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Article

Dinámica de uso de suelo e índice verde en Poza Rica, Veracruz

Dynamics of land use and green index in *Poza Rica*, *Veracruz*

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Resumen

Se analizó la dinámica de uso de suelo y vegetación en Poza Rica, Veracruz, de 1997 a 2016 y se relacionó con la percepción que los habitantes de la ciudad tienen respecto a los servicios ecosistémicos que proveen las áreas verdes (AV). Para ello se georreferenciaron las AV y, mediante un muestreo por conglomerados, se estimó el número de árboles, lo que permitió construir un Índice Verde Urbano (IVU). Adicionalmente, se encuestó a 100 pobladores dedicados a diferentes actividades remuneradas: académicos (25), amas de casa (21), comerciantes (37) e industriales (17). Los resultados indican que la mancha urbana se incrementó 98 %, al pasar de 1 587 ha en 1997 a 3 145 ha en 2016; las áreas que se reconvirtieron fueron, en su mayoría, zonas destinadas a la agricultura y la ganadería. Este hecho impacta directamente en el IVU que resultó ser de 12.21830 m^2 *per capita* y 0.13 527 árboles por habitante, con tasas medias de crecimiento anual negativas para ambos IVU: -0.83 y -0.01, respectivamente. La totalidad de los encuestados reconoce la importancia de las áreas verdes en la ciudad, aunque solo 52 % conoce sus efectos positivos en la regulación de la temperatura, el ciclo hidrológico y la calidad del aire. Los académicos, amas de casa y comerciantes mostraron mayor interés por conservar e incrementarlas AV. La educación ambiental destacó como un eje prioritario para lograr que los ciudadanos respeten las AV, y eventualmente se incremente su número.

Palabras clave: Análisis de componentes principales, arbolado urbano, áreas verdes, escala de *Likert*, servicios ecosistémicos, SIG.

Abstract

The dynamics of land and vegetation use in *Poza Rica, Veracruz*, from 1997 to 2016 were analyzed and related to the perception that the inhabitants of the city have regarding the ecosystem services provided by green areas (GA). Thus, the GAs were georeferenced and by means of cluster sampling, the number of trees in the city was estimated, which allowed the construction of an Urban Green Index (UGI). Additionally, 100 residents of different paid activities were surveyed: academics (25), housewives (21), merchants (37) and industrialists (17). Results indicate that the urban sprawl increased by 98 %, from 1 587 ha in 1997 to 3 145 ha in 2016, the areas that were reconverted were mostly areas agriculture and livestock. This fact directly impacts the UGI, which turned out to be 12.21830 m^2 *per cápita* and 0.13527 trees per inhabitant, with negative annual average growth rates for both UGI: -0.83 and -0.01, respectively. All respondents recognize the importance of green areas in the city, although only 52 % know their positive effects on the regulation of temperature, hydrological cycle and air quality Scholars, housewives and merchants showed greater interest in preserving and increasing GA in the city. Environmental education stood out as a priority axis to ensure that citizens respect the GA, and eventually increase their number.

Key words: Principal component analysis, urban trees, green areas, Likert scale, ecosystem services, GIS.

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Introduction

Anthropogenic activities and the population explosion have motivated the increase in the global temperature of the planet with greater intensity in the last century, by converting green areas into areas of urban use, which has caused alterations in the frequency of regular weather events, and, consequently, the intensification of natural disasters and the alteration of the water cycle (IPCC, 2014). The green area is considered as part of the public space, and represents, from a planned, integrated and systematic approach, the management of trees, shrubs and other vegetation within the city (Benavides and Fernández, 2012).

The presence of green areas accessible to the enjoyment of the citizen is one of the priority factors to measure degrees of human well-being and urban sustainability (Santana, 2010). Some of the most common indicators to assess these factors are the per capita area (m^2), location, distribution and accessibility to green areas (Bascuñán *et al*., 2007). The World Health Organization (WHO) estimates that the extension of green spaces in a city should be between 9 and 15 m^2 per person and one tree for every three people (Castro, 2005).

