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Article

Estructura y diversidad de la vegetación arbórea de un bosque de galería en el estado de Puebla

Structure and diversity of the tree vegetation of a gallery forest in *Puebla* State

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Resumen

Los bosques de galería ocupan franjas transversales a lo largo de las corrientes fluviales, con una estructura y función ecosistémica particular. Un ejemplo de ellos se ubica en la ribera del río Xaltatempa, en Puebla, al que se le analizaron las variables de la vegetación arbórea y su relación con la calidad del agua. Se establecieron seis unidades de muestreo de 1 000 m^2, distanciadas entre sí por 2 km, en las que se midieron e identificaron todos los árboles y arbustos con DAP≥1 cm; con ello se calculó su índice de valor forestal (IVF), índice de valor de importancia (IVI), índice de heterogeneidad de *Shannon-Weaver* (H') e índice de similitud de *Sørensen* (ISS); adicionalmente, se tomaron muestras de agua del río para determinar sus principales características químicas. Los resultados indican diferencia estadística entre sitios (α≤0.05), en la que la especie más importante por su diámetro, altura y cobertura fue *Platanus mexicana* (ÍVF=300.00), como por su dominancia, densidad y frecuencia (ÍVI=182.71). La riqueza específica (H'=0.54) se concentró solo en seis especies: *Alnus acuminata*, *Ligustrum lucidum*, *Parathesis serrulata*, *Pinus patula*, *Platanus mexicana* y *Quercus rugosa*; en cuanto al ISS la combinación pareada de los sitios 4 (1 586 msnm) y 5 (1 536 msnm) hizo coincidir a *Alnus acuminata, Ligustrum lucidum* y *Platanus mexicana* (ÍSS=1.00). La estructura (fragmentada) y la diversidad (muy baja) de la vegetación arbórea del bosque de galería, hacen evidente un efecto antrópico, sin que se manifiesten cambios en la calidad del agua del río Xaltatempa.

Palabras clave: Bosque de galería, índice de heterogeneidad de *Shannon-Weaver*, índice de similitud de *Sørensen*, índice de valor de importancia, valor forestal, vegetación ribereña.

Abstract

The gallery forests occupy transversal strips along the fluvial currents, with a particular ecosystemic structure and function. An example of them is located on the banks of the *Xaltatempa* river, in *Puebla*, which was analyzed the variables of the tree vegetation and its relationship with water quality. Six sampling units of 1 000 m^2, separated from each other by 2 km, were established, in which all trees and shrubs with DBH≥1 cm were measured and identified; with this, their forest value index (FVI), importance value index (IVI), Shannon-Weaver heterogeneity index (H ') and Sørensen similarity index (SSI) were calculated; In addition, water samples were taken from the river to determine its main chemical characteristics. The results indicate statistical difference between sites (α≤0.05), in which the most important species by diameter, height and coverage was *Platanus mexicana* (FVI = 300.00), as by its dominance, density and frequency (IVI = 182.71). The species richness (H '= 0.54) was concentrated in only six species: *Alnus acuminata*, *Ligustrum lucidum*, *Parathesis serrulata, Pinus patula*, *Platanus mexicana* and *Quercus rugosa*; as for the SSI, the paired combination of sites 4 (1 586 masl) and 5 (1 536 masl), coincided with *Alnus acuminata, Ligustrum lucidum* and *Platanus mexicana* (SSI = 1.00). The structure (fragmented) and diversity (very low) of the tree vegetation of the gallery forest make evident an anthropic effect, without having changes in the water quality of the *Xaltatempa* River.

Keywords: Gallery forest, Shannon-Weaver heterogeneity index, Sørensen's similarity index, importance value index, forestry value, riparian vegetation.

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Introduction

The gallery forest is a plant formation characterized by its connection to the bank of a river or equivalent hydrological entity (Santiago *et al.,* 2014); it is a complex and fragile forest community, which plays a fundamental role in ecological, hydrological and biodiversity terms for the conservation of rivers (Meli *et al.,* 2017).

