords: exotic species, native species, spatial distribution, species origin, street trees, urban trees.

## Resumen

El proceso de urbanización va más allá del remplazo de sistemas preexistentes, transformando el terreno de tal forma que representa amenazas ecológicas preocupantes. En estos nuevos sistemas, la vegetación original es removida o remplazada con una combinación de especies nativas y exóticas. Este trabajo se enfocó en generar una lista de especies actualizada de los árboles y arbustos del paisaje urbano de Xalapa (Veracruz, México), describiendo la proporción de especies nativas y exóticas. Para ello, se utilizó un enfoque de ciudad completa comprendida por una retícula de 106 sitios de muestreo. Se registró un total de 140 especies de árboles y arbustos, de los cuales 32 no habían sido registrados anteriormente para la ciudad. Las especies exóticas representaron más de la mitad de las especies registradas, las cuales en conjunto con las especies nativas estuvieron distribuidas de forma desigual a lo largo y ancho de la ciudad. Las especies más frecuentes fueron: laurel de la India (*Ficus benjamina*), tulipán chino (*Hibiscus rosa-sinensis*), buganvilia (*Bougainvillea glabra*), azalea (*Rhododendron* sp.), cedro blanco (*Cupressus lusitanica*) y boj de hoja pequeña (*Buxus microphylla*). Es notable que los sitios en los que no se registró ninguna especie de árbol o arbusto estuvieron localizados cerca del centro histórico de la ciudad, así como en sus periferias. Los resultados de este trabajo deben ser considerados cuidadosamente, ya que la distribución desigual de la diversidad de plantas en áreas urbanas puede comprometer los beneficios que provee la vegetación a los habitantes, así como sus funciones ecológicas.

Palabras clave: especies exóticas, especies nativas, distribución espacial, origen de especie, arbolado de alineación, árboles urbanos.

## Introduction

Urbanization is a process in which humans establish and develop cities (Vlahov and Galea, 2002; Berkowitz *et al.*, 2003; United Nations, 2014). This process implies the transformation of preexisting non-urban systems into urban novel ones with unique physical, biological, and social traits (Alberti *et al.*, 2003; Grimm *et al.*, 2008; Pickett *et al.*, 2011). In general, urban areas are established to fulfill human modern housing needs, which have varied along regions and through time (Berry, 2008). Thus, as the urbanization process tends to replace original vegetation, as well as many other important local changes, it represents a threat for biodiversity in larger scales (Czech and Krausman, 1997; Czech *et al.*, 2000; McKinney, 2006; Kowarik, 2011; Aronson *et al.*, 2014).

As a crucial ecological component of urban areas, its vegetation provides important social and environmental benefits to urban dwellers (Dwyer *et al.*, 1992; Tyrväinen *et al.*, 2005; Manning, 2008), as well as a wide array of resources for wildlife species that dwell within cities (Ortega-Álvarez and MacGregor-Fors, 2011; Antonini *et al.*, 2013; Ramírez-Restrepo and Halffter, 2013; Lintott *et al.*, 2014). Moreover, it is noteworthy that tree and shrub diversity, composition, cover, and spatial distribution within a city are basically driven by the interaction between physical (e.g., topography), ecological (e.g., preexistent vegetation type) and human factors (e.g., planting, pruning, preference for some species, socioeconomics; Zipperer *et al.*, 1997; Dwyer *et al.*, 2000; Ramage *et al.*, 2013), often representing part of the identity of cities (Konijnendijk, 2008; Li *et al.*, 2011). In general, urban trees and shrubs are located on sidewalks, median strips, and urban greenspaces (e.g., woodlands, parks, cemeteries, gardens; Konijnendijk *et al.*, 2005; Ardila *et al.*, 2012), commonly aggregated and distributed unevenly throughout cities (Escobedo and Nowak, 2009; McConnachie and Shackleton, 2010; Cohen *et al.*, 2012).

Although urban vegetation has received important attention by urban ecologists in the past (Rowntree, 1984; Jim, 1988; Zipperer *et al.*, 1997; Luck *et al.*, 2009; Ortega-Álvarez *et al.*, 2011), little is known about their ecological patterns and processes in highly biodiverse regions; woefully, Latin America is not an exception (MacGregor-Fors and Ortega-Álvarez, 2013; Pauchard and Barbosa, 2013). Although many studies on trees and shrubs in Mexican urban areas have been concentrated in Mexico City (e.g., Díaz-Betancourt *et al.*, 1987; Cruz, 1989; López-Moreno and Díaz-Betancourt, 1989; López-Moreno, 1991; Chacalo and Corona, 2009; Ortega-Álvarez *et al.*, 2011), there is a growing number of studies focusing on different aspects of urban trees and shrubs (e.g., diversity, origin, spatial distribution, environmental function, landscape architecture, management, social perception) in other cities, such as: Monterrey, Nuevo León (Alanís, 2005); Mérida, Yucatán (Sosa and Flores, 1993; Orellana *et al.*, 2003; López-Falfán, 2008); Campeche, Campeche (Niembro-Rocas, 1992); Chihuahua, Chihuahua (Alcalá *et al.*, 2008); Morelia, Michoacán (Conejo, 2011; Sánchez and Peralta, 2013; Camacho-Cervantes *et al.*, 2014); and Xalapa, Veracruz (Arias, 1983; García-Campos, 1993; Ruiz-Montiel *et al.*, 2014).