One of the current problems of cities has its origin in the loss of green areas, which results in social conflicts such as insecurity, and environmental conflicts such as pollution and loss of biodiversity (Neckel *et al.,* 2009). However, despite its importance, the study of green areas and their relationship with social welfare has been a topic that has not been addressed (Bascuñán *et al*., 2007).

At the international level, some studies such as that of Escobedo *et al*. (2011) in the United States of America, and Tovar (2006) in Colombia, focus on the analysis of the services that green areas and in particular urban trees offer in cities, but do not address ecosystem services (SE) in a global context) that green areas provide to citizens.

The concept of ecosystem services (SE) refers to the goods and services provided by the components or processes of ecosystems and that contribute directly to human well-being; they are of four types: provision, regulation, support and culture (Wardle and Jonsson, 2014). The study of SE constitutes a research area that allows the implementation of integrated solutions to current problems in cities such as the frequency and intensity of rainfall and temperature regulation (Dobbs *et al*., 2014).

The population increase and urban pressure for new habitable areas have reduced the international requirements of green areas in Mexico (Benavides and Fernández, 2012). In this way, the Urban Green Index has become a useful instrument to motivate municipalities to include within their land plans, the creation and conservation of green areas for citizen welfare, as well as establishing methodological mechanisms for their measurement and calculation (Ponce *et al.,* 2013).

In cities like *Parral* (Chile) it was shown that an urban planning program that prioritizes environmental protection, through the creation of green areas, substantially improves the quality of life of its inhabitants, going from less than 10 m^2 to 55 m^2 of green surface per inhabitant, which in addition to that it favored the concurrence, since more than 150 000 people go on weekends to visit the parks and urban gardens (Mena *et al*., 2011).

In Mexico, studies such as those by Alanís (2005) in *Monterrey* (*Nuevo León*), López (2008) in *Mérida* (*Yucatán*), Benavides and Fernández (2012) and Velasco *et al.* (2013) in Mexico City have confirmed how green areas in cities contribute to social well-being, by promoting a healthy coexistence, which improves the mood of users and reduces aggressive behaviors, crime, negative feelings (fear, anger, depression) and with this intrafamily and community violence. In addition, being public spaces they become meeting points that all groups can access, favoring social inclusion (Bascuñán *et al.,* 2007).

In this context, the aims of this work were to analyze the dynamics of land and vegetation use in *Poza Rica* (*Veracruz*) from 1997 to 2016; and, relate the changes in land and vegetation use coverage with the perception that the inhabitants of the city have regarding the ecosystem services provided by green areas, through the creation of Urban Vegetation Indexes to propose restoration strategies aligned to the needs of the population.

Materials and Methods

Study area

The study was carried out in the *Poza Rica de Hidalgo* municipality, *Veracruz* State, Mexico, located between 20.53 N and -97.45 W (Figure 1), with a total area of 4 688 ha. *Poza Rica* has a very high degree of human development due to the oil zone in which it is located and an average annual population increase rate of 0.73 %, which in 2015 hosted 200 119 inhabitants (INEGI, 2015). The city's climate is classified as Aw (warm humid) with an average annual temperature of 24.5 °C, an average rainfall of 1 106 mm and an altitude below 200 m (INEGI, 2016).