From a physical and structural point of view, they can rarely form pure masses of a single species, so there is an alternation, which, as Sánchez (1986) pointed out, can change at a short distance or appear in combinations of plant associations. In the rivers, the distribution patterns of the species are related to microtopography and edaphic variables (Cortés and Islebe, 2005); while altitudinal gradients are associated with changes in the characteristics of riparian vegetation, including its diversity, its structural and functional properties (Ward *et al*., 2002; Acosta *et al.,* 2008).

In the riparian zones, the tree diversity has a well- defined vertical component, from the surface of the water to the canopy, where distinctive strata of vegetation are found (Granados *et al*., 2006); such diversity can be assessed from the number of tree species in a particular site (Meli *et al.,* 2017). The tree structure is an axis of environmental organization of vital importance for the ecosystem balance of the gallery forests (Romero *et al*., 2014).

It can be defined by the type, number, spatial arrangement and temporal ordering of the elements that constitute it; in this context, the most important are the structures of species, the spatial and dimensional disposition of the ecosystem (Aguirre, 2002). The vertical structure is the way in which the arboreal component is distributed on the vertical axis, that is, the height above the ground. A first tendency assumes that the nature of the canopy is changing, since the forest is growing in patches all the time; according to this, three phases are recognized: clear phase, reconstruction phase and mature phase or equilibrium state (Román *et al*., 2012; Meli *et al*., 2014).

The vertical layout of the arboreal vegetation of the gallery forest is essential to maintain water quality, buffer the sedimentation processes of the riverbeds

(Granados *et al*., 2006), provide protection against soil erosion and provide a habitat for aquatic and terrestrial organisms (Camacho *et al.,* 2006). The horizontal structure refers to the way in which the components of the community are distributed in the land they occupy, this distribution is given mainly by the heights of the trees (Román *et al.,* 2012; Meli *et al.,* 2014).

At present, the assessment of the structure and condition of gallery forests requires detailed information regarding their richness, abundance and ecological diversity, in order to generate management strategies that guarantee the provision of environmental services (Méndez *et al*., 2014; Meli *et al*., 2017). However, rivers and plant communities that develop on their banks have been subjected to intense historical pressure by the various human activities, which has led to its transformation since ancient times (Richardson *et al*., 2007).

Thus, the objective of this research was to describe the structure and diversity of the arboreal vegetation of the gallery forest, and its relationship with the water quality of the *Xaltatempa* River.

Materials and Methods

Study area

The *Xaltatempa* River is located in the *Tetela de Ocampo* municipality in the state of *Puebla*, between 19º43'00 "- 19º57'06" N, and 97º38'42 "- 97º54'06" W; Its altitudinal range is from 1 680 to 1 451 m. It is part of the zone of temperate climates of the *Sierra Norte*, within which, as it moves from south to north, humidity increases (García, 2004). The *Sierra* is made up of hills, mountainous areas and intermontane valleys, and on the northern hydrographic slope of the state of *Puebla*, which is made up of the different partial basins of the rivers that flow into the Gulf of Mexico.

The average annual temperature is 13.9 °C and the average annual rainfall is 1 260 mm (García, 2004). Most of the territory is covered with temperate forests and fog, in which the following species stand out: *Abies religiosa* (Kunth) Schltdl. *et* Cham., *Alnus acuminata* Kunth, *Pinus ayacahuite* Ehren. ex Schltdl., *Pinus patula* Schiede ex Schltdl. *et* Cham., *Pinus teocote* Schiede ex Schltdl. *et* Cham., *Platanus mexicana* Moric., *Quercus oleoides* Schltdl. *et* Cham. and *Quercus rugosa* Née.

Sampling sites

The criteria for the selection of the sampling sites in the river, which has a length of approximately 12 km, were based on their location in the altitudinal elevation between 1 680 and 1 451 m to represent the conditions of the gallery forest. On the riverbank six rectangular plots of 20 × 50 m (1 000 m²) were established, with 10 m wide at each edge of the normal channel of the water flow, which were separated from each other by 2 km. To locate the coordinates of the plots, a receiver of the South S750-G2® global positioning system was used.

