Traditional medicinal knowledge of tropical trees and its value for restoration of tropical forests

Conocimiento tradicional medicinal de árboles tropicales y su valor para la restauración de bosques tropicales

Juana García-Flores[1,2]*, Mario González-Espinosa[1], Roberto Lindig-Cisneros[2], and Alejandro Casas[2]

[1]Departamento de Conservación de la Biodiversidad, El Colegio de la Frontera Sur (ECOSUR), San Cristóbal de las Casas, Chiapas, México.
[2]Instituto de Investigaciones en Ecosistemas y Sustentabilidad (IIES) - Universidad Nacional Autónoma de México (UNAM), Morelia, Michoacán, México.

*Corresponding author: jgarcia@iies.unam.mx

Abstract
Background: Traditional medicinal knowledge (TMK) accounts for attending nearly 80 % of the worldwide needs of health and may guide biodiversity restoration efforts in tropical regions where the greatest diversity of medicinal plants occurs.
Questions: Can TMK become a strategy to be used in identifying medicinal tree species, with both cultural and ecological importance, that should be considered in tropical forest restoration actions?
Study site and dates: The study was conducted during 2015 in four communities of the Sierra region of southern Tabasco, Mexico.
Methods: We obtained from the literature a checklist of medicinal trees native to the study region. We conducted semi-structured interviews and a workshop in each community; we obtained ethnobotanical data about the most common illnesses and the most frequently used plant species for attending them. We identified priority species for forest restoration, and calculated indexes of knowledge richness (IKR) and cultural significance (ICS).
Results: We recorded a total of 45 tree species. Adult and elder women showed the highest TMK. The main illnesses detected were gastrointestinal (93-97 %) and those related with pain and fever (67-97 %), which were treated with 13 and 16 species, respectively. On average, the IKR was less than 50 % of all species recorded. *Gliricidia sepium, Bursera simaruba* and *Piper auritum* had high ICS values, while *Brosimum alicastrum, Ceiba pentandra* and *Castilla elastica* had low values and are considered high priority for forest restoration actions.
Conclusions: TMK is important to select tree species in tropical forest restoration actions in southeastern Mexico.
Key words: ethnobotany, forest restoration, medicinal trees, traditional medicinal knowledge, tropical forests.

Resumen
Antecedentes. El conocimiento tradicional medicinal (CTM) permite atender necesidades de salud de 80 % de la población mundial y puede servir como guía para recuperar biodiversidad en regiones tropicales, ya que la mayor diversidad de plantas medicinales incluye especies tropicales.
Pregunta. ¿Provee el CTM una estrategia para identificar especies arbóreas que por su importancia cultural y ecológica conviene emplear en proyectos de restauración de bosques tropicales?
Sitio y fechas. El estudio se realizó en 2015, en cuatro comunidades rurales de la región Sierra de Tabasco, México.
Métodos. Con base en revisión bibliográfica se obtuvo un listado de referencia sobre árboles medicinales nativos de la región. Efectuamos entrevistas semiestructuradas y un taller participativo en cada comunidad; se documentaron usos medicinales, enfermedades recurrentes, listados libres de especies medicinales y aquellas con prioridad para emplearse en acciones de restauración. Calculamos índices de riqueza de conocimiento (*IRC*) y de significancia cultural (*ICS*).
Resultados. Registramos 45 especies arbóreas medicinales nativas. Las mujeres adultas y ancianas mostraron el mayor CTM. Las principales enfermedades fueron gastrointestinales (93-97 %) y las asociadas a dolores y fiebre (67-97 %), tratadas con 13 y 16 especies, respectivamente. El IRC reflejó un conocimiento promedio menor a 50 %. *Gliricidia sepium, Bursera simaruba* y *Piper auritum* tuvieron valores altos de ICS, mientras que *Brosimum alicastrum, Ceiba pentandra* y *Castilla elastica* mostraron valores bajos y son consideradas con alta prioridad para la restauración forestal.
Conclusiones. El CTM es importante para seleccionar especies arbóreas en la restauración de los bosques tropicales del sureste de México.
Palabras clave: árboles medicinales, bosques tropicales, conocimiento tradicional medicinal, etnobotánica, restauración forestal.

Traditional ecological knowledge (TEK) is a cumulative body of knowledge, practices and beliefs about the relationship of living beings with their environment, which evolve through adaptive processes and is culturally communicated across generations (Berkes 1993). TEK is crucial for carrying out local actions for conservation, ecological restoration and recovering biological populations, particularly those of useful species (Levy-Tacher *et al.* 2012, Casas *et al.* 2014, 2016, Chekole 2017). TEK provides decision makers with valuable information about distribution, abundance, biotic interactions, behavior, recovering capacity of organisms and ecosystems following disturbance, among other issues. In addition, TEK has proved its usefulness in identifying valuable ecosystems and resources to be protected and recovered, as well as management experiences to shorten the ways for attaining sustainable management strategies (Casas *et al.* 2014, 2016). Some ecological restoration efforts have started from documenting the most valuable resources, among them edible, fuel, and timber producing plants (Vázquez-Yanes *et al.* 1999, Lindig-Cisneros 2017). Yet few studies have been conducted considering medicinal plants (Charnley *et al.* 2008, Suárez *et al.* 2012, Velázquez-Rosas *et al.* 2018), notwithstanding that this group of plants commonly is the largest in ethnobotanical inventories (Toledo *et al.* 1995).

Traditional medicinal knowledge (TMK) is a crucial component of TEK. Both TMK and TEK study botanical, zoological, ecological, and technological knowledge combining empirical, rational, logical knowledge and symbolic, mythological and magical thinking that distinguishes the human being as a social and cultural being (Fagetti 2011). TMK focuses on elements associated to treat illnesses (Fagetti 2011), while TEK analyses more general aspects of biological species and their environment and ecosystems (Berkes 1993, Casas *et al.* 2016). TMK and TEK are locally generated and transmitted from generation to generation through oral, practical or written means (Foster 1953, Pochettino & Lema 2008); however, TMK has played a crucial role in survival and has helped humanity to face threats to its physical, emotional and spiritual integrity; it is widely used for attending health problems, both for preventing and treating illnesses of many populations (WHO 2013). The use of TMK occurs predominantly in poor rural areas, commonly involving traditional physicians recognized within and among communities (Cabrera *et al.* 2015). Traditional medicine is practiced in almost all countries of the world (WHO 2013), covering nearly 80 % of the global needs of health (Akerele 1993, Fabricant & Farnsworth 2001, WHO 2002). Its use is key for people with poor access to official health services, and it is the main way of providing health help for indigenous communities (Hamilton 2004, Quinlan & Quinlan 2007, WHO 2013).

Despite the relevance of TEK and TMK, their loss is occurring worldwide (Anyinam 1995, Cox 2000, Lulekal *et al.* 2008, Brito *et al.* 2017). Among the multiple and complex factors influencing such process, authors like Linares & Bye (1987), Toledo (1987), Berkes & Turner (2005) have identified: (1) decreasing interest of young people to learn and transmit traditional knowledge (Phillips & Gentry 1993, Luoga *et al.* 2000, Voeks & Leony 2004, Reyes-García *et al.* 2013); (2) loss of the original languages in which that knowledge is transmitted (Benz *et al.* 2000, Maffi 2005); (3) modernization (Quinlan & Quinlan 2007) and new economic contexts (Reyes-García *et al.* 2005) favoring disarticulation of communities, migration, loss of culture and use of local medicinal flora (Vandebroek & Balick 2012, Alencar *et al.* 2014), and their replacement by modern patented medicines (Luziatelli *et al.* 2010, Reyes-García *et al.* 2013). The increasing loss of traditional knowledge may be expected to have consequences on the resilience of socio-ecological systems (Brito *et al.* 2017) since it tends to weaken the resources and ecosystems value and the need and relevance to maintain them (Toledo *et al.*1992, Voeks 1996, Weldegerima 2009, Silalahi *et al.* 2015, Brito *et al.* 2017).

Most of biodiversity on Earth occurs in tropical regions, particularly in those areas identified as "hotspots", which however are rapidly decreasing (Ryan 1992, Begossi *et al.* 2000, Myers *et al.* 2000). It has been recognized that in these areas live most of the indigenous peoples (Mace & Pagel 1995, Moore *et al.* 2002, Maffi 2005), and that they are the main custodians and stewards of ecosystems and biological diversity of "hotspots". In Mexico, tropical ecosystems are important reservoirs of the country's biodiversity, harboring nearly 17 % of its flora (Rzedowski 1998, Challenger & Soberón 2008). However, extensive land-use change through deforestation aimed to establish pastures for livestock raising, traditional agriculture, and establishing plantations of commercial crops has reduced the extent and increased the isolation of the remaining fragments of original forest habitats (Challenger 1998, Koleff *et al.* 2012).

It has been estimated that only one-half of the original cover of tropical rain forest of Mexico remains relatively well preserved (Masera *et al.* 1992, Challenger & Soberón 2008, Koleff *et al.* 2012). In the state of Tabasco, where this study was conducted, the estimated original cover of tropical rain forest was 21.7 % of the State´s area, only 1.6 % of which remained at the beginning of this century (Sánchez-Munguía 2005). Ecological restoration implies the process of recovering ecosystems degraded, damaged or destroyed by natural and anthropogenic causes (SER 2004); it is based on a historical past with the aim of achieving short-term community benefits along with long-term social commitments to promote locally the ecological integrity, sustainability and long-term resilience of communities and ecosystems in the face of climate change (Suding 2011, DeFries *et al.* 2012, Suding *et al.* 2015). Programs aimed to forest cover restoration are urgent that may consider merging extant TEK and TMK in order to facilitate their local social construction, long-term adoption and foster wider use of biodiversity (González-Espinosa *et al.* 2008, Ramírez-Marcial *et al.* 2014, García-Barrios & González-Espinosa 2017).

The purpose of this study was to identify tree species that are used medicinally through traditional medicinal knowledge (TMK) which could be included in restoration practices aimed to increase forest cover. The study was conducted in four Zoque-Maya communities in the southern mountainous region of the state of Tabasco, in southeastern Mexico. We followed an ethnobotanical approach in documenting the use

of native medicinal trees, the most important illnesses attended with them, and their cultural value for local people as important species in restoration actions. We also obtained the indexes of cultural significance of the species and knowledge wealth, and we identified the role of gender to discriminate whether it is men or women who possess this wealth of knowledge. Our study aims to illustrate the relevance of TMK for selecting tree species and designing strategies of ecological restoration of tropical forests.