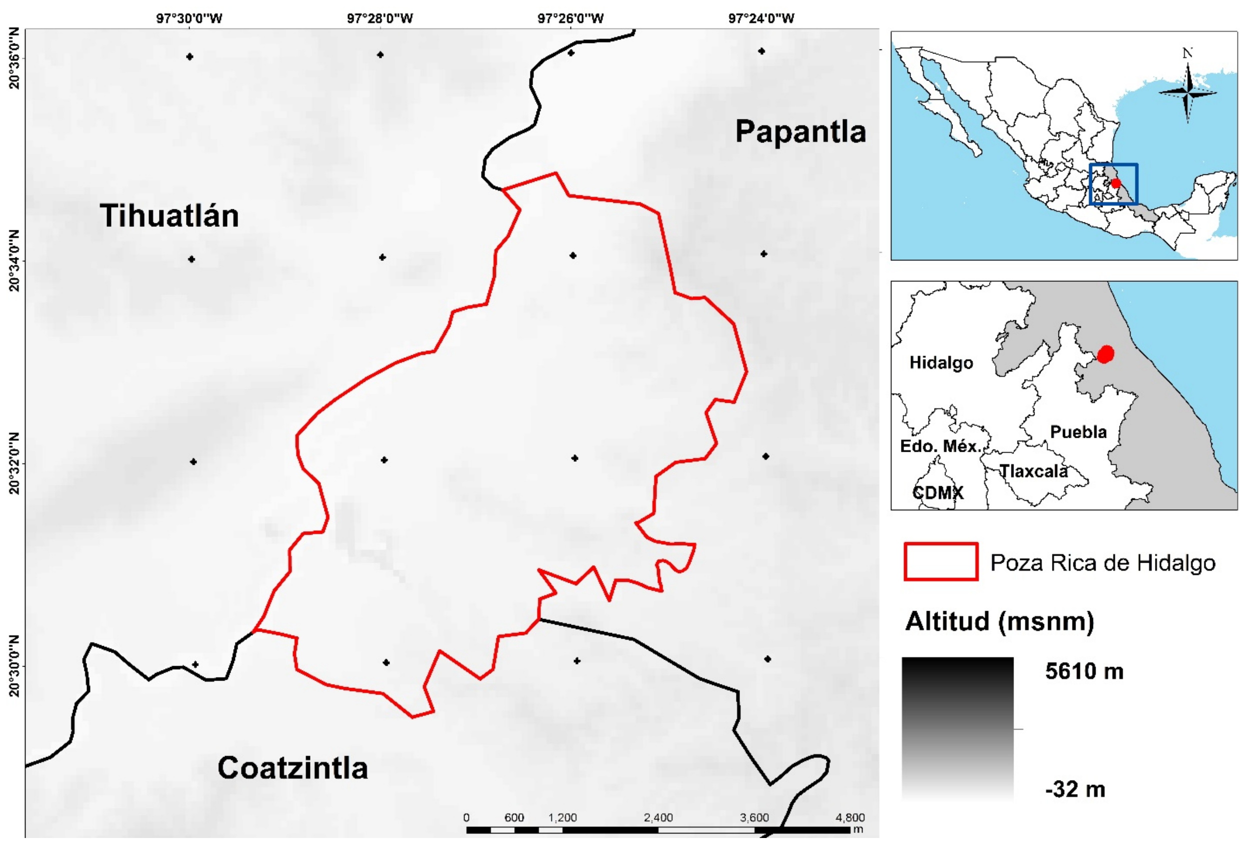


Figure 1. Geographic location of *Poza Rica de Hidalgo* municipality, *Veracruz*.

Dynamics of change in land and vegetation use

Changes in land and vegetation use coverage of the city of *Poza Rica* were analyzed using the land and vegetation use charts of the I, II, III, IV, V and VI series of the National Institute of Statistics, Geography and Informatics (INE-INEGI, 1997; INEGI 2001, 2005, 2009, 2013 and 2016). With the help of the Quantum GIS Development Team Software (QGISDT, 2018) the areas (ha) were calculated by series according to their land use and compared to each other to determine the dynamics of change.