Within each one of them, botanical identifications and measurements were made to the trees and bushes: for heights with the Nikon® Laser telephometer /hypsometer; for diameters and sites with Stanley® diametric tape. The identification of species was supported by specialized bibliography (Pennington and Sarukhán, 2005). In order to measure the water quality, two samples of the river water (250 mL) were taken for each sampling site, which were sent to the *Laboratorio Agroindustrial, Suelos, Plantas y Agua*, *Colegio de Postgraduados* (Agroindustrial Laboratory, Soils, Plants and Water, Postgraduate School) (Colpos) to determine its main chemical characteristics: pH, electrical conductivity (EC, µS cm^{-1}), chlorine (Cl, $mmol_c$ L^{-1}), sulfates (SO_4^{2-}, $mmol_c$ L^{-1}), calcium (Ca^{2+}, $mmol_c$ L^{-1}) and sodium (Na^+, mmolc L^{-1}).

Response variables

In order to evaluate the two-dimensional structure of tree vegetation, the forest value index (FVI) was applied, which was calculated as follows (Corella *et al*., 2001):

$$FVI = Relative\ diameter + Relative\ height + Relative\ cover$$

To classify the stages of development of the trees, the following diametric categories were considered: sapling (<5 cm), thicket (6-12 cm), *vardascal* (12-30 cm), high pole (31-50 cm) and *fustal* (> 50 cm).

For tree diversity, the importance value index (IVI) was used, which served to rank the importance of each species in the riparian vegetation, based on the variables of dominance (AR), density (DR) and relative frequency (FR). (Smith and Smith, 2007):

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

The Shannon-Weaver heterogeneity index (H ') was also calculated, which allowed to know the degree of uncertainty, to predict the species to which an individual taken at random in any site belongs; that is, the diversity that exists in the gallery forest (Somarriba, 1999):

$$H' = -\sum_{i=1}^{s} P_i\, ln(P_i)$$

Where:

s = Number of species

P_i = Proportion of individuals of the *i* species

Sørensen similitude index (SSI) was determined too in order to establish the floristic similitude among the sampling sites, based upon the species presenceabsence relation; the assumption is 1 when there is a maximum similitude and 0 when it is minimum (Chao *et al*., 2005):

$$SSI = \frac{2C}{A + B}(100)$$

Where:

A = Number of species in site 1

B = Number of species in site 2

C = Number of common species in sites 1 and 2

Statistical analysis

One-way analysis of variance (ANOVA) was used, with means comparison tests by the Tukey method (α ≤0.05), independent for each sampling site. Excel was used, as well as the multiple response surface optimization model (Montgomery, 2006) with the Minitab® 17 software (Minitab, 2017).

Results and Discussion

Structure of the tree vegetation

In the gallery forest of the *Xaltatempa* River 0.6 ha^{-1} were inventoried, which brought a density of 820 trees ha^{-1} which belong to the following species: *Alnus acuminata* Kunth (*aile*), *Platanus mexicana* Moric. (*papalote*), *Ligustrum lucidum* Ait. (*trueno*), *Pinus patula* Schiede ex Shltdl. & Cham., (*pino llorón*), *Quercus rugosa* Née (*encino*) and *Parathesis serrulata* Sw. (*naranjillo*).

With respect to the FVI, the species that obtained the highest values in all the sites was *Platanus mexicana* (*papalote* or kite), with an average value for the six sampling sites of 244.92. As it can be observed in Table 1, the species with the highest value per site were: *Platanus mexicana*, *Alnus acuminata* and *Pinus patula* (site 1); *Platanus mexicana*, *Alnus acuminata*, *Pinus patula* and *Parathesis serrulata* (site 2); *Platanus mexicana* (site 3); *Platanus mexicana, Ligustrum lucidum* and *Alnus acuminata* (site 4); *Platanus mexicana, Alnus acuminata* and *Ligustrum lucidum* (site 5); *Platanus mexicana, Quercus rugosa, Alnus acuminata* and *Parathesis serrulata* (site 6). Therefore, the structural importance of the gallery forest of the *Xaltatempa* River for its FVI is concentrated in two main species: *Platanus mexicana* (150.65 to 300) and *Alnus acuminata* (12.39 to 145.23).

