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Evaluación del deterioro de la vegetación leñosa y de la cultura tradicional en el bosque templado de la Mixteca Alta Oaxaqueña

TESIS QUE PARA OBTENER EL GRADO ACADÉMICO DE DOCTOR EN CIENCIAS

PRESENTA:

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En la Ciudad de Oaxaca de Juárez siendo las 13:00 horas del día 03 del mes de noviembre del 2012 se reunieron los miembros de la Comisión Revisora de Tesis designada por el Colegio de Profesores de Estudios de Posgrado e Investigación del **Centro Interdisciplinario de Investigación para el Desarrollo Integral Regional, Unidad Oaxaca (CIIDIR-OAXACA)** para examinar la tesis de grado titulada: "Evaluación del deterioro de la vegetación leñosa y de la cultura tradicional en el bosque templado de la Mixteca Alta Oaxaqueña".

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Resumen. La Mixteca Alta oaxaqueña se caracteriza por presentar un paisaje fragmentado con graves problemas de erosión. Además, en esta zona habitan poblaciones de origen mixteco que se caracterizan por su alto grado de marginación. En este estudio se realizó un análisis del estado de la vegetación y los factores que condicionan diferencias en la diversidad de remanentes de bosque de encino estacional, así como de los factores sociales relacionados con el conocimiento tradicional sobre el uso de plantas de los bosques en tres municipios de la región. El objetivo de estos estudios fue generar información que permita abordar la conservación de los bosques de encino estacionales en la Mixteca Alta oaxaqueña desde dos enfoques: el primero relacionado con el deterioro de la vegetación y el segundo con el deterioro de la cultura tradicional en la región. Para el primer enfoque, se realizó muestreo en doce fragmentos de bosque y se analizó la relación entre la diversidad de plantas leñosas en los fragmentos y aspectos relacionados con el área, la heterogeneidad ambiental y el disturbio en cada uno. Un modelo de Ecuaciones Estructurales Lineales mostró que la diversidad aumenta con la heterogeneidad topográfica y la perturbación humana. Al considerar estas dos variables, la diversidad disminuyó con el tamaño del fragmento probablemente porque proporcionalmente los fragmentos pequeños tienen mayor perímetro que los grandes y favorecen a las plantas pioneras. Para resolver el segundo enfoque, se analizó el efecto de seis atributos sociales de informantes en tres municipios de la región sobre el conocimiento tradicional (TK) de plantas útiles nativas de bosques de encino estacionales en esta zona. Se realizaron 316 entrevistas sobre el uso de106 plantas colectadas. Se calcularon dos índices para evaluar el TK de cada uno de los informantes. Los atributos sociales considerados fueron: municipio, edad, género, dominio del idioma nativo, nivel de escolaridad y tiempo proporcional de la vida del informante que ha estado ausente de la comunidad. El municipio es considerado aquí como un atributo social de los informantes ya que sus características determinan el contexto social en que se han desarrollado. Encontramos que TK tiende a ser mayor en las comunidades caracterizadas por tener la mayor proporción de hablantes de idioma mixteco, mayor proporción de personas analfabetas, menor grado de escolaridad promedio y menor acceso a servicios tales como suelo diferente a tierra, agua entubada y drenaje. La relación del TK con el dominio de idioma nativo, realización de actividades en campo y edad de los informantes es positiva, mientras que con la escolaridad y proporción de tiempo fuera de la comunidad es negativa. Se concluye que las estrategias de conservación en bosques fragmentados deben considerar tanto los atributos de los remanentes, tales como heterogeneidad ambiental, el disturbio y las especies que deben ser conservadas, como los atributos sociales de las poblaciones humanas y su relación con el ecosistema.

Palabras clave: Bosques de encino estacionales, disturbio antropogénico, heterogeneidad topográfica, conocimiento tradicional, atributos sociales.

Abstract. The Mixteca Alta region, in the state of Oaxaca, Mexico, is characterized by a fragmented landscape with severe erosion. Moreover, in this area live Mixtec populations that are characterized by their high degree of marginalization. In this study, we conducted two analyses: first, we analyze the factors that determine differences in diversity of fragmented seasonally dry oak forest; second, we analyze social factors related to traditional knowledge on the use of forest plants in three municipalities of the region. The objective of these studies is to generate information that allows address the conservation of

seasonally dry oak forest in the Mixteca Alta, Oaxaca from two approaches: the first related to the deterioration of the vegetation and the second related to the deterioration of the culture in the region. To solve the first approach, we sampled in twelve forest fragments and analyzed the relationship between woody plant diversity in the fragments and aspects related to the area, environmental heterogeneity and disturbance in each. Linear Structural Equation model showed that diversity increases with topographic heterogeneity and human disturbance. When considering these two variables, diversity decreased with fragment size, probably because small fragments have proportionally greater perimeter than large, and favor the development of pioneer species. To solve the second approach, we explore the effect of six social attributes of informants in three municipalities of the region on the traditional knowledge of useful plants from native oak forests in this area. We conducted 316 interviews based on 106 collected plants. Two indices were calculated to assess the traditional knowledge of each informant. Social attributes considered were: municipality, age, gender, native language proficiency, education level and time proportional to the informant's life that has been absent from the community. We find that traditional knowledge tends to be higher in communities characterized by having the highest proportion of Mixtec language speakers, higher proportion of illiterates, lower average education level and lower access to housing services such as non-dirty floor, piped water and drainage. Traditional knowledge is positively related with native language proficiency, involvement in field activities and age of the informant. The relationship of traditional knowledge with education level and proportion of the informant´s life spent outside the community is negative. We conclude that conservation strategies in fragmented forests must consider both the remaining attributes, such as environmental heterogeneity,

disturbance and species should be preserved, as the social attributes of human populations and their relationship with the ecosystem.

Key words: seasonally dry oak forest, human disturbance, topographic heterogeneity, traditional knowledge, social attributes.

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Yuku ninu xian Kumasi ini-ri jin-ro, kua'a kiti nchaka-ro nuni cháa ñú-un nayuu roó nta'u nta'u, ntukuiñi-ro

ARBOL DE CERRO DE YUKU NINU

Cerro de Yucuninu mi aprecio es para ti. Tú alimentas a tantos animales, y cuando sufres incendios te quedas sin bosque. Qué triste! qué triste!

Fragmento. Poeta mixteco Juan de Dios Ortiz Cruz, de San Miguel el Grande, Tlaxiaco

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Introducción

La Región Mixteca, en el estado de Oaxaca, es conocida por su extensa deforestación y erosión y su marginación extrema (Anónimo, 2005), que dio inicio con la introducción de ganado y sistemas de producción inadecuados durante la época de la Colonia (Butterwort. 1990; Arredondo *et al.*, 1981; Martínez *et al.*, 1986; Rodríguez *et al.*, 2005; Martínez, 2006; Pérez, 2006).

En esta zona, la complejidad topográfica, sequías prolongadas y manejo inadecuado de los recursos han provocado la aceleración de los procesos erosivos del suelo (Butterwort, 1990; Martínez *et al.*, 1986). Lo anterior, aunado al decremento en la cobertura vegetal, ha originado alteraciones importantes en las funciones del ecosistema, pérdida de servicios ambientales, merma de tierras fértiles y baja calidad de los cultivos (Butterwort, 1990; Rodríguez *et al.*, 2005; Cotler *et al.*, 2007).

El panorama en la actualidad es un paisaje fragmentado donde se llega a observar el material parental expuesto a cielo raso. De acuerdo con Anta *et al.* (2006), el 20% de la superficie de la Mixteca se encuentra fragmentada, 48% desmontada y sólo el 32% se considera conservada.

Estas condiciones aceleran el proceso de desertificación y el desabasto de alimentos y agua, por lo que las oportunidades para sobrevivir son escasas y muchas personas se ven obligadas a salir de sus hogares en busca de otras alternativas de vida. Esto ha traído consigo también la pérdida de valores y conocimiento tradicional, creándose de esta manera un círculo vicioso en el cual el desconocimiento de formas apropiadas de manejo de los recursos incrementa aún más la problemática planteada (Martínez, 2006).

La conservación de los ecosistemas requiere conocer sus propiedades intrínsecas, como su diversidad biológica y los procesos que la modifican, pero además es necesario conocer las relaciones que se establecen con el ser humano, particularmente la manera en que las poblaciones humanas perciben al bosque, la importancia que el ecosistema tiene para ellos y de qué manera la penetración de la cultura occidental está afectando esta percepción (Carlson y Maffi, 2003; Howard, 2003; Raynor y Kostka, 2003; Aguilar-Santelises, 2007).

El enfoque ecosistémico es una estrategia para manejar la tierra, el agua y los recursos bióticos y para mantener o restaurar los sistemas naturales, sus funciones y valores de tal manera que se promueva la conservación y el uso sostenible de una forma justa y equitativa. Este enfoque constituye un marco para el análisis amplio, en el que concurren las dimensiones social, económica y ambiental que facilitan una mayor aproximación a lo que está ocurriendo en el ecosistema, así como también la proyección de acciones futuras, para encauzar su sostenibilidad, a través de la integración de factores ecológicos, económicos y sociales dentro de un marco geográfico definido por límites ecológicos. Dicho enfoque reconoce que los seres humanos con su diversidad cultural, constituyen un componente integral de muchos ecosistemas (Arellano-Acosta, 2002; Secretaría del Convenio sobre Diversidad Biológica, 2004), ya que las comunidades indígenas y locales tienen un papel importante en el manejo de la biodiversidad, de tal manera que el valor del conocimiento tradicional ha sido reconocido por científicos y políticos y se ha convertido en un factor de la legislación internacional (Mauro & Hardison, 2000).

Así, en el enfoque ecosistémico existen tres aspectos diferentes. En el primero se visualizan las propiedades de los ecosistemas y la forma en que se ven modificados por su interacción con características ambientales, tanto naturales como de origen antropogénico; en el segundo se analiza la percepción del humano acerca de los ecosistemas de su entorno y en el tercero se integran los dos primeros aspectos para la generación de planes y acciones de conservación y restauración de paisajes. En este estudio se exploran los dos primeros aspectos de este enfoque con la finalidad de sentar las bases para su integración en planes de manejo y conservación de bosques templados en la Mixteca Alta oaxaqueña. Para alcanzar este objetivo, este estudio se compone de tres capítulos. El primero analiza la diversidad florística y los factores ambientales que la modifican en remanentes de bosque de encino estacionalmente secos de la Mixteca. El segundo analiza el estado actual del conocimiento tradicional de uso de las plantas por parte de los habitantes de la zona y su relación con características sociales de los informantes. El tercer capítulo resume las conclusiones obtenidas en los dos primeros.

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Capítulo I

Factors affecting woody plant diversity in fragmented seasonally dry oak forests, in the Mixteca Alta, Oaxaca, Mexico *

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Factors affecting woody plant diversity in fragmented seasonally dry oak forests, in the Mixteca Alta, Oaxaca, Mexico.

Factores que afectan la diversidad de especies leñosas en fragmentos de bosque de encino estacionalmente seco de la Mixteca alta oaxaqueña, México.

Remedios Aguilar-Santelises[1] and Rafael F. del Castillo[2].

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Abstract. We explored the relationship between fragment area, topographic heterogeneity, and disturbance intensity with tree and shrub layers diversity in seasonally dry oak forest remnants in the Mixteca Alta, Oaxaca, Mexico. The fragments are distributed in a matrix of eroded lands and crop fields, have a complex topography, and are disturbed by plant extraction and trail opening. Sampling was conducted in twelve, 12 - 3,211 ha, fragments. Topographic heterogeneity was estimated by the fragment's standard deviation in slope-aspect, slope, and altitude. The density of stumps and roads were used as estimators of disturbance intensity. Fragment Fisher's α diversity ranked from 0.95 to 4.55 for tree layer; and 2.99 to 8.51, for shrub layer. Structural analysis model showed that the diversity of woody plants increases with topographic heterogeneity and disturbance in the remnants. When these two variables were considered, diversity tends to decrease with fragment size probably because smaller fragments have a greater perimeter-to-area ratio and therefore proportionally offer more opportunities for pioneer species colonization. Indeed, the tree-to shrub-layer diversity ratio increased with fragment size. Conservation strategies in fragmented forests must consider the fragment´s environmental heterogeneity, the disturbance type and intensity, and the species to be preserved.

Key words: fragmentation, seasonally dry oak forest, human disturbance, species-area relationship, topographic heterogeneity, structural equation modeling.