Particularly, the city of Xalapa-Enriquez (referred to as Xalapa hereafter) has recently received special attention as it represents an excellent urban laboratory due to its location and orography that promote highly biodiverse wildlife communities (Capitanachi *et al.,* 2001; Williams-Linera *et al.*, 2002; MacGregor-Fors *et al.*, 2015). Previous studies have assessed the woody vegetation of Xalapa in specific areas of the city, most of which include greenspaces (e.g., Arias, 1983; García-Campos, 1993; Díaz-Betancourt and López-Moreno, 1993; Capitanachi and Amante, 1995; SCDEPEV, 2010; Lemoine, 2012; Ruiz-Montiel *et al.*, 2014); however, there is an important dearth of knowledge regarding the woody vegetation along its streetscapes, including its spatial distribution.

In this study, we focused on the streetscape of Xalapa using a city-wide survey approach. City-wide surveys take into account the spatial heterogeneity of the ecological, infrastructure, and social conditions of the city, allowing studies to have a representative sample of its most frequent scenarios (Turner, 2003; Davies *et al.*, 2011; McCaffrey and Mannan, 2012). Based on previous studies, we expected that the surveyed trees and shrubs would show: (1) low species richness (López-Moreno and Díaz-Betancourt, 1991; Li *et al*., 2011; Yang *et al*., 2012), (2) high representation of exotic species (Castillo-Campos, 1991; López-Moreno and Díaz-Betancourt, 1991; Kuruneri-Chitepo and Shackleton, 2011; Wang *et al.*, 2012), and (3) an uneven distribution of richness across the city (Landry and Chakraborty, 2009; Kuruneri-Chitepo and Shackleton, 2011; Kendal *et al*., 2012).

## Objectives

To generate an updated species list of trees and shrubs of the streetscape of Xalapa based on a city-wide approach, describing their native/exotic ratio.

## Materials and methods

### Study area

We performed this study in the city of Xalapa (19°32'37" N, 96°54'37" W), including its conurbation with Banderilla (Municipality of Banderilla), Guadalupe Victoria (Municipality of Tlalnehuayocan), and Bugambilias (Municipality of Emiliano Zapata). The urban continuum of Xalapa has a territory of ~60 km² and is an updated version of that proposed by Lemoine (2012), based on MacGregor-Fors (2010), and current ongoing research (Muñoz-Robles *et al.,* unpublished data) (Fig. 1). Following its 600 m elevation gradient (1120 m - 1720 m asl; Inegi, 2009), Xalapa has a semicalid climate on its southeast side, while a temperate climate dominates its northwestern section (Soto and Gómez, 1993). The original vegetation of the region was diverse, comprised mainly of pine forests, oak forests, cloud forests, and tropical dry forests (Castillo-Campos, 1991). Currently, ~20% of the city's area is covered by woody vegetation (Lemoine, 2012) and, as in many other cities in the world, it is comprised of a mixture of native and exotic species, basically confined to greenspaces (e.g., parks, streets, gardens; Castillo-Campos, 1991; García-Campos, 1993; Ruiz-Montiel *et al*., 2014).

### Field surveys and plant identification

To establish sampling sites across Xalapa, we used a polygon of the city from ongoing research (Muñoz-Robles *et al*., unpublished data). Briefly, we delimited the polygon of

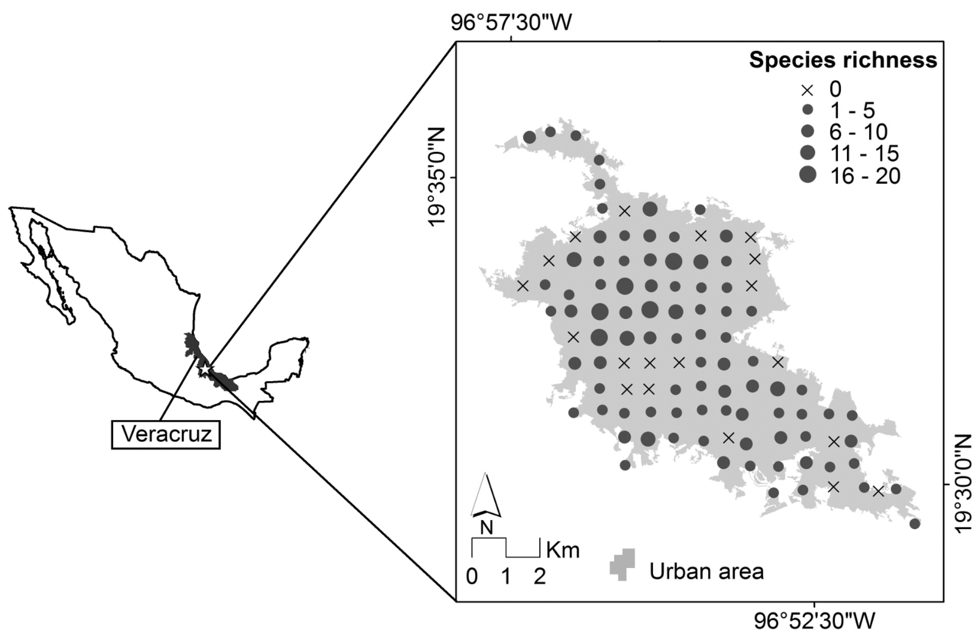


Figure 1. Map of study area depicting the location of Xalapa in central Veracruz and the distribution of surveyed tree and shrub species richness throughout the city.