Table 1. Species with the greatest forest value index (FVI) for the gallery forest of *Xaltatempa* River*, Puebla*.

Site	Species	Dir	Alr	Cor	FVI
1	*Alnus acuminata*	21.21	21.73	7.50	50.45
	Pinus patula	4.43	03.70	0.33	8.46
	Platanus mexicana	74.36	74.57	92.17	241.09
2	*Alnus acuminata*	7.15	9.15	0.71	17.01
	Parathesis serrulata	3.51	5.14	0.17	8.83
	Pinus patula	5.28	4.12	0.39	9.78
	Platanus mexicana	84.06	81.59	98.72	264.38
3	*Platanus mexicana*	100.00	100.00	100.00	300.00
4	*Alnus acuminata*	7.34	9.21	0.80	17.34
	Ligustrum lucidum	11.54	21.46	1.97	34.97
	Platanus mexicana	81.12	69.33	97.24	247.69
5	*Alnus acuminata*	48.21	48.40	48.62	145.23
	Ligustrum lucidum	2.29	1.72	0.11	4.12
	Platanus mexicana	49.51	49.88	51.27	150.65
6	*Alnus acuminata*	2.28	9.86	0.06	12.19
	Parathesis serrulata	1.14	4.23	0.01	5.38
	Platanus mexicana	92.96	72.77	99.77	265.50
	Quercus rugosa	3.63	13.15	0.15	16.93

Dir = Relative diameter; Alr = Relative height; Cor = Relative cover

Platanus mexicana was also the species with the highest FVI (244.92), considered high, when compared to the study conducted by Zarco *et al.* (2010), who when studying the structure and diversity of the arboreal vegetation of the *Agua Blanca* state park in *Tabasco* State, recorded the highest FVI of 79.09 for *Rinorea guatemalensis* S. Watson.

In the studied area was observed a colonization behavior that was manifested in greater proportion by *Platanus mexicana* that, like *Alnus acuminata* and *Pinus patula*, disperse their seeds by wind. According to Sánchez (1986) there is a constant succession caused by the effects of water floods that act as a control factor from their return period and considers that the species are subject to a process of constant colonization.

This is corroborated by the information in Table 2, which shows that the stages of development corresponding to young trees predominate; for *Alnus acuminata*, 35.02 % of *vardascal*; for *Ligustrum lucidum* 51.13 % of *vardascal*; for *Parathesis serrulata*, 56.25% of thicket; for *Pinus patula* 48.95 % of thicket; for *Platanus mexicana* 29.36% of *fustal* and for *Quercus rugosa* 43.35% of thicket.

Table 2. Stages of development of tree species in the gallery forest of the *Xaltatempa* River, *Puebla*.

Species	**Sapling (%)**	**Thicket (%)**	***Vardascal* (%)**	**High pole (%)**	***Fustal* (%)**	**Total (%)**
Alnus acuminata	5.00	19.82	35.02	26.15	14.01	100
Ligustrum lucidum	0.00	29.03	51.13	16.62	3.22	100
Parathesis serrulata	0.00	56.25	43.75	0.00	0.00	100
Pinus patula	0.00	48.95	22.52	28.53	0.00	100
Platanus mexicana	6.66	17.62	18.51	27.85	29.36	100
Quercus rugosa	0.00	43.35	25.64	31.01	0.00	100

As reported by Sanchez (1986) for the *Pilón* River, in this research, pure or codominant conglomerates of *Platanus mexicana*, *Quercus rugosa, Pinus patula, Ligustrum lucidum* and *Alnus acuminata* were recorded; however, the most common thing throughout the gallery forests is that there is no strict dominance for any species.