Characterization of urban trees and calculation of the Urban Green Index

To determine the green areas in the city of Poza Rica, a satellite image was used QuickBird available in Google Earth; with the support of the Quantum GIS Development Team software (QGISDT, 2018) and supervised classification, polygons with green areas were georeferenced and validated in the field. In addition, from October 2018 to January 2019, in each of the polygons the trees and species present were sampled with the methodology of the National Forest Inventory and Soil (Conafor, 2012). In order to differentiate the arboreal and herbaceous tree stratum, the records were discriminated against individuals with stem diameters smaller than 7.5 cm, and total height and crown diameters less than 1 m.

Green areas (m^2) and the number of counted trees (trees present in a Study Area: APAE) served as the basis for calculating the annual Green Urban Index (IVU), which was calculated in m^2 *per capita* and number of trees per inhabitant for the 2010-2019 period. The resident population in *Poza Rica* (PT) was estimated from the population recorded in 2015 (200 119 inhabitants) and the average annual population growth of the city (0.73 %) (INEGI, 2015). The IVU was calculated from the following formula (Cano, 2009):

$$IVU = \left(\frac{APAE}{PT}\right)$$

Social perception of the ecosystem services provided by green areas

Between February and March 2019, a survey was applied to 100 inhabitants of *Poza Rica*, distributed in different parts of the city, which included shopping centers, schools, private homes and industrial areas. According to Infante and Zárate (1990), a sample is statistically sufficient from 30 observations, so the number of surveys applied does not violate any sampling assumption and the estimators obtained are distributed under normality assumptions and tend to be unbiased.

The survey considered the economic activity carried out by the respondent, and to facilitate data collection in the field, the questions were asked based on a Likert scale (very high, high, medium, low and very low) (Bozal, 2006), and were grouped into two main axes that collected perceptions about: (1) Knowledge about the ecosystem services that green areas provide to cities, which included questions related to the importance of temperature regulation, hydrological cycle and quality of breathable air; and (2) Importance of the restoration of green areas, particularly urban trees in *Poza Rica*.

The data collected by the survey were captured in a spreadsheet, with the help of the R software (R Project, 2019), a Principal Components Analysis (ACP, for its acronym in Spanish) was executed to establish, by developed economic activity, the knowledge that respondents have about ecosystem services provided by urban trees, and the importance they give to conservation and restoration. For this analysis it was necessary to re-categorize the Likert scale as follows: very high (took the value of 5), high (4), medium (3), low (2) and very low (1).

Results and Discussion

Dynamics of change in land and vegetation use

The comparison between land and vegetation use coverage from 1997 to 2016 (Table 1) shows how the urban area increased by 98 %, from 1 587 ha in 1997 to 3 145 ha in 2016, and mainly displaced to grassland areas (1 325 ha). This fact has been documented by INEGI (2015) who states that the increase in the urban area of *Poza*

Rica, resulted from the boom that oil activity had in the region from 2000 to 2013, which coincides with Orozco and García (2014) who for peri-urban areas of *Toluca* (State of Mexico) determined that the growth of these areas is influenced by the development of economically profitable activities.