Xalapa following spatial aggregation and communication criteria on an up-to-date high-quality satellite image. We then set a 750 m × 750 m grid on the polygon of the city and considered the centroid of cells as sampling sites. Finally, we adjusted the position of sampling sites *in situ* to the nearest accessible public area where sampling was feasible. The resulting number of sampling sites was 110, which for security reasons at some peri-urban areas of the city was reduced to 106 (Fig. 1).

We surveyed trees and shrubs in 106 sites, identifying all species present in an area of 150 $m^2$ per site. Due to the complexity of urban areas and their streetscapes, we used three procedures depending on the nature of the sampling site, considering the same survey area: (1) two 75 m transects on both sidewalks of streets without median-strips, (2) three 50 m transects on both sidewalks and the median-strip, when the latter were present, and (3) two 50 m transects on both sides of pathways of greenspaces and a parallel one 5 m away from the pathway.

All trees (including palms) and shrubs (including hedges) inside the surveyed area were recorded and identified to species level, whenever possible. When we were not able to identify an individual in the field, we collected a sample for further identification in the herbarium (Herbario XAL, Inecol). We identified the recorded trees and shrubs using available identification keys and specialized literature (Arias, 1983; Benítez *et al*., 2004; Calderón and Rzedowski, 2005; Pennington and Sarukhán, 2005; Vásquez, 2007; Chacalo and Corona, 2009; the "Flora de Veracruz" series; and those in www.tropicos.org). Some species that could not be determined in the herbarium were identified by an expert botanist (G. Castillo-Campos, pers. com.). Nevertheless, three tree individuals could not be identified as we could not get a field sample during the fieldwork due to their height and/or location. We will deposit all collected samples with herbarium minimum requirements in the Herbarium XAL (Inecol).

### Data analysis

Although we could not identify all recorded trees and shrubs to species level, we considered all identified taxa as species because we are certain that they belong to different species. After identifying all recorded tree and shrub species, we determined their origin and categorized them in native and exotic. We based the native/exotic categorization in relation to the region of study (central Veracruz), considering species as exotic if they do not occur naturally in central Veracruz (Richardson *et al*., 2000; Lodge and Shrader-Frechette, 2003; Jørgensen and Fath, 2008). We also contrasted our results with those reported in previous studies considering taxonomical changes in a world-wide database (Tropicos: www.tropicos.org). In order to set our species list into context, we compared it with previous local and regional studies (Arias, 1983; García-Campos, 1993; Díaz-Betancourt and López-Moreno, 1993; Capitanachi and Amante, 1995; SCDEPEV, 2010; Lemoine, 2012; Ruiz-Montiel *et al.,* 2014).

We used basic statistics to describe average, standard deviation, and data distribution of tree and shrub richness species recorded per sampling site. We carried out a two-sample Kolmogorov-Smirnov test to compare the distributions of the proportions of both native and exotic species. Due to the non-normality of our data (i.e., native and exotic tree and shrub species richness assessed with one sample Kolmogorov-Smirnov test: $D = 0.60$, $P < 0.001$; $D = 074$, $P < 0.001$, respectively), we carried out a Wilcoxon rank-sum test for paired data to compare the values of native and exotic richness. We performed all statistical procedures in R (R Development Core Team, 2012).

## Results

We recorded a total of 1116 trees and shrubs in our city-wide survey. Of them, we identified 140 species (Table 1), 126 to the species level, eight to genus, and three to family, while three specimens could not be identified at all, reason why they were not considered in further analyses. From the 49 recorded families, the one with highest representation was Arecaceae (12 species), followed by Fabaceae (10 species), Fagaceae (9 species), and Malvaceae (8 species). It is noteworthy that almost half (47%) of the recorded families were represented by a single species. In relation to their distribution in the city, the six most frequent species were: Weeping Fig (*Ficus benjamina*; 32% of the sampling sites), Chinese Hibiscus (*Hibiscus rosa-sinensis*; 19% of the sampling sites), Paper Flower (*Bougainvillea glabra*; 15% of the sampling sites), Rhododendron (*Rhododendron* sp.; 15% of the sampling sites), Mexican Cypress (*Cupressus lusitanica*; 15% of the sampling sites), and Little-leaf Boxwood (*Buxus microphylla*; 15% of the sampling sites; Fig. 2, Table 1).

From the trees and shrubs we could identify and relate to their geographical origin (n = 131 species), 55.7% are exotic and 44.3% are original of central Veracruz. When considering the six most frequent species (found in > 15 sampling sites), only one is native to central Veracruz (Mexican Cypress–*Cupressus lusitanica*). An important difference found between the surveyed sites from greenspaces (i.e., Cerro de la Galaxia, Cerro Macuiltepetl, Ecologic Reserve Tejar-Garnica, Seminario Mayor, Parque Natura) and the rest of highly developed urban areas was a higher presence of native tree and shrub species (68% in five greenspaces; 36% in 101 highly developed urban sites).

Regarding all tree and shrub species richness across Xalapa, we recorded values ranging from 0–20 species per sampling site, with an average of 4.8 (± SD 4.9) species. After excluding the 19 sites where we did not record any tree or shrub (located basically in the downtown and peripheral areas of the city; Fig. 1), native tree and shrub richness per sampling site ranged from 0–10 species, with an average of 1.8 (± SD 2.1) species. Contrastingly different to native species, exotic species richness was higher, with up to 15 species per sampling site (average: 3.9 ± SD 3.7 species). According to the Wilcoxon rank-sum test for paired data, significant differences exist between the amount of native and exotic species per sampling site, with the later showing higher numbers ($V = 661.5$, $P < 0.001$).