Resumen. Exploramos la relación entre el área, la heterogeneidad topográfica y el disturbio en remanentes de bosque de encino estacionales en la Mixteca Alta, Oaxaca, México. Una matriz de suelo erosionado y cultivos rodea los fragmentos, que están afectados por extracción vegetal y caminos y presentan topografía compleja. Muestreamos la vegetación en doce fragmentos de 12 a 3,211 ha. Estimamos la heterogeneidad ambiental con las desviaciones estándar en pendiente, orientación y altitud del fragmento, y la intensidad de disturbio, por la densidad de tocones y el área afectada por caminos. La diversidad α de Fisher varió entre 0.95 y 4.55 para el estrato arbóreo y 2.99 y 8.51 para el arbustivo. Un modelo de ecuaciones estructurales lineales mostró que la diversidad aumenta con la heterogeneidad topográfica y la perturbación humana. Al considerar estas dos variables, la diversidad disminuyó con el tamaño del fragmento probablemente porque proporcionalmente los fragmentos pequeños tienen mayor perímetro que los grandes y favorecen a las pioneras. La razón entre la diversidad del estrato arbóreo y el arbustivo aumentó con el tamaño del fragmento. Las estrategias de conservación en bosques

fragmentados deben considerar la heterogeneidad ambiental, el disturbio y las especies que deben ser conservadas.

Palabras clave: fragmentación, bosques de encino estacionalmente secos, disturbio, relación especies-área, heterogeneidad ambiental, modelaje de ecuaciones estructurales.

Introduction

Fragmentation processes involve habitat losses and the splitting of the remaining habitat into pieces of various sizes and isolation degrees (Laurance, 2008). Currently, a large part of the land surface is being affected by human activities causing ecosystem fragmentation and jeopardizing biodiversity through habitat reduction, isolation increase, and alterations in biotic and abiotic factors in the remaining fragments (Saunders *et al.*, 1991; Fahrig, 2003; Wade *et al.*, 2003; Otálora *et al.*, 2011). Several factors have been associated with biodiversity in fragmented landscapes. These include fragment size per se, based on the species-area theory (Arrhenius (1921); Preston (1962), and MacArthur and Wilson (Harris, 1984; Tjorve, 2003), environmental heterogeneity (Gaston, 2000; Tews *et al.*, 2004; Clarke and Gaston, 2006), and disturbances, both of natural and anthropogenic origin (Bustamante and Grez, 1995; Williams-Linera *et al.*, 2002; Wade *et al.*, 2003; Davis, 2004).

A positive relationship between biodiversity and fragment or habitat area has been identified for nearly a century by the widely-known species-area relationship (Arrhenius, 1921; Preston, 1962; Bustamante and Grez, 1995). This relationship can be described in a probabilistic model following a geometric (Arrhenius, 1921) or logarithmic series (Preston, 1962) enabling the researcher to estimate the biodiversity of an ecosystem from a known area. Several theoretical and empirical studies in fragmented landscapes have found a close relationship between patch biodiversity and patch size (Hill and Curran, 2001, 2003; Echeverría *et al.,* 2007; Pincheira-Ulbrich *et al.,* 2008).

Although the species-area relationship is one of the main subjects in biogeography (Hill and Curran 2001, 2003; Echeverría *et al.,* 2007; Pincheira-Ulbricht *et al.,* 2008; Blakely and Didham, 2010), it is not clear which mechanisms are at work. Numerous studies have suggested that environmental heterogeneity, which is usually positively correlated with area, is the main factor explaining biodiversity (Boecklen, 1986; Freemark and Merriam, 1986; Baz and García-Boyero, 1995; Brose 2001; Aström *et al.,* 2007; Blakely and Didham, 2010). Indeed, heterogeneous environments offer greater diversity of niches for the establishment of different species (Boecklen, 1986; Baz and García-Boyero, 1995; Peterson *et al.,* 1997; Tews *et al.,* 2004; Hannus and von Numers, 2008). Complex topography is one of the most distinctive features of environmental heterogeneity in mountain ecosystems by altering soil deep, moisture content, stoniness, compaction, and permeability, among other environmental properties, thereby creating more niches per area than those occurring on a flat surface (Bunting, 1964; Balvanera and Aguirre, 2006; Aström *et al.,* 2007).

Disturbance is another important factor affecting diversity. Disturbance has been defined as a more or less discrete event in time and space, altering the structure of populations, communities or ecosystems, causing drastic changes in resource availability or physical environment (Saunders *et al.*, 1991; Bustamante and Grez, 1995; Laurance, 2004; di Bella *et al.*, 2008), facilitating the spread of short-lived early successional species (Saunders *et al.*, 1991), and the invasion of exotic species that compete with native species for resources (Santos and Tellería, 2006; Stevenson and Rodriguez, 2008). Although disturbance is an important component of many ecosystems, there is no consensus on how it impacts biodiversity (Miller *et al.*, 2011). Disturbance could be of natural origin, such as storms, telluric events and tree falls, and anthropogenic, as is the case of human settlements, roads, deforestation and fire. In this study we will focus on human disturbances, which oftentimes are difficult to measure directly, but can be estimated by their effects on the fragments of natural ecosystems. The occurrence of roads and stump-density are examples of human disturbances (López, 2001; Williams-Linera *et al.*, 2002; Herrera *et al.*, 2004; Rudas *et al.*, 2007), and they may modify the ecosystem structure and composition by: (a) affecting microclimatic conditions (Gucinski *et al*., 2001); (b) promoting the invasion of exotic species (Brown *et al.* 2004, 2006); (c) allowing the uncontrolled extraction of natural products (Young, 1994; Verburg *et al.*, 2004); (d) setting up barriers between populations that may decrease gene flow and dispersal (Forman and Alexander, 1998); and (e), reducing seed production (SEMARNAT, 2005; Alelign *et al.*, 2007), all of which may jeopardize species persistence.

Disturbance is also related with fragment area and habitat heterogeneity. For instance, native species richness per unit area may decrease significantly in small-sized and highly disturbed fragments (Ross *et al.*, 2002; Echeverría *et al.*, 2007). Furthermore, road construction and deforestation induces habitat fragmentation, promotes changes in the physical environment, and alter the biota balance (Saunders *et al.*, 1991; Fahrig, 2003;

Wade *et al.*, 2003; Otálora *et al.*, 2011). Environmental changes in fragmented communities are most dramatic at the edges than in the core of the fragments (Murcia, 1995; Laurance *et al.*, 2000; Forero-Molina and Finegan, 2004). Some studies have shown that basal area significantly declines with decreasing path size (Lezcano *et al.*, 2004; Echeverria *et al.*, 2007). The fragment species composition is also affected. The shrub layer diversity to tree layer diversity ratio could be an indicator of disturbance since these life forms usually have different environmental requirements. Shrubs, for instance, tend to have greater survivorship and biomass in open microsites (Asbjornsen *et al*., 2004b).

In summary, biodiversity may be directly or indirectly associated with fragment area, topographic heterogeneity and disturbance intensity. For both conservation purposes and ecological studies, it is important to identify the major factors that influence biodiversity in remnant fragments. Few studies have explored simultaneously the possible role that each of the above factors plays on fragment diversity. Most of these studies have explored only fragment size and environmental heterogeneity (Freemark and Merriam, 1986; Baz and García-Boyero, 1995; Boecklen, 1986; Brose, 2001; Graham and Blake, 2001), but very few have included the effects of area and disturbance on biodiversity (Aström *et al.*, 2007). We are only aware of an exploratory study that considers simultaneously the relationship between habitat size, environmental heterogeneity, and disturbance with diversity (Blakely and Didham, 2010). This study, carried out with insects, surprisingly found a negative relationship between biodiversity and habitat size under experimentally controlled conditions, due explicitly to experimental manipulation in which smaller habitats were modified to be more heterogeneous than larger habitats. This was accomplished by experimentally reversing resource concentration and enhancing drought disturbance, while holding constant colonization–extinction dynamics and habitat heterogeneity. The Mixteca Alta in southern Mexico provides a suitable landscape for exploring these relationships but in a natural habitat and with woody plants. This region is highly fragmented (Asbjornsen *et al.,* 2004b; Martínez and Noriega, 2006), has a complex topography (González-Leyva, 2007), and has been affected by disturbance associated with the presence of nearby human settlements (Asbjornsen *et al.*, 2004a). In this region, we aimed to explore the possible relationships between fragment area, topographic heterogeneity, and intensity of anthropogenic disturbance on fragment biodiversity of trees and shrubs. Based on the empirical evidence and theoretical studies described above, we expected (1) a positive relationship between fragment biodiversity and both area and topographic heterogeneity; and (2), a negative relationship between fragment biodiversity and disturbance intensity.

Methods

Study site and sampling design. The study site is located in Nochixtlán District, Oaxaca, Mexico, at 17°0'-17°50'N and 97°0'-97°25' W, between 1,800 to 2,800 m. The study area is mountainous, with a complex geology and topography. The climate is temperate and semi-humid. Annual rainfall varies between 500 and 800 mm. A seasonally dry oak forest comprises most of the vegetation above 1,500 m (Asbjornsen *et al.*, 2004a). The main species are: *Quercus liebmannii*, *Q. acutifolia*, and *Q. laurina*. Endemic species are also relatively abundant (García-Mendoza *et al.*, 1994). Paleontological evidence shows that the Mixteca Alta has been populated since the late Holocene by people who based their use of resources on wise water management (Guerrero-Arenas *et al*., 2010). The Spanish conquest was accompanied by the introduction of sheep, goats and diverse crops, causing an intense process of deforestation. After 500 years, this process has resulted in a highly fragmented landscape:80% of its soils are affected by water erosion (González-Leyva 2007, Guerrero-Arenas *et al*. 2010).

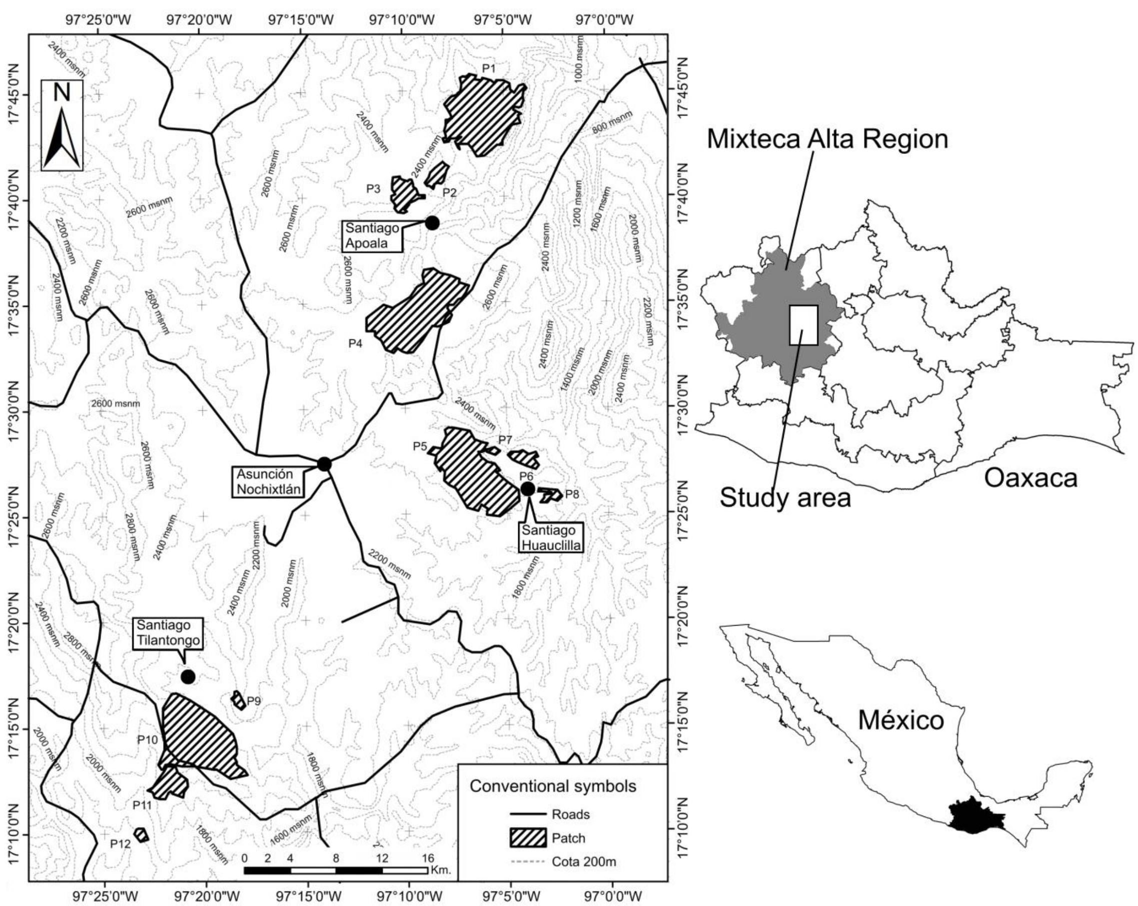

Figure 1. Study site in the Mixteca Alta, Oaxaca, Mexico, showing the seasonally dry oak forest fragments in which woody plants were sampled (see Methods and Table 1).