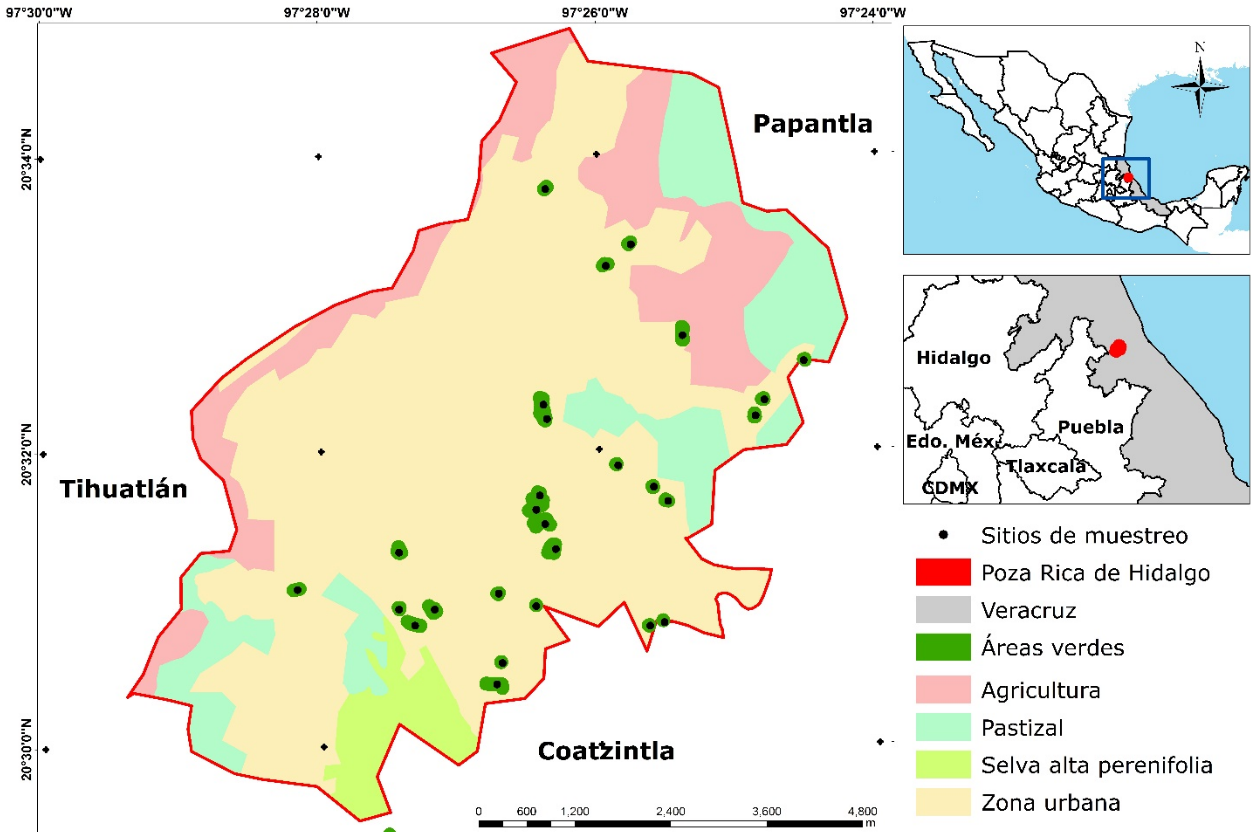
Table 1. Coverage changes in land and vegetation use in *Poza Rica, Veracruz* from 1997 to 2016.

Land use and Vegetation	**Hectares (ha)**						**Changes 1997-2016**	
	1997	**2001**	**2005**	**2009**	**2013**	**2016**	**ha**	**%**
Agriculture	787	1 312	1 254	1 458	694	694	-93	-12
Grassland	1 974	659	659	648	628	649	-1 325	-67
Tropical Rain Forest	340	192	192	0	261	200	-140	-41
Urban Zone	1 587	2 524	2 583	2 582	3 105	3 145	1 558	98
Total	4 688	4 688	4 688	4 688	4 688	4 688	0	0

INEGI (2015) considered that the urban growth of *Poza Rica* has been concentric, disorganized and without including social welfare elements such as the creation of green areas, which, according to Moreno-Mata and Sánchez-Moreno (2018), causes irregular settlements that emphasize social inequalities and increase insecurity.

Characterization of urban trees and calculation of the Urban Green Index

The location of the green areas in *Poza Rica* are illustrated in Figure 2, which sum up 251.73 ha. The total sampled area (27 sites) was 9.06 ha, where 1 003 trees were counted, which allows an estimation of 27 869 trees in the city.



Sitios de muestreo = Sampling sites; *Áreas verdes* = Green areas; *Agricultura* = Agriculture; *Pastizal* =Grassland; *Selva alta perinifolia* = High evergreen forest; *Zona urbana* = Urban area.