Bock and Bock (1989) pointed out that some species of gallery forests act in many cases as pioneers, such as *Platanus wrightii* S. Watson, which, despite producing a large number of seedlings, has a high percentage of mortality due to desiccation, together with the loss of shoots during the increasing flow of rivers. This could explain why in the vegetation of the *Xaltatempa* River the percentages of individuals in stages of high *latizal* and *fustal* have not been high, without ceasing to consider that the riparian ecosystem is dynamic and successional. In this sense, Treviño *et al.* (2001) highlighted a strong human influence on this type of forests, where the distribution of their vegetation in favorable areas and their high productivity cause them to be used for harvesting wood. However, Canizales *et al.* (2010) showed that human activities do not always affect the richness, diversity and distribution of the species of a gallery forest.

Diversity of the arboreal vegetation

The diversity of tree species in the *Xaltatempa* River gallery forest is only concentrated in six: *Alnus acuminata* (*aile*), *Ligustrum lucidum* (*trueno*, thunder), *Platanus mexicana* (*papalote*, kite), *Quercus rugosa* (oak), *Pinus patula* (weeping pine) and *Parathesis serrulata* (*naranjillo*); the latter, with a very low density per hectare, is little known in the area and is a shrub less than 7 m high with little or none forest use.

As noted in Table 3, *Platanus mexicana* (182.71) was the most prominent species, by its IVI while *Parathesis serrulata* recorded the lowest value (7.82), which may be due to the fact that it is an introduced species and is currently not dominant in this vegetation and its presence as well as that of *Ligustrum lucidum.*in the gallery forest has not been clarified at all.

Table 3. Descriptive values for the horizontal structure of tree species in the *Xaltatempa* River gallery forest, *Puebla.*

Species	AR (%)	DR (%)	FR (%)	IVI (%)
Alnus acuminata	7.80	15.03	33.75	56.58
Ligustrum lucidum	1.04	6.70	5.40	13.14
Parathesis serrulata	0.40	2.02	5.40	7.82
Pinus patula	0.43	3.85	5.50	9.78
Platanus mexicana	62.39	71.72	48.60	182.71
Quercus rugosa	27.94	0.68	1.35	29.97
Total	100	100	100	300

AR = Relative dominance; DR = Relative density; FR = Relativa frecuency; IVI = Importance value index

Platanus mexicana was the only one found along the banks of the *Xaltatempa* River, where the soils are sandy clay and humid all year round. Although in this river diversity is very low, this single species adds a value of high importance, when compared to that obtained in the research made by Díaz *et al.* (2012), who identified 110 species in the riparian forests of the *Kakada* River in Venezuela, with an importance value of 163.7 for the 10 most outstanding.

However, in the work carried out by Treviño *et al.* (2001) in two rivers in south central *Nuevo León*, Mexico, 25 tree species were recorded, but only four of them were considered dominant according to their importance value *(Taxodium mucronatum* Ten., *Platanus occidentalis* L., *Populus wislizeni* S. Watson and *Salix nigra* Marshall).

This is an important coincidence with the present study for the *Platanus* genus, which is predominant in riparian zones; the values reached for the IVI in the rivers of *Nuevo León, Cabezones* River and *Ramos* River with 0.37 and 1.27, respectively, were extremely low with respect to *P. mexicana* (182.71) only, in the *Xaltatempa* River, *Puebla.*

Regarding the values of diversity per site, number 6 was dominated by *Alnus acuminata, Platanus mexicana, Quercus rugosa* and *Parathesis serrulata*, and recorded the highest H', of 0.73; such site was located in the lowest part of the river at 1 451 masl, while the number 3 located in the middle of the river at 1 617 masl and with a unique predominance of *P. mexicana*, was the one that had the lowest H', equal to zero (Table 4). Despite the value of H 'at site 6, it had the lowest density with 180 ind ha^{-1}; 100 % of them corresponded to *P. mexicana* in the *fustal* stage and *Quercus rugosa* with 33.33 % in thicket. It was site 2 that presented the highest density with 1 350 ind ha^{-1} with mostly young trees (thicket and *vardascal* stages).