Materials and methods

Study area. The study was conducted in the municipality of Tacotalpa (between 17° 20' and 17° 42' North; 92° 32' and 92° 55' West; elevation 20-1,000 m) in the Sierra region of the state of Tabasco (INEGI 2005), and in the eco-geographic unit of the abrupt northern slopes of the Sierra Norte of Chiapas (Ortiz-Pérez *et al*. 2005) in southeastern Mexico. The regional climate is warm-humid, with rains throughout the year, with annual rainfall of 1,500-4,500 mm (INEGI 2015). The area belongs to the Grijalva-Usumacinta hydrological region and the Grijalva-Villahermosa river basin, in which the Puxcatán, Almandros, Amatán, Chinal, and Tacotalpa rivers converge (INEGI 2005). The geology is characterized by Tertiary sedimentary rocks (shale-sandstones and limestones); dominant soils include shallow and rocky lithosols in the slopes and gleysols in lower areas, whose texture is generally clay, silt or silty clay, with problems of excess moisture due to poor drainage in low areas (INEGI 2005, Bensusán 2011).

Vegetation mostly includes secondary plant associations and small relicts of tropical rain forest (Miranda & Hernández-X 2014, Rzedowski 2006), mostly with a high degree of human disturbance (Ramírez-Marcial *et al*. 2014). In the less accessible areas, an average density of 32 stems per hectare belonging to at least four tree species has been reported for the pasture-dominated landscape (Grande-Cano *et al*. 2009). Salazar-Conde *et al*. (2004) report loss of tropical rain forest cover (with *Brosimum alicastrum* as dominant species) reaching up to 80 % within the last quarter of the past century.

We worked in four communities: Oxolotán (OX, 1,886 inhabitants, 10.4 % speak indigenous language); Cerro Blanco Quinta Sección (CB, 565 inhabitants, 7.1 % speak indigenous language); Tomás Garrido Canabal (TG, 389 inhabitants, 8.5 % speak indigenous language), and La Cumbre (LC, 238 inhabitants, 19.1 % speak indigenous language) (INEGI 2010). People of these communities belong to the Mayan ethnic groups Ch'ol, Chontal, and Tzotzil, yet a significant proportion belong to the Zoque and Mestizo groups. The degree of poverty is high in almost all communities except Oxolotán, where it has been estimated at an intermediate level (INEGI 2010) (Figure 1).

Ethnobotanical studies. We obtained a preliminary checklist of medicinal trees occurring in the area through a literature review of floristic and ethnofloristic sources (Maldonado-Mares 2005, Magaña-Alejandro 2006, López-Hernández

1994, Ramírez-Marcial *et al*. 2014), which was used as a reference for other steps of the research. In addition, we identified whether or not those species receive any management, particularly if there were previous experiences of using them in restoration programs in the area or somewhere else.

Fieldwork started by asking permission from local authorities, as well as informing people and asking their consent for participating in the interviews. We then carried out semi-structured interviews (Albuquerque *et al*. 2014, Brito *et al*. 2017), during September and October 2015, to men and women of the four communities. We used the qualitative method called "snow ball" (Bernard 1995) for sampling interviewees recognized as experts in relation to the medicinal flora of the region.

In the OX community we conducted 28 interviews, 29 in CB, 26 in TG, and 24 in LC (See Appendix 1). We recorded name, gender and age of people interviewed, and questions were addressed to explore their ability to recognize medicinal flora using printed photographs of the species included in the reference checklist referred to above. In addition, we explored people's identification of medicinal uses, illnesses treated with them, their form of administration, and their opinion on whether the tree species should be used in forest restoration activities in the region. This opinion was generally based on the low availability of the resource and the difficulty of natural regeneration of certain species. By means of the free listing technique we analyzed the most valuable species among medicinal trees.

We carried out a workshop in each community in October 2015 with the participation of the people interviewed: 18 people in CB, 16 in OX, 13 in LC, and 11 in TG. The workshops aimed at collectively selecting those medicinal tree species that could be considered with a high priority for forest restoration. We asked the people to name the 10 species of trees considered the most recommended to carry out actions of forest restoration (including their propagation and reintroduction to floristically enrich fallow stands); participants indicated the highest priority by number 1 and successively down until 10. We also asked them to comment about their criteria for their selection, which was commonly based on the low availability of the resource.

Data processing and analysis. We categorized the individually interviewed women and men from each community in different age groups. In addition, we categorized the most common illnesses and related affections, according to the information of the interviewees. We determined the most important illnesses in each community, the number of species used for treating the same illness, and the number of illnesses treated by each species. In each community we obtained the percentage of interviewees who considered each of the tree species with priority in restoration actions; we also obtained the percentage of the communities in which it was considered with some value of importance to a species.

We analyzed the amount of knowledge on use of medicinal trees through the Index of Knowledge Richness (IKR), following Toscano (2006), Castellanos-Camacho (2011), and Medellín-Morales *et al*. (2017). We identified whether men

or women possess this wealth of knowledge. For calculating this index we used the reference checklist and the free listing of medicinal trees reported by people interviewed in each community, using the formula:

$$IKR = \Sigma([SU]_i/[SU]_{total}).$$

In which, *IKR* is the proportion of species of medicinal trees reported by each interviewee in relation to the number of medicinal tree species reported by all people interviewed in the whole region; $[SU]_i$ is the number of species of medicinal trees recorded by the interviewee with respect to $[SU]_{total}$,

the total number of species of medicinal trees reported in the whole region by all the interviewees. Values of this index may vary from 0 to 1, being 1 the maximum value of richness value of the medicinal trees of the region.

For determining the species that are culturally most significant because of their use as medicines, we calculated the Index of Cultural Significance (*ICS*), based on parameters of quality (perceived effectiveness as medicines), intensity (use frequency), and exclusiveness (the plant as main or a non-substitutable component of a remedy) of the use of each species, based on Turner (1988) and Stoffle *et al.* (1990). For this study, we considered only the different medicinal
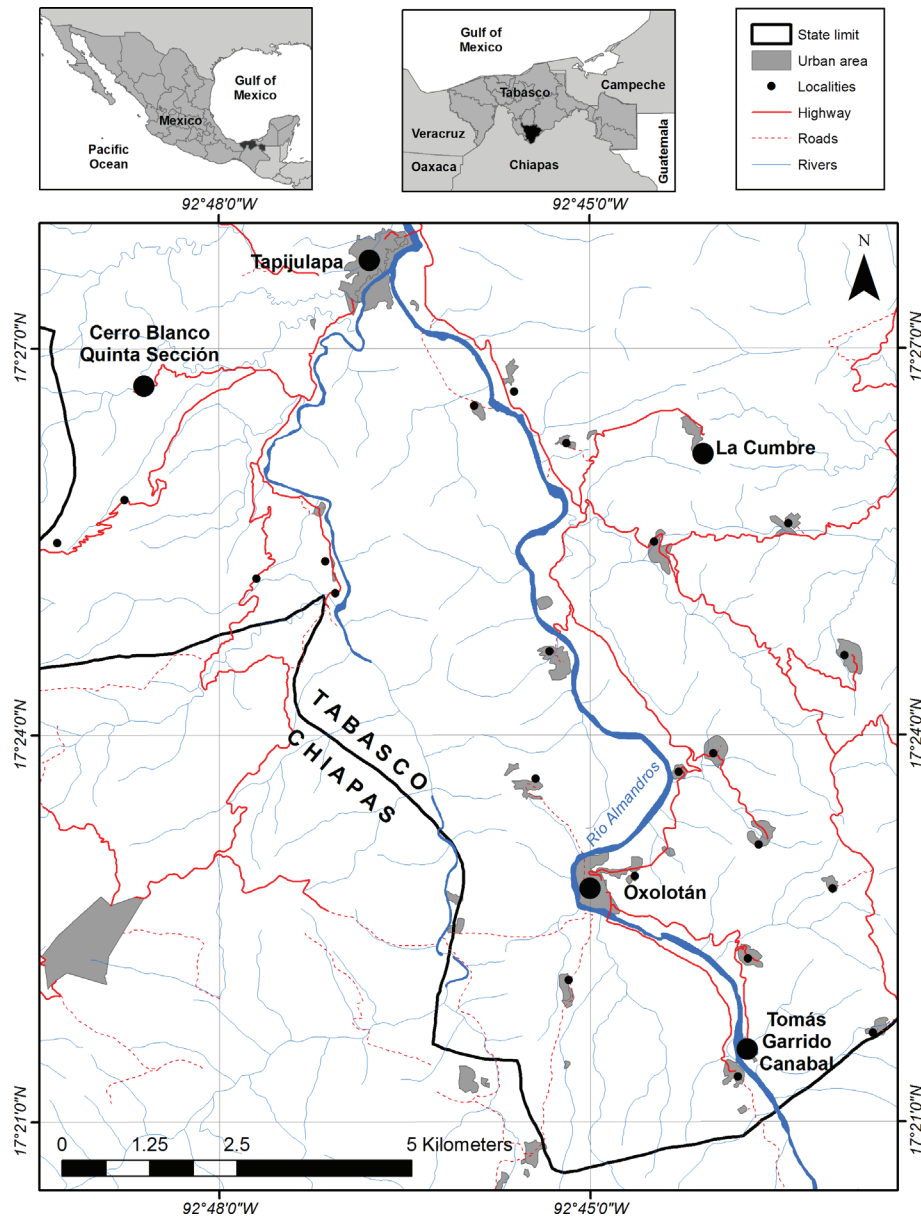

Figure 1. Study area and location of studied communities in the Sierra region of southern Tabasco, Mexico.

uses reported by people. We adapted the *ICS* for this study as follows:

$$ICS = \Sigma(q \times I \times e)u_n/N_{inf}$$

The expanded formula being*:*

$$ICS = (q_1 \times I_1 \times e_1)u_1 + (q_2 \times I_2 \times e_2)u_2 + (q_3 \times I_3 \times e_3)u_3 \ldots + (q_n \times I_n \times e_n)u_n/N_{inf}$$

The formula indicates the sum of 1 to *n* medicinal uses (*u*) for a species, where *q* = medicinal uses (use values from 5 to 0.5, according to categories of illnesses mentioned by the interviewees); *I* = intensity of use (values from 5 to 1, where 5 = very intense, 4 = intense, 3 = intermediate intense, 2 = low, 1 = very low); *e* = exclusivity of use (values from 2 to 0.5, where 2 = high, 1 = intermediate, and 0.5 = low); N_{inf} = total number of informants of people interviewed.

We finally analyzed the Cumulative Importance of Cultural Significance (*CICS*) of each species recorded in each community following the index of cultural importance by Stoffle *et al.* (1990). The *CICS* makes reference to the sum of *ICS* of each species of medicinal trees recorded in each community.