Figure 2. Spatial delimitation of the existing green areas in *Poza Rica, Veracruz*, georeferenced from a QuickBird satellite image and validated in the field by supervised classification.

The 1 003 trees counted in the 27 sampling sites belong to 17 species, *Ehretia tinifolia* L. (tight stick) being the species with the largest number of individuals (583) (Table 2). According to Conafor (2009), the dominance of this species is explained as it is native and from its priority as a species of reforestation in urban areas.

Table 2. Tree species identified in the green areas of *Poza Rica, Veracruz*.

Species	**Common Name**	**Frequency**	
		%	**n**
Ehretia tinifolia L.	*Palo prieto*	58.13	583
Roystonea regia Kunth	*Palma real*	11.76	118
Ficus comosa Roxb	*Benjamina o higuera de Java*	7.28	73
Tabebuia rosea Bertol	*Palo de rosa*	5.78	58
Cocos nucifera L.	*Palmera real o palma de coco*	4.99	50
Swietenia macrophylla King	*Caoba*	4.59	46
Terminalia catappa L.	*Almendro de la india o almendro*	2.89	29
Delonix regia Bojer	*Framboyán*	1.10	11
Parmentiera aculeate Kunth	*Chote*	0.60	6
Pinus spp.	Pine	0.90	9
Other species (7)*		1.99	20
Total		100	1 003

**Citrus aurantifolia* Christm (*Limón agrio*); *Cedrela odorata* L. (*Cedro*); *Enterolobium cyclocarpum* (Jacq) Griseb. (*Orijuelo*); *Manilkara zapota* L. (*Zapote)*, *Tamarindus indica* L. (*Tamarindo*); *Mangifera indica* L. (*Mango*); *Persea gratissima* Gaertn (*Aguacate*).

For the calculation of the IVU from 2010 to 2019 the 251.73 ha (2 517 300 m^2) of green areas and the number of estimated trees (27 869) were considered. The green area and the number of trees were taken as constants from 2010 to 2019 from the longevity of the trees (Conafor, 2009).

Table 3 shows the IVU per m^2 *per capita* and the IVU of the number of trees per inhabitant, in both estimates a decreasing trend can be seen. In this regard, Checa (2016) establishes that the population increase in cities causes the reduction of green areas, which according to Moreno-Mata and Sánchez-Moreno (2018) has an impact on the quality of life of its inhabitants as they do not have access to recreational areas.

Table 3. Urban Green Index in *Poza Rica* city, Veracruz, from 2010 to 2019, estimated per m^2 *per capita* and number of trees per inhabitant.

Year	Population	Green Urban Index	
		m^2 *per capita*	Number of trees per inhabitant
2010	192 920	13.04841	0.14446
2011	194 339	12.95314	0.14340
2012	195 768	12.85859	0.14236
2013	197 208	12.76470	0.14132
2014	198 658	12.67153	0.14029
2015	200 119	12.57902	0.13926
2016	201 580	12.48785	0.13825
2017	203 052	12.39732	0.13725
2018	204 534	12.30749	0.13626
2019	206 027	12.21830	0.13527

According to the WHO criteria, the IVU per m^2 *per capita* in *Poza Rica* is within the recommended parameters (from 9 to 15 m^2 per person) to be for 2019 of 12.21830. However, the IVU of number of trees per inhabitant was much lower (0.13527 in 2019) when the recommended is 0.33333 (one tree for every three inhabitants). According to INEGI (2015), social welfare in *Poza Rica* has declined as a result of the decentralization of *Petróleos Mexicanos* (the Mexican oil company), which caused the activity to be reduced in the region.

