Article

Hemeroby index for the assessment of the conservation of pine-oak forests in a micro-watershed

Bernardo Antonio Marino Maldonado[1]

Marco Antonio Alvarado Vázquez[2]

Ismael Cabral Cordero[3]

Marco Antonio Guzmán Lucio[2]

[1]Centro de Investigación Orográfica. México.

[2]Departamento de Botánica, Facultad de Ciencias Biológicas, Universidad Autónoma de Nuevo León. México.

[3]Departamento de Botánica, Ecología y Manejo de Biodiversidad. Universidad Autónoma Agraria Antonio Narro. México.

*Autor por correspondencia, correo-e: bernardo.marino@gmail.com

Abstract

The conservation of soil and vegetation is essential to maintain the proper functioning of a watershed, because of the fundamental importance that both components have for the hydrological and ecological processes that occur in it. The term hemerobia represents a measure of the anthropic impact on the flora. Applied to vegetation, the index or degree of hemerobia corresponds to the distance or separation between a current plant community and a potential natural one, or its successional state of climax under the total absence of anthropogenic influence.The

conservation status of the pine-oak forest in a micro-watershed of the *Gran Sierra Plegada* (Great Fold Mountains), in the state of *Nuevo León*, was assessed by means of a descriptive study and the estimation of the hemeroby index. This index was obtained by comparing the vegetation of interest with the potential natural vegetation; by evaluating specific indicators, it integrates various aspects of the composition, structure and use of the vegetation into a single value. The index assumes that the changes between the two vegetation statuses are the result of human activity, and therefore it indicates the degree of anthropic impact on the vegetation. The studied forest has various degrees of hemeroby. It can be concluded that the conservation status of the micro-watershed area is not optimal.
Key words: Pine-oak forest, conservation, hemeroby, forest management, micro-watershed, vegetation.

Fecha de recepción/Reception date: 3 de junio de 2016

Fecha de aceptación/Acceptance date: 15 de agosto de 2017.

Introduction

The conservation of soil and vegetation is essential to maintain the proper functioning of a watershed, given the crucial importance of both these components for the hydrological and ecological processes occurring in it.

The soil is the essential biophysical support for the vegetation cover through which rain water seeps. At the same time, vegetation is an element that protects it against hydric and eolic erosion, and an essential factor in the regulation of runoff (Lindholm and Stenbeck, 1993). The loss of both elements has an impact on the entire ecosystem to which they belong, as they affect multiple processes, as well as its biotic and abiotic components, causing the loss of biodiversity or the reduction or annulment of the ecosystem's ability to provide resources and environmental services, including the capture of moisture and the recharge of the aquifers, the regulation of the weather, carbon sequestration, and the abatement of air pollution (Cantú-Ayala *et al.*, 2013).

The vegetation in the *Gran Sierra Plegada* (Great Fold Mountains), within the *Cumbres de Monterrey* National Park (Spanish acronym, PNCM) has been severely affected in the last decades. Between the years 1975 and 1995, the surface area of the forests decreased by 13.68 % (6 858 ha), and that of submontane shrubs, by 29 % (7 457 ha). Conversely, the secondary vegetation increased by 37.86 % (7 063 ha), and the naked soils by 758 % (5 458 ha) (Murillo-Sánchez, 2002). An area of 4 237 ha in the PNCM is estimated to have erosion and loss of soil issues; furthermore, 56 549 ha are particularly susceptible to erosion (Pronatura Noreste A.C., 2011). The main disturbance factors are overgrazing, forest fires and pests; the uncontrolled exploitation of forest resources and the change of land use (Cantú-Ayala *et al.*, 2013).

Although these issues have been recently addressed in over 1 740 ha (Rovalo-Merino *et al*., 2013), the efforts have been centered on those areas that provide an easy access for vehicles. Nevertheless, certain areas that require attention are not easily accessible.

The term and the concept of hemeroby were proposed by Jalas (1955); the word comes from the Greek *hemeros* (cultivated, tamed) and *bios* (life), and it stands for a measure of the anthropic impact on the flora. It was further developed by Sukopp (1972) and Kowarik (1988) and applied at a landscape and ecosystem level (Steinhardt *et al*., 1999; Winter, 2012; Kiedrzynski *et al*., 2014; Walz y Stein, 2014). Applied to vegetation, the hemeroby rate or index corresponds to the distance or separation between a current vegetation community and a potential natural vegetation community, or its peak successional status in the total absence of anthropogenic influence (Walz and Stein, 2014). It is measured by assessing the indicators for the vegetation and the environment, whose integration determines the hemeroby index, expressed in a scale.

Today there is an ongoing debate regarding how many and which markers should be assessed; this is reflected in the diversity of methodologies followed by the various authors who have worked with the hemeroby index so far. For example, Grabherr *et al.* (1998) use 18 markers, including the dead timber volume, and they consider nine possible degrees of hemeroby; Steinhardt *et al.* (1999) incorporate markers for the morphological and chemical features of the soil and consider only seven degrees of hemeroby.