Table 4. Values of species richness using the Shannon-Weaver index (H') for the gallery forest of the *Xaltatempa* River, *Puebla*.

Site	Number of species	Density (ind ha^{-1})	Basimetric area (m^2 ha^{-1})	H'
1	3	1 300	143.64	0.59
2	4	1 350	241.74	0.66
3	1	530	158.41	0.00
4	3	790	352.39	0.67
5	3	770	230.30	0.62
6	4	180	144.98	0.73
Mean	3	820	235.72	0.54
DE (σ)	1.61	255	71.48	0.04
CV (%)	12.00	18.83	21.71	20.11

DE = Standard deviation; CV = Coefficient of variation.

The isolated amount corresponded to site 3, located at 1 617 meters above sea level, with only *Platanus mexicana*, a species that was found in all the sites sampled. Thus, the average of different species for the arboreal vegetation proximal to the *Xaltatempa* River was three, with an average density of 820 ind ha^{-1}, which was distributed in the five stages of development sapling, thicket, *vardascal*, high pole and *fustal* (Table 2). In terms of structural composition and diversity, the dominant species for their highest values in H' were *Alnus acuminata* (0.28) and *Platanus mexicana* (0.23). *Ligustrum lucidum, Pinus patula, Quercus rugosa* and *Parathesis serrulata* recorded low H' and population values.

There are few studies carried out in Mexico on the structure and diversity of the gallery forest, in addition to the complication involved in the comparison of the results with other investigations due to the differences in sampling methods. The average value obtained (0.54) for diversity H 'was very low for the arboreal vegetation of the gallery forest of the *Xaltatempa* River, if the index for tropical forests is taken as a reference, between 3.85 and 5.85 (Knight, 1975). In this context, the study conducted by Santiago *et al.* (2014) obtained a Shannon diversity index of 1.8 to 2.6 in the gallery forest of *Sierra de Quila, Jalisco*, with only six dominant species, as in the present study, being *Alnus acuminata* a species in common.

The low diversity H 'of the present study, could also be due to the fact that the vegetation of the *Xaltatempa* River is discontinuous (due to its orographic and topographic position in the *Sierra Norte de Puebla*). In this regard, Camacho *et al*. (2006) when addressing the riparian vegetation of the *Tembembe* River canyon, found that in the upper-middle portion of the river (1 110 to 1 700 masl) the dominant species were *Alnus acuminata, Trema micrantha* L. and *Daphnopsis salicifolia* Kunth, with an average H 'of 1.69; which explains that large discontinuities also influence species diversity.

The low diversity of species was also recorded by Canizales *et al.* (2010) who, when studying the diversity and structure of the arboreal stratum of the gallery forest of the *Ramos* River in the state of *Nuevo León*, detected seven species, but only two of them, *Taxodium mucronatum* and *Platanus occidentalis*. Díaz *et al*. (2012) found in the riverbank forest of the

Kakada River, *Caura* River basin in Venezuela, 110 species represented by ferns, shrubs, trees, lianas, epiphytes and herbs, whose highest H' value was 3.11 in seasonally flooded forests in banks and dykes, with an average density of 738 ind ha^{-1} and an average basal area of 29.4 m^2 $ha^{-1.}$ The latter are lower results than those of a temperate forest, like the one of the present investigation, with average density of 820 ind ha^{-1} and basal area of 235.72 m^2 ha^{-1} (Table 4).