Results

Traditional medicinal knowledge of tropical tree species. The reference checklist included 21 species of medicinal trees, belonging to 21 genera and 14 plant families. Based on the free listing technique, we recorded 22 species and 2 morphospecies, belonging to 22 genera and 16 plant families. From the reference checklist and the free listing, in the OX community we summed a total of 34 species, belonging to 30 genera and 16 plant families; values for the other communities were: 31 species, belonging to 29 genera and 19 plant families in TG; 30 species belonging to 28 genera and 15 plant families in LC, and 28 species belonging to 26 genera and 15 plant families in CB. A total of 45 tree species with at least one medicinal use were recorded in the four studied communities (Table 1).

We recorded 14 categories of recurrent illnesses that are treated with medicinal tree species within the study region (Table 2). The most common illnesses registered were gastrointestinal (93-97 %) which are attended with 13 species, and those associated to pain and fever (67-97 %), which are attended with 16 species (Tables 3 and 4). The species that were reported for treating the highest number of illnesses were *Persea americana* and *Cecropia obtusifolia* (8 categories of illnesses); *Genipa americana* was not reported to be used as medicine in the communities studied, although it is reported in other communities of the state of Tabasco (Table 4).

Knowledge Richness and Cultural Significance of the Species studied. Most interviews were carried out to women since the snow ball technique conducted to them, because of their expertise in using medicinal plants. Ages of women were 29

to 100, whereas men were 34 to 87 years old (Appendix 1).

The community of OX had the highest value of *IKR* (0.62), representing 62 % of the species reported (21 of 34 species reported in the community). In OX the highest *IKR* was registered among elder women from 71 to 80 years old. In TG the highest *IKR* (0.58) was registered among women from 61 to 70 years old, whereas in CB it was 0.57 among younger women, 41-50 years old; in LC the *IKR* was 0.53 among women 41-70 years old. Values of *IKR* in all communities averaged 10 to 11 species of medicinal trees (Table 5, Appendix 1).

The species with the highest cultural importance, according to the cumulative cultural significance was *Gliricidia sepium*, which had the highest values of *ICS* in the communities OX, CB, and TG. *Bursera simaruba, Piper auritum, Pimenta dioica, Theobroma cacao, Guazuma ulmifolia,* and *Byrsonima crassifolia* were classified in the category of high cultural importance (Table 6).

Priority species for ecological restoration. Information resulting from workshops indicated that 15 tree species are of high interest for actions of forest restoration. This selection is mainly due to the local criterion of low availability of a resource and the difficulty of reproduction since some species are "rogadas", as people say, which means that they do not seem to reproduce easily in the wild. These species were also considered as important by 61-100 % of the people interviewed in each community (Table 7). Such is the case of *Manilkara zapota* which was considered by all people interviewed in OX and TG as a species that should be considered in restoration actions; the same was recorded for *Brosimum alicastrum* in TG (Table 7). *Annona reticulata, Tabebuia rosea, Persea americana* and *Brosimum alicastrum* received an importance value in the workshops, providing support to their use as priority species in ecological restoration actions in the four communities (100 %). On the other hand, because of their widespread occurrence in the region, *Bursera simaruba, Cecropia obtusifolia, Gliricidia sepium, Erythrina americana* and *Piper auritum* did not receive importance values in any community (0 %). *Pseudobombax ellipticum* is a species was not known to occur in the forest areas by any participant in the workshops and interviews (Table 7).

Discussion

Cultural significance of tree species and its value for ecological restoration. In total, we identified 45 species of trees with medicinal use in the region. This group of species includes elements of both primary and secondary vegetation. Such number of tree species represents 5.5 % of the species reported by Toledo *et al.* (1995) in his study of useful plant species from the tropical rainforest of Mexico. The main categories of illnesses in the study area are gastrointestinal, as well as those causing pain and fever, similarly as reported in other studies among indigenous peoples (Sepúlveda 1993, Magaña-Alejandro *et al.* 2010, Gómez-Álvarez 2012). In this study, we found different species used for treating different illnesses, which we interpret as conferring resilience to

Table 1. Tropical medicinal tree species included in the reference list (*) and the free list (**) in the four study communities in southern Tabasco, Mexico.

Family	Species	Oxolotán	Cerro Blanco	Tomás Garrido	La Cumbre
Anacardiaceae	*Spondias mombin* L.**			x	
	Spondias purpurea L.**			x	x
Annonaceae	*Annona reticulata* L.*	x	x	x	x
	Annona muricata L.**	x	x	x	x
Bignoniaceae	*Handroanthus guayacan* (Seem.) S.O.Grose**	x		x	
	Parmentiera aculeata (Kunth) L.O.Williams**		x		x
	Tabebuia rosea DC.*	x	x	x	x
Bixaceae	*Bixa orellana* L.**	x		x	
Burseraceae	*Bursera graveolens* Triana & Planch.**	x			
	Bursera simaruba (L.) Sarg.*	x	x	x	x
Caricaceae	*Carica mexicana* (A.DC.) L.O.Williams**			x	
Clusiaceae	*Mammea americana* L.**	x			
Cochlospermaceae	*Cochlospermum vitifolium* Spreng.**				x
Euphorbiaceae	*Croton draco* Schltdl.**		x	x	
Lamiaceae	*Cornutia pyramidata* L.**			x	
Lauraceae	*Persea americana* Mill.*	x	x	x	x
Leguminosae	*Acacia cornigera* (L.) Willd.**	x			
	Cassia grandis L.**	x	x		x
	Erythrina americana Mill.*	x	x	x	x
	Gliricidia sepium (Jacq.) Kunth*	x	x	x	x
	Haematoxylum campechianum L.**	x			
	Inga jinicuil Schltdl.**	x			
	Inga punctata Willd.**	x			
	Senna sp.**		x		
Malpighiaceae	*Byrsonima crassifolia* Kunth*	x	x	x	x
Malvaceae	*Ceiba pentandra* (L.) Gaertn*	x	x	x	x
	Guazuma ulmifolia Lam.*	x	x	x	x
	Pachira aquatica Aubl.*	x	x	x	x
	Pseudobombax ellipticum (Kunth) Dugand*	x	x	x	x
	Theobroma cacao L.*	x	x	x	x
Meliaceae	*Cedrela odorata* L.*	x	x	x	x
	Trichilia havanensis Jacq. **	x		x	x
Moraceae	*Brosimum alicastrum* Sw.*	x	x	x	x
	Castilla elastica Sessé in Cerv.*	x	x	x	x
	Ficus glaucescens Miq.**				x
Myrtaceae	*Pimenta dioica* (L.) Merr.*	x	x	x	x
	Psidium guajava L.**	x	x	x	x
Piperaceae	*Piper auritum* Kunth *	x	x	x	x
Rubiaceae	*Blepharidium mexicanum* Standl.**		x		
	Genipa americana L.*	x	x	x	x
	Sickingia salvadorensis Standl.**				x
Sapotaceae	*Manilkara zapota* (L.) P. Royen*	x	x	x	x
	Pouteria sapota (Jacq.) H. E. Moore & Stearn*	x	x	x	x
	Pouteria sp.**	x			
Urticaceae	*Cecropia obtusifolia* Bertol.*	x	x	x	x

Table 2. Categories of recurrent illnesses treated with medicinal tree species in the region and their description.

No.	Category of illness	Use values	Illnesses and symptoms in the category
1	Gastrointestinal	5	vomiting, parasites, constipation, diarrhea, gastritis, colitis, stomach pain-infection, dysintery
2	Respiratory	5	cold, cough, flu, asthma, hoarseness
3	Dermatolological	5	wounds, ulcers, sores, burns, blows, fungus, dandruff (hair not cane), pimples
4	Pain and/or fever	4	fever, muscle pain, bone pain, headache, earache, toothache, nosebleeds
5	Women´s health issues	4	cramps, menstrual problems, infections, childbirth related issues
6	Urological	4	urinary infections, kidney pain, prostate problems
7	Ocular	3	infections, cataracts, conjunctivitis, red teary eyes
8	Cancer	3	
9	Diabetes	3	blood sugar and glucose imbalances
10	Smallpox, chicken pox, measles	2	
11	Blood related problems	2	anemia, leukemia, high cholesterol, high triglyceride levels, varicose veins, high or low blood pressure
12	Insect and animal bites	1	
13	Ceremonies and spirit/sould related problems	1	ritual use, fright, protection, air, evil eye, smudging, crying in children, weakness
14	Others	0.5	nerves, insomnia, convulsions

Table 3. Percentage of recurrent illnesses treated with medicinal tree species in the four study communities. Number of interviews in each community are in parentheses.

Communities							
Oxolotán (28)		Cerro Blanco (29)		Tomás Garrido (26)		La Cumbre (24)	
Category of Illness	%	Category of Illness	%	Category of Illness	%	Category of Illness	%
Gastrointestinal	93	Gastrointestinal	97	Pain and/or fever	92	Gastrointestinal	96
Pain and/or fever	89	Pain and/or fever	97	Smallpox, chicken pox, measles	77	Pain and/or fever	67
Dermatolological	75	Dermatolological	62	Gastrointestinal	73	Ceremonies and spirit/sould related problems	50
Diabetes	43	Ceremonies and spirit/sould related problems	62	Dermatolological	58	Smallpox, chicken pox, measles	38
Smallpox, chicken pox, measles	39	Smallpox, chicken pox, measles	59	Ceremonies and spirit/sould related problems	46	Women´s health issues	33
Blood related problems	36	Women´s health issues	31	Blood related problems	42	Diabetes	33
Respiratory	29	Diabetes	31	Urological	38	Dermatolological	29
Ceremonies and spirit/sould related problems	25	Ocular	28	Women´s health issues	35	Blood related problems	21
Ocular	25	Urological	17	Diabetes	27	Respiratory	17
Women´s health issues	21	Respiratory	14	Ocular	12	Ocular	4
Urological	14	Blood related problems	10	Insect and animal bites	4	Insect and animal bites	4
Cancer	0	Others	7	Others	4	Others	4
Insect and animal bites	0	Insect and animal bites	3	Respiratory	0	Urological	0
Others	0	Cancer	3	Cancer	0	Cancer	0

Table 4. Recurrent illnesses in the region and medicinal tree species that treat these illnesses in the four study communities of Tabasco, Mexico.