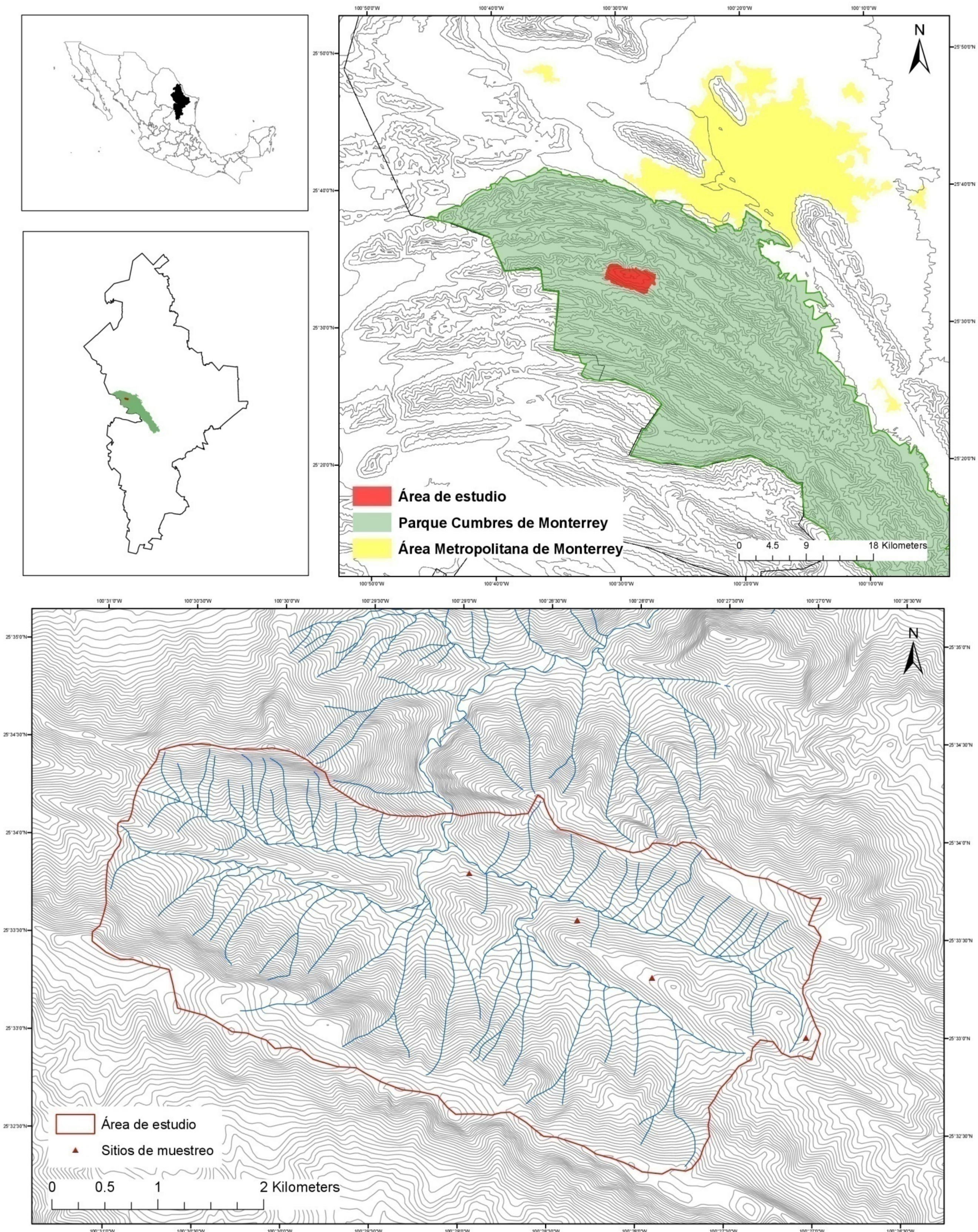
More recent works continue to incorporate changes; thus, Stoll (2007, 2008) modified the method used by Grabherr *et al.* (1998), adapting it to the conditions of the native vegetation of Chile and assessing the conservation status of the vegetation of *Quebrada Honda*, in the Region of *Maule*, Chile (Stoll, 2008); furthermore, he raised the number of markers to eight, with five degrees of hemeroby.

The present study focuses on the assessment of the conservation status of the vegetation of a micro-watershed to which access is difficult, using the hemeroby index to obtain a diagnosis that may contribute to guide management actions. The presence of conditions or risk factors for the vegetation of the micro-watershed was also determined.

Materials and Methods

Study area

The *San Judas-Agua del Toro* micro-watershed is located at the coordinates 25°34’25 N and 100°27’43 W, at the northern end of the Great Fold Mountains, in the Eastern *Sierra Madre*, southwest of the city of Monterrey, in the municipality of *Santa Catarina*, *Nuevo León* (Figure 1). Access to this micro-watershed is difficult, as there are no roads for any type of vehicle, and the terrain is very steep.


N
Área de estudio
Parque Cumbres de Monterrey
Área Metropolitana de Monterrey
0 4.5 9 18 Kilometers
N
Área de estudio
Sitios de muestreo
0 0.5 1 2 Kilometers

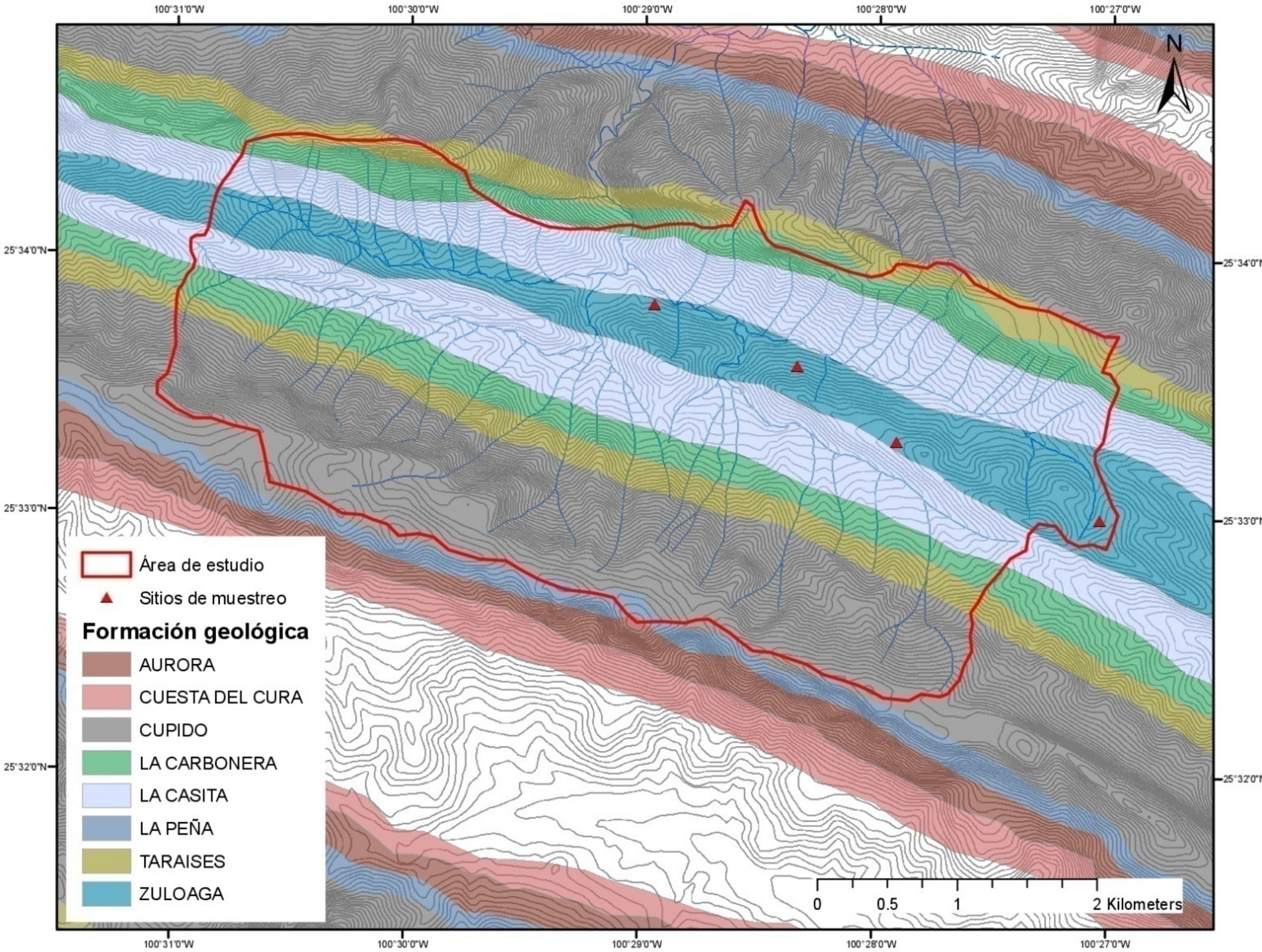
Área de estudio = Study area; Sitios de muestreo = Sampling sites; Parque Cumbres de Monterrey = *Cumbres de Monterrey* National Park; Área Metropolitana de Monterrey = Metropolitan Area of *Monterrey.*

Figure 1. Study area and sampling sites 1, 2, 3 and 4 from left to right.