Table 1. Environmental variables and diversity of trees and shrubs found in twelve fragments of seasonally dry oak forest at the Mixteca Alta of Oaxaca, Mexico.

	SAMPLING PLOTS (Num.)	AREA SIZE (Ha)	TOPOGRAPHIC HETEROGENEITY Altitude (masl) s.d.	Slope (%) s.d.	Slope aspect (-cos(radφ)) s.d.	ANTHROPOGENIC DISTURBANCE Road-effect (m^2 ha^{-1})	Loggin (number of stumps ha^{-1})	DIVERSITY (Fisher's α) Trees	Shrubs
P1	13	2943	153	16	0.56	0.11	30	3.22	7.76
P2	14	156	71	23	0.59	0.00	14	1.74	6.52
P3	30	363	25	7	0.65	0.23	108	1.47	2.49
P4	28	2834	74	13	0.68	0.08	21	4.55	10.27
P5	50	2499	131	14	0.70	0.29	61	3.41	13.29
P6	8	218	99	19	0.71	0.12	73	3.47	7.56
P7	6	12	30	7	0.22	0.00	65	0.95	5.55
P8	10	83	53	14	0.75	0.00	29	1.78	5.19
P9	9	75	78	11	0.39	0.21	0	1.96	8.02
P10	27	3211	140	18	0.76	0.16	120	3.68	8.51
P11	17	486	173	15	0.66	0.11	23	3.77	6.89
P12	4	84	69	12	0.34	0.00	24	2.97	7.31

Data collection. We selected and characterized our study fragments using Landsat ETM+ satellite imagery (2005, path 24, Row 48, Band 4/7/1, pixel=30 m). The geographic projection was UTM WGS84 14n zone. Geographic corrections were conducted with control points from digitalized 1: 50,000 road maps, and a second degree polynomial model (Cayuela et. al., 2006b). Accuracy ranges from 0.25-0.45 pixels, corresponding to 7.5 – 13.5 m. Atmospheric corrections were performed using the Chávez reflectivity model (Chuvieco, 2006; Cayuela *et. al*., 2006b), which transforms the original digital numbers into reflectivity values in the corrected images. Elevation digital models were generated using ENVI 4.3 software. The topographic correction was performed using the Teillet *et. al*. (1982) and Riaño *et. al*. (2000) semi-empiric method and the PCI Geomatics software version 7.0. Classification was supervised with PCI Geomatics software version 7.0 using the maximum likelihood criterion. Six class signatures were obtained: (1) bare land, (2) body water, (3) grasslands-shrub lands, (4) croplands, (5) urban areas, and (6) native forest. The obtained classification was checked with 300 independent control points located in the field with Google Earth software (image's date 2004 to 2007). We haphazardly selected 12 seasonally dry oak forest fragments with contrasting areas ranging from 12 to 3,211 ha (Table 1). The area of the selected fragments was estimated using Fragstats (McGarigal and Marks, 1995). Sampling plots were randomly selected within each fragment using the extension Random Sites (Arc View 3.X, public domain), with the restriction that each sampling point should be located at least 70 m away from other sampling points or from the fragment edge to avoid overlapping and to decrease edge effects and the probability of autocorrelation between nearby sampling points (Fig. 1).

Vegetation sampling was conducted on 216 plots distributed among the twelve selected fragments, using4 to 50 sampling points per fragment, depending on fragment size. All plots were geo-referenced, using a GPS (GARMIN 60csx) with a 5 m resolution. In order to analyze the diversity and structure of the vegetation, we sampled the individuals of both the tree and the shrub layer. All woody plants ≥ 2.5 cm DBH and ≥ 2.5 m height found in the sampling plots were included in the tree layer; whereas all woody plants < 2.5 cm DBH or < 2.5 m height were included in the shrub layer. Sampling plots of 102.06 m^2 and 12.56 m^2 were used for the tree and the shrub layer respectively. Specimens of all species found in the sampling plots were deposited at the Herbarium OAX. The tree and shrub diversity per fragment was assessed using Fisher's α because it is relatively insensitive to sample size (Fisher *et al.*, 1943; Magurran, 2004).

Topographic heterogeneity was evaluated by the standard deviation (sd) of altitude (m), slope (%), and slope-aspect ($-\cos \varphi$, where φ is the slope angle in radians) of each fragment. Slope-aspect is defined as main compass direction (North, North East, East, South East, South, South West, West, and North West) that a slope faces (Physical Geography Dictionary, 2012). We used the Hawhtool extension of ArcGis to select randomly 50 points (pixel=30 m), with at least 70 m apart. The selected points were overlapped on the slope, altitude and slope-aspect layers from the digital elevation model to obtain the respective values for each point. Anthropogenic disturbance was estimated by assessing the intensity of logging and the proportion of the fragment area expected to be affected by roads or zone of influence of roads within each fragment. Logging intensity was evaluated by the density of stumps (ha^{-1}) in each plot. Previous works have found that road effects on biodiversity depend on species, topography and road type, but usually range between 100 and 200 m on each side of the road (Forman et al., 1997). Based on these studies, we defined a buffer area of 150 m width on both sides of the roads in the study area, to estimate the proportion of the fragment expected to be affected by roads. For this purpose, we used EPS data from INEGI (2011, scale 1:50,000). Road-effect zone was estimated as the ratio of the road buffer area to the total area of the fragment. In our study sites, all roads were of similar width, suggesting the same intensity of use.

Data analysis. In order to disentangle the relationships between fragment area, topographic heterogeneity, anthropogenic disturbance and woody plant species diversity, we developed a model based on structural equation modeling, using the CALIS procedure from SAS 9.1 software package (SAS Institute, 1989). Since large fragments are probably both, more heterogeneous and less disturbed than small fragments, it is important to explore to which extent biodiversity is directly affected by fragment area, topographic heterogeneity and disturbance, or indirectly through the associations among these explanatory variables. Structural equation modeling (SEM) allows the testing of complex relationships among variables, partitioning direct and indirect effects, and making quantitative predictions about the relative contribution of each variable in the model (Grace and Pugesek, 1997). This method, based in covariance analysis, can be used to model multivariate relations and to test multivariate hypotheses (Bollen, 1989). An important attribute of structural equation modeling is that it allows the estimation of conceptual unmeasured (latent) variables based on a set of measurable (manifest) variables (Grace and Pugesek, 1997). The accepted models obtained from such analysis can indicate the role of different factors in a system and the strength of their relationships (Spitale *et al*., 2009). Further details of the SEM methodology can be found in Grace and Pugesek (1997), Spitale *et al.* (2009), Hayduk (1987) and Reed *et al.* (2009). In our model, biodiversity is the endogenous (response) latent variable, estimated by the sum of tree and shrub biodiversity (manifest variables). Topographic heterogeneity, anthropogenic disturbance, and fragment area are our exogenous (explanatory) variables. Topographic heterogeneity is a latent variable estimated by the standard deviation of altitude, slope, and slope-aspect. Anthropogenic disturbance is a latent variable estimated by the exogenous manifest variables: road-effect zone, as defined above, and stump density (Fig. 2).

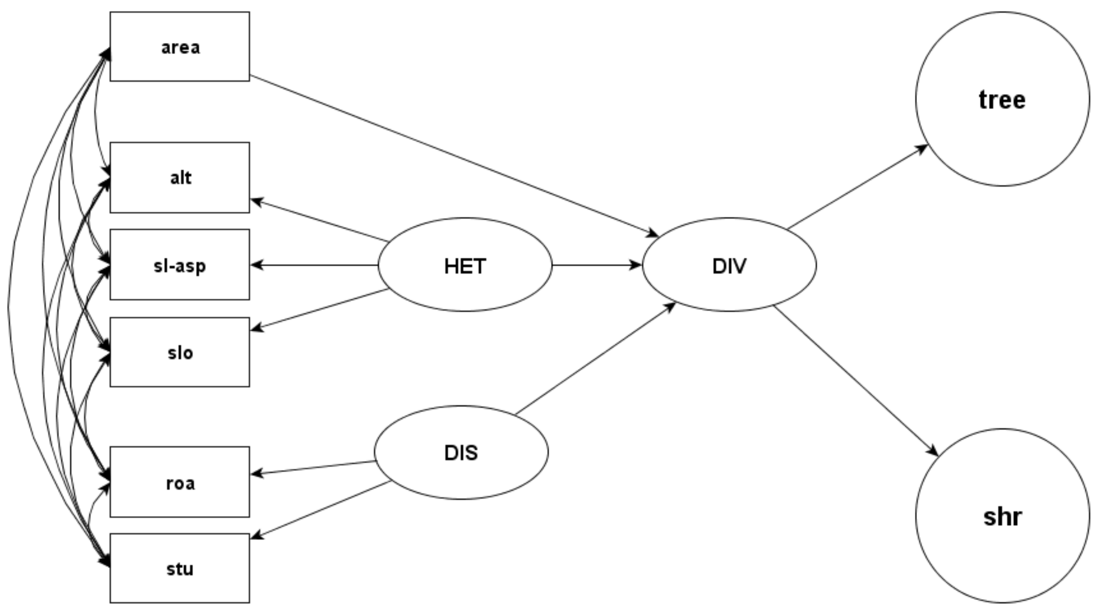

Figure 2. A priori structural equation model representing the possible effect of area, topographic heterogeneity, and disturbance on diversity of trees and shrubs in fragments of seasonally dry oak forest in the Mixteca Alta of Oaxaca. In rectangular shapes, we represent manifest variables (area= fragment area, alt = altitude standard deviation, sl-asp = slope aspect standard deviation, slo = slope standard deviation, roa = road-zone effect, stu = stump density, tree= tree Fisher's α, shru= shrub Fisher's α), in oval shapes latent variables (HET= topographic heterogeneity, DIST= anthropogenic disturbance, DIV= fragment diversity). Single-headed arrows indicate one-way variance of the latent variable; double-headed arrows indicate covariance among manifest variables.

All the response and predictor variables were standardized (mean = 0, sd = 1) and did not show evidence of deviations from normality. Direct relations among variables (single-headed arrows in Figs. 2 and 4) were estimated as standardized coefficients from the covariance matrix. Non-directional standardized correlation coefficients were also calculated among explanatory manifest variables (double-headed arrows in Fig. 2). The initial structural model was reduced to the most parsimonious model by means of a stepwise specification search, eliminating in each step the path with the lowest coefficient (in absolute value) until all the remaining coefficient paths were significant (Hayduk, 1987; Grace and Pugesek, 1997; Reed *et al.,* 2009; Blakely and Didham, 2010). The resulting model in each reduction step was checked by its goodness-of-fit index (GFI), its chi-square probability value (*p*), and its Akaike's information criterion (AIC) (Hayduk, 1987). In each step, the fitted indices were compared against the previous model. The best model was the one with the GFI nearest to 0.9; the greatest *p* value, which should be > 0.1; and the lowest AIC value (Mulaik *et al.,* 1989; Stoelting, 2002).

Results

Tree canopy sampling was composed by 3,301 specimens from 46 species (Annex 1). Shrub layer was composed by 7,453 specimens from 116 species (Annex 2). Fisher´s α diversity ranks from 0.95 to 4.55 for tree layer, and 2.99 to 8.51 for shrub layer (Table 1). The shrub layer-to-tree layer diversity ratio decreased significantly with the size of the fragment ($r^2 = 0.315$, $p<0.01$, Fig. 3). The final and most parsimonious model for species diversity in the seasonally dry oak forest remnants of the Mixteca Alta region had acceptable goodness-of-fit indices (GFI = 0.899, p = 0.171, AIC = -1.595, Hayduck, 1987, Fig. 4).