Medicinal tree species	Respiratory	Gastrointestinal	Dermatological	Pain and/or fever	Women´s health issues	Urological	Ocular	Cancer	Diabetes	Smallpox, chicken pox, measles	Blood related problems	Insect and animal bites	Ceremonies and spirit/ sould related problems	Others	Total number of illnesses treated with the species
Persea americana	X	X	x	x	x	x					x		x		8
Cecropia obtusifolia			x	x	x					x	x	x	x	x	8
Annona reticulata		X		x	x		x	x			x		x		7
Tabebuia rosea	X	X	x	x	x					x	x				7
Gliricidia sepium		X	x	x			x			x			x		6
Guazuma ulmifolia	X	X	x	x		x			x						6
Cedrela odorata	X	X		x	x	x							x		6
Piper auritum	X	X		x		x					x	x			6
Manilkara zapota		X		x	x	x			x		x				6
Pouteria sapota		X	x			x					x		x	x	6
Bursera simaruba		X	x	x	x						x				5
Theobroma cacao		X	x	x						x			x		5
Pimenta dioica	X	X		x	x								x		5
Erythrina americana			x	x							x			x	4
Byrsonima crassifolia		X		x	x						x				4
Pachira aquatica				x		x			x		x				4
Castilla elastica	X			x									x		3
Ceiba pentandra			x		x										2
Brosimum alicastrum			x												1
Genipa americana															0
Pseudobombax ellipticum															0
Total number of species that treat the category of illness	7	13	11	16	10	7	2	1	5	2	11	2	9	3	

Table 5. Index of Knowledge Richness (*IKR*) of the four study communities. The total number of medicinal tree species (MTS) is the sum resulting from the floristic reference list and the free list; S = number of species.

Community	Total no. interviews	Total no. MTS	Max. *IKR*	S_{max}	Min. *IKR*	S_{min}	Mean *IKR*	S_{mean}
Oxolotán	28	34	0.62	21	0.06	2	0.33	11
Cerro Blanco	29	28	0.57	16	0.11	3	0.36	10
Tomás Garrido	26	31	0.58	18	0.19	6	0.35	11
La Cumbre	24	30	0.53	16	0.13	4	0.32	10

the local capacities for attending health. However, we also identified tree species that may be used for treating different illnesses (up to eight), which is an indicator of the use value of particularly important species; yet it is also an indicator of vulnerability of the traditional health systems since if populations of these species are affected by disturbance, the local capacities for attending health might be affected. Traditional knowledge associated with the use of a particularly declining species also runs that same risk of disappearing at local or regional scales (Albuquerque *et al.* 2006, Shaheen *et al.* 2017); in our study, an example of this coupling between ecology and knowledge seems to be the case of *Pseudobombax*

ellipticum, which is not reported any longer to be extant in the region and therefore no associated uses of it were detected.

The analysis of the cultural significance of species (as an integral representation of the multiplicity of uses of a plant species) is a quantitative ethnobotanical evaluation for understanding the most meaningful resources in a human cultural context (Turner 1988, Stoffle *et al.* 1990, Bennett & Prance 2000, Almeida *et al.* 2005, Albuquerque & Lucena 2005, Silva & Albuquerque 2005, Silva *et al.* 2006, Helida *et al.* 2015), and may be particularly helpful for designing strategies of protection and conservation of biological diversity (Turner 1988, Gupta 2004, Reyes-García *et al.* 2006,

Table 6. Index of cultural significance (ICS) and cumulative index of cultural significance (CICS) of medicinal tree species in the four study communities in southern Tabasco, Mexico. Levels of cultural significance are based on Turner (1988): very high ≥ 100; high = 50-99; moderate = 20-49; low = 5-19; very low = 1-4; unimportant = 0.

Species	ICS/ community				CICS	Cumulative level of cultural significance
	Oxolotán	Cerro Blanco	Tomás Garrido	La Cumbre		
Gliricidia sepium	33	46	36	20	135	very high
Bursera simaruba	13	40	11	25	89	high
Piper auritum	35	31	18	4	87	high
Pimenta dioica	26	7	21	22	75	high
Theobroma cacao	18	20	16	11	65	high
Guazuma ulmifolia	9	15	17	19	60	high
Byrsonima crassifolia	14	19	6	11	50	high
Persea americana	14	7	10	13	45	moderate
Cedrela odorata	17	5	17	3	42	moderate
Pouteria sapota	15	13	9	4	41	moderate
Tabebuia rosea	11	11	9	7	37	moderate
Annona reticulata	12	0	9	8	29	moderate
Cecropia obtusifolia	8	2	6	14	29	moderate
Manilkara zapota	6	3	9	3	20	moderate
Castilla elastica	3	5	6	2	16	low
Erythrina americana	0	0	8	2	10	low
Pachira aquatica	3	2	1	3	9	low
Ceiba pentandra	1	0	2	0	3	very low
Brosimum alicastrum	1	0	0	0	1	very low
Genipa americana	0	0	0	0	0	unimportant
Pseudobombax ellipticum	0	0	0	0	0	unimportant

Table 7. Priority species in the study communities for use in ecological restoration. W = Workshops, VI = Value of importance, range from 1 to 10, where 1 is the species of greatest priority for restoration projects; I = Interviews, Percentage of interviewed who consider the priority species for restoration.

| | | Priority species for restoration in each community | | | | | | | | % Species priority. Community workshops |
| | | Oxolotán | | Cerro Blanco | | Tomás Garrido | | La Cumbre | | |
No.	Species	W (VI)	I (%)	W (VI)	I (%)	W (VI)	I (%)	W (VI)	I (%)	
1	*Annona reticulata*	8	82	2	90	3	96	1	83	100
2	*Tabebuia rosea*	7	68	1	79	8	88	8	79	100
3	*Persea americana*	9	61	5	69	5	81	10	67	100
4	*Brosimum alicastrum*	5	82	8	72	2	100	5	71	100
5	*Pimenta dioica*	6	89	3	97		81	4	83	75
6	*Genipa americana*	3	68	9	62	9	73		58	75
7	*Manilkara zapota*	4	100	4	97	4	100		79	75
8	*Pouteria sapota*		89	6	86	1	96	6	79	75
9	*Pachira aquatica*		54	7	62		58	2	75	50
10	*Byrsonima crassifolia*	10	64		31	7	62		33	50
11	*Theobroma cacao*	2	75		41	6	96		88	50
12	*Cedrela odorata*	1	89		66		77	3	79	50
13	*Ceiba pentandra*		54		59	10	65	7	67	50
14	*Castilla elastica*		64	10	62		50		58	25
15	*Guazuma ulmifolia*		36		21		38	9	63	25
16	*Bursera simaruba*		32		17		23		29	0
17	*Cecropia obtusifolia*		14		3		0		17	0
18	*Gliricidia sepium*		25		28		27		33	0
19	*Erythrina americana*		36		38		38		29	0
20	*Piper auritum*		4		14		15		0	0
21	*Pseudobombax ellipticum*		7		0		8		0	0

Hoffman & Gallaher 2007). Our study emphasizes ecological restoration, since our efforts are aimed at identifying species of local interest that can be used to recover deforested or degraded forest areas.

A number of studies have been reported where species with high cultural importance may be severely impacted by local exploitation (*e.g.* Albuquerque & Lucena 2005, Albuquerque 2006). According to Turner (1988), the higher the number of uses of a plant species, the higher the probability of having a higher cultural value for a community. This value may vary for a species in different contexts of knowledge, use, human culture, and environmental conditions (Turner 1988, Pei *et al.* 2009). Although most valuable resources may probably be most affected, these may also be those on which peoples have developed management experiences (Casas *et al.* 1997, 2007, 2016, 2017). It has been documented in different parts of Mexico that plant species highly valued by people but with a restricted distribution and scarce availability, as well as other indicators of vulnerability to extraction (long life cycle, specialized breeding system, low capacity of recovering to disturbance, among other features), are those on which people develop more careful and complex manage-

ment techniques (Arellanes *et al.* 2013, Blancas *et al.* 2010, 2013, Rangel-Landa *et al.* 2017). Managed or not, these species may be in risk to disappear if high use intensity prevails on them; yet if there are management techniques available the restoration programs would be benefited.

In this study, *Persea americana* and *Cecropia obtusifolia* are not the most culturally valued species, yet they are widely used for attending the highest number of illnesses; moderate values of cultural significance of these species are due to the low frequency and exclusiveness of their uses. *Gliricidia sepium, Bursera simaruba* and *Piper auritum,* have high and very high cultural importance. This would suggest using these species in actions of ecological restoration. However, the quantitative ethnobotanical analysis does not reflect the real interest that people have in using these species in ecological restoration projects. In the case of *Gliricidia sepium* and *Piper auritum*, because of their growth habit and habitat restricted to highly lighted spots, it would not be expected to contribute to creating a forest cover. In addition, none of these two species are valued as a source of fuelwood or other timber uses. Finally, this appreciation is also explained because some of these species are locally abundant and, as

people say "they grow by themselves", which makes reference to the fact that these species reproduce and grow easily and their products are also easily obtained. Similar cases are also the species *Cecropia obtusifolia* and *Erythrina americana.*

Particular attention deserves the case of *Brosimun alicastrum*, a species of very low cultural significance but yet considered a priority species for ecological restoration. This latter consideration is based on the recognition of its low availability, which makes necessary to walk long distances to reach its useful products. Similar are the cases of *Manilkara zapota* and *Cedrela odorata,* the latter a species registered in the official Mexican norms for protection NOM 059, due to its scarcity (SEMARNAT 2010) and progressive population depletion (Hernández-Ramos *et al.* 2018). From these cases, a few lessons can be extracted. First, ethnobotanical and cultural value considerations for protection and restoration should not be restricted to a single use criterion but they should consider their broad spectrum of uses and benefits. Second, the local perception of distribution, abundance and vulnerability of the populations should be considered. Third, the local experiences about managing plant species are crucial because they reflect the local worries of people to maintain those plants, and they may also provide particular techniques to planning successful actions.

Species of medicinal trees recorded in this study and with high priority for their use in forest restoration practices are part of the primary vegetation (*Brosimun alicastrum* and *Manilkara zapota*), while *Pouteria sapota*, *Genipa americana* and *Pimenta dioica* are part of both primary and secondary forests. *Castilla elastica*, *Cedrela odorata*, and *Guazuma ulmifolia* are pioneer species in secondary vegetation, as well as *Ceiba pentandra*, *Tabebuia rosea*, *Anonna reticulata*, *Persea americana*, *Theobroma cacao* and *Byrsonima crassifolia* (Pennington & Sarukhán 2005, Parker 2008, González-Espinosa & Ramírez-Marcial 2013). Most tree species selected for medicinal use in the study area are part of the secondary vegetation, which is not surprising since as Toledo *et al.* (1995) and other authors have reported, secondary forests are the main providers of medicinal products, nearly twice than primary forests. Stepp (2004) and Voeks (2004) mention that anthropic landscapes are the main source of medicines in tropical forests. In addition, numerous authors (Toledo *et al.* 1992, Voeks 1996, Chazdon & Coe 1999, among others) identify disturbed areas as sites where medicinal plants are particularly abundant.