From the hydrological point of view, the area is a tributary micro-watershed to the sub-basin of the *Santa Catarina* river, which is part of the *Bravo* – *San Juan* River Basin (IAENL, 2011); its surface area is 28.2 km^2, along which recharge areas for the three hydrogeological units of the *Campo Buenos Aires* aquifer – the main source of underground water for *Monterrey* and its metropolitan area– are located (De León-Gómez *et al*., 1998; Masuch-Oesterreich *et al*., 2001; Conagua, 2009; ITESM, 2009; Conagua, 2011); it is characterized by exhibiting a deficit over its mean annual recharge (Conagua, 2011).

The Great Fold Mountains are an orographic system formed by sedimentary rocks of the Mesozoic era corresponding to geological formations that have their origin in the ocean of the higher Jurassic and Cretaceous periods (SGM, 2008); there are, besides, continental alluvial deposits of the Tertiary and Quaternary periods of the Cenozoic era.

The *Campo Buenos Aires* aquifer consists of three hydrogeological units located in certain sets of those geological formations: the Cretaceous Unit, in the limestone of the *Cupido, Aurora* and *Cuesta del Cura* formations; the Jurassic Unit, in the limestone of the *Zuloaga* formation, and the Alluvial Unit, on the gravel of the alluvial deposits (Conagua, 2009). Outcrops of the *Cupido* and *Zuloaga* formations and alluvial deposits were observed in the studied micro-watershed; therefore, it is a recharge area for the three aquifer units (Figure 2).

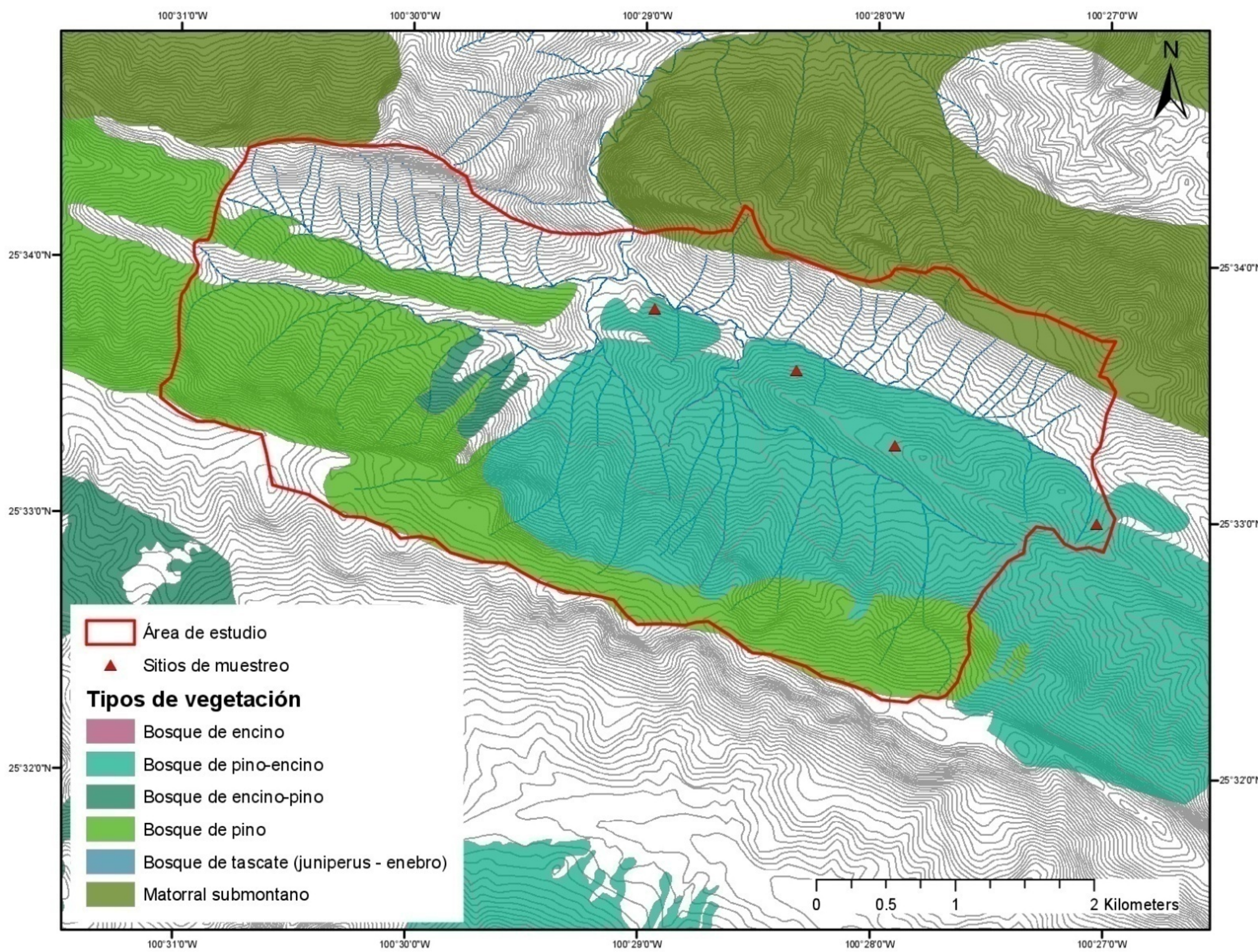


Área de estudio = Study area; Sitios de muestreo = Sampling sites; Formación geológica = Geological formations

Figure 2. Geological formations in the study area and sampling sites.

The area has two different types of climate: BS_0hw, dry semi-warm, and BS_1kw, semi-dry temperate; the mean annual precipitation ranges between 432.3 mm and 688.6 mm, and the mean annual temperature, between 14.0 and 20.7 °C (SMN, 2012, 2013). The predominant vegetation is the pine-oak forest, followed by submontane and xerophytic shrubs (Pronatura Noreste A.

C., 2011) (Figure 3). The occurring soil types are lithosols, regosols, rendzines and xerosols (Inegi, 1986).



Área de estudio = Study area; Sitios de muestreo = Sampling sites; Tipos de vegetación = Vegetation types; Bosque de encino = Oak forest; Bosque de pino-encino = Pine-oak forest; Bosque de encino pino = Oak-pine forest; Bosque de pino = Pine forest; Bosque de táscate (juniperus-enebro) = Juniper forest; Matorral submontano = Submontane shrub

Figure 3. Vegetation types in the study area and sampling sites.

Stoll's method (2007) was chosen to estimate the hemeroby index, due to the similarities in topography and vegetation type (mountain canyon and temperate forest) between the area studied by Stoll and the present area, as well as because it is the most simplified among the methods reviewed in the literature.