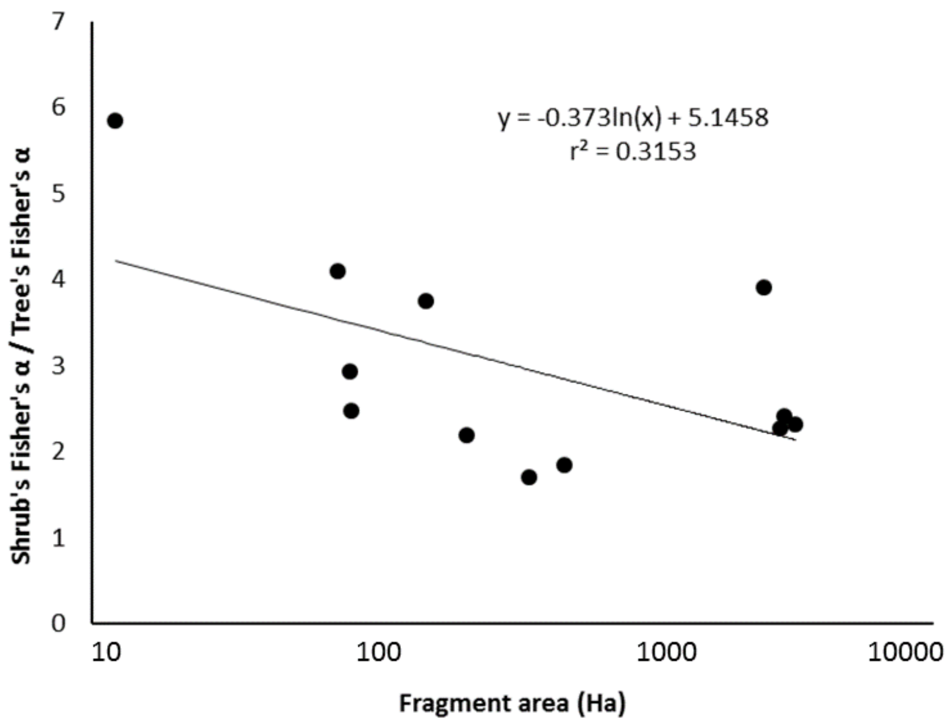

Figure 3. Regression analysis between the shrub-to-tree Fisher's α ratio *vs*. fragment area in seasonally dry oak forest remnants in the Mixteca Alta, Oaxaca, Mexico.

Our SEM analysis revealed that disturbance, habitat heterogeneity, and fragment area have significant contributions to the species diversity. Of these drivers of species diversity, habitat heterogeneity, here estimated in terms of topographic variables, is the most important and has a positive effect on species diversity. When habitat heterogeneity is considered, the size of the fragment has a significant but negative effect on diversity. Two out of the three explanatory variables used to estimate topographic heterogeneity were significant: the slope-aspect heterogeneity and the altitude heterogeneity. According to our

SEM analysis, the species Fisher´s α diversity in the fragment tends to increase in fragments with high variation in elevation and low variation in slope-aspect. Human disturbance also affected significantly and positively the diversity of the fragments. Of the manifest variables used to estimate disturbance, only stump density, an indicator of the intensity of plant extraction, was significant.

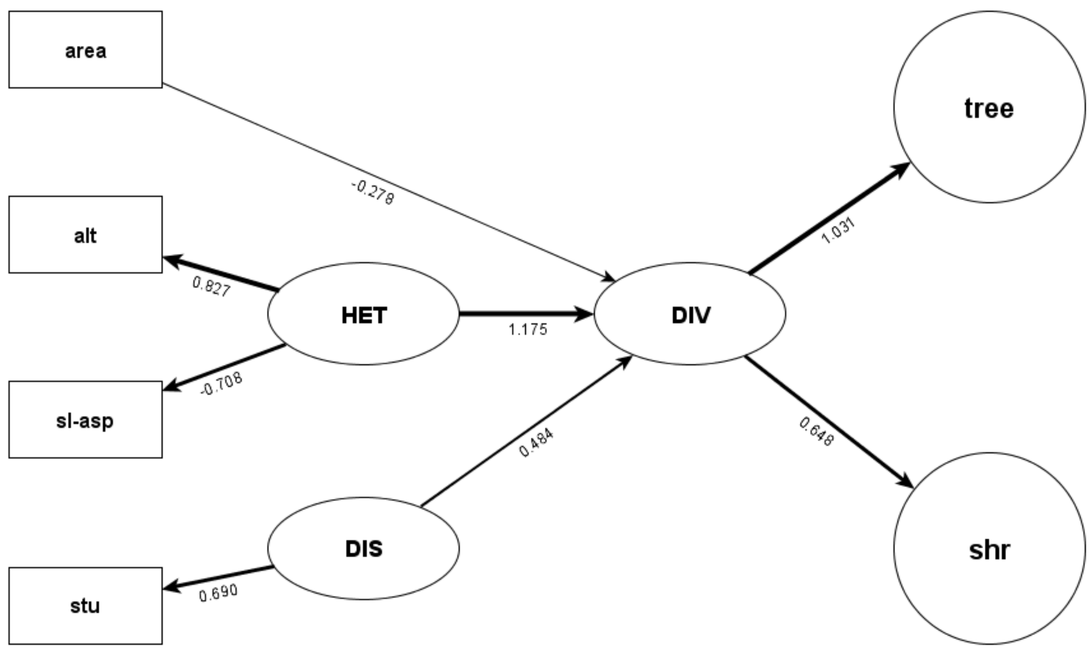

Figure 4. Reduced structural equation model to disentangle the effect of area, topographic heterogeneity, and disturbance on diversity of trees and shrubs in seasonally dry oak forest fragments in the Mixteca Alta region of Oaxaca, Mexico. Numbers on the arrows are the standardized coefficients for each of the paths. Only significant relationships are noted in the diagram ($p < 0.05$). The size of the arrows is proportional to the strength of the path. In rectangular shapes, we represent manifest variables (area= fragment area, alt = altitude standard deviation, sl-asp = slope aspect standard deviation, slo = slope standard deviation, roa = road density, stu = stump density, tree= tree Fisher's α, shru= shrub Fisher's α), in oval shapes latent variables (HET= topographic heterogeneity, DIST= anthropogenic disturbance, DIV= fragment diversity). Single-headed arrows indicate one-way variance of the latent variable; double-headed arrows indicate covariance among manifest variables.

Discussion

Structural equation modeling revealed the effect of anthropogenic disturbance, fragment area, and topographic heterogeneity on woody plant diversity in remnants of seasonally dry oak forest in the Mixteca Alta, southern Mexico. In accordance with our hypotheses, woody plant species diversity per fragment can be explained directly by the topographic heterogeneity, the intensity of anthropogenic disturbance and the fragment area, as has been shown in other studies (Ross *et al*., 2002; Cayuela *et al*., 2006a; Echeverría *et al*., 2007). Our results indicate that, when topographic heterogeneity and human disturbance are taken into account, the effect of fragment size on diversity is negative in the seasonally dry oak forest of the Mixteca region. More specifically, smaller fragments with similar altitude and slope-aspect and human disturbance level tend to be more diverse than large fragments.

Edge effects provide a possible explanation to this result since the perimeter to area ratio is greater in small fragments. Small fragments bring more opportunities for light tolerant species to become established on them, favoring a greater diversity of species. Some species may find the habitat of the edges of the fragment more suitable for survival and reproduction than the core of the fragment (e.g., Bernabe *et al.* 1999; Asbjornsen *et al*., 2004b). Indeed, in our study shrubs were proportionally more diverse than trees in smaller than in large fragments. Shrubs are usually more light-demanding than trees, and their abundance has been found to decrease significantly with the abundance of trees in oak forest in the adjacent Sierra Norte (Zacarías-Eslava and del Castillo, 2010). More attention to edge effects should be paid in future studies to explore the possible role of edge effects in this result.

The negative effect of the area on diversity obtained in our analysis suggests that we have not omitted any important diversity driver that is positively associated with fragment area, in which case, a positive, not a negative effect of area on diversity would be obtained. Our results, therefore, suggest that environmental factors associated with topography are one of the most important diversity drivers for woody plants in the seasonally dry oak forest remnants of the Mixteca Region.

Both heterogeneity in altitude and heterogeneity in slope-aspect within the fragments showed a significant relationship with habitat heterogeneity. However, their combined on diversity effects are opposite, according to our SEM analysis. This result suggests that a higher effect of topographic heterogeneity on species diversity can be achieved with a combination of high heterogeneity in altitude with low heterogeneity in slope-aspect. Thus, these two variables should be considered together when analyzing the impact of habitat heterogeneity on diversity. The involvement of climatic effects affecting species diversity and associated with topography may help to interpret this result. The mean annual temperature, for instance, is well known to decrease linearly with altitude (e.g., Zacarías-Eslava and del Castillo, 2010). Throughout the same slope-aspect, a given mean temperature is expected to be found only at a unique elevation point, ignoring microclimatic differences caused by variations in shading by vegetation or micro topography. However, the same mean temperature can be found at different elevations in the mountain if the orientation of the slope changes. North-facing slopes, for instance, are usually colder than south-facing slopes, at the same elevation in the Northern Hemisphere. The same temperature that is found on the north facing side of a mountain at a given elevation is expected to be found at a higher elevation at other slope orientation. In this way, the combination of high heterogeneity in both slope-aspect and elevation may reduce the total environmental variation of the fragment because different combinations of altitude and orientation can render the same climate.

Disturbance is a factor that undoubtedly alters ecosystem biodiversity, even if there is no consensus on how it works (Mackey and Currie, 2000, 2001). Most studies have developed indices to assess the total effect of disturbance without distinguishing the partial effect of each source of disturbance on biodiversity (Ross *et al.*, 2002). Stump density reveals logging activities in the fragments, whereas road-effect zone is an indicator of the accessibility of the fragment to anthropogenic activities (Forman *et al*., 1997), as well as potential invasion by exotic species. Only logging, as disturbance indicator, was significant in our study. In the study site, logging is manual and selective. Logged trees are scattered over the landscape, creating small gaps in the fragments. In seasonally dry oak forests, each small opening may decrease soil moisture creating inappropriate conditions for native sapling development (Asbjornsen *et al.*, 2004a, 2004b; Brown *et al.*, 2004). In turn, the new conditions in these open spaces may allow the establishment of resilient and short-lived species, such as pioneer species. The above leads to species turnover and an increased biodiversity, by allowing to certain extent the coexistence of pioneer and shade-tolerant species in the same fragment. The effect of roads on diversity in the study area was not significant, probably because the roads in the area are used primarily for communication between indigenous villages, which are characterized by very low population densities. As a result, the effect of human disturbance in this area is probably due mainly to logging, either for fuel or for the production of small-scale wood that will be used for construction or tool manufacturing s for local use.

Conservation implications. Our results provide evidence of the importance of selecting fragments with high variation in topographic heterogeneity which may favor a great diversity of species. The kinds and intensities of disturbance are also crucial since they may not have a common effect on the species. The consideration of the species to be preserved is also crucial in developing conservation strategies, since different species may have different requirements, and some strategies may benefit only a limited number of species and harm others.

Conclusions

Using data of twelve fragments and structural equation modeling techniques, we were able to test and confirm a three factor model that characterized the diversity of woody plant species of a seasonally dry oak forest in the Mixteca Alta, Oaxaca, Mexico. Topographic heterogeneity, human disturbance and fragment size in that order of importance, play a significant role on woody plant diversity of these fragments. Topographic heterogeneity had a positive relationship with diversity. Fisher's α diversity increased significantly with fragment heterogeneity in slope-aspect or altitude. Disturbance, here estimated as fragment's stump density, showed also a positive relationship with diversity. Small fragments with similar levels of topographic heterogeneity and disturbance tend to be more diverse than large fragments, probably because small fragments have a greater perimeter-to-area ratio and therefore convey more opportunities for the successful establishment of species that are benefited by open, less dense habitats such as edge, resilient and pioneer species. Structural equation modeling showed to be an appropriate technique for disentangling the contribution of several factors related with biodiversity. Conservation strategies of fragmented landscapes must consider not only fragment size but the type and intensity of disturbance affecting the fragments and the species that need to be preserved.

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Capítulo II

Ethno botanical study of seasonally dry oak forests in the Mixteca Alta, Oaxaca and social resident features affecting the traditional knowledge of plants use

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Ethno botanical study of seasonally dry oak forests in the Mixteca Alta, Oaxaca and social resident features affecting the traditional knowledge of plants use.

Abstract. We explore the effect of six social attributes of informants in three municipalities of the Mixtea Alta of Oaxaca, Mexico, on traditional knowledge (TK) about native useful plants from seasonal oak forests in the region. We conducted 316 semistructured interviews on the use of 106 plants collected in the area. Recorded uses were classified into eleven different types. Two indices were calculated to assess the TK of each informant. Social attributes considered were: informant municipality, age, gender, native language proficiency, education level and proportional time in his/her life that has been absent from the community. We use multivariate analysis to test the effect of social attributes on TK. We find that TK tends to be higher in communities characterized by having the highest proportion of Mixtec language speakers, higher proportion of illiterates, lower average education level, and lower access to services such as non-dirty floor, piped water and drainage. Traditional knowledge is positively related with native language proficiency, involvement in field activities and age of the informant. The relationship of traditional knowledge with education level and proportion of the informant´s life spent outside the community is negative. The findings in this study allow us to assess the proportional weight of each social factor involved in traditional knowledge.

Key words: traditional knowledge, social attributes, municipality attributes.