The study area has been drastically impacted by humans for many centuries. Several important cultures inhabited and managed the regional forests for thousands of years. Yet the most drastic destruction started in the mid-20th century, with governmental programs aimed to transform tropical rain forests into pastures and monocultures over extensive areas (Tudela 1989, Sánchez-Munguía 2005); this process has advanced until the present with strong consequences on losing of biodiversity and traditional cultures (Gómez-Pompa *et al.* 1972, Gómez-Pompa & Kaus 1999, Toledo 1987, Toledo *et al.* 1995, Sheil & Lawrence 2004, Reyes-Tagle 2007, González-Cruz *et al.* 2014).

This study aspires to contribute with some methodological elements and insights for linking local medicinal knowledge, values and experiences with ecological research to design strategies for restoration of tropical rain forests. Both ecological and human cultural roles of species deserve to be considered when planning ecological restoration actions. Structural and functional roles of species are important, as well as their role in satisfying local needs and technical experiences for managing the relevant resources. Ethnobotanical and ecological research are both important for recovering resources, their populations and the ecosystems where they occur (Garibaldi & Turner 2004). Particularly important are long-lived trees, which are valuable resources and help to put in perspective long-term conservation and sustainable use actions, which are particularly important in tropical forests (Janzen 1970, Gómez-Pompa *et al.* 1972, Novotny *et al.* 2006, Wuethrich 2007, Chazdon 2008).

Due to its identification of medicinal tree species with both cultural and ecological importance should TMK become part of a strategy to be considered in tropical forest restoration actions? Our results show that through TMK we can identify culturally important species for their medicinal uses, we also find that the species that are culturally important are not those considered with priority for their management of propagation and reintroduction in the area for forest restoration. The TMK information shows that regardless of the high values of cultural significance of the species, the criterion for selecting them for restoration is not restricted to the importance of their use, but also, and mainly, to their low availability and the perception of difficulties regarding their natural regeneration.

Our results also provide information on the pressure received by some culturally significant and abundant species (*e.g. Gliricidia sepium*, *Bursera simaruba*, *Piper auritum, and Cecropia obtusifolia*); their wide availability is sustaining increasing use associated to their perceived medicinal value. On the other hand, other species with very low availability have few medicinal uses. We consider that the TMK in particular, as well as TEK when other non-medicinal uses are associated to medicinal trees of the region, are relevant to design local strategies of restoration of tropical forests; it is to be expected that when selecting species of local cultural interest, the long-term ecological restoration actions may be more probably successful due to the involvement of local actors from the early stages of the process.

The role of gender in traditional medicinal knowledge. The highest values of *IKR* in all communities were recorded among adult and elder women, particularly in Oxolotán, where expert traditional physicians are recognized and, although institutional health services are available, local people still consult them. The localities of Tomás Garrido and La Cumbre have also local experts, mainly for attending births and cultural illnesses. We recorded the lowest number of medicinal trees in the Cerro Blanco community, which could be associated with the ages of the women interviewed, 25 adults and 4 elderly women (see Appendix 1). In addition, it could be due to the particular fact that we were not able

to interview any men there that could possibly add to the knowledge of some other species. According to Stagegaard *et al.* (2002) and Luoga *et al.* (2000) knowledge of the medicinal flora may be different between men and women, and these authors argue that women have a deeper knowledge of the medicinal properties of herbaceous plants, while men recognize the medicinal attributes of trees and lianas. However, our results show that adult and elderly women have the greatest wealth of knowledge on medicinal tree species detected in this study, contrary to the reports by Stagegaard *et al.* (2002) and Luoga *et al.* (2000). Our finding is consistent with the pattern reported in other tropical regions (Kainer & Duryea 1992, Coe & Anderson 1996, Gollin 1997, Begossi *et al.* 2000, Voeks & Nyawa 2001, Kothari 2003, Voeks 2007). Age is also positively related to a higher TMK, a finding similarly reported by Case *et al.* (2005), Quinlan & Quinlan (2007), Eyssartier *et al.* (2008), Silalahi *et al.* (2015) and Shaheen *et al.* (2017), among others.

In our study, we observed that women have a relevant role in the preservation of medicinal culture, since they have a high wealth of traditional knowledge about medicinal trees in the region. Adult and elderly women recognize species with medicinal uses as well as their low availability for their use. This knowledge input from women has contributed to the selection of species that can be used in programs to restore the forest cover of the tropical forest of the region.

We report an average IKR value of less than half the total number of medicinal trees registered in this study. The wealth of knowledge about the medicinal uses of native tree species can be considered a reference to the current status of the TMK and may also indicate that the current status of the TMK is possibly eroding in the Maya and Zoque communities of the region. This could have negative implications at the local and regional scales (Albuquerque *et al.* 2006, Shaheen *et al*. 2017). This study suggests that the maintenance of TMK in the local communities can be attained by selecting tree species of medicinal interest for forest restoration programs.

We conclude that TMK provides useful criteria for the identification of the cultural significance of the tree species included in this study; it also reflects the interest that local people have in the management of the species, in particular those considered to be high priority for restoration actions of the tropical forest. This traditional knowledge provides information on the uses, cultural values and local experiences of species management, which may be considered useful in a comprehensive analysis of possible restoration actions in tropical forests.

Acknowledgements

Literature cited

Akerele O. 1993. Nature´s medicinal bounty; don´t throw it away. *World health forum* **14**: 390-395.

Albuquerque UP, Lucena RFP. 2005. Can apparency affect the use of plants by local people in tropical forests? *Interciencia* **30**: 506-511.

Albuquerque UP. 2006. Re-examining hypotheses concerning the use and knowledge of medicinal plants: a study in the Caatinga vegetation of NE Brazil. *Journal of Ethnobiology and Ethnomedicine* **2**: 30.
DOI: https://doi.org/10.1186/1746-4269-2-30

Albuquerque UP, Lucena RF, Monteiro JM, Florentino AT, Almeida CFC. 2006. Evaluating two quantitative ethnobotanical techniques. *Ethnobotany Research and Applications* **4**: 51-60.

Albuquerque UP, Alves-Ramos M, Farias-Pavia-Lucena R, Leal-Alencar N. 2014. Methods and techniques used to collect ethnobiological data. *In*: Albuquerque UP, Cruz LVF, Lucena RFP, Alves RRN, eds. *Methods and Techniques in Ethnobiology and Ethnoecology*, Springer.

Alencar NL, Santoro FR, Albuquerque UP. 2014. What is the role of exotic medicinal plants in local medical systems? A study from the perspective of utilitarian redundancy. *Revista Brasileira de Farmacognosia* **24**: 506-515.
DOI: https://doi.org/10.1016/j.bjp.2014.09.003

Almeida CFCBR, Lima-Silva TC, Amorim ELC, Maia MBS, Albuquerque UP. 2005. Life strategy and chemical composition as predictors of the selection of medicinal plants from the Caatinga (Northeast Brazil). *Journal of Arid Environments* **62**: 127-142.
DOI: https://doi.org/10.1016/j.jaridenv.2004.09.020

Anyinam C. 1995. Ecology and ethnomedicine: Exploring links between current environmental crisis and indigenous medical practices. *Social Science and Medicine* **40**: 321-329. DOI: https://doi.org/10.1016/0277-9536(94)E0098-D

Arellanes Y, Casas A, Arellanes A, Vega E, Blancas J, Vallejo M, Torres I, Rangel-Landa S, Moreno AI, Solís L, Pérez-Negrón E. 2013. Influence of traditional markets on plant management in the Tehuacán Valley. *Journal of ethnobiology and ethnomedicine* **9**: 38.
DOI: https://doi.org/10.1186/1746-4269-9-38

Begossi A, Hanazaki N, Peroni N. 2000. Knowledge and use of biodiversity in Brazilian hot spots. *Environment, Development and Sustainability* **2**: 177-193.
DOI: https://doi.org/10.1023/A:1011409923520

Bennett BC, Prance GT. 2000. Introduced Plants in the Indigenous Pharmacopeia of Northern South America. *Economic Botany* **54**: 90-102.
DOI: https://doi.org/10.1007/BF02866603

Bensusán N. 2011. *Retos de la gestión sustentable de los servicios de agua y saneamiento en comunidades rurales.* Caso de estudio de Tacotalpa, Tabasco. Naciones Unidas. CEPAL. México.

Benz B, Cevallos JE, Santana FM, Rosales JA, Graf MS. 2000. Losing knowledge about plant use in the Sierra de Manantlan Biosphere Reserve, Mexico. *Economic Botany* **54**: 183-191. DOI https://doi.org/10.1007/BF02907821

Berkes F. 1993. Traditional ecological knowledge in perspective. *In*: Inglis JT, Ed. *Traditional Ecological Knowledge: Concepts and Cases,* 1-9. Canadian Museum of Nature/International Development Research Centre, Ottawa. e-ISBN: 1552502570

Berkes F, Turner N. 2005. Conocimiento, aprendizaje y la flexibilidad de los sistemas socioecológicos. *Gaceta Ecológica* **77**: 5-17.

Bernard RH. 1995. *Research methods in Anthropology: Qualitative and quantitative approaches.*Second Edition. New York: Altamira Press. ISBN 0-8039-5244-9.—ISBN 0-8039-5245-7 (pbk.)

Blancas J, Casas A, Rangel-Landa S, Moreno-Calles A, Torres I, Pérez-Negrón E, Solís L, Delgado-Lemus A, Parra F, Arellanes Y, Caballero J, Cortés L, Lira R, Dávila P. 2010. Plant management in the Tehuacán-Cuicatlán Valley, México. *Economic Botany* **64**: 287-302.
DOI: https://doi.org/10.1007/s12231-010-9133-0

Blancas J, Casas A, Pérez-Salicrup D, Caballero J, Vega E. 2013. Ecological and socio-cultural factors influencing plant management in Náhuatl communities of the Tehuacán Valley, Mexico. *Journal of Ethnobiology and Ethnomedicine* **9**: 39. DOI: https://doi.org/10.1186/1746-4269-9-39

Brito CC, Silva TC, Albuquerque UP, Ramos MA, Ferreira Júnior WS, Barros FN, Costa Neto EM, Medeiros PM. 2017. The use of different indicators for interpreting the local knowledge loss on medical plants. *Revista Brasileira de Farmacognosia* **27**: 245-250.
DOI: https://doi.org/10.1016/j.bjp.2016.09.006

Cabrera PAJ, Juárez MH, Sánchez GE, Castelán GM, Almazán MBT. 2015. Los saberes en medicina tradicional y su contribución al desarrollo rural: estudio de caso Región Totonaca, Veracruz. *Revista Mexicana de Ciencias Agrícolas* **6**: 1791-1805.