Directed stratified sampling was used, according to three criteria: geological formation (*Zuloaga* Formation), vegetation (mixed pine-oak forest) and altitude (1 460 m, 1 660 m, 1 860 m, and 1 960 m). Four sampling sites were established (figures 1, 2 and 3) encompassing the total longitude and four different altitudes in the mixed forest strip located in the *Zuloaga* Formation.

A 20 m x 10 rectangular plot established longitudinally to the curves of the terrain was used to characterize the vegetation in each sampling site. This sampling intensity was due to limitations in time and mobility resulting from the difficulty to access the work area. However, when possible, representative sites of the physiognomic variations observed in the forest strip of interest were carefully selected. The arboreal stratum in the total area of each plot (200 m^2), the shrub stratum in two cater-cornered inner 25 m^2 subplots, and the herbaceous stratum in five 1 m^2 inner subplots were considered. All individuals that were not branched from the base were regarded as belonging to the arboreal stratum. The following attributes were registered: species, height and crown diameter, for trees and shrubs, and species and cover only, for the herbaceous vegetation. The frequency, density, cover and importance values were estimated for each taxon; these data were then used to calculate the Shannon-Wiener diversity and equity index, the Margalef´s richness index, and Simpson's dominance (Mostacedo and Fredericksen, 2000; Melo and Vargas, 2002).

The hemeroby index was estimated for each sampling site through the aggregation and average of eight criteria or markers assessed per site (Stoll, 2007): the composition of the arboreal stratum (1), the composition of the shrub and herbaceous strata (2), the type of regeneration of tree species (3), the use of the vegetation (4), the use of the environment (5), the stratification (6), the diversity of species of the arboreal stratus (7), and the diversity of species of the shrub and herbaceous strata (8).

The comparisons between the assessed vegetation and the corresponding natural potential vegetation for the various criteria were made based on the descriptions of the mixed pine-oak forest community cited in descriptive studies carried out in the region (Rojas-Mendoza, 1965; Marroquín, 1968; Rzedowski, 1978; Baca-Venegas, 2000; Jiménez *et al.*, 2001).

Criterion 1 (composition of the arboreal stratus). The current and potential covers of each species were compared; the presence or absence of taxa, the expected potential cover, and the cover of neophyte species were included.

A basic table of cover categories (Table 1) was used to establish potential cover categories according to the consulted information (Table 2). Based on the cover obtained in field, a current cover category was assigned to each registered arboreal taxon. The categories obtained from the comparison were later correlated with a matrix (Table 3).

Table 1. Cover categories of arboreal species.

	Current	Cover		Potential	Cover
1a	Dominant AS	> 50 %	1p	Dominant AS	> 50 %
2a	Subdominant AS	26 - 50 %	2p	Subdominant AS	26 - 50 %
3a	Mixed AS	6 - 25 %	3p	Mixed AS	6 - 25 %
4a	Dispersed AS	1 – 5 %	4p	Dispersed AS	1 - 5 %
			5p	Rare neophyte AS	1 - 5 %
0a	Absent (potentially expected) AS	0 %	6p	Abundant neophyte AS	> 5 %

Table 2. Potential natural composition of the mixed pine-oak forest.

Category	Cover	Arboreal species (EA)
1p	> 50 %	*Pinus spp.*
2p	26 – 50 %	*Quercus spp.*
3p	6 – 25 %	*Arbutus xalapensis* Kunth
4p	1 – 5 %	*Prunus serotina* Ehrh., *Chiococca pachyphylla* Wernham
5p	1 – 5 %	*Decatropis bicolor* (Zucc.) Radlk.
6p	> 5%	
0a	0 %	

Table 3. Matrix for calculating the Retention Value (RV).

	1p	2p	3p	4p	5p	6p
1a	0	-0.5	-1	-1.5	-2	-2
2a	-0.5	0	-0.5	-1	-1.5	-2
3a	-1	-0.5	0	-0.25	-0.5	-0.5
4a	-1.5	-1	-0.25	0	-0.25	-0.25
0a	-1.5	-1	-0.5	0	0	0

The correlation value for each cover category was added to obtain the value of Criterion 1.

$$C1 = RV_{n1} + RV_{n2} + RV_{nx} \ldots.$$

Where:

C1 = Criterion 1

RV_n = Retention value of species "*n*"

Criterion 2 (composition of the shrub and herbaceous strata). The presence and relative cover of species indicating disturbance in both strata were assessed; the neophyte and native species that are foreign to the assessed vegetal community were considered, as were the species that indicate changes in the cover of the respective stratum, based on the information available in the literature. Specific categories were established for the comparison (Table 4). A cover index was obtained for each of the taxa belonging to one of the categories, based on a matrix (Table 5).

Table 4. Marker species in the shrub and herbaceous strata.

Neophyte	Marker species foreign to the community	Marker species indicating changes in the degree of cover
	Koeberlinia spinosa Zucc. *Leucaena greggii* S.Watson	*Gymnosperma glutinosum* Less. *Ageratina espinosarum* (A.Gray) R.M.King & H.Rob. *Litsea novoleontis* Bartlett
Pp1 = 1	Pp2 = 0.5	Pp3 = 0.5

Table 5. Correlation table for the cover index of marker species.

Degree of cover	Cover index
≤ 5 %	1
> 5 - 17.5%	2
> 17.5 - 37.5%	3
> 37.5 - 62.5%	4
> 62.5%	5

The disturbance index was then calculated using the following formula:

$$Di = \left(\sum(Dp \times Ci)\right) \times \frac{\sum Cover\ of\ marker\ \ sp.}{\sum Cover\ of\ \ shrub\ and\ herbaceous\ spp.}$$

Where:

Di = Disturbance index

Dp = Disturbance probability

Ci = Cover index

Finally, the value of the criterion was determined by correlating the disturbance index with the values shown in Table 6.

Table 6. Correlation table for the disturbance index.

Disturbance index	Criterion 2
< 0.001	5
0.001 – 2.0	4
> 2.0 – 5.0	3
> 5.0 – 10.0	2
> 10.0	1

Criterion 3 (type of regeneration of arboreal species). The relative regeneration cover of each present arboreal species was estimated, by counting the young individuals and the seedlings. According to the classification shown in Table 7, each taxon was assigned a representative factor.

Table 7. Types of regeneration and corresponding factors.

Types of regeneration	Factor
Typical AS	0.5
Foreign/native AS	0.3
Neophyte AS	0.1

The value of the criterion is the sum of the products of the relative covers of each species in regeneration and the corresponding factor, as shown in the following formula:

$$C3 = \sum(Relative\ cover \times Factor)$$

Criterion 4 (use of vegetation). The intensity, type and use history of the vegetation in the study area were estimated based on personal communications with the owner of the plot and direct in-field observation of the factors involved in each use type. For example, in order to evaluate the intensity in the use type "grazing", the presence and number of cattle, the perceptible compacting of the soil, the appearance of the vegetation and the disturbance marker species brought about by overgrazing. The correspondence factors were established (Table 8).