Resumen. Analizamos el efecto de seis atributos sociales de informantes sobre el conocimiento tradicional (TK), en tres municipios de la Mixtea Alta de Oaxaca, México, acerca del uso de plantas nativas de bosques de encino estacionales en la región. Realizamos 316 entrevistas sobre el uso de106 plantas colectadas en la zona. Los usos registrados fueron catalogados en once tipos distintos. Se calcularon dos índices para evaluar el TK de cada uno de los informantes. Los atributos sociales considerados fueron: municipio, edad, género, dominio del idioma nativo, nivel de escolaridad y tiempo proporcional de la vida del informante que ha estado ausente de la comunidad. Usamos análisis multivariado para analizar el efecto de los atributos sociales sobre el conocimiento tradicional. Encontramos que TK tiende a ser mayor en las comunidades caracterizadas por tener la mayor proporción de hablantes de idioma mixteco, mayor proporción de personas analfabetas, menor grado de escolaridad promedio y menor acceso a servicios tales como suelo diferente a tierra, agua entubada y drenaje. La relación del TK con el dominio de idioma nativo, realización de actividades en campo y edad de los informantes es positiva, mientras que con la escolaridad y proporción de tiempo fuera de la comunidad es negativa. Los hallazgos en este estudio nos permiten evaluar el peso proporcional de cada atributo social involucrado en el conocimiento tradicional.

Palabras clave: conocimiento tradicional, atributos sociales, atributos municipales.

Introduction

Knowledge of natural resources has insured the survival of indigenous people in their native habitats for centuries in conditions of relative isolation (Gómez-Pompa, 1993; Marcus, 1982; Turner and Miksicek ,1984). As a consequence, traditional knowledge can be crucial for biodiversity conservation and its sustainable use (Frei *et al.*, 1998; Toledo, 1990, 1996; Tresierra, 2005). This knowledge is an important cultural component, which usually is transmitted orally and by imitation (Escobar, 2001). The extended contact with dominant societies corrode and corrupt indigenous cultures, a process known as acculturation (Caballero and Cortés, 2001; Lozoya, 1989; Toledo, 1978, 1980, 1982, 1996; Vásquez-Dávila, 1992). This multidimensional process involves, among other things, the adoption of a different language, beliefs, values and the integration of members of the minority group into the social structure of the majority group (Hazuda *et al.*, 1988). The loss of traditional knowledge is an obvious consequence of this process, for which some empirical support is available (Godoy *et al.*, 2005; Hellier *et al.*, 1999).

Identifying how traditional knowledge is distributed among people within the same group can help elucidate the major social factors involved in acculturation. However, most studies on traditional knowledge do not evaluate the variation of knowledge among individuals of the same group (Reyes-García, 2006a). Gender, age, language, education, contact with other cultures, and whether or not the activities of the people involve contact with their surrounding native ecosystem, are likely factors that might affect traditional knowledge (Zent, 2001; Bermúdez and Velázquez, 2002; Maffi, 2002, 2005; Carlson and Maffi, 2003; Hernández *et al.*, 2005; Pieroni, 2003; Torre-Cuadros and Ross, 2003;

Alvarado, 2005, Arango-Caro, 2004; Canales-Martínez *et al.*, 2006; Reyes-García *et al.*, 2006c; Toscano, 2006). An important fact about the factors that may influence traditional knowledge is that probably do not act in isolation but in combination with each other. Understanding acculturation is particularly important for those ecosystems that are culturally and biodiversity rich, but endangered at the same time. We found an example of such kind of ecosystem in the Mixteca Alta region, Oaxaca, Mexico. At this zone, coexist Mixtec people and seasonally dry oak forest.

The Mixteca region called *ÑuuSavi* ("place of the rain") in native language (Martinez, 2006), is divided into three geographical areas: the Mixteca Baja, with elevations below 1,200 m, located in northern Oaxaca and southern Puebla, the Mixteca Alta with altitudes of 1,200 and 2,800 meters above sea level in western Oaxaca; and Mixteca de la Costa, which stretches along the Pacific coast of Oaxaca (Lind, 2008). Mixtecs belong to an ancient culture settled in this region for thousands years whose economy was mainly based on the cultivation of corn, beans, squash, various vegetables and fruits by using the coa (agricultural tool which has a metal blade in a half moon and a handle to direct it), and the exploitation of wild plants and animals (Lind, 2008). The Spanish conquest was accompanied by the introduction of sheep, goats and diverse crops, causing an intense process of deforestation. After 500 years, this process has resulted in a highly fragmented landscape, with 80% of its soils being affected by water erosion (González-Leyva, 2007).

Main vegetation is composed by seasonally dry oak forest. This vegetation type usually develops between 1,600 and 2,900 m in humid temperate climate. The species of the tree layer varies according to the region (Torres, 2004). In this type of vegetation either temperate or xeric, inhabit the greatest diversity of the genus *Quercus* (Valencia and Nixon, 2004). The services that these forests provide are: vegetation cover, water capture, habitat for other species, carbon capture, clean air production, climate regulation, raw material for construction, and recreation (Sanchez et al., 2003). The importance of *Quercus* forests lies mainly in the fact that along with the genus *Pinus* constitute most of the vegetation cover in areas of temperate and semi humid climate. Use of these ecosystems has been reduced and inadequate, but is overexploited, wasted and even eradicated in some places for commercial or subsistence uses (Gutierrez-Ramos and Bárcenas, 2008). The genus *Quercus* has an extensive economic and cultural value, including current and potential uses: medicinal, food, handicraft, fodder, construction, furniture, fuel, production of tannins and coloring of the crust (Gutierrez-Ramos and Barcenas, 2008). In view of the favorable characteristics to the human species and the high degree of transformation over centuries, some scientists consider that these ecosystems are the least preserved in the country. Loss of this vegetation type is estimated at around 70% of its original extent (Sanchez et al., 2003). Few ethno biological studies are available in these areas and none have attempted to study and quantify acculturation.

Our aim is to test if traditional knowledge on plants use can be explained based on informant's social attributes like gender, age, native language proficiency, education, proportion of the informant life spent out of his/her native town, and the main activities of the people in three municipalities of the Mixtec Alta region.

Methods

Study site and sampling design. The study site is located in Nochixtlán District, Oaxaca, Mexico, at 17°0'-17°50'N and 97°0'-97°25' W, between 1,800 to 2,800 m. Vegetation is composed principally by fragmented seasonally dry oak forest, surrounded by a matrix composed by crops, human settlements and eroded soil (Asbjornsen *et al.*, 2004a).

Data collection. We selected three municipalities in the Nochixtlán District, at the Mixteca Alta, Oaxaca. All of them have human settlements originated in the Mixtec culture and make use of the natural resources of the area, particularly the seasonally dry oak forest. The municipal head of each of them is an average of two hours away by land, from the county seat. However, social and economic development is different between municipalities. Data on native language, illiteracy, average education, and housing goods, were obtained from the population and housing census 2005 and 2010 (INEGI, 2010; Table 1).

We interviewed 316 native people randomly selected from Santiago Apoala, Santiago Huauclilla, and Santiago Tilantongo municipalities. Gender, age, native language proficiency, education, time spent outside the community (greater than six months), and whether his/her daily main activity involvement in field activities in the surrounding native forest were recorded for each informant (Table 2). Time spent outside the community was transformed into a new variable called proportion of the informant life spent out of his/her native town (PILSOT). We asked if he/she can identify, name, and give the uses of 106 species of native plants collected in seasonally dry oak forest remnants. For this purpose, we showed pressed specimens of native species to each informant. The interviews were conducted in Spanish. In some cases, however, the help of a translator was required.

Registered uses were classified into eleven categories, based on the work of Vasquez (1995), Padilla (2007) and Aguilar-Santelises (2007) (Table 3). We obtained a list of useful species showing the different types of use according with this classification for each one of the species (Annex 3).

Table 1. Demographic and social characteristics in three municipalities at the Mixteca Alta region, Oaxaca, Mexico (INEGI, 2010)

	Apoala	Huauclilla	Tilantongo
Total population	621	334	675
Men *vs* women ratio	0.93	0.80	0.83
Population ≥ 3 years old who speak an indigenous language (%)	86.55	0.92	32.59
Population ≥ 3 years old who do not speak Spanish (%)	12.61	0.00	0.32
Population ≥ 15 years old illiterate (%)	41.79	12.69	14.09
Average education grade (years)	3.87	5.39	6.35
Houses with dirt floors (%)	14.75	13.51	31.61
Houses with electric power (%)	95.08	95.50	90.80
Houses with piped water (%)	4.37	71.17	59.77
Houses with drainage (%)	34.97	89.19	14.37
Houses without any good (%)	32.79	5.41	14.37

Table 2. Demographic and social characteristic of 316 informants selected from three municipalities in the Mixteca Alta, Oaxaca, Mexico

	Apoala			Huauclilla			Tilantongo		
Informant number:									
total, men, women	97	45	52	97	44	53	122	40	82
Age:									
mínimum, máximum, average	5	79	39	5	90	47	5	85	30
Education:									
minimum, maximum, average	0	18	4	0	17	6	0	19	6
Native language proficiency (%):									
null, medium, high	5	11	84	96	4	0	27	47	26
Involvement in field activities:									
no, yes		20	77		33	64		23	99
Average proportion of the informant life spent out of his/her native town			6			14			12

Data analysis. We assess the usefulness of the native forest for each informant in two ways: First, by the proportion of useful species reported by each informant (P_u) relative to the number of species examined (P_v) (equation 1); second, by average diversity of uses per useful species given by the informant (equation 2).

$$I_u = \frac{P_u}{P_v} \qquad \text{(equation 1)}$$

$$I_d = \frac{1}{P_u}\sum_{s=1}^{P_u} u_s \qquad \text{(equation 2)}$$

Where:

I_u is the utility index for informant *i*,

P_u is the total useful plant reported by the informant *i*,

P_v is the total species reviewed by the informant *i*,

I_d is the use diversity index for informant *i*,

u_s is the number of uses of species *s* reported by the informant *i*.

Principal Component Analysis was performed in order to determine the social factors that characterize each municipality. Statistical analysis was performed by General Linear Models (GLM), using GLM procedure of SAS (SAS Institute, 1989), to quantify the relationship between social variables with both, the utility index and the use diversity index. Analysis used the type III sum of squares, because is non-sequential. For education and age variables, there were tested linear and quadratic effects in the model. Significant variable selection was carried out in a backward process until all variables in the model had a $p<0.05$. Residuals for each significant variable were estimated in order to know the contribution of each one to the dependent variable, adjusted for the other significant variables.

Results

All plant species used in the interview were reported for at least one type of use. Livestock, entertainment, medicinal, edible and fuel were the most important types of use for this set of plants (Annex 2). All species had at least four use types, and 31 species had more than eight types of use. *Juniperus flaccida, Alnus jorullensis, Arbutus xalapensis,* *Quercus crassifolia, Q. desertícola, Q. liebmannii, Q. rugosa,* and *Malacomeles denticulata* were the most important species, all with 10 use types.

Table 3. Anthropocentric categories used to classify the types of oak forest plant use in three municipalities at the Mixteca Alta region, Oaxaca, Mexico.

Type of use	Acronym	Description
Agricultural	AGR	Plants or parts thereof used as fertilizer for growing various products
Fuel	CMB	Includes plants and tangles used as firewood to light the fire, and to make charcoal
Edible	CMS	Plants that can be consumed by people, either as food, seasoning, candy or which are used in the preparation of food and beverages
Construction	CST	Preparation of tables, props and andirons for building houses and for furniture
Domestic	DOM	Plants used for household chores: cleaning the property and persons, separators tortilla, wrap meats, fruits ripen, etc.
Entertainment	ENT	Plants used primarily by children to play or elaborate toys
Tools	HER	To develop various agricultural implements such as rudders, plows, handles peaks, etc.
Medicinal	MED	Relieve various ailments, including so-called "*cultural diseases*" (*mal de ojo* or *mal de aire*) or to improve the health of people
Ornament	ORN	Plants used to decorate houses, altars, temples and processions for their beauty, scent or a shadow.
Livestock	PEC	Fooder and medicine for animals
Others	OTR	Various activities that can't be included in the other categories

The Principal Component Analysis shows important social differences among the three municipalities, most of which was explained by the first two components. The first principal component explains 70 % of the total variance, while the second component explains 30 %. Variables related to cultural attributes, namely, indigenous language proficiency, illiteracy and average education level explained most of the variation in the first component.   In the second component, variables related to economic welfare, such as housing services explained most of the variation (Table 4). Apoala municipality differs from Tilantongo and Huauclilla municipalities because of its higher native language proficiency, lower proportion of illiterate population and lower average school education. Furthermore, Huauclilla municipality differs of Tilantongo municipality by housing characteristics, such as the type of ground and the presence of piped water (Figure 1).