Casas A, Pickersgill B, Caballero J, Valiente-Banuet A. 1997. Ethnobotany and domestication in xoconochtli, Stenocereus stellatus (Cactaceae), in the Tehuacán Valley and la Mixteca Baja, México. *Economic Botany* **51**: 279-292.
DOI: https://doi.org/10.1007/BF02862097

Casas A, Otero-Arnaiz A, Pérez-Negrón E, Valiente-Banuet A. 2007. In situ management and domestication of plants in Mesoamerica. *Annals of Botany* **100**: 1101-1115. DOI: https://doi.org/10.1093/aob/mcm126

Casas A, Camou A, Otero-Arnaiz A, Rangel-Landa S, Cruse-Sanders J, Solís L, Torres I, Delgado A, Moreno-Calles AI, Vallejo M, Guillén S, Blancas J, Parra F, Farfán-Heredia B, Aguirre-Dugua X, Arellanes Y, Pérez-Negrón E. 2014. Manejo tradicional de biodiversidad y ecosistemas en Mesoamérica: el Valle de Tehuacán. *Investigación Ambiental Ciencia y Política Pública* **6**: 23-44

Casas A, Lira R, Torres I, Delgado A, Moreno-Calles AI, Rangel-Landa S, Blancas J, Larios C, Solís L, Pérez-Negrón E,Vallejo M, Parra F, Farfán-Heredia B, Arellanes Y, Campos N. 2016. Ethnobotany for sustainable ecosystem management: a regional perspective in the Tehuacán Valley. *In*: Lira R, Casas A, Blancas J, eds. *Ethnobotany of Mexico*, 179-206. Springer, New York, NY.
DOI: https://doi.org/10.1007/978-1-4614-6669-7_8

Casas A, Torres I, Delgado-Lemus A, Rangel-Landa S, Ilsley C, Torres-Guevara J, Cruz A, Parra F, Moreno-Calles AI, Camou A, Castillo A, Ayala-Orozco B, Blancas JJ, Vallejo M, Solís L, Bullen A, Ortiz T, Farfán B. 2017. Ciencia para la sustentabilidad: investigación, educación y procesos participativos. *Revista Mexicana de Biodiversidad* **88**: 113-128.
DOI: https://doi.org/10.1016/j.rmb.2017.10.003

Case RJ, Pauli GF, Soejarto DD. 2005. Factors in maintaining indigenous knowledge among ethnic communities of Manus Island. *Economic Botany* **59**: 356-365.
DOI: https://doi.org/10.1663/0013-0001(2005)059[0356: FIMIKA]2.0.CO;2

Castellanos-Camacho LI. 2011. Conocimiento etnobotánico, patrones de uso y manejo de plantas útiles en la cuenca del río Cane-Iguaque (Boyacá-Colombia); una aproximación desde los Sistemas de Uso de la Biodiversidad. *Ambiente and Sociedad* **14**: 45-75.
DOI: http://dx.doi.org/10.1590/S1414-753X2011000100004

Challenger A. 1998. *Utilización y Conservación de los Ecosistemas Terrestres de México: pasado, presente y futuro*. Instituto de Biología, Universidad Nacional Autónoma de México. México. ISBN: 9709000020

Challenger A, Soberón J. 2008. Los ecosistemas terrestres. *In*: Sarukhán J, coord. *Capital Natural de México, vol. I: Conocimiento Actual de la Biodiversidad*, 87-108. Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México. ISBN: 978-607-7607-03-8

Charnley S, Fischer AP, Jones ET. 2008. *Traditional and local ecological knowledge about forest biodiversity in the Pacific Northwest*. General Technical Report PNW-GTR-751, US. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Chazdon RL. 2008. Beyond deforestation: restoring forests and ecosystem services on degraded lands. *Science* **320**: 1458-1460. DOI: https://doi.org/10.1126/science.1155365

Chazdon R, Coe FG. 1999. Ethnobotany of woody species in second-growth, old-growth and selectively logged forests of Northeastern Costa Rica. *Conservation Biology* **13**: 1312-1322. DOI: https://doi.org/10.1046/j.1523-1739.1999.98352.x

Chekole G. 2017. Ethnobotanical study of medicinal plants used against human ailments in Gubalafto District, Northern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **13**: 55. DOI: https://doi.org/10.1186/s13002-017-0182-7

Coe FG, Anderson GJ. 1996. Ethnobotany of the Garífuna of Eastern Nicaragua. *Economic Botany* **50**: 71-107. DOI: https://doi.org/10.1007/BF02862114

Cox PA. 2000. Will tribal knowledge survive the millennium? *Science* **287**: 44-45. DOI: https://doi.org/10.1126/science.287.5450.44

DeFries RS, Ellis EG, Chapin III FS, Matson PA, Turner II BL, Agrawal A, Crutzen PJ, Field C, Gleick P, Kareiva PM, Lambin E, Liverman D, Ostrom E, Sanchez PA, Syvitski J. 2012. Planetary opportunities: A social contract for global change science to contribute to a sustainable future. *BioScience* **62**:

603-606. DOI: https://doi.org/10.1525/bio.2012.62.6.11

Eyssartier C, Ladio AII, Lozada M. 2008. Cultural transmission of traditional knowledge in two population of Northwestern Patagonia. *Journal of Ethnobiology and Ethnomedicine* **4**: 1-8. DOI: https://doi.org/10.1186/1746-4269-4-25

Fabricant DS, Farnsworth NR. 2001. The value of plants used in traditional medicine for drug discovery. *Environmental Health Perspectives* **109**: 69-75.
DOI: https://doi.org/10.1289/ehp.01109s169

Fagetti A. 2011. Fundamentos de la medicina tradicional mexicana. *In*: Argueta A, Corona ME, Hersch P, eds. *Saberes Colectivos y Diálogo de Saberes en México*, 137-151. Universidad Nacional Autónoma de México, México. ISBN: 978-607-02-2367-9

Foster GM. 1953. Relationships between Spanish and Spanish-American folk medicine. *The Journal of American Folklore* **66**: 201-217. DOI: https://doi.org/10.2307/537230

García-Barrios L, González-Espinosa M. 2017. Investigación ecológica participativa como apoyo de procesos de manejo y restauración forestal, agroforestal y silvopastoril en territorios campesinos. Experiencias recientes y retos en la sierra Madre de Chiapas, México. *Revista Mexicana de Biodiversidad* **88**: 129–140. DOI: https://doi.org/10.1016/j.rmb.2016.10.022

Garibaldi A, Turner N. 2004. Cultural Keystone species: Implications for conservation and restoration. *Ecology and Society* **9**: 1.

Gollin LX. 1997. Taban Kenyah: a preliminary look at the healing plants and paradigms of the Kenyah Dayak people of Kayan Mentarang. *In*: Sorensen K, Morris B, eds. *People and Plants of Kayan Mentarang*, 135-148. Jakarta WWF, Indonesia. ISBN-10: 2880852153 ISBN-13: 978-2880852153

Gómez-Álvarez R. 2012. Plantas Medicinales en una aldea del Estado de Tabasco, México. *Revista Fitotecnia Mexicana* **35**: 43-49.

Gómez-Pompa A, Vazquez-Yanes C, Guevara S. 1972. The tropical rain forest: a nonrenewable resource. *Science* **177**: 762-765. DOI: https://doi.org/10.1126/science.177.4051.762

Gómez-Pompa A, Kaus A. 1999. From pre-Hispanic to future conservation alternatives: lessons from Mexico. *Proceedings of the National Academy of Sciences* **96**: 5982-5986. DOI: https://doi.org/10.1073/pnas.96.11.5982

González-Cruz G, García-Frapolli E, Fernández AC, Rada JMD. 2014. Conocimiento tradicional maya sobre la dinámica sucesional de la selva. Un caso de estudio en la Península de Yucatán. *Etnobiología* **12**: 60-67.

González-Espinosa M, Ramírez-Marcial N, Camacho-Cruz A, Rey-Benayas JM. 2008. Restauración de bosques en montañas tropicales de territorios indígenas de Chiapas, México. *In*: González-Espinosa M, Rey-Benayas JM, Ramírez-Marcial N, eds. *Restauración de Bosques en América Latina*, 137-162. Fundación Internacional para la Restauración de Ecosistemas (FIRE)/Editorial Mundi-Prensa México. México. ISBN: 9789687462493

González-Espinosa M, Ramírez-Marcial N. 2013. Comunidades vegetales terrestres. *In*: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad (CONABIO)/Gobierno del Estado de Chiapas. *La Biodiversidad en Chiapas: Estudio de Estado*, 21-42. México. ISBN Vol II: 978-607-8328-00-0

Grande-Cano JD, Losada H, Cortés J, Rivera JG, Maldonado NM, Pérez-Gil F. 2009. Los árboles dispersos en potreros de la región de la Sierra de Tabasco, México. *Revista Brasileira de Agroecologia* **4**. <http://revistas.aba-agroecologia.org.br/index.php/rbagroecologia/article/view/90920> (accessed april 23, 2019).

Gupta AK. 2004. WIPO-UNEP Study on the Role of Intellectual Property Rights in the Sharing of Benefits Arising from the Use of Biological Resources and Associated Traditional Knowledge. World Intellectual Property Organization (WIPO)/United Nations Environment Programme (UNEP), India.

Hamilton AC. 2004. Medicinal plants, conservation and livelihoods. *Biodiversity and Conservation* **13**: 1477-1517. DOI: https://doi.org/10.1023/B:BIOC.0000021333.23413.42

Helida A, Zuhud EAM, Hardjanto H, Purwanto Y, Hikmat A. 2015. Index of cultural significance as a potential tool for conservation of plant diversity by communities in The Kerinci Seblat National Park. *Jurnal Manajemen Hutan Tropika* **21**: 192-201. DOI: http://dx.doi.org/10.7226/jtfm.21.3.192

Hernández-Ramos J, Reynoso-Santos R, Hernández-Ramos A, García-Cuevas X, Hernández-Máximo E, Cob-Uicab JV, Sumano-López D. 2018. Distribución histórica, actual y futura de *Cedrela odorata* en México. *Acta Botanica Mexicana* **124**: 117-134.
DOI: https://doi.org/10.21829/abm124.2018.1305

Hoffman B, Gallaher T. 2007. Importance indices in ethnobotany. *Ethnobotany Journal* **5**: 201-218.

INEGI [Instituto Nacional de Estadística y Geografía]. 2005. *Prontuario de información geográfica municipal de los Estados Unidos Mexicanos, Tacotalpa, Tabasco*. Clave geoestadística 27015. Instituto Nacional de Estadística y Geografía. México.

INEGI. 2010. *Censo de Población y Vivienda*. Instituto Nacional de Estadística y Geografía. México.

INEGI. 2015. *Anuario estadístico y geográfico por entidad federativa 2015*. Instituto Nacional de Estadística y Geografía. México.