Table 8. Aspects of the use of the vegetation and corresponding factors.

Intensity	F1	Use type	F2	History of use	F3
Low	1	Final forestry use	3	Current (≤ 10 years)	1
		Preparatory forestry use	1		
Medium	2	Grazing	2	Historical (> 10 years)	0.5
		Agriculture	2.5		
High	3	Tourism	1	Both	1.5
		Others	1		

The product of the factors is the Influence Number, which corresponds with a specific criterion value (Table 9).

Table 9. Correspondence for the Influence Number.

Influence number	Criterion 4
≤ 1	5
1 to 6	4
6 to 11	3
11 to 16	2
> 16	1

Criterion 5 (use of the environment). The type of use of the environment around the site at a distance of not more than 1 km was determined based on in-field observations. A criterion value corresponds to each use type (Table 10).

Table 10. Uses of the environment in the study area.

Use	Criterion
Adult native forest without perceptible use	5
Semi-dense or semi-open forest with evident uses	3
Surface areas used for agriculture or forestry	1

Criterion 6 (stratification). The observed structure was compared with the potential structure cited in the literature for the same type of vegetation, assigning it a class based on the stratification types shown in Table 11.

Table 11. Stratification classification.

Stratification class	Criterion
Typical stratification	5
Modified stratification	4 to 2
Non-corresponding stratification	1

Criterion 7 (richness of arboreal species). The registered number of arboreal species was contrasted with the minimum number and with the most frequent number of arboreal taxa under natural conditions, as documented in the bibliography (Table 12).

Table 12. Species intervals for comparison.

Species intervals	**C7 and C8**
Current number of species < minimum number	1
Minimum number ≤ current number < most frequent number	3
Current number ≥ most frequent number	5

Criterion 8 (richness of species of the shrub and herbaceous strata). The registered number of species in the shrub and herbaceous strata was compared with the minimum number and with the most frequent number of species under natural conditions as reported in the literature, as shown in Table 12.

Once the criteria were obtained, their values were averaged in order to estimate the index or degree of hemeroby by sampling site. The average of the degrees in the sampled sites was subsequently calculated in order to estimate the overall hemeroby index for the pine-oak forest in the study area. The index was then interpreted according to the classification shown in Table 13.

Table 13. Definition of the degrees of hemeroby.

Degree of hemeroby	**Definition**	**Value**
α-Euhemerobic	Without the presence of the natural component (a very strong unilateral influence)	1
β-Euhemerobic	Distant from the natural (a strong, ongoing influence through time)	2
Mesohemerobic	Semi-natural (evident, periodical cultural influence)	3

Oligohemerobic	Almost natural (low influence, clearly recognizable natural vegetation)	4
Ahemerobic	Natural (null/insignificant cultural influence)	5

The conditions and risk factors for the vegetation in the watershed were determined through in-field observation and direct communication with the owner of the plot, who was requested information regarding the current and past activities carried out in the plot and their degree of intensity.

Results

Characterization of the vegetation

A total of 36 species were registered, corresponding to 34 genera and 23 families (tables 14 and 15). The arboreal stratus of the vegetation is dominated by *Quercus canbyi* Trel. (index of importance value: 92.51), *Pinus arizonica* Engelm. (64.17) and *Quercus laeta* Liebm. (55.98); and the shrub stratum is dominated by *Rhus virens* Lindh. ex A.Gray (51.73), *Leucaena greggii* S.Watson (48.50), and *Decatropis bicolor* (Zucc.) Radlk. (46.53). In the herbaceous stratum, the most dominant species are *Gymnosperma glutinosum* Less. and *Ageratina espinosarum* (A.Gray) R.M.King & H.Rob. (tables 16, 17 and 18).

Table 14. Species registered in the study area.

Family	**Species**
Acanthaceae	*Ruellia* sp.
Agavaceae	*Agave montana* Villarreal
Amaranthaceae	*Chenopodium* sp.

Anacardiaceae	*Rhus virens* Lindh. ex A.Gray
	Rhus integrifolia Benth. & Hook. f. ex S. Watson
Apocynaceae	*Cynanchum maccartii* Shinners
Asteraceae	*Ageratina espinosarum* (A.Gray) R.M.King & H.Rob.
	Dyssodia pinnata (Cav.) B.L. Rob.
	Gymnosperma glutinosum Less.
	Parthenium sp.
Berberidaceae	*Berberis trifoliolata* Moric.
Cactaceae	*Opuntia* sp.
Ericaceae	*Arbutus xalapensis* Kunth
	Comarostaphylis polifolia (Kunth) Zucc. ex Klotzsch
Euphorbiaceae	*Croton incanus* Kunth.
Fabaceae	*Leucaena greggii* S. Watson
	Senna lindheimeriana (Scheele) H.S.Irwin & Barneby
Fagaceae	*Quercus canbyi* Trel.
	Quercus laeta Liebm.
Koeberliniaceae	*Koeberlinia spinosa* Zucc.
Lauraceae	*Litsea novoleontis* Bartlett
Liliaceae	*Dasylirion texanum* Scheele
Orobanchaceae	*Castilleja lanata* A. Gray
Pinaceae	*Pinus arizonica* Engelm.
Poaceae	*Aristida* sp.
	Bouteloua gracilis (Wild. ex Kunth) Lag. ex Griffiths
	Muhlenbergia sp.
Pteridaceae	*Astrolepis integerrima* (Hook) D.M. Benham & Windham
	Cheilanthes sp.
	Notholaena sp.
Rosaceae	*Cercocarpus mojadensis* CK Schneid.
	Lindleya mespiloides Kunth
	Prunus serotina Ehrh.
Rubiaceae	*Chiococca pachyphylla* Wernham
Rutaceae	*Decatropis bicolor* (Zucc.) Radlk.

Selaginellaceae	*Selaginella lepidophylla* (Hook. & Grev.) Spring

Table 15. List of species by growth stratum in the study area.