Table 4. Results of the principal component analysis of social factors in three municipalities in the Mixteca Alta, Oaxaca, Mexico. Variable contributions, based on correlations

	Factor 1	Factor 2
Houses with piped water (%)	0.178	0.000
Population ≥ 15 years old illiterate (%)	0.175	0.007
Population ≥ 3 years old who do not speak Spanish (%)	0.174	0.009
Population ≥ 3 years old who speak an indigenous language (%)	0.170	0.017
Men *vs* women ratio	0.132	0.107
Average education grade (years)	0.127	0.121
Houses with dirt floor (%)	0.015	0.387
Houses with drainage (%)	0.030	0.351

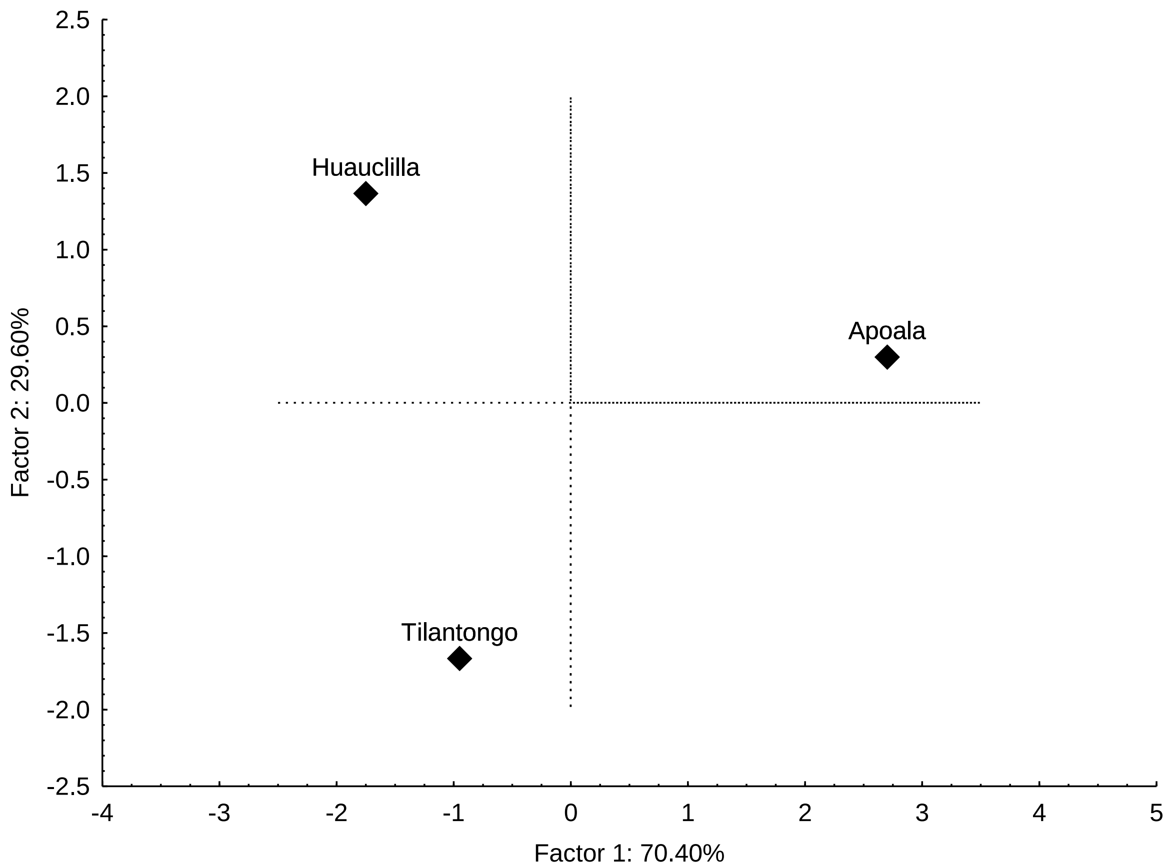

Figure 1. Principal component analysis for social attributes from three municipalities at the Mixteca Alta, Oaxaca, Mexico.

The GLM analysis shows that *Iu* is affected by municipality, age of the informant, proportion of the informant life spent out of his/her native town, PILSOT, involvement in field activities, and education level (Table 5). When the effect of the other variables is considered, locality is the main contributor to the utility index, following by the age of the information, involvement in field activities and education, following that order. Among municipalities, the lowest average utility index was found in Huauclilla, and the highest in Apoala, with Tilantongo displaying intermediate value between these two extremes (Figure 2a). The relationship between the age of the informant and *Iu* is hump-shaped. Informants older than 30 y and younger than 60 y showed the highest *Iu* on average (Figure 2b). The informant involvement in field activities increased the *Iu* value relative to those not involved in field activities. Both PILSOT and education level were negatively associated with *Iu* (Figure 2 c-e). We found no effect of gender on the utility index among informants.

Table 5. Summary of the general linear model analysis testing for the effect of social attributes of the informants on the utility index (*Iu*) in three municipalities of the Mixteca Alta, Oaxaca, Mexico.

Source	df	Mean square	F-Value	
Model	6	15.37	21.33	***
Error	309	0.72		
Total	315			
Source	df	Mean square	F-Value	
Mun	2	20.80	28.86	****
Age^2	1	14.16	19.65	****
PILSOT	1	7.92	10.98	**
Field	1	4.17	5.79	*
Edu	1	3.03	4.20	*
Parameter	Estimator	Standard error	t Value	
Independent term	- 0.04	0.08	-0.58	*ns*
Mun Apoala	0.55	0.12	4.67	****
Mun Tilantongo	0.00	.	.	.
Mun Huauclilla	-0.40	0.12	-3.38	***
Age^2	-0.24	0.05	-4.43	****
PILSOT	-0.18	0.05	-3.31	**
Field	0.12	0.05	2.41	*
Sch	-0.11	0.06	-2.05	*

Mun = municipality; *Age*= age of the informant (y), *PILSOT*= proportion of the informant life spent out of his/her native town (%), *Field* = involvement in field activities (yes, no), *Edu*= average education (y); *ns* = non-significant, * p<0.05, ** p<0.01, *** p<0.001, **** p<0.0001

Table 6. Summary of the general linear model analysis testing for the effect of social attributes of the informants on the use diversity index (*Id*) in three municipalities of the Mixteca Alta, Oaxaca, Mexico.

Source	df	Mean square	F-Value	
Model	5	9.22	10.63	****
Error	310	0.87		
Total	315			
Source	df	Mean square	F-Value	
Age	1	4.29	4.95	*
Age^2	1	7.77	8.96	**
Field	1	10.08	11.62	***
PILSOT	1	6.40	7.38	***
Lang	1	3.87	4.46	*
Parameter	Estimator	Standard error	t Value	
Independent term	0.00	0.05	0.00	*ns*
Age	0.12	0.05	2.22	*
Age^2	-0.17	0.06	-2.99	**
Field	0.19	0.06	3.41	***
PILSOT	-0.15	0.06	-2.72	**
Lang	0.12	0.06	2.11	*

Age= age of the informant (y), *Field* = involvement in field activities (yes, no), *PILSOT*= proportion of the informant life spent out of his/her native town (%), *Lang* = language proficiency (null, medium, high); *ns* = non-significant, * p<0.05, ** p<0.01, *** p<0.001, **** p<0.0001

On the other hand, the use diversity index, *Id*, was significantly associated with the informant's age, involvement in field activities, PILSOT, and native language proficiency in that importances order (Table 5). As in the case of the utility index, the relationship between *Id* and the age of the informant was quadratic, with the highest values found among 30 – 60 y old people. Involvement in field activities and language proficiency have a positive effect on use diversity index, meanwhile PILSOT shows negative effect (Figure 3 c-d). We found no effect of gender and education level on *Id*.

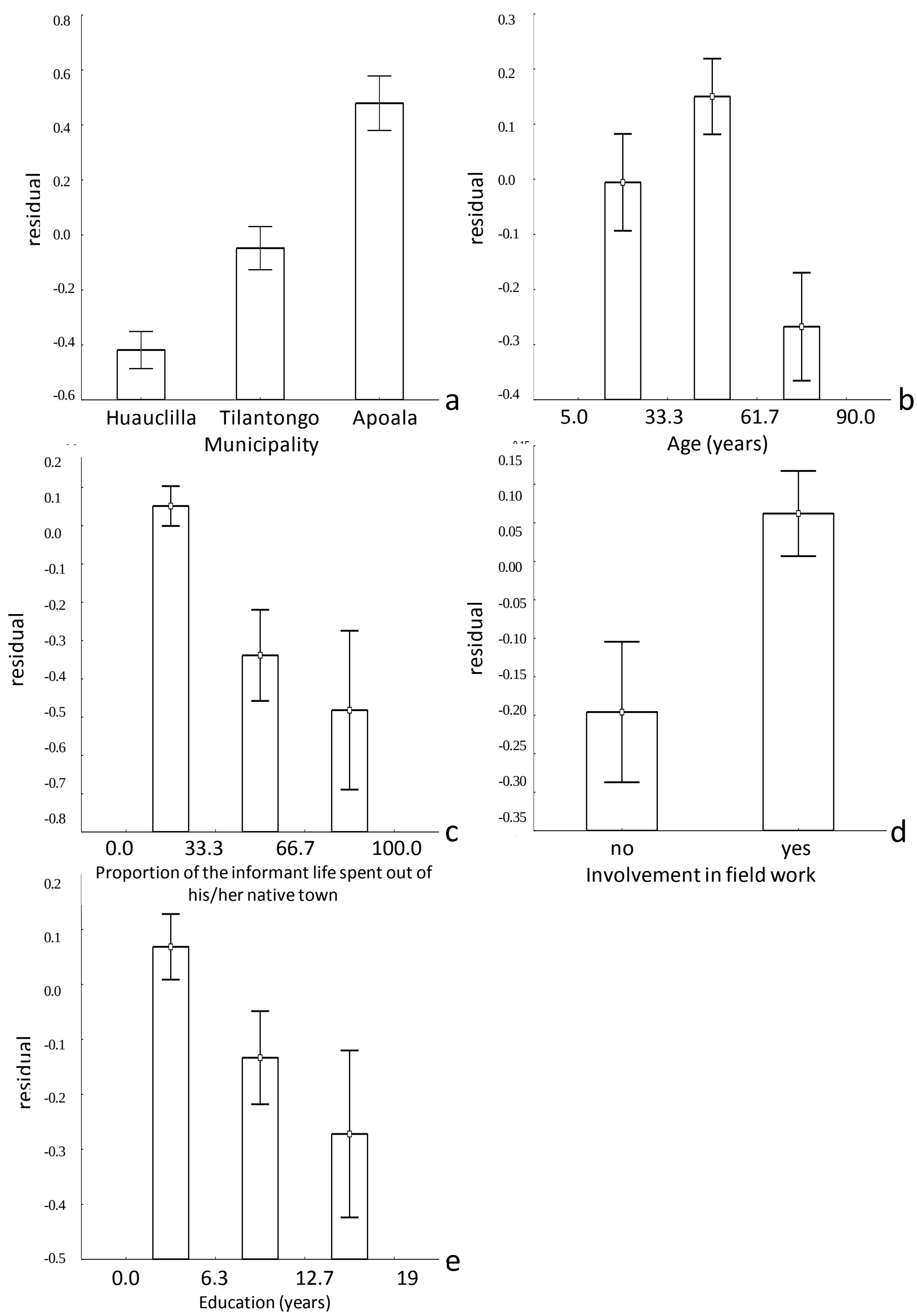

Figure 2. Relationship between the utility index (mean ± 1 SE) with: a) locality; b) age; c) proportion of the informant life spent out of his/her native town; d) involvement in field activities; and e) education on about the plant uses in the Mixteca Alta, Oaxaca, Mexico.