As predicted, the spatial distribution of tree and shrub species richness showed to be unequally distributed across the city, with the richest sites (with > 15 tree and shrub species) located in the northern part of the city (Fig.1). Interestingly, sampling sites with the highest values of exotic species were also located in the northern-central portion of the city (Fig. 3). We found no clear spatial distribution patterns for neither native nor exotic species richness across the city (Fig. 3). Still, the few sampling sites at which we recorded 100% native trees and shrubs are mainly located on peripheral areas of Xalapa, while those where we recorded 100% exotic trees and shrubs are dispersed throughout the city (Fig. 4). Although the proportion of recorded native and exotic tree and shrub species ranged from 0%–100% per site, the average percentage of exotics was of 65.7% (± SD 31.7% species), and was of 33.0% (± SD 31.4%) for natives, with the frequency distribution of native/exotic ratios showing significant differences (two-sample Kolmogorov-Smirnov test: $D = 0.44$, $P < 0.001$; Fig. 4).

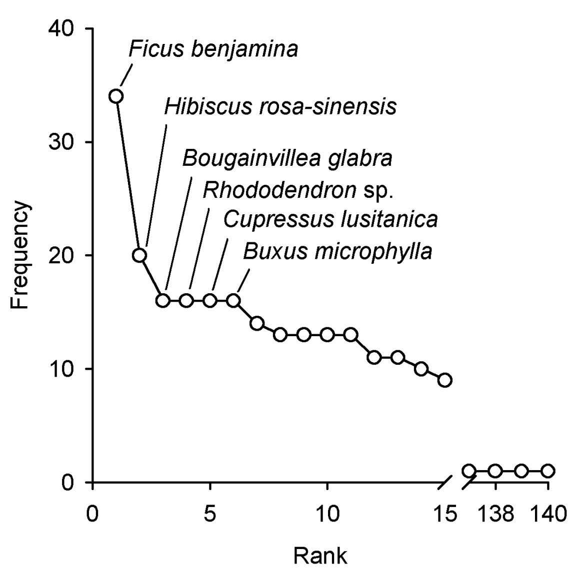


Figure 2. Rank-frequency plot of surveyed tree and shrub species in Xalapa.

## Discussion and conclusion

Urban vegetation is dynamic due to the human forces behind its presence and abundance (McPherson *et al.*, 1997; Zipperer *et al.*, 1997; Hope *et al.*, 2006; Ortega-Álvarez *et al.*, 2011; Ramage *et al.*, 2013). Our results show that tree and shrub species richness of the streetscape of Xalapa is high, with an important exotic component, and unevenly distributed across the city. Due to the human forces driving its streetscape, the unique location of the

TABLE 1. List of recorded tree and shrub species in the streetscape of Xalapa, Veracruz, ordered alphabetically by family.

| *Family* | *Species* | *Origin*[1] | *Frequency*[2] |
|---|---|---|---|
| Acanthaceae | *Pachystachys lutea* Ness [c, d] | Exotic | 2 |
| Adoxaceae | *Sambucus nigra* L.[*] | Native | 4 |
| | *Viburnum suspensum* Lindl.[*] | Exotic | 3 |
| Altingiaceae | *Liquidambar styraciflua* L. [a, b, c, d, e, f, g] | Native | 9 |
| Anacardiaceae | *Mangifera indica* L. [a, b, c, e] | Exotic | 1 |
| | *Spondias purpurea* L. [c] | Native | 1 |
| Annonaceae | *Annona cherimola* Mill. [a, b, d, e, g] | Native | 2 |
| Apocynaceae | *Nerium oleander* L. [b, c, d] | Exotic | 7 |
| Araliaceae | *Dendropanax arboreus* (L.) Decne. & Planch. [a, b] | Native | 1 |
| | *Oreopanax xalapensis* (Kunth) Decne. & Planch. [a, b, d, g] | Native | 1 |
| | *Schefflera actinophylla* (Endl.) Harms[*] | Exotic | 2 |
| | *Schefflera arboricola* (Hayata) Merr. [c, d, e] | Exotic | 5 |
| Araucariaceae | *Araucaria heterophylla* (Salisb.) Franco [a, b, d, e, f] | Exotic | 2 |
| Arecaceae | Arecaceae sp. 1 | - | 1 |
| | Arecaceae sp. 2 | - | 1 |
| | *Caryota urens* L. [d, e] | Exotic | 1 |
| | *Chamaedorea elegans* Mart. [c, d] | Native | 3 |
| | *Chamaedorea klotzschiana* H. Wendl.[*] | Native | 1 |
| | *Chamaedorea schiedeana* Mart. [b] | Native | 1 |
| | *Chamaedorea* sp. | Native | 1 |
| | *Dypsis lutescens* (H. Wendl.) Beentje & J. Dransf. [d, e] | Exotic | 5 |
| | *Elaeis guineensis* Jacq.[*] | Exotic | 1 |
| | *Hyophorbe* sp.[*] | Exotic | 1 |
| | *Syagrus romanzoffiana* (Cham.) Glassman[*] | Exotic | 7 |
| | *Washingtonia robusta* H. Wendl. [a, b, d] | Exotic | 1 |
| Asteraceae | *Dahlia imperialis* Roezl ex Ortgies [d] | Exotic | 1 |
| | *Verbesina turbacensis* Kunth[*] | Native | 1 |
| | *Vernonia patens* Kunth[*] | Native | 6 |
| Betulaceae | *Carpinus caroliniana* Walter [a, b, d, e, f, g] | Native | 3 |
| Bignoniaceae | *Jacaranda mimosifolia* D. Don [a, b, c, d, e, f] | Exotic | 11 |
| | *Spathodea campanulata* P. Beauv. [a, b, d, e, f] | Exotic | 3 |
| | *Tabebuia* sp.[*] | Native | 1 |
| Burseraceae | *Bursera simaruba* (L.) Sarg. [b, c, d, g] | Native | 5 |
| Buxaceae | *Buxus microphylla* Siebold & Zucc. [b, d] | Exotic | 16 |
| Casuarinaceae | *Casuarina cunninghamiana* Miq. [d, e, f, g] | Exotic | 3 |
| | *Casuarina equisetifolia* L. [a, b, c, d, f] | Exotic | 1 |
| Celastraceae | *Euonymus japonicus* Thunb. [b, d] | Exotic | 1 |
| Clethraceae | *Clethra macrophylla* M. Martens & Galeotti [d, f] | Native | 2 |