Stratum	Family	Species
Arboreal	Fabaceae	*Leucaena greggii* S.Watson
	Fagaceae	*Quercus canbyi* Trel.
		Quercus laeta Liebm.
	Ericaceae	*Arbutus xalapensis* Kunth
	Pinaceae	*Pinus arizonica* Engelm.
	Rosaceae	*Prunus serotina* Ehrh.
	Rubiaceae	*Chiococca pachyphylla* Wernham
Shrub	Anacardiaceae	*Rhus integrifolia* Benth. & Hook. f. ex S. Watson
		Rhus virens Lindh. ex A.Gray
	Agavaceae	*Agave montana* Villareal
	Berberidaceae	*Berberis trifoliolata* Moric.
	Cactaceae	*Opuntia* sp.
	Ericaceae	*Arbutus xalapensis* Kunth
		Comarostaphylis polyfolia (Kunth) Zucc. ex Klotzsch
	Fabaceae	*Leucaena greggii* S.Watson
	Koeberliniaceae	*Koeberlinia spinosa* Zucc.
	Lauraceae	*Litsea novoleontis* Bartlett
	Liliaceae	*Dasylirion texanum* Scheele
	Rosaceae	*Lindleya mespiloides* Kunth
	Rutaceae	*Decatropis bicolor* (Zucc.) Radlk.
Herbaceous	Acanthaceae	*Ruellia* sp.
	Amaranthaceae	*Chenopodium* sp.
	Apocynaceae	*Cynanchum maccartii* Shinners
	Asteraceae	*Ageratina espinosarum* (A.Gray) R.M.King & H.Rob.
		Dyssodia pinnata (Cav.) B.L. Rob.
		Gymnosperma glutinosum Less.
		Parthenium sp.
	Euphorbiaceae	*Croton incanus* Kunth
	Fabaceae	*Senna lindheimeriana* (Scheele) H.S.Irwin & Barneby

Orobanchaceae	*Castilleja lanata* A. Gray
Poaceae	*Aristida* sp. *Bouteloua gracilis* (Wild. ex Kunth) Lag. ex Griffiths *Muhlenbergia* sp.
Pteridaceae	*Astrolepis integerrima* (Hook.) D.M. Benham & Windham *Cheilanthes* sp. *Notholaena* sp.
Selaginellaceae	*Selaginella lepidophylla* (Hook. & Grev.) Spring

Table 16. Importance and diversity values for the species of the arboreal stratum in the study area.

Species	Absolute abundance	Relative frequency	Relative density	Relative dominance	I.V.I.
Quercus canbyi Trel.	41	23.08	42.71	26.72	92.51
Pinus arizonica Engelm.	21	23.08	21.88	19.22	64.17
Quercus laeta Liebm.	15	15.38	15.63	24.97	55.98
Arbutus xalapensis Kunth	5	15.38	5.21	12.72	33.31
Chiococca pachyphylla Wernham	3	7.69	3.13	2.87	13.68
Prunus serotina Ehrh.	2	7.69	2.08	3.44	13.22
Leucaena greggii S.Watson	8	7.69	8.33	10.06	26.08
S = 7	N = 95				
Richness (Margalef index)				1.3	
Diversity (Shannon-Wiener index)				1.5	
Dominance (Simpson's index)				0.2	
Equity				0.8	

Table 17. Importance and diversity values for the species of the shrub stratum in the study area.

Species	Absolute abundance	Relative frequency	Relative density	Relative dominance	I.V.I.
Leucaena greggii S.Watson	88	10.34	27.50	10.65	48.50
Decatropis bicolor (Zucc.) Radlk.	94	10.34	29.38	6.81	46.53
Rhus virens Lindh. ex A.Gray	37	13.79	11.56	26.37	51.73
Rhus integrifolia Benth. & Hook. f. ex S.	3	3.45	0.94	6.93	11.31

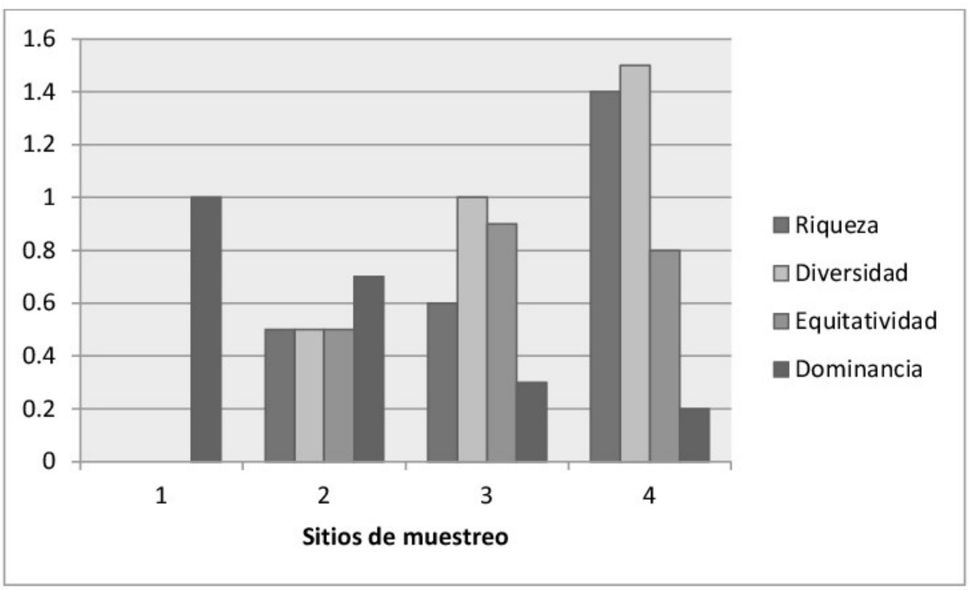
Watson					
Arbutus xalapensis Kunth	1	3.45	0.31	0.42	4.19
Berberis trifoliolata Moric.	22	13.79	6.88	13.02	33.69
Cercocarpus mojadensis CK Schneid.	9	6.90	2.81	6.33	16.04
Prunus serotina Ehrh.	2	3.45	0.63	0.46	4.54
Koeberlinia spinosa Zucc.	16	3.45	5.00	9.11	17.56
Comarostaphylis polyfolia (Kunth) Zucc. ex Klotzsch	12	6.90	3.75	11.17	21.82
Litsea novoleontis Bartlett	26	10.34	8.13	6.25	24.72
Lindleya mespiloides Kunth	3	3.45	0.94	0.49	4.88
Dasylirion texanum Scheele	1	3.45	0.31	0.05	3.81
Agave montana Villareal	4	3.45	1.25	1.19	5.89
Opuntia sp.	3	3.45	0.94	0.72	5.11
S = 15	N = 169				
Richness (Margalef index)				2.4	
Diversity (Shannon-Wiener index)				1.9	
Dominance (Simpson's index)				0.1	
Equity				0.7	

Table 18. Diversity values for the species of the herbaceous stratum in the study area.