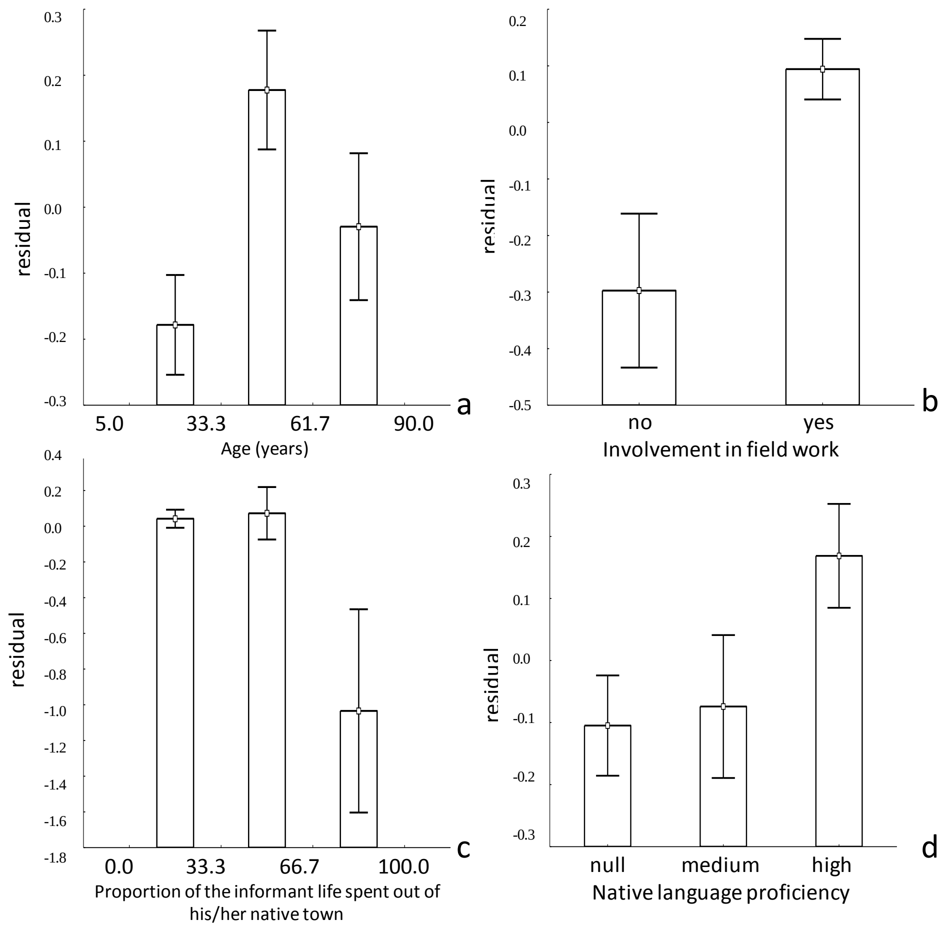

Figure 3. Graphic effect of: a) age; b) involvement in field activities; c) proportion of the informant life spent out of his/her native town; and d) language proficiency on use diversity index about the plant uses in the Mixteca Alta, Oaxaca, Mexico.

Discussion

We have provided evidence that native plants of the Mixteca Alta are important in the daily life of the people in this region. Four use types are most relevant: forage and veterinary medicine for livestock, human medicine, food, and firewood, in that order of importance. According with INEGI (2005), cattle breeding is one of the most important economic activities in this region. All species of plants surveyed were reported as forage or veterinary medicine for at least one informant. The use of medicinal plants is common, probably because of the higher prices of commercial medicines and the wide variety of diseases that native plants are known to cure. In this regard, wild plants are also used to treat cultural diseases, a kind of malady that is believed to be caused by unnatural or mysterious forces, involving in some cases witchcraft. The uses of native plants for food are also diverse, including direct consumption or as material for the preparation of drinks and dishes in traditional cuisine. Firewood is still a very popular use of native woody plants in particular oaks, which wood is well-known for its high calorific content. Data from Instituto Nacional de Estadística, Geografía e Informática (INEGI, 2010) reveal that in the three municipalities studied a relatively high proportion of the houses use firewood as major source of heating. The wide variety of uses and the fact that all plants surveyed had a least one use reveals a heavy dependence of the local people on the natural resources of their environment.

Nevertheless, the traditional knowledge about useful plants is not homogeneously distributed among the population. Both, the utility index and use diversity index are biased toward lowest values. That is, most of the knowledge about the uses of native plants is concentrated in very few people. Our statistical analyses shows that part of the differences in the knowledge about useful plants among informants can be explained by their social and cultural differences. Municipality, age of the informant, involvement in field activities, proportion of the informant life spent out of his/her native town, education level, and native language proficiency were associated with the knowledge people have about useful plants. Of these variables, involvement in field activities, the fraction of time spent out their native town and the age of the informant were common to both of the measured indices. Gender was not significantly associated with neither of the two indices. Other studies have recognized that women have an important role on the maintenance of the traditional knowledge (Maffi, 2002, 2005; Howard, 2003; Alvarado, 2005). Apparently the relationship between traditional knowledge and gender lies in the different ways men and women use natural resources, based on the role that each gender play in the community. For instance, some studies have found significant gender differences on the proportion of species used for food or medicine, but not between total resource uses (Alvarado, 2005; Hanazaki *et al*., 2000; Vásquez-García *et al.*, 2009). In our particular case, we found some evidence that men were more aware of the usefulness of plants for tool manufacturing; whereas women tend to identify native plants based on their use for food or for household chores. Future studies should pay attention to gender-oriented uses of natural resources.

The average number of useful native plants given by the people in the Mixteca Alta, Oaxaca depended heavily on the municipality. Indeed, municipality was the most important factor affecting this number. Apparently, cultural and economic differences among municipalities explain this result. Indeed, we found the highest average number of useful plants in Apoala. This municipality contrasts with the other two studied municipalities by the highest preservation of its native culture according to our PCA analysis. Apoala for instance, has the lowest average level of education, and is the only municipality with Mixtec-speaking people who do not speak Spanish. By contrast Huauclilla has the highest average education level and Mixtec-speaking people are very rare. Huauclilla has the lowest average number of useful plants. Thus, people from less acculturated municipalities, knows proportionately more useful plants than the people from more acculturated municipalities. That is supported by Case *et al.* (2005), whom found that

Usiai men and women living in villages far from Lorengau, the major town in Manus province in New Guinea, have the highest attainment of plant knowledge within Manus province.

Traditional knowledge shows significant differences based in age groups for both, utility and use diversity indices. However, contrary to what we expected, we found that the older group shows both index values lower than those of middle age, and the utility index is lower than that recorded for the younger age group. In our study, some older people interrupted the interview after seeing few specimens and often they recognized only a small fraction of the specimens shown. This result is similar to that found by Case et al. (2005) between the residents of two towns in New Guinea. The authors justify this result on the discomfort felt by older respondents when trying to identify uses of plants depicted in pictures or in specimens collected from the wild. Perhaps because many of them suffer from visual defects, they require touching or tasting the plants for an accurate identification. Likely older people recognize less than younger plants because they tend to visit less frequently and field sites are more likely to forget due to conditions appropriate to their age.

Involvement in field activities is directly related with both, utility and use diversity indices. People frequently involved in field work, show a greater traditional knowledge than people who do not work in the field. Other studies have shown a direct relationship between the occupation of the inhabitants and traditional knowledge. For example, Hanazaki *et al*. (2000) found that people engaged regularly in forestry in the Atlantic Forest coast, Brazil, knew more medicinal plants than other people because of their greater permanence in the forest. This is supported by Byg and Balslev (2004), who point out that learning of the local knowledge has to be done largely through observation and practice in close proximity to the resources themselves rather than through language.

The proportion of the informant life spent out of his/her native town and education level shows negative relationship with traditional knowledge. Both variables are factors that may contribute to erode the knowledge of traditional culture. In Mixtec communities, primary schools are available in most towns; however, for higher education level, the students should move to other towns. The time spent outside the native community for education or any other reason, expose people to different lifestyles to their community, reducing the contact with their own culture and natural resources. The final result could be a loss of interest in the people's own culture, and a loss of opportunities to learn traditional culture, while adopting new ways of life (Byg and Balslev 2004), in the process called acculturation (Zent, 2001; Byg and Balslev, 2004; Maffi, 2005).

In this study the proficiency in Mixtec language seems to affect the traditional knowledge of plant uses. Some studies point to the relationship between native language and traditional knowledge in indigenous communities (Maffi, 2002, 2005; Zent, 2001). However, language proficiency effect show been the weakest among the social attributes significant on traditional knowledge. This is probably due to the fact that the vast majority of the population speaks Spanish and only a small portion, particularly in the municipality of Santiago Apoala, people speaks exclusively Mixtec. In fact, many people in the community recognized that the Mixtec language is being lost and that, although the younger generation is interested in learning it, is no longer possible because there are no people in the community who teaches it, particularly in Huauclilla municipality. Extensive knowledge about useful plants in the region could indicate that, although there is evidence that the native language is being lost, it may be preserved traditional knowledge among the people.

In general, both indices were affected similarly for age, municipality and proportion of the informant life spent out of his/her native town. However, the municipality and education level affected only the utility index, while language proficiency affected only diversity of uses index. Apparently, the informants who were subject to a higher degree of acculturation, whether belonging to municipalities with more education and more services in homes or having received more formal education, showed less knowledge about useful species, while informants with more native language proficiency showed greater diversity of uses of the species. These results show that both indices are complementary and together can give a better idea of how the social attributes of the informants may influence the traditional knowledge on the use of plants in oak seasonal forest in the Oaxacan Mixteca Alta.

Conclusions

One of the main objectives of quantitative ethnobotany, according to Martin (2000) is that it be found patterns of variation on traditional knowledge and their relationship with social factors that affect them. The findings in this study allow us to achieve this objective, showing how different social factors are related to traditional knowledge. Municipality, age, education, involvement in field work, proportional life time spent outside the community, and native language proficiency were show to have significant influence on traditional knowledge. We do not found gender effect. Our results show the importance of understanding how traditional knowledge is modified in indigenous communities in order to contribute to the conservation of cultural and biological diversity.

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CAPITULO III

Conclusiones generales

El uso de técnicas de modelaje de ecuaciones estructurales en doce fragmentos de bosque de encino estacional en la Mixteca Alta oaxaqueña, nos permitió probar y confirmar un modelo de tres factores que caracteriza la diversidad de los remanentes. La heterogeneidad topográfica, el disturbio antropogénico y el tamaño del área de los remanentes en ese orden, jugaron un papel significativo en la diversidad de las especies leñosas en los bosques de encino. La heterogeneidad topográfica mostró un efecto positivo relacionado con la diversidad. El valor α de Fisher se incrementó significativamente con la heterogeneidad en orientación o altitud del fragmento. El disturbio, estimado por la densidad de tocones en el fragmento y la porción del área afectada por caminos, mostró también un efecto positivo sobre la diversidad. Fragmentos pequeños con niveles similares de heterogeneidad topográfica y disturbio tienden a ser más diversos que los fragmentos mayores, probablemente porque los primeros tienen una mayor relación perímetro-área y por lo tanto presentan más oportunidades para el establecimiento exitoso de especies que se benefician por los espacios abiertos, tales como especies pioneras y resilientes. El análisis de ecuaciones estructurales lineales mostró ser una técnica apropiada para desentrañar la contribución de varios factores relacionados con la diversidad.

Uno de los principales objetivos de la etnobotánica cuantitativa es encontrar patrones de variación en el conocimiento tradicional y su relación con factores sociales que pueden modificarlo. Los hallazgos en este estudio nos permiten alcanzar este objetivo, mediante la obtención de pesos proporcionales de cada uno de los atributos sociales involucrados en el conocimiento tradicional. El municipio de origen, edad, nivel educativo, acceso a actividades de campo, tiempo proporcional de ausencia de la comunidad y dominio del idioma nativo están directamente relacionados con el conocimiento tradicional.

Los resultados obtenidos en estos estudios aportan contribuciones importantes tanto al estudio de los factores que alteran la diversidad de plantas en ecosistemas templados, incluyendo el disturbio de tipo antropogénico, así como de la importancia que los recursos naturales en estos ecosistemas tienen para las poblaciones humanas y los factores sociales que pueden determinar diferencias en el conocimiento tradicional sobre el uso de los recursos. Las estrategias de conservación en paisajes fragmentados deben considerar no solamente las características de los fragmentos y las especies que deben ser conservadas, sino la relación que existe entre las poblaciones humanas y el uso de los ecosistemas. Como lo señalan diversos autores (Toledo, 1980, 1982; Carlson *et al.,* 2003; Pieroni, 2003; Byg and Balslev, 2004; Godoy *et al.* 2005), la integración de estos dos elementos puede contribuir al diseño de planes que permitan la conservación de los ecosistemas y a la vez contribuyan a mejorar las condiciones de vida de las comunidades indígenas.

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Annex 1. Floristic list of tree layer species (DBH ≥ 2.5 cm and height ≥ 2.5 m), recorded in twelve seasonally dry oak forest remnants in the Mixteca Alta of Oaxaca, Mexico. P1 to P12 = Fragments in consecutive order.

Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Cupressaceae												
Juniperus flaccida Schltdl.	X	X	-	X	X	X	X	X	X	-	X	-
Pinaceae												
Pinus sp.	-	-	-	X	-	-	-	-	-	-	-	-
Anacardiaceae												
Actinocheita filicina (DC.) F.A. Barkley	-	-	-	-	-	-	-	-	-	-	-	X
Pistacia mexicana Kunth	-	-	-	-	-	X	-	X	-	-	-	X
Rhus schiedeana Schltdl.	-	-	-	-	-	-	-	-	X	-	-	X
R. standleyi F.A. Barkley	X	-	-	X	X	X	-	X	-	-	-	-
Asteraceae												
Ageratina mairetiana (DC.) R.M. King & H. Rob.	-	-	-	-	-	-	-	-	-	-	X	-
Critonia hebebotrya DC.	-	-	-	-	-	-	-	-	-	X	-	-
Montanoa frutescens (Mairet ex DC.) Hemsl.	-	-	-	-	-	X	-	-	-	-	-	-
Betulaceae												
Alnus jorullensis Kunth	-	-	-	-	-	-	-	-	-	X	-	-
Buddlejaceae												
Buddleja parviflora Kunth	-	X	-	X	X	X	-	-	-	-	X	-
Burseraceae												
Bursera bipinnata (DC.) Engl.	-	-	-	-	-	-	-	-	-	-	-	X
Ericaceae												
Arbutus xalapensis Kunth	X	X	X	X	X	-	-	-	-	X	X	-
Comarostaphylis discolor (Hook.) Diggs	-	-	-	X	-	-	-	-	-	X	-	-
C. polifolia (Kunth) Zucc. ex Klotzsch	-	-	-	-	X	X	-	-	X	-	-	-
Fabaceae												
Acacia pennatula (Schltdl. & Cham.) Benth. subsp. *pennatula*	-	-	-	-	-	-	-	-	-	-	-	X
Brongniartia mollis Kunth	-	-	-	-	X	-	-	-	-	-	-	-
Calliandra grandiflora (L'Hér.) Benth.	-	-	-	-	X	-	-	-	-	-	-	-
Eysenhardtia polystachya (Ortega) Sarg.	-	-	-	X	X	X	-	-	-	-	-	X
Leucaena diversifolia (Schltdl.) Benth.	-	-	-	-	X	-	-	-	-	-	-	-
Mimosa lactiflua Delile ex Benth.	-	-	-	-	-	-	-	-	-	-	-	X
Rhynchosia discolor M. Martens & Galeotti	-	-	-	-	X	-	-	-	-	-	-	-

Annex 2. Cont.

Scientific name	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**P7**	**P8**	**P9**	**P10**	**P11**	**P12**
Fagaceae												
Quercus acutifolia Née	X	X	-	X	X	X	-	X	-	X	X	-
Q. candicans Née	X	-	-	-	-	-	-	-	-	-	-	-
Q. castanea Née	X	X	X	X	-	-	-	-	-	X	X	-
Q. crassifolia Humb. & Bonpl.	X	-	X	-	-	-	-	-	-	X	-	-
Q. deserticola Trel.	-	-	-	-	-	-	-	-	-	X	X	-
Q. dysophylla Benth.	-	-	-	X	-	-	-	-	-	-	-	-
Q. laeta Liebm.	-	X	X	X	X	-	-	-	-	-	-	-
Q. laurina Bonpl.	-	-	X	X	-	-	-	-	-	X	X	-
Q. liebmannii Oerst. ex Trel.	X	X	X	X	X	X	X	X	X	X	X	X
Q. obtusata Bonpl.	X	X	X	X	-	-	-	-	-	X	-	-
Q. rugosa Née	X	-	X	X	X	-	-	-	-	X	X	-
Garryaceae												
Garrya laurifolia Hartw. ex Benth.	-	-	-	X	X	X	-	X	-	X	-	-
Lauraceae												
Litsea glaucescens Kunth	-	-	-	-	X	-	-	-	-	-	-	-
Rhamnaceae												
Ceanothus caeruleus Lag.	-	-	-	-	X	-	-	-	X	-	-	-
Rhamnus serrata Humb. & Bonpl. ex Willd.	-	-	-	-	-	-	-	-	X	-	-	X
Rosaceae												
Cercocarpus macrophyllus C.K. Schneid.	X	-	-	X	-	-	-	-	-	X	X	-
Malacomeles denticulata (Kunth) G.N. Jones	-	-	-	-	-	X	-	-	-	X	-	-
Prunus serotina subsp. *capuli* (Cav.) McVaugh	-	-	-	X	-	-	-	-	-	X	X	-
Vauquelinia australis Standl.	-	-	-	-	-	-	-	-	-	X	-	-
Sapindaceae												
Dodonaea viscosa Jacq.	-	-	-	-	X	X	X	X	X	-	-	-
Solanaceae												
Cestrum anagyris Dunal	-	-	-	-	-	-	-	-	-	X	-	-
No determinated												
n.d. 2	-	-	-	-	-	-	-	-	-	-	X	-
Arecaceae												
Brahea dulcis (Kunth) Mart.	X	-	-	-	-	-	X	X	-	-	X	X
Nolinaceae												
Nolina longifolia (Karw. ex Schult. f.) Hemsl.	X	-	-	X	X	-	-	-	-	-	-	-
Total species in fragment	13	8	8	19	19	12	4	8	7	18	14	10

Annex 2. Floristic list of shrub layer species (DBH < 2.5 cm or height < 2.5 m) recorded in twelve seasonally dry oak forest remnants in the Mixteca Alta of Oaxaca, Mexico. P1 to P12 = Fragments in consecutive order.

Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Cupressaceae												
Juniperus flaccida Schltdl.	X	X	X	X	X	-	X	X	X	-	-	-
Pinaceae												
Pinus sp.	-	-	-	-	X	-	-	-	-	-	X	-
Anacardiaceae												
Actinocheita filicina (DC.) F.A. Barkley	-	-	-	-	-	-	-	-	-	-	-	X
Asclepias linaria Cav.	-	X	-	-	-	-	-	-	-	-	-	-
Pistacia mexicana Kunth	-	-	-	-	-	X	-	X	-	-	-	X
Rhus schiedeana Schltdl.	-	-	-	-	-	-	-	-	X	X	-	X
R. standleyi F.A. Barkley	X	X	-	X	X	X	X	X	X	X	X	-
Asteraceae												
Ageratina calophyla (Greene) R.M. King & H. Rob.	-	X	-	X	X	X	X	X	X	X	X	X
A. espinosarum (A. Gray) R.M. King & H. Rob.	-	X	-	-	-	-	X	-	X	-	-	X
A. mairetiana (DC.) R.M. King & H. Rob.	-	-	-	-	-	-	-	-	-	-	X	-
A. petiolaris (Moc. ex DC.) R.M. King & H. Rob.	X	X	-	X	X	-	-	-	-	X	X	-
A. scorodonioides (A. Gray) R.M. King & H. Rob.	-	-	-	-	X	-	-	-	-	-	-	-
Archibaccharis serratifolia (Kunth) S.F. Blake	-	-	-	-	X	-	-	-	-	-	-	-
Baccharis conferta Kunth	-	-	X	-	X	-	-	-	-	-	-	-
Baccharis serrifolia DC.	X	X	-	X	X	-	-	-	-	-	X	-
Bidens pilosa L.	X	X	X	-	X	X	-	X	-	X	X	-
Brickellia secundiflora (Lag.) A. Gray	-	-	-	X	X	-	-	-	-	-	X	-
B. veronicifolia (Kunth) A. Gray	-	X	-	X	X	X	X	X	X	-	X	X
Coreopsis mutica DC.	-	-	-	X	-	-	-	-	-	-	-	-
Critonia hebebotrya DC.	-	-	-	-	-	-	-	-	-	X	-	-
Eupatorium sp.	-	-	-	X	-	-	-	-	-	-	-	-
Lagascea helianthifolia Kunth	-	-	-	-	-	X	-	-	-	-	-	-
Perymenium discolor Schrad.	-	-	-	X	X	X	X	-	-	-	-	-

Annex 2. Cont.

Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Pittocaulon praecox (Cav.) H. Rob. & Brettell	-	-	-	-	-	-	-	-	-	X	-	-
Roldana barba-johannis (DC.) H. Rob. & Brettell	-	-	-	-	-	-	-	-	-	X	-	-
R. oaxacana (Hemsl.) H. Rob. & Brettell	-	-	-	X	X	-	-	-	-	-	-	-
Rumfordia floribunda DC.	-	-	-	-	-	-	-	-	-	X	-	-
Senecio callosus Sch. Bip.	-	-	-	-	X	-	-	-	-	-	-	-
Stevia lucida var. *oaxacana* (DC.) Grashoff	-	X	-	X	X	-	-	-	-	X	-	-
S. ovata Willd.	-	-	-	-	-	-	-	-	-	-	X	-
Tagetes lucida Cav.	-	-	-	-	X	-	-	-	-	-	-	-
Verbesina oncophora B.L. Rob. & Seaton	X	X	-	X	X	-	X	-	-	-	X	X
V. virgata Cav.	-	-	-	-	X	-	-	-	-	-	-	-
Viguiera benziorum B.L. Turner	-	-	-	-	X	-	-	-	-	X	-	-
Asteraceae sp.	X	-	-	-	-	-	-	-	-	-	-	-
Berberidaceae												
Berberis moranensis Schult. & Schult. f.	-	-	-	-	-	X	X	-	-	X	-	-
Bignoniaceae												
Tecoma stans (L.) Juss. ex Kunth	-	X	-	-	-	-	-	-	X	-	-	-
Boraginaceae												
Lithospermum calycosum (J.F. Macbr.) I.M. Johnst.	-	-	-	X	X	-	-	-	-	-	-	-
Buddlejaceae												
Buddleja parviflora Kunth	-	-	-	-	-	X	-	-	-	-	X	-
Burseraceae												
Bursera bipinnata (DC.) Engl.	-	-	-	-	-	-	-	-	-	-	-	-
Cactaceae												
Ferocactus macrodiscus (Mart.) Britton & Rose	-	X	-	-	X	-	-	-	-	-	-	-
Mammillaria haageana Pfeiff.	-	X	-	X	-	-	-	-	X	-	X	X
M. kraehenbuehlii (Krainz) Krainz	-	-	-	-	X	-	X	-	-	-	-	-
Mammillaria sp.	-	X	-	-	X	-	-	-	-	-	-	-
Opuntia lasiacantha Pfeiff.	X	X	-	X	-	-	-	-	-	-	-	-
O. streptacantha Lem.	-	-	-	-	X	-	-	X	-	-	-	-
Ericaceae												
Arbutus xalapensis Kunth	X	-	X	-	X	X	-	-	-	X	X	-

Annex 2. Cont.

Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Chimaphila maculata (L.) Pursh	-	-	X	-	-	-	-	-	-	-	-	-
Comarostaphylis discolor (Hook.) Diggs	-	-	-	X	-	-	-	-	-	X	X	-
C. polifolia (Kunth) Zucc. ex Klotzsch	-	-	-	-	X	X	X	X	X	X	-	-
Fabaceae												
Acacia pennatula (Schltdl. & Cham.) Benth. subsp. *pennatula*	-	-	-	-	-	-	-	-	-	-	-	X
A. tequilana S. Watson	-	-	-	X	X	-	-	-	-	-	-	-
Brongniartia mollis Kunth	-	-	-	-	X	-	-	-	-	-	-	-
Calliandra grandiflora (L'Hér.) Benth.	X	-	-	X	X	-	-	X	-	-	-	-
Dalea aff. *lutea* (Cav.) Willd.	X	X	-	X	X	-	-	-	-	-	-	-
Desmodium sp.	-	-	-	X	X	-	-	-	-	-	-	-
Eysenhardtia polystachya (Ortega) Sarg.	-	-	-	-	X	-	-	-	-	-	-	T
Harpalyce formosa DC.	-	-	-	-	-	X	X	X	-	-	-	-
Leucaena diversifolia (Schltdl.) Benth.	-	-	-	-	X	-	-	-	-	-	-	-
Lysiloma acapulcense (Kunth) Benth.	-	-	-	-	X	-	-	-	-	-	-	-
L. divaricatum (Jacq.) J.F. Macbr.	-	-	-	X	-	-	-	-	-	-	-	-
Mimosa lactiflua Delile ex Benth.	-	-	-	-	-	-	-	-	-	-	-	X
Rhynchosia discolor M. Martens & Galeotti	X	-	-	-	X	-	-	X	-	-	-	-
Tephrosia sp.	-	-	-	X	-	-	-	-	-	-	-	-
Fabaceae sp.	-	-	-	-	X	-	-	-	-	-	-	-
Fagaceae												
Quercus acutifolia Née	X	X	-	X	X	X	-	-	-	X	X	X
Q. castanea Née	X	-	-	-	-	-	-	-	-	X	X	-
Q. crassifolia Humb. & Bonpl.	-	-	X	-	-	-	-	-	-	-	-	-
Q. deserticola Trel.	-	-	-	-	-	-	-	-	-	X	-	-
Q. laeta Liebm.	-	X	X	-	-	-	-	-	-	-	-	-
Q. laurina Bonpl.	-	-	X	-	X	-	-	-	-	X	X	-
Q. liebmannii Oerst. ex Trel.	X	X	-	X	X	X	-	X	-	X	-	X
Q. obtusata Bonpl.	-	-	-	X	-	-	-	-	-	X	-	-
Q. rugosa