Janzen DH. 1970. Herbivores and the number of tree species in tropical forests. *The American Naturalist* **104**: 501-528. DOI: https://doi.org/10.1086/282687

Kainer KA, Duryea M. 1992. Tapping women's knowledge: Plant resource use in extractive reserves, Acre Brazil. *Economic Botany* **46**: 408-425.
DOI: https://doi.org/10.1007/BF02866513

Koleff P, Urquiza-Haas T, Contreras B. 2012. Prioridades de conservación de los bosques tropicales en México: reflexiones sobre su estado de conservación y manejo. *Ecosistemas* **21**: 6-20.

Kothari B. 2003. The invisible queen in the plant kingdom: Gender perspectives in medical ethnobotany. *In*: Howard PL, ed. *Women and Plants: Gender Relations in Biodiversity Management and Conservation*, 150-164. London and New York: Zed Books Ldt. ISBN: 9781842771570

Levy-Tacher S, Ramírez-Marcial N, González-Espinosa M, Román-Dañobeytia F. 2012. Rehabilitación ecológica de áreas agropecuarias degradadas en la Selva Lacandona: una alternativa fincada en el conocimiento ecológico tradicional

maya. *In*: Bello E, Naranjo EJ, Vandame R, eds. *La Otra Innovación para el Ambiente y la Sociedad en la Frontera Sur de México, 248-258*. El Colegio de la Frontera Sur, Chiapas, México. ISBN: 978-607-7637-45-5

Linares E, Bye R. 1987. A study of four medicinal plant complexes of Mexico and adjacent United States. *Journal of Ethnopharmacology* **19**: 153-183.
DOI: https://doi.org/10.1016/0378-8741(87)90039-0

Lindig-Cisneros R. 2017. *Ecología de la restauración y restauración ambiental*. Universidad Nacional Autónoma de México. ISBN: 9786070294495

López-Hernández E. 1994. *La Vegetación y la Flora de la Sierra de Tabasco (Municipios de Tacotalpa y Teapa), México*. Universidad Juárez Autónoma de Tabasco. Villahermosa, Tabasco, México.

Lulekal E, Kelbessa E, Bekele T, Yineger H. 2008. An ethnobotanical study of medicinal plants in Mana Angetu District, southeastern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **4**: 10. DOI: https://doi.org/10.1186/1746-4269-4-10

Luoga E, Witkowski E, Balkwill K. 2000. Differential utilization and ethnobotany of trees in Kitulanghalo Forest Reserve and surrounding communal lands, Eastern Tanzania. *Economic Botany* **54**: 328-343.
DOI: https://doi.org/10.1007/BF02864785

Luziatelli G, Sörensen M, Theilade I, Mölgaard P. 2010. Asháninka medicninal plants: a case study from the native community of Bajo Quimiriki, Junín, Perú. *Journal of Ethnobiology and Ethnomedicine* **6**: 1-21.
DOI: https://doi.org/10.1186/1746-4269-6-21

Mace R, Pagel M. 1995. A latitudinal gradient in the density of human languages in North America. *Proceedings of the Royal Society: Biological Sciences* **261**: 117-121. DOI: https://doi.org/10.1098/rspb.1995.0125

Maffi L. 2005. Linguistic, cultural, and biological diversity. *Annual Review of Anthropology* **34**: 599-617.
DOI: https://doi.org/10.1146/annurev.anthro.34.081804.120437

Magaña-Alejandro MA. 2006. *Catálogo de nombres vulgares y científicos de plantas de Tabasco*. Universidad Juárez Autónoma de Tabasco. Villahermosa, Tabasco, México. ISBN: 9685748950

Magaña-Alejandro MA, Gama Campillo LM, Mariaca-Méndez R. 2010. El uso de las plantas medicinales en las comunidades Maya-Chontales de Nacajuca, Tabasco, México. *Polibotánica* **29**: 213-262.

Maldonado-Mares F. 2005. *Flora medicinal del Estado de Tabasco, uso, manejo y conservación*. Universidad Juárez Autónoma de Tabasco. Villahermosa, Tabasco, México.

Masera O, Ordóñez MJ, Dirzo R. 1992. Emisiones de carbono a partir de la deforestación en México. *Ciencia* **43**: 151-153.

Medellín-Morales S, Barrientos-Lozano L, Mora-Olivo A, Almaguer-Sierra P, Mora-Ravelo GS. 2017. Diversidad de conocimiento etnobotánico tradicional en la reserva de la biosfera "El Cielo", Tamaulipas, México. *Ecología Aplicada* **16**: 49-61. DOI: http://dx.doi.org/10.21704/rea.v16i1.904

Miranda F, Hernández-X E. 2014. *Los Tipos de Vegetación de México y su clasificación*. Edición conmemorativa 1963-2013. Colec. Ediciones Científicas Universitarias. FCE, CONABIO. México. ISBN: 9786071618634; 9786078328086

Moore JL, Manne L, Brooks T, Burgess ND, Davies R, Rahbek C, Williams P, Balmford A. 2002. The distribution of cultural and biological diversity in Africa. *Proceedings of the Royal Society of London B: Biological Sciences* **269**: 1645-1653. DOI: https://doi.org/10.1098/rspb.2002.2075

Myers N, Mittermeier R, Mittermeier GC, Dafonseca GAB, Kent J. 2000. Biodiversity hotspots for conservation priorities. *Nature* **403**: 853-858. DOI: https://doi.org/10.1038/35002501

Novotny V, Drozd P, Miller SE, Kulfan M, Janda M, Basset Y, Weiblen GD. 2006. Why are there so many species of herbivorous insects in tropical rainforests? *Science* **313**: 1115-1118. DOI: https://doi.org/10.1126/science.1129237

Ortiz-Pérez MA, Siebe C, Cram S. 2005. Diferenciación geográfica de Tabasco. *In*: Bueno-Soria J, Álvarez-Noguera F, Santiago S, eds. *Biodiversidad del Estado de Tabasco*, 305-322. Instituto de Biología, UNAM-CONABIO. México. ISBN: 970-9000-26-8

Parker T. 2008. *Trees of Guatemala*. The Tree Press, Austin, Texas. ISBN-10: 0971873909 ISBN-13: 978-0971873902

Pei S, Zhang G, Huai H. 2009. Application of traditional knowledge in forest management: ethnobotanical indicators of sustainable forest use. *Forest Ecology and Management* **257**: 2017-2021.
DOI: https://doi.org/10.1016/j.foreco.2009.01.003

Pennington T, Sarukhán J. 2005. *Árboles tropicales de México: manual para la identificación de las principales especies*. Universidad Nacional Autónoma de México. México DF: Fondo de Cultura Económica, ISBN: 9789681678555

Phillips O, Gentry AH. 1993. The useful plants of Tambopata, Peru: II. Additional hypothesis testing in quantitative ethnobotany. *Economic Botany* **47**: 15-32.
DOI: https://doi.org/10.1007/BF02862204

Pochettino ML, Lema VS. 2008. La variable tiempo en la caracterización del conocimiento botánico Tradicional. *Darwiniana* **46**: 227-239.
DOI: https://doi.org/10.14522/darwiniana.2014.462.285

Quinlan MB, Quinlan RJ. 2007. Modernization and medicinal plant knowledge in a Caribbean horticultural village. *Medical Anthropology Quarterly* **21**: 169-192.
DOI: https://doi.org/10.1525/maq.2007.21.2.169

Ramírez-Marcial N, González-Espinosa M, Musálem-Castillejos K, Noguera-Savelli E, Gómez-Pineda E. 2014. Estrategias para una construcción social de la restauración forestal en comunidades de la cuenca media y alta del Río Grijalva. *In*: González-Espinosa M, Brunel-Manse C, coords. *Montañas, Pueblos y Agua. Dimensiones y Realidades de la Cuenca Grijalva,* 528-564. El Colegio de la Frontera Sur/Juan Pablos Editor. México. ISBN-10: 6078429019; ISBN-13: 978-6078429011

Rangel-Landa S, Casas A, García-Frapolli E, Lira R. 2017. Sociocultural and ecological factors influencing management of edible and non-edible plants: the case of Ixcatlán, Mexico. *Journal of ethnobiology and ethnomedicine* **13**: 59. DOI: https://doi.org/10.1186/s13002-017-0185-4

Reyes-García V, Vadez V, Huanca T, Leonard W, Wilkie D. 2005. Knowledge and consumption of wild plants: a comparative study in two Tsimane' villages in the Bolivian Amazon. *Ethnobotany Research and Applications* **3**: 201-207.

Reyes-García V, Huanca T, Vadez V, Leonard W, Wilkie D. 2006. Cultural, practical and economic value of wild plants: A quantitative study in the Bolivian Amazon. *Economic Botany* **60**: 62-74.
DOI: https://doi.org/10.1663/0013-0001(2006)60[62:CPAEVO]2.0.CO;2

Reyes-García V, Guéze M, Luz AC, Paneque-Gálvez J, Macía MJ, Orta-Martínez M, Pino J, Rubio-Campillo X. 2013. Evidence of traditional knowledge loss among a contemporary indigenous society. *Evolution and Human Behavior: official journal of the Human Behavior and Evolution Society* **34**: 249-257.
DOI: https://doi.org/10.1016/j.evolhumbehav.2013.03.002

Reyes-Tagle Y. 2007. La protección del conocimiento tradicional a través de las bases de datos y registros en la Convención sobre Diversidad Biológica y la Convención de Lucha Contra la Desertificación. *Agenda Internacional* **14**: 25-39.

Ryan CJ. 1992. *Life Support: Conserving biological diversity.* Worldwatch Paper 108. Washington, DC: Worldwatch Institute. ISBN-10: 1878071092; 978-1878071095

Rzedowski J. 1998. Diversidad y orígenes de la flora fanerogámica de México. *In*: Ramamoorthy TP, Bye R, Lot A, Fa J, eds. *Diversidad Biológica de México: Orígenes y Distribución*, 129-145. Instituto de Biología, UNAM. ISBN: 9683665888

Rzedowski J. 2006. *Vegetación de México.* 1ra. Edición digital, Comisión Nacional para el Conocimiento y Uso de la Biodiversidad. México.

Salazar-Conde EC, Zavala-Cruz J, Castillo-Acosta O, Cámara-Artigas R. 2004. Evaluation spatial and temporal of the vegetation Sierra Madrigal, State of Tabasco, México (1973-2003). *Investigaciones Geográficas* **54**: 7-23.

Sánchez-Munguía A. 2005. *Uso del suelo agropecuario y desforestación en Tabasco 1950-2000.* Universidad Juárez Autónoma de Tabasco. México.

SEMARNAT [Secretaría del Medio Ambiente y Recursos Naturales]. 2010. Norma Oficial Mexicana NOM-059-SEMARNAT-2010, Protección ambiental – Especies nativas de México de flora y fauna silvestres – Categorías de riesgo y especificaciones para su inclusión, exclusión o cambio – Lista de especies en riesgo. *Diario Oficial de la Federación*. 2da Sección, 30 de diciembre de 2010.