Species	**Absolute abundance**	**Relative frequency**	**Relative density**
Selaginella lepidophylla (Hook. & Grev.) Spring	851	6.06	80.21
Gymnosperma glutinosum Less.	28	12.12	2.64
Ageratina espinosarum (A.Gray) R.M.King & H.Rob.	23	3.03	2.17
Muhlenbergia sp.	70	12.12	6.60
Bouteloua gracilis (Wild. ex Kunth) Lag. ex Griffiths	6	3.03	0.57
Aristida sp.	8	6.06	0.75
Cheilanthes sp.	19	6.06	1.79
Astrolepis integérrima (Hook.) D.M. Benham & Windham	5	3.03	0.47
Notholaena sp.	1	3.03	0.09
Senna lindheimeriana (Scheele) H.S.Irwin & Barneby	1	3.03	0.09
Croton incanus Kunth	3	6.06	0.28
Castilleja lanata A. Gray	1	3.03	0.09
Dyssodia pinnata (Cav.) B.L. Rob.	12	6.06	1.13

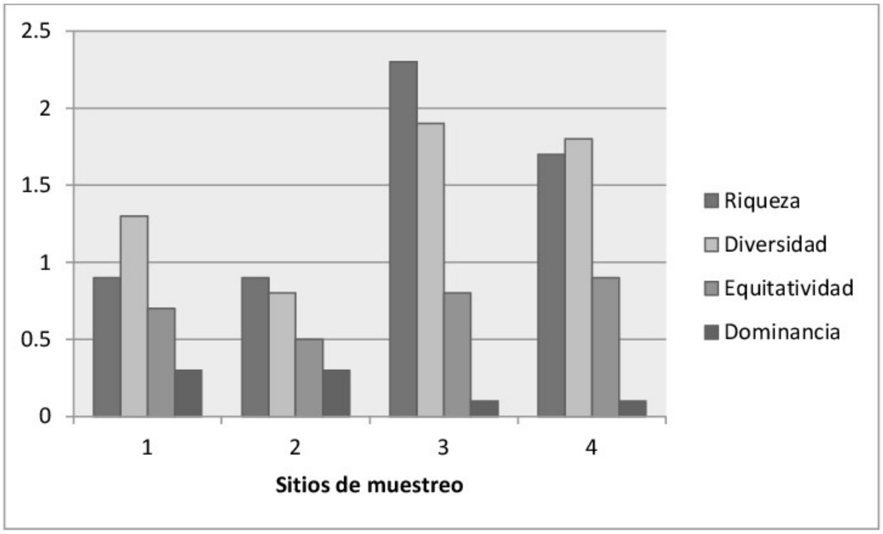
Parthenium sp.	22	6.06	2.07
Ruellia sp.	7	6.06	0.66
Chenopodium sp.	2	3.03	0.19
Cynanchum maccartii Shinners	2	3.03	0.19
S = 17	N = 1061		
Richness (Margalef index)			2.4
Diversity (Shannon-Wiener index)			0.9
Dominance (Simpson’s index)			0.1
Equity			0.3

The ecological indices estimated by stratum for each sampling site are shown in figures 4, 5 and 6.



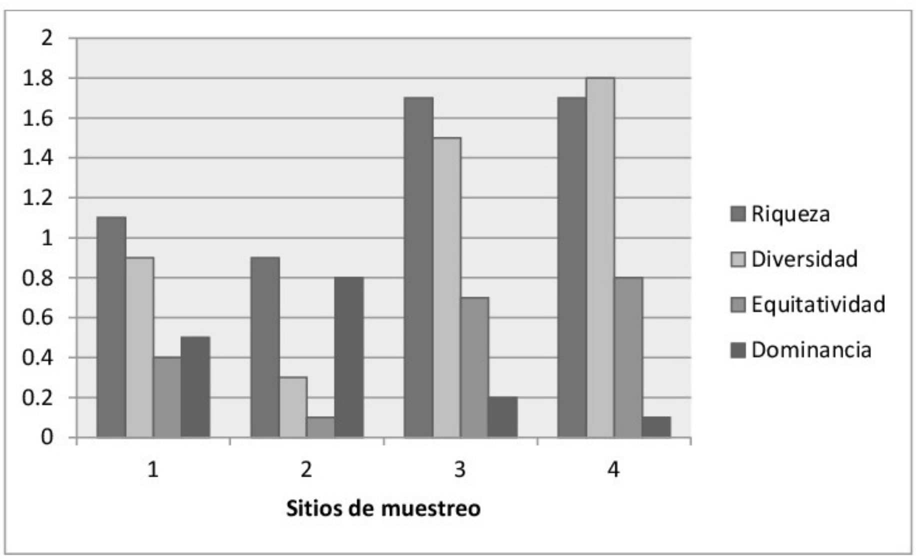
Sitios de muestreo = Sampling sites; Riqueza = Richness; Diversidad = Diversity; Equitatividad= Equity; Dominancia = Dominance

Figure 4. Ecological indices of the arboreal stratum by sampling site.



Sitios de muestreo = Sampling sites; Riqueza = Richness; Diversidad = Diversity; Equitatividad= Equity; Dominancia = Dominance

Figure 5. Ecological indices of the shrub stratum per sampling site.

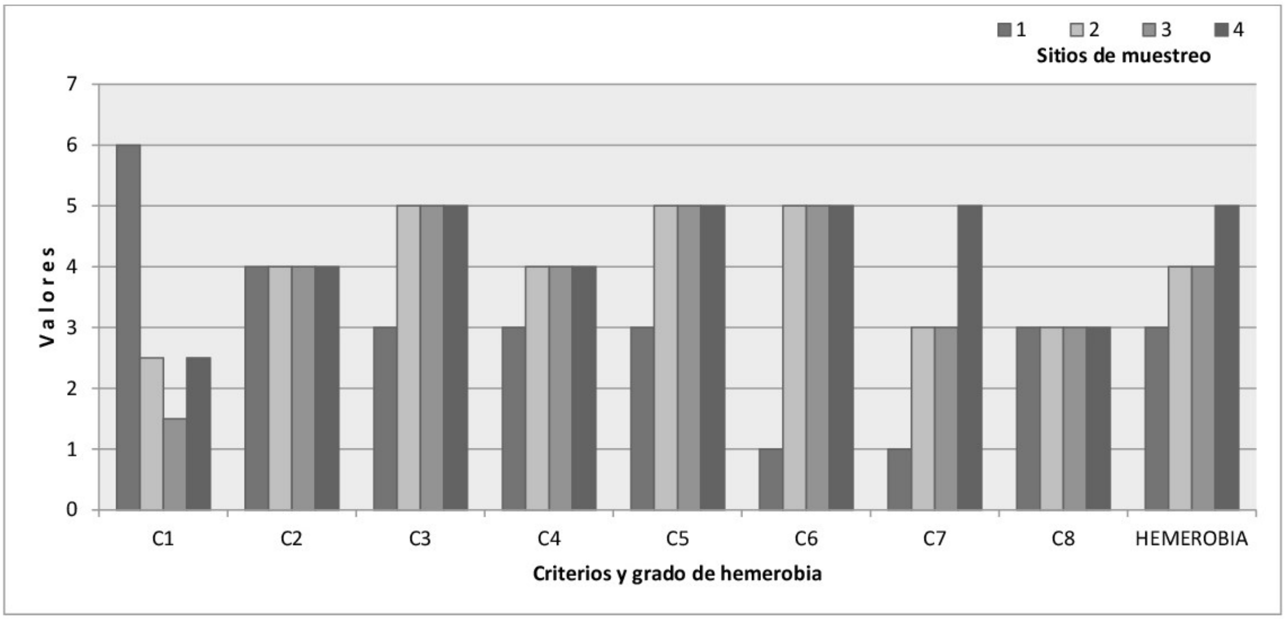


Sitios de muestreo = Sampling sites; Riqueza = Richness; Diversidad = Diversity; Equitatividad= Equity; Dominancia = Dominance

Figure 6. Ecological indices of the herbaceous stratum by sampling site.