Table 1. List of recorded tree and shrub species in the streestscape of Xalapa, Veracruz, ordered alphabetically by family. (Continued...)

| *Family* | *Species* | *Origin*[1] | *Frequency*[2] |
|---|---|---|---|
| Cornaceae | *Cornus florida* L.[*] | Native | 1 |
| Cupressaceae | *Callitropsis macrocarpa* (Hartw. ex Gordon) D.P. Little[*] | Exotic | 2 |
| | *Chamaecyparis pisifera* (Siebold & Zucc.) Endl. [b, d, e, f] | Exotic | 5 |
| | *Cupressus lusitanica* Mill. [a, b, c, d, e, f, g] | Native | 16 |
| | *Cupressus sempervirens* L. [a, c, d, e] | Exotic | 4 |
| | *Platycladus orientalis* (L.) Franco [c, d] | Exotic | 2 |
| Ericaceae | *Rhododendron* sp. [c, d **] | Exotic | 16 |
| Euphorbiaceae | *Codiaeum variegatum* (L.) Rumph. ex A. Juss. [c, d] | Exotic | 3 |
| | *Croton draco* Schltdl. & Cham. [a, b, e, g] | Native | 1 |
| | *Euphorbia cotinifolia* L. [a, b, c, d, e, g] | Native | 6 |
| | *Euphorbia pulcherrima* Willd. ex Klotzsch [b, c, d] | Exotic | 5 |
| Fabaceae | *Acacia pennatula* (Schltdl. & Cham.) Benth. [a, b, c, e, g] | Native | 6 |
| | *Bauhinia variegata* L. [b, c, d] | Exotic | 1 |
| | *Caesalpinia pulcherrima* (L.) Sw.[*] | Native | 1 |
| | *Calliandra houstoniana* (Mill.) Standl.[*] | Native | 1 |
| | *Cassia fistula* L.[*] | Exotic | 1 |
| | *Erythrina americana* Mill. [a, b, d, e, g] | Native | 6 |
| | *Inga inicuil* Schltdl. & Cham. ex G. Don [a, b, c, d, e, f, g] | Native | 1 |
| | *Leucaena diversifolia* (Schltdl.) Benth. [d, f] | Native | 1 |
| | *Senna septemtrionalis* (Viv.) H.S. Irwin & Barneby[*] | Native | 1 |
| | *Senna* sp. | - | 1 |
| Fagaceae | *Quercus acutifolia* Née [a, b, e, g] | Native | 1 |
| | *Quercus* aff. *acutifolia* Née [a, b, e, g] | Native | 1 |
| | *Quercus castanea* Née [g] | Native | 1 |
| | *Quercus cortesii* Liebm.[*] | Native | 1 |
| | *Quercus germana* Schltdl. & Cham. [a, b, e, g] | Native | 2 |
| | *Quercus peduncularis* Née[*] | Native | 1 |
| | *Quercus sapotifolia* Liebm.[*] | Native | 1 |
| | *Quercus sartorii* Liebm.[*] | Native | 1 |
| | *Quercus xalapensis* Bonpl. [e, f, g] | Native | 1 |
| Juglandaceae | *Juglans pyriformis* Liebm. [d, e] | Native | 1 |
| Lamiaceae | *Rosmarinus officinalis* L. [c, d] | Exotic | 2 |
| Lauraceae | *Cinnamomum verum* J. Presl[*] | Exotic | 2 |
| | *Litsea glaucescens* Kunth [c, d, e] | Native | 2 |

[1] Origin: native/exotic in relation to central Veracruz.
[2] Frequency: number of sampling sites where the species was recorded (n = 106). [a] Arias (1983), [b] García-Campos (1993), [c] Díaz-Betancourt & López-Moreno (1993), [d] Capitanachi & Amante (1995), [e] SCDEPEV (2010), [f] Lemoine (2012), [g] Ruiz-Montiel *et al.* (2014).
[*] Not previously reported to the urban area of Xalapa.
[**] These two shrubs may comprise several taxonomic entities, nevertheless, for practical matters, we report them here as one unknown species.