Finally, Fernández *et al.* (2012) recorded a 0.42 H 'index with 53 species in the understory of the gallery forest in the Eastern Plains region of Colombia; they argued a high beta diversity for a value lower than that of the actual study (H'= 0.54). In the sampling sites, the paired combinations show that the combination of sites 4 and 5 was where the highest value was obtained (1.00), which indicates that *Alnus acuminata, Ligustrum lucidum* and *Platanus mexicana* were found in both sites (Table 5). The next value was 0.86 and corresponds to the combinations of the paired sites 1 and 2, where the common species were *Alnus acuminata, Pinus patula* and *Platanus mexicana.*

Table 5. Paired combinations through Sørensen's similitude index (SSI) for the gallery forest of the *Xaltatempa* River, *Puebla*.

Num.	Combination	A	B	A+B	C	SSI
1	Site 1 × site 2	3	4	7	3	0.86
2	Site 1 × site 3	3	1	4	1	0.50
3	Site 1 × site 4	3	3	6	2	0.67
4	Site 1 × site 5	3	3	6	2	0.67
5	Site 1 × site 6	3	4	7	3	0.86
6	Site 2 × site 3	4	1	5	1	0.40
7	Sitio 2 × site 4	4	3	7	2	0.57
8	Site 2 × site 5	4	3	7	2	0.57
9	Site 2 × site 6	4	4	8	3	0.75
10	Site 3 × site 4	1	3	4	1	0.50
11	Site 3 × site 5	1	3	4	1	0.50
12	Site 3 × site 6	1	4	5	1	0.40
13	Site 4 × site 5	3	3	6	3	1.00
14	Site 4 × site 6	3	4	7	2	0.57
15	Site 5 × site 6	3	4	7	3	0.86

In sites 1 and 6 with the same value, the coincident species were *Alnus acuminata* and *Platanus mexicana*; also, in sites 5 and 6, *Alnus acuminata* and *Platanus mexicana* coexisted. In contrast, the lowest index (0.40) was concentrated in two paired combinations between sites 2 and 3, and 3 and 6 with the same species, *Platanus mexicana*.

When applying the SSI in the gallery forest of the *Xaltatempa* River, the average for the six sampling sites was 0.64, which indicates that *Alnus acuminata, Ligustrum lucidum, Platanus mexicana, Quercus rugosa, Pinus patula* and *Parathesis serrulata* were present at least in one site; for this reason, the ISS has a relation of dependence on the total of species in the studied ecosystem and on the number of shared species (Chao *et al*., 2005).

In the paired combinations, sites 4 (1 586 m) and 5 (1 536 m) recorded the highest SSI (1.00). In this regard, Treviño *et al.* (2001) recognized a great similarity between arboreal populations dominated by *Platanus occidentalis, Populus wislizenii, Salix nigra* and *Taxodium mucronatum* located in the *Cabezones* and *Ramos* rivers, with an SSI = 0.649 that is high for 25 registered tree species, but only with four dominant ones. In the case of the *Xaltatempa* River, there were six species and two dominant ones: *Platanus mexicana* and *Alnus acuminata.*

Fernández *et al.* (2012), when studying the biodiversity associated with forest plantations of *Pinus caribaea* Morelet and *Eucalyptus pellita* F. Muell. calculated a high beta diversity (84.1 %). However, the Sørensen quantitative coefficient was low (0.16) for the paired pine *vs* eucalyptus combination. This suggests that, despite sharing a high percentage of species, the abundances were distributed unequally, which makes them structurally different in dissimilar communities, according to the set of conditions and factors that regulate succession.

Camacho *et al.* (2006) obtained a maximum coefficient of similarity of Sørensen (75 %) in sites with a density of 3 200 to 3 300 ind ha^{-1} although these were not the sites that shared the largest number of species (seven) of riparian vegetation of the *Tembembe* River. This situation is similar to that recorded in the present study in which the sites with most coincidences (combination 4 and 5) were not necessarily the ones with the highest density of trees, since the maximum was located at site 2 with 1 350 ind. $^{-1}$ (Table 4), in the upper part of the river, at 1 656 masl.