Conservation status of the vegetation

Figure 7 shows the criteria and estimated degrees of hemeroby per sampling site.



Valores = Values; Sitios de muestreo = Sampling sites; Criterios y grados de hemorobia = Criteria and degrees of hemeroby; Hemorobia = Hemeroby.

Figure 7. Values of the criteria and degrees of hemeroby per sampling site.

Based on the average of the degrees of hemeroby of all the sampling sites, an overall degree of hemeroby of 4 was estimated. This indicates that the vegetation corresponds to an oligohemerobic or almost natural site, in which there is a low anthropic influence and a clearly recognizable natural vegetation.

Risk conditions for the vegetation

Three conditions or risk factors were observed in the study area: 1) the presence of cattle, which has existed in the micro-watershed for several decades –cattle and goats in the past, but currently only cattle (Figure 8); 2) the existence of areas with a partial or total loss of the vegetation cover, hydric erosion and erosion gullies (Figure 9); the surface of these areas was estimated in more than 45 ha, distributed in a stretch of 4 km, along which a gradient was observed in the intensity of the loss of vegetation cover; 3) the presence of patches of trees of the *Pinus* genus, with symptoms of a likely infestation by debarker insects, *Dendroctonus* spp. (Figure 10).

Figure 8. Presence of cattle in the study area.

Figure 9. Panoramic view of areas with loss of vegetation cover.

Figure 10. Patch with trees of the *Pinus* spp. with symptoms of infestation by *Dendroctonus* spp.

Discussion

Although the estimated overall hemeroby index indicates that its vegetation has a low anthropic impact, there was a variation between the estimated indices for the sampling sites. The degree of hemeroby increases from site 1 to site 4, indicating that the anthropic impact on the vegetation diminishes from site 1 to site 4 (Figure 7). This variation seems to be in accordance with the geographic gradient as to the intensity of the aforementioned loss of vegetation cover.

At the same time, this gradient seems to be related to the presence of a nucleus of historical and current livestock activity within the micro-watershed; as for this nucleus, site 1 is the closest (less than 1 km away from an abandoned pasture), and site 4 is the most distant; this may be a possible explanation of the increase in values of hemeroby as the distance from the said nucleus increases.

This is reflected in the correspondence between the hemeroby values and those estimated for diversity in the various growth strata in each sampling site. Thus, the richness, diversity and equity increase generally from site 1 to site 4, while the dominance value decreases (figures 4, 5 and 6).

Marker species for disturbance, such as *Gymnosperma glutinosum* and *Leucaena greggii* (González-Elizondo, 1996; Estrada-Castillón *et al*., 2013) were found in all the sites, most abundantly in site 1. The former is dominant in the herbaceous stratum, and the latter, in the shrub-arboreal stratum.

The identification of *Koeberlinia spinosa* –not characteristic of pine-oak forests, but, rather, of the thorny bushes of *Tamaulipas*, which are located in sites subjected to semiarid climatic conditions– is worth mentioning. Its presence was considered to be an indication of disturbance.

On the other hand, the areas with loss of vegetation cover may be providing positive feedback to anthropogenic impact, as they exert an influence on the rest of the vegetation through the border effect. These areas are characterized by changes both in the abiotic (air humidity, humidity content and temperature of the soil, degree of insolation, erosion foci, etc.) and the biotic characteristics, such as the favored presence of neophyte species and a reduction of the seed bank (Peña-Becerril *et al*., 2005; Santos and Tellería, 2006). Again, site 1 is the closest one to the areas with the most notorious desertification process.

A personal communication with the owner of the study area corroborated the presence, in recent decades, of cattle and goats in large numbers; today there are only cattle. Areas with a loss of vegetation cover exhibit characteristics that are typical of areas that are affected by trampling by cattle. Both these facts and those mentioned above justify the hypothesis that uncontrolled grazing activities have been and continue to be the main cause of estimated anthropic impact on the vegetation in the study area.

Although the authors regard the approach to the hemeroby index presented herein as useful, they recommend caution in considering the effectiveness of the method used for its estimation. On one hand, as we mentioned at the beginning of this paper, there is disagreement between authors as to the markers that should be assessed for its estimation. On the other hand, and independently from this fact, since the estimation is based on a comparison between the studied vegetation and its potential natural counterpart free of impact, as a reference point, the availability of descriptive studies of the latter is required; this is difficult or impossible to attain due to the reduced surface area of primary vegetation present in Mexico. For this reason, potential natural conditions that are mere assumptions and cannot be proven must be used as a reference.

Furthermore, although the outcome of the present work is considered to be pertinent, in an illustrative sense, with regard to the application of the hemeroby index, we are aware of its intrinsic limitations, which are due to the limited sampling effort carried out resulting from the difficulties of access and mobility in the work area.

It is our hope that, as the hemeroby index gains greater diffusion among the Mexican scientific community and is applied by more researchers, its use will be assessed, proposed and perfected in such a way that its application may contribute to the obtainment of essential information for implementing actions for the management and conservation of the vegetation of Mexico.

Conclusions

The conservation status of the pine-oak forest of the studied micro-watershed is not optimal, as the hemeroby index and the estimated community attributes show. Provided that the hemeroby index indicates the degree of anthropic impact on the vegetation, and taking into account the history of the use of the studied micro-watershed, a possible cause of the observed disturbance is uncontrolled grazing.
Therefore, it is suggested that the convenience of characterizing the livestock activity in the micro-watershed based on the number of animal units present and on the pasture coefficient of the vegetation, as well as carrying out a complete study of the vegetation in the rest of the micro-watershed –with a sufficiently intense sampling effort–, in order to develop a management plan that is pertinent to its current conditions. It is equally necessary to address the disturbance present in the area by means of a thorough assessment of the areas that exhibit loss of vegetation and soil, in order to develop and apply a management plan in the area. Finally, we suggest confirming the presence of an infestation by debarker insects in those areas where signs of their presence were observed, and, if such pests are proved to be present, proceeding at once to their management.

Acknowledgements

The first author thanks his scientific colleagues and mountaineer partners for their support in field work, specially to Conrado González and Ugo Silva, as well as to Enrique Neri and Dayana Pruneda. A very particular acknowledgement with deep respect and love, in spite of her impossibility to read it, to Capita, mountain dog who always, in an unconditional and loyal way, was a tireless companion in every crossing through canyons, glens, forests, scrublands, harbors and hilltops. She will always be in our memories.

Conflict of interests

The authors declare no conflict of interests.

Contribution by author

Bernardo Antonio Marino Maldonado: responsible for the project, field work, data processing, results analysis and writing of the manuscript; Marco Antonio Alvarado Vázquez: support in methodology, results analysis and review and correction of the manuscript; Ismael Cabral Cordero: support in methodology; Marco Antonio Guzmán Lucio: support in the interpretation of results.