Table 1. List of recorded tree and shrub species in the streetscape of Xalapa, Veracruz, ordered alphabetically by family. (Continued...)

| *Family* | *Species* | *Origin*[1] | *Frequency*[2] |
|---|---|---|---|
| Lauraceae | *Persea americana* Mill. [a, b, c, d, e, g] | Native | 6 |
| Lythraceae | *Lagerstroemia indica* L. [b, d] | Exotic | 3 |
| | *Punica granatum* L. [c, d] | Exotic | 2 |
| Magnoliaceae | *Magnolia grandiflora* L. [a, b, d, e] | Native | 3 |
| | *Magnolia schiedeana* Schltdl. [d] | Native | 1 |
| | *Magnolia soulangeana* Soul.-Bod. [b, d] | Exotic | 1 |
| | *Ceiba aesculifolia* (Kunth) Britten & Baker f. [d] | Native | 1 |
| | *Ceiba* sp. | - | 1 |
| | *Heliocarpus americanus* L. [g] | Native | 3 |
| | *Heliocarpus mexicanus* (Turcz.) Sprague[*] | Native | 1 |
| | *Hibiscus radiatus* Cav.[*] | Exotic | 1 |
| | *Hibiscus rosa-sinensis* L. [b, c, d, g] | Exotic | 20 |
| | *Hibiscus syriacus* L. [b] | Exotic | 1 |
| | *Malvaviscus arboreus* Cav. [b, c, d, f, g] | Native | 2 |
| Melastomataceae | *Tibouchina urvilleana* (DC.) Cogn. [b, d] | Exotic | 1 |
| Meliaceae | *Melia azedarach* L. [a, b, d, e] | Exotic | 3 |
| | *Trichilia havanensis* Jacq. [a, b, c, d, e, g] | Native | 5 |
| Moraceae | *Ficus benjamina* L. [b, c, d, e, f] | Exotic | 34 |
| | *Ficus carica* L. [c, d, e] | Exotic | 1 |
| | *Ficus elastica* Roxb. ex Hornem. [a, b, d, e] | Exotic | 1 |
| | *Ficus microcarpa* L. f. [a, b, d, e] | Exotic | 6 |
| Myrtaceae | *Callistemon citrinus* (Curtis) Skeels [a, b, c, d, e, f] | Exotic | 4 |
| | *Eucalyptus camaldulensis* Dehnh.[*] | Exotic | 2 |
| | *Eugenia uniflora* L.[*] | Exotic | 1 |
| | *Pimenta dioica* (L.) Merr. [a, b, c, d, e] | Native | 2 |
| | *Psidium cattleyanum* Sabine[*] | Exotic | 1 |
| | *Psidium guajava* L. [a, b, c, d, e, g] | Native | 13 |
| | *Syzygium samarangense* (Blume) Merr. & L.M. Perry [b, d, e] | Exotic | 10 |
| Nyctaginaceae | *Bougainvillea buttiana* Holttum & Standl. [c] | Exotic | 5 |
| | *Bougainvillea glabra* Choisy [b, c] | Exotic | 16 |
| Oleaceae | *Fraxinus uhdei* (Wenz.) Lingelsh. [a, b, c, d, e] | Native | 8 |
| | *Jasminum mesnyi* Hance [b, c] | Exotic | 1 |
| | *Ligustrum japonicum* Thunb. [b, d] | Exotic | 1 |
| | *Ligustrum lucidum* W.T. Aiton [a, b, c, d, e] | Exotic | 11 |
| | *Ligustrum ovalifolium* Hassk. [c, d] | Exotic | 2 |
| | *Ligustrum sinense* Lour.[*] | Exotic | 1 |
| | *Ligustrum vulgare* L. [d] | Exotic | 2 |
| Papaveraceae | *Bocconia frutescens* L. [c, d, g] | Native | 3 |

Table 1. List of recorded tree and shrub species in the streestscape of Xalapa, Veracruz, ordered alphabetically by family. (End).

| *Family* | *Species* | *Origin*[1] | *Frequency*[2] |
|---|---|---|---|
| Pinaceae | *Pinus patula* Schltdl. & Cham. [a, b, c, d, e, f, g] | Native | 1 |
| Platanaceae | *Platanus mexicana* Moric. [a, b, d, e, f, g] | Native | 5 |
| Podocarpaceae | *Podocarpus macrophyllus* (Thunb.) Sweet* | Exotic | 1 |
| Primulaceae | *Ardisia compressa* Kunth* | Native | 2 |
| | *Myrsine coriacea* (Sw.) R. Br. ex Roem. & Schult.* | Exotic | 2 |
| Proteaceae | *Grevillea robusta* A. Cunn. ex R. Br. [a, b, d, e, f, g] | Exotic | 1 |
| | *Macadamia tetraphylla* L.A.S. Johnson [d] | Exotic | 1 |
| Rhamnaceae | *Frangula capreifolia* (Schltdl.) Grubov [a, b, e, g] | Native | 1 |
| Rosaceae | *Eriobotrya japonica* (Thunb.) Lindl. [a, b, c, d, e, f, g] | Exotic | 14 |
| | *Prunus persica* (L.) Batsch [a, b, c, d, e] | Exotic | 9 |
| | *Prunus* sp. | - | 1 |
| | *Rosa* sp. [b, c, d] ** | Exotic | 13 |
| | Rosaceae sp. | - | 1 |
| Rubiaceae | *Coffea arabica* L. [b, c, d, f, g] | Exotic | 6 |
| | *Gardenia jasminoides* J. Ellis [b, c, d] | Exotic | 3 |
| | *Palicourea padifolia* (Humb. & Bonpl. ex Schult.) C.M. Taylor & Lorence [g] | Native | 1 |
| | *Randia aculeata* L.* | Native | 3 |
| Rutaceae | *Casimiroa edulis* La Llave [a, b, d, e] | Native | 1 |
| | *Citrus limon* (L.) Osbeck [a, b, c, d, e, f] | Exotic | 6 |
| | *Citrus maxima* (Burm.) Merr. [a, b, c, d, e, g] | Exotic | 13 |
| | *Citrus reticulata* Blanco [a, b, c, d, e] | Exotic | 13 |
| | *Murraya paniculata* (L.) Jack [c, d] | Exotic | 2 |
| Salicaceae | *Salix babylonica* L. [a, b, d, e, g] | Exotic | 1 |
| Solanaceae | *Brugmansia candida* Pers. [b, d, g] | Exotic | 6 |
| | *Brugmansia suaveolens* (Humb. & Bonpl. ex Willd.) Sweet* | Exotic | 2 |
| Theaceae | *Camellia japonica* L. [b, c, d] | Exotic | 2 |
| Verbenaceae | *Duranta repens* L. [b, d] | Native | 3 |
| Unidentified | Sp. 1 | - | 1 |
| | Sp. 2 | - | 1 |
| | Sp. 3 | - | 1 |