Water quality

Regarding the chemical results of the water samples of the *Xaltatempa* River, the pH remained within the neutrality with a slight tendency towards alkalinity (7.64 to 7.75), as a result of the transport of various carbonate materials and the tributaries from springs (Table 6). The electrical conductivity increased towards the lower parts of the river and reached up to 695.11 μS cm^{-1}; therefore, the concentration of chlorides, sulfates, carbonates and sodium, also presented a slight increase in direct relation to the EC, which was higher towards the lowest site (1 451 m).

Table 6. Chemical composition of water in six sampling sites in the gallery forest of *Xaltatempa* River, *Puebla*.

Chemical characteristic	Site 1 (1 680 m)	Site 2 (1 656 m)	Site 3 (1 617 m)	Site 4 (1 586 m)	Site 5 (1 536 m)	Site 6 (1 451 m)
pH	7.64	7.68	7.70	7.71	7.73	7.75
EC (μS cm^{-1})	384.50	391.28	440.00	493.77	555.10	695.11
Cl ($mmol_cL^{-1}$)	0.29	0.29	0.31	0.31	0.33	0.33
SO_4^{2-} ($mmol_cL^{-1}$)	0.15	0.24	0.37	0.45	0.50	0.57
Ca^{2+} ($mmol_cL^{-1}$)	0.18	0.18	0.20	0.22	0.23	0.27
Na^+ ($mmol_cL^{-1}$)	0.92	0.99	1.15	1.18	1.20	1.20

The neighboring vegetation of the *Xaltatempa* River was mostly of the evergreen shrub type, with a very low herbaceous species predominance, due to the fact that in the season of greatest rainfall (June to October), the river flow increases at flooding the lower parts of its edges, which favors the anaerobial condition which prevents the development of herbs all year round. Five vertical strata are found, from the presence of individuals at different life stages, but only *Platanus mexicana* and *Alnus acuminata* had commercial size.

In this regard, Colonnello (1990) and Granados *et al.* (2006) stated that only those species adapted to a low oxygen condition in the soil, tolerance to short flood periods and deep root systems can adapt and become successful in a river environment; in the actual study, *Platanus mexicana* and *Alnus acuminata* were the best adapted species.

In the six sampling sites, located between 1 451 and 1 680 masl, the analysis of the water quality of the *Xaltatempa* River did not reveal anthropogenic effects that caused pollution; which suggests that the arboreal vegetation of the gallery forest fulfills its stabilizing function, reduces the threats of erosion and landslides that could result in sedimentation of bodies of water, and thus endanger the conservation of the habitat.

The EC slightly increased towards the lower parts of the river; however, the water samples indicated that the concentration of electrolytes is adequate for human consumption, as well as for agricultural and forestry activity, since drinking water has an EC of 5-50 mS m^{-1}, according to the quality indexes of water (Torres *et al.,* 2009). For this reason, the accumulation of chlorides, sulphates, carbonates and sodium also showed a slight increase in direct relation to the EC (Table 6), towards the lower parts of the river, as a result of the dragging of the various minerals along its 12 km.

Conclusions

The structure of the arboreal vegetation of the gallery forest of the *Xaltatempa* River, measured through diameters, heights and relative coverage, as well as by the stages of development, indicated that the most important species was *Platanus mexicana,* whose presence was recorded throughout the river edge and with higher values than the rest of the species.

The diversity of the arboreal vegetation shows a low specific richness, with only six species, *Alnus acuminata, Ligustrum lucidum, Parathesis serrulata, Pinus patula, Platanus mexicana* and *Quercus rugosa.* By paired combinations, *Alnus* *acuminata, Ligustrum lucidum* and *Platanus mexicana* were always found in the middle part of the river.

The water quality of the *Xaltatempa* River, measured through various chemical parameters, had a tendency of higher concentration of chlorides, sulphates, carbonates and sodium, towards the lower part of the river as a consequence of the dragging of these minerals, where the vegetation is more diverse, without quality demerit for its use and consumption.

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Conflict of interests

The author declares no conflict of interests.

Contribution by author

Jesús Mao Estanislao Aguilar Luna is responsible for the whole study described in this paper.

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