Social perception of the ecosystem services provided by green areas

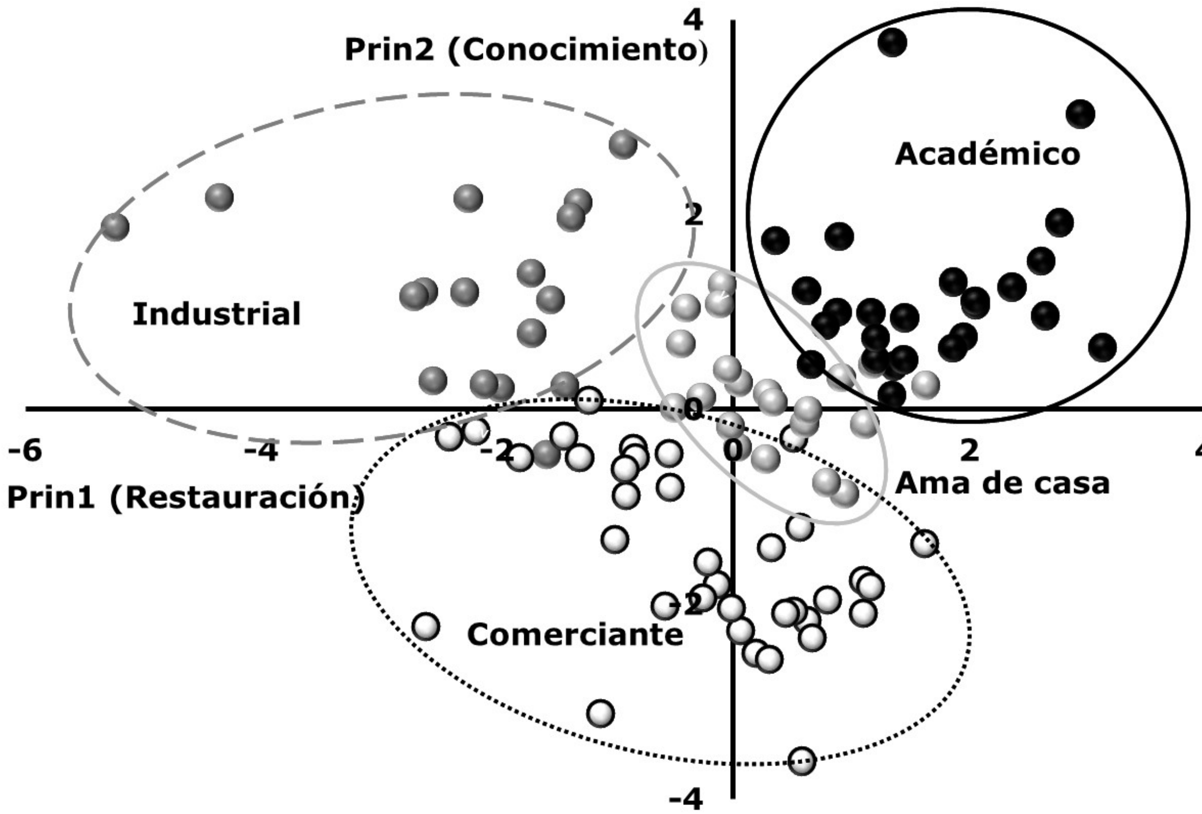
The application of the survey to 100 inhabitants in *Poza Rica* city, distributed in different parts of the city, allowed to collect their perception regarding the recognition and knowledge about the benefits that urban trees have in the regulation of temperature, hydrological cycle and quality of breathable air (ecosystem services).

Four economic activities were distinguished: academic (25), housewives (21), merchants (37) and industrial workers (17).

Of those surveyed, 56 % were women and 44 % men, 100 % recognize, although only 52 % know, the importance of green areas (particularly urban trees) in the regulation of temperature, hydrological cycle and air quality breathable. The total population surveyed said that no tree can have negative effects, provided they are planted in appropriate places and given the correct forestry management. In this regard, Checa (2016) established that, in general, the inhabitants of a city tend to relate green areas to quality of life.