[1] Origin: native/exotic in relation to central Veracruz.
[2] Frequency: number of sampling sites where the species was recorded (n = 106). [a] Arias (1983), [b] García-Campos (1993), [c] Díaz-Betancourt & López-Moreno (1993), [d] Capitanachi & Amante (1995), [e] SCDEPEV (2010), [f] Lemoine (2012), [g] Ruiz-Montiel *et al.* (2014).
* Not previously reported to the urban area of Xalapa.
** These two shrubs may comprise several taxonomic entities, nevertheless, for practical matters, we report them here as one unknown species.

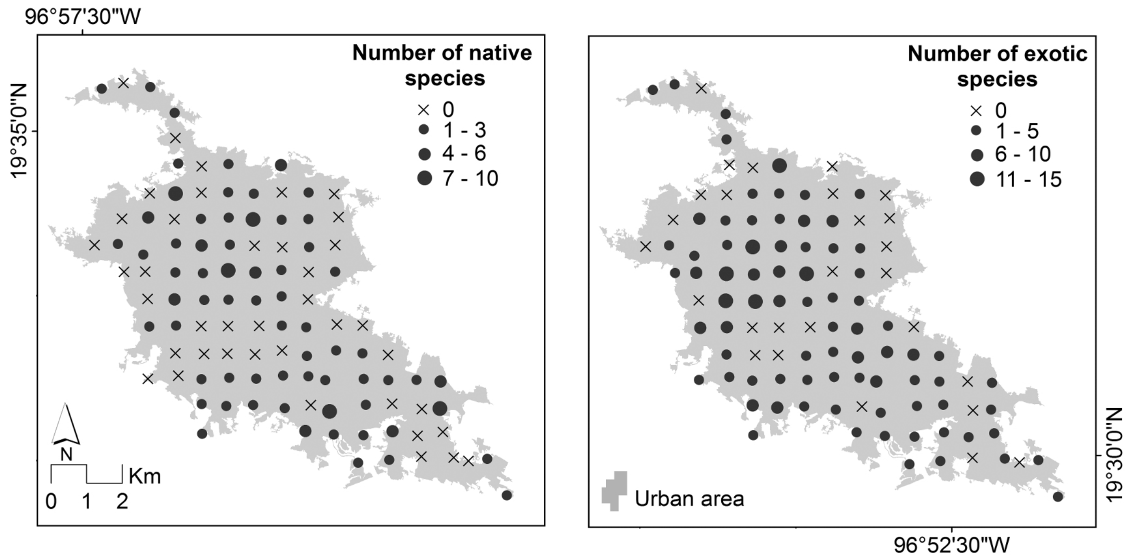


FIGURE 3. Spatial distribution of native and exotic trees and shrubs recorded in the streetscape of Xalapa.

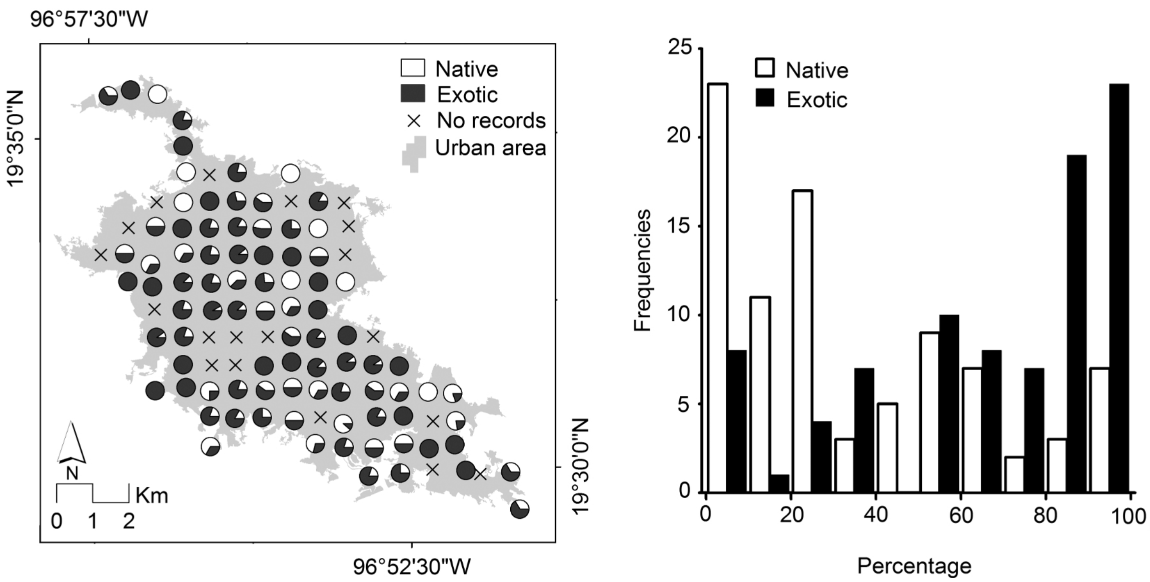


FIGURE 4. Distribution of the origin (native/exotic) of trees and shrubs recorded in the streetscape of Xalapa.