Sepúlveda J. 1993. *La salud de los pueblos indígenas en México.* Secretaría de Salud. Instituto Nacional Indigenista. Impresiones y grabados M. Serna. México.

Shaheen H, Qaseem MF, Amjad MS, Bruschi P. 2017. Exploration of ethno-medicinal knowledge among rural communities of Pearl Valley; Rawalakot, District Poonch Azad Jammu and Kashmir. *Plos One* **12**: 1-32.
DOI: https://doi.org/10.1371/journal.pone.0183956

Sheil D, Lawrence A. 2004. Tropical biologists, local people and conservation: new opportunities for collaboration. *Trends in Ecology and Evolution* **19**: 634-638.
DOI: https://doi.org/10.1016/j.tree.2004.09.019

Silalahi M, Supriatna J, Walujo EB, Nisyawati. 2015. Local knowledge of medicinal plants in sub-ethnic Batak Simalungun of North Sumatra, Indonesia. *Biodiversitas* **16**: 44-54.
DOI: https://doi.org/10.13057/biodiv/d160106

Silva ACO, Albuquerque UP. 2005. Woody medicinal plants of the Catinga in the state of Pernambuco (Northeast Brazil). *Acta Botanica Brasilica* **19**: 17-26.
DOI: http://dx.doi.org/10.1590/S0102-33062005000100003

Silva VA, Andrade LHC, Albuquerque UP. 2006. Revising the cultural significance index: the case of the Fulni-ô in northeastern Brazil. *Field Methods* **18**: 98-108.
DOI: https://doi.org/10.1177/1525822X05278025

SER [Society for Ecological Restoration]. 2004. Ponencia introductoria de SER lnternational sobre la restauración ecológica. SER y Tucson: Society for Ecological Restoration International.

Stagegaard J, Sorensen M, Kvist L. 2002. Estimations of the importance of plant resources extracted by inhabitants of the Peruvian Amazon flood plain forests. *Perspectives in Plant Ecology, Evolution and Systematics* **5**: 103-122. DOI: https://doi.org/10.1078/1433-8319-00026

Stepp JR. 2004. The role of weeds as sources of pharmaceuticals. *Journal of Ethnopharmacology* **92**: 163-166. DOI: https://doi.org/10.1016/j.jep.2004.03.002

Stoffle RW, Halmo DB, Evans MJ, Olmsted JE. 1990. Calculating the cultural significance of American Indian plants: Paiute and Shoshone ethnobotany at Yucca Mountain, Nevada. *American Anthropologist* **92**: 416-432.
DOI: https://doi.org/10.1525/aa.1990.92.2.02a00100

Suárez A, Williams-Linera G, Trejo C, Valdez-Hernández JI, Cetina-Alcalá VM, Vibrans H. 2012. Local knowledge helps select species for forest restoration in a tropical dry forest of central Veracruz, Mexico. *Agroforestry systems* **85**: 35-55.
DOI: https://doi.org/10.1007/s10457-011-9437-9

Suding K. 2011. Toward an era of restoration in ecology: successes, failures and opportunities ahead. *Annual Review of Ecology, Evolution and Systematics* **42**: 465-487. DOI: https://doi.org/10.1146/annurev-ecolsys-102710-145115

Suding K, Higgs E, Palmer M, Callicott JB, Anderson CB, Baker M, Gutrich JJ, Hondula KL, LaFevor MC, Larson BMH, Randall A, Ruhl JB, Schwartz KZS. 2015. Committing to ecological restoration. *Science* **348**: 638-640.
DOI: https://doi.org/10.1126/science.aaa4216

Toledo VM. 1987. La etnobotánica en Latinoamérica. Vicisitudes, contextos, desafíos. Memorias del IV Congreso Latinoaméricano de Botánica. Simposio de etnobotánica: perspectivas en Latinoamérica. Medellín, Colombia.

Toledo VM, Batis AI, Becerra R, Esteban M, Ramos CH. 1992. Products from the tropical rain forests of Mexico: an ethnoecological approach. *In*: Plotkin M, Famolare L, eds. *Sustainable Harvest and Marketing of Rain Forest Products,* 99-109. Island Press, Washington, DC. ISBN-10: 1559631686; 978-1559631686

Toledo VM, Batis AI, Becerra R, Martínez E, Ramos HC. 1995. La Selva útil: Etnobotánica cuantitativa de los grupos indígenas del Trópico húmedo de México. *Interciencia* **20**: 177-187.

Toscano GJY. 2006. Uso tradicional de plantas medicinales en la vereda San Isidro, Municipio de San José de Pare-Boyacá: Un estudio preliminar usando técnicas cuantitativas. *Acta Biológica Colombiana* **11**: 137-146.

Tudela F. 1989. *La modernización forzada del trópico: El caso*

de Tabasco. Proyecto integrado del Golfo. El Colegio de México. ISBN: 968120419 0

Turner NJ. 1988. "The importance of a rose": Evaluating the cultural significance of plants in Thompson and Lillooet interior Salish. *American Anthropologist* **90**: 272-290. DOI: https://doi.org/10.1525/aa.1988.90.2.02a00020

Vandebroek I, Balick MJ. 2012. Globalization and loss of plant Knowledge: challenging the paradigm. *Plos One* **7**: e37643. DOI: https://doi.org/10.1371/journal.pone.0037643

Vázquez-Yanes C, Batis MAI, Alcocer SMI, Gual DM, Sánchez DC. 1999. *Árboles y arbustos nativos potencialmente valiosos para la restauración ecológica y la feforestación.* Reporte técnico del proyecto J084. CONABIO-Instituto de Ecología, UNAM, México.

Velázquez-Rosas N, Silva-Rivera E, Ruiz-Guerra B, Armenta-Montero S, Trejo González J. 2018. Traditional Ecological Knowledge as a tool for biocultural landscape restoration in northern Veracruz, Mexico: a case study in El Tajín region. *Ecology and Society* **23**: 6. DOI: https://doi.org/10.5751/ES-10294-230306

Voeks RA. 1996. Tropical forest healers and habitat preference. *Economic Botany* **50**: 381-400.
DOI: https://doi.org/10.1007/BF02866520

Voeks RA. 2004. Disturbance pharmacopoeias: Medicine and myth from the humid tropics. *Annals of the Association of American* Geographers **94**: 868-888.
DOI: https://doi.org/10.1111/j.1467-8306.2004.00439.x

Voeks RA. 2007. A women reservoirs of traditional plant knowledge? Gender, ethnobotany and globalization in northeast Brazil. *Singapore Journal of Tropical Geography* **28**: 7-20. DOI: https://doi.org/10.1111/j.1467-9493.2006.00273.x

Voeks RA, Nyawa S. 2001. Healing flora of the Brunei Dusun. *Borneo Research Bulletin* **32**: 178-195.

Voeks RA, Leony A. 2004. Forgetting the forest: assessing medicinal plant erosion in Eastern Brazil. *Economic Botany* **58**: 294-306.
DOI: https://doi.org/10.1663/0013-0001(2004)58[S294:FTFAMP]2.0.CO;2

Weldegerima B. 2009. Review on the importance of documenting ethnopharmacological information on medicinal plants. *African Journal of Pharmacy and Pharmacology* **3**: 400-403.

WHO [World Health Organization]. 2002. Medicina tradicional: necesidades crecientes y potencial. Ginebra: Organización Mundial de la Salud. <http://www.who.int/iris/handle/10665/67296> (accessed January 16, 2019).

WHO. 2013. WHO traditional medicine strategy: 2014-2023. World Health Organization. Geneva, Switzerland. <http://apps.who.int/iris/bitstream/10665/92455/1/9789241506090_eng.pdf> (accessed January 16, 2019).

Wuethrich B. 2007. Reconstructing Brazil's Atlantic rainforest. *Science* **315**: 1070-1072.
DOI: https://doi.org/10.1126/science.315.5815.1070

Appendix 1

Index of Knowledge Richness (*IKR*) by age range of women and men in each study community; n= number of interviewees; *S* = Number of known species; Max.= maximum, Min.= minimum.

	Oxolotán									
	Women (*IKR*)					Men (*IKR*)				
Age range	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}
20-30	0	–	–	–	–	0	–	–	–	–
31-40	1	0.41	14	–	–	0	–	–	–	–
41-50	5	0.53	18	0.26	9	0	–	–	–	–
51-60	4	0.41	14	0.18	6	3	0.44	15	**0.06**	2
61-70	7	0.35	12	0.12	4	0	–	–	–	–
71-80	5	**0.62**	21	0.29	10	0	–	–	–	–
81-90	2	0.59	20	0.38	13	1	0.32	11	–	–
91-100	0	–	–	–	–	0	–	–	–	–
No. interviewees (%)	24 (86%)					4 (14 %)				

	Cerro Blanco Quinta Sección				
	Women (*IKR*)				
Age range	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}
20-30	1	0.39	11	–	–
31-40	8	0.50	14	**0.11**	3
41-50	8	**0.57**	16	0.18	5
51-60	8	0.54	15	0.29	8
61-70	3	0.39	11	0.21	6
71-80	1	0.43	12	–	–
81-90	–	–	–	–	–
91-100	–	–	–	–	–
No. interviewees (%)	29 (100%)				

	Tomás Garrido Canabal									
	Women (*IKR*)					Men (*IKR*)				
Age range	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}
20-30	1	0.23	7	–	–	–	–	–	–	–
31-40	3	0.48	15	0.26	8	1	0.42	13	–	–
41-50	5	0.42	13	0.29	9	–	–	–	–	–
51-60	3	0.55	17	0.23	7	3	0.35	11	**0.19**	6
61-70	4	**0.58**	18	0.23	7	2	0.45	14	0.35	11
71-80	–	–	–	–	–	2	0.32	10	0.29	9
81-90	–	–	–	–	–	1	0.26	8	–	–
91-100	1	0.48	15	–	–	–	–	–	–	–
No. interviewees (%)	17 (65%)					9 (35%)				

		La Cumbre								
		Women (*IKR*)					Men (*IKR*)			
Age range	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}	n	Max. *IKR*	S_{Max}	Min. *IKR*	S_{Min}
20-30	1	0.37	11	_	_	_	_	_	_	_
31-40	1	0.20	6	_	_	1	0.33	10	_	_
41-50	2	**0.53**	16	0.27	8	1	0.27	8	_	_
51-60	3	0.30	9	0.17	5	1	0.43	13	_	_
61-70	5	**0.53**	16	**0.13**	4	1	0.27	8		
71-80	3	0.40	12	0.37	11	3	0.30	9	0.23	7
81-90	_	_	_	_	_	1	0.27	8	_	_
91-100	1	0.23	7	_	_	_	_	_	_	_
No. interviewees (%)	16 (67%)					8 (33%)				