A large number of respondents (83 %) considered that the number of trees in public areas (green areas) of *Poza Rica* is not sufficient, and they propose reforestation schemes to increase them. In addition, 65 % consider that the health of the trees is from regular to bad, and they expressed that the responsibility of maintaining the urban trees is not only of the government but of society, since the benefits are for society. In this regard, Peña *et al.* (2014) and Checa (2016) identified that the protection, conservation or reforestation of green areas in cities is more efficient when carried out by the community than when government agencies intervene.

From the Principal Components Analysis (ACP) it turned out that in the first component (Prin1) the variables related to the knowledge about the ecosystem services that the green areas provide to the cities were grouped and explains 43.6 % of the total variance; the second (Prin2) groups the Importance of the Restoration of the green areas, and explains 32.72 % (Figure 3). The academics and industrialists showed the highest levels of knowledge about the ecosystem services that urban trees provide to the city; however, those related to the industrial sector were the most reluctant to restore. According to IPCC (2014), this reaction can be explained as sustainable industrial processes production costs increase and profits decrease.



Académico = Academic; *Restauración* = Restoration; *Comerciante* = Merchants; *Ama de casa* = Housewives.

Figure 3. Factors on knowledge of ecosystem services (Prin1) and willingness to restore urban trees (Prin2) in the city of *Poza Rica*, *Veracruz*.

The academics showed the greatest interest in restoring urban trees, followed by housewives and merchants. The IPCC (2014) and Checa (2016) postulate that the levels of awareness about current and future environmental problems are higher in the social strata with medium to low remuneration (subsistence), as they are the ones that most suffer climate changes.

A high percentage of respondents (73 %) consider that society has no environmental education, which causes people not to respect urban trees, limiting their development. The remaining 27 % considered that the main constraints for urban tree growth in the city are related to improper forestry management (11 %), lack of water (10 %) and pressure for space due to population growth (6 %). In this regard, Pérez *et al.* (2018) stated that when users of green areas are unaware of the benefits they provide, they tend not to value them and, in many cases, to damage them.

Finally, all respondents are aware that the effects of the current climate such as the intensity in the hot seasons and the irregularity in the rains are due to the loss of the ecosystem services that the green areas provide to the city, since their surface is not enough to the population growth. In this regard, they stated that in the restoration and/or reforestation campaigns, 49 % prefer trees to spare, 26 % trees with showy flowers and 25 % trees with fruits, because they keep the environment fresh, regulate temperature, give beauty to the place and are a source of food.

Conclusions

The green areas in *Poza Rica* city, *Veracruz* are not enough to meet the demand of a population that has increased urban land use by 98 % from 1997 to 2016. The Urban Green Index in m^2 *per capita* (12.21830) and in number of trees per inhabitant (0.13527) with average negative annual growth rate, -0.83 and -0.01 respectively; are the consequence of an urban pressure for new habitable areas where the degree of citizen welfare and urban sustainability is not valued.

Of the surveyed citizens, all recognized the importance of green areas in the city; however, only 52 % know the ecosystem services they provide in the regulation of temperature, hydrological cycle and breathable air quality. Although 100 % are aware that the degradation of the green areas and their insufficient extension in the face of population growth, it contributes to the effects of the current climate such as the intensity in the hot seasons and the irregularity in the rains. The academic sector, housewives and merchants were those who showed greater availability to restore and increase the green areas in the city, propose cooperation schemes where environmental education is contemplated since they consider that the deterioration of the existing green areas occurs because citizens do not respect them.

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Conflict of interests

The authors declare no confict of interests.

Contribution by author

Alberto Santillán Fernández: conceptualization and study design, statistical analysis and writing of the final manuscript; Ilse Joselín Gómez Cruz: data collection in the field and data analysis; Cindy Emiliano Terrazas and Javier Vera López: data analysis and writing of the original manuscript; Benigno Rivera Hernández: making of cartographic maps through GIS and data review; Jaime Bautista Ortega: writing of the original manuscript writing of the original manuscript.

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