city of Xalapa in a highly biodiverse region did not prevent the replacement of its vegetation in the urbanization process, completely shifting its species composition (Castillo-Campos, 1991; Williams-Linera *et al.,* 2002).

Throughout the globe, street tree species richness varies among urban areas, with some medium-sized cities, as Toledo (Ohio, USA; ~ 225 km$^2$) showing high values (170 species; Subburayalu and Sydnor, 2012), while others, also larger than Xalapa (e.g., Bangalore, India: ~740 km$^2$; Curitiba, Brazil: ~430 km$^2$; Bangkok, Thailand: ~1570 km$^2$) have fewer species (108, 122, 127, respectively; Thaiutsa *et al.*, 2008; Nagendra and Gopal, 2010; Bobrowski and Biondi, 2012) than those we report for Xalapa. Although comparing street tree richness of different cities is complex due to the nature of the surveys, as well as the location of the cities, it is clear that Xalapa has a considerably high number of tree and shrub species richness along its streetscape. When we compared our results with previous studies focused on the urban vegetation of Xalapa, we noted 32 species that had not been previously reported for the city, of which half are native and half are exotic. It is notable that we recorded a higher number of species when compared to a study of vegetation in public spaces of Xalapa (102 tree species; Arias, 1983); nonetheless, the number of species reported in greenspaces of Xalapa is higher (187 tree and shrub species; Capitanachi and Amante, 1995; ~185 woody species; García-Campos, 1993). These comparisons show the kind of results that city-wide surveys can provide, often underestimating species from urban greenspaces, which are often unevenly distributed throughout cities (also recorded for other wildlife groups; Nilon *et al.*, 2011).

Previous studies have suggested that urban tree and shrub species composition changes with time (López-Moreno and Díaz-Betancourt, 1991; Dwyer *et al.*, 2000; Alanís, 2005). In Xalapa, this is the case of the exotic Weeping Fig (*F. benjamina*), by far the most frequent species of the streetscape of Xalapa (Fig. 2). This exotic species is not reported by Arias (1983), but is reported in the subsequent published literature of urban vegetation for the city. Regardless that this species has caused urban-related problems (e.g., urban sidewalks cracks) and has even been considered as inadequate for planting in urban areas (Conejo, 2011; Moro and Westerkamp, 2011; Vargas-Garzón and Molina-Prieto, 2012), the Weeping Fig has been extensively planted throughout the country since the mid-1990s (Vargas-Garzón and Molina-Prieto, 2012), becoming a dominant urban tree in many cities.

As expected, we recorded a high proportion exotic species. This is consistent with previous studies that have found important number of exotic species dominating urban streetscapes (e.g., 62.8%: López-Moreno and Díaz-Betancourt, 1991; 56%: Kuruneri-Chitepo and Shackleton, 2011; 61.8%: Ortega-Álvarez *et al.*, 2011; ≥ 50%: Sjöman *et al.*, 2012; 48.3%: Wang *et al.*, 2012). The high proportion of exotics in Xalapa is due to the import of plant species from other parts of Mexico and the rest of the world for several reasons (e.g., ornamental, edibility, erosion control; Castillo-Campos, 1991; Eldredge, 2002; Verhoef and Morin, 2010). High tree and shrub species richness recorded in the streetscape of Xalapa is heavily biased by the introduction of exotic species, pattern that has been recorded in cities from around the globe (McKinney, 2008).

Regarding the spatial distribution of the studied tree and shrub species, it was not surprising to find an unequal distribution of species richness values across the city; such pattern has been reported for other urban areas from around the world (Landry and Chakraborty, 2009; Kuruneri-Chitepo and Shackleton, 2011; Kendal *et al.*, 2012). The unequal distribution of greenspaces and woody vegetation across Xalapa has been reported previously by García-Campos (1993) and Lemoine (2012), but to our knowledge, there are no previous studies that report the unequal spatial distribution of woody plant species richness along its streetscapes. Nevertheless, further studies are needed to identify the processes behind this pattern, exploring which variables could be associated with this particular spatial configuration of species richness in Xalapa.

Our results, mainly the unequal distribution of tree and shrub species richness across the streetscape of Xalapa, as well as the high proportion of recorded exotics should be considered carefully, as they have been associated to the irregular distribution of the benefits that vegetation can provide to citizens (Garzón *et al.,* 2004; Escobedo and Nowak, 2009; McConnachie and Shackleton, 2010; Cohen *et al.,* 2012; Kendal *et al.,* 2012). Also, the high proportion of exotic species needs to be considered due to the potential negative effects of such species, including a vast array of detrimental effects that have been documented on local, and even regional, ecological processes (Vitousek *et al.*, 1997; Schmidt and Whelan, 1999; Richardson *et al.*, 2000; McKinney, 2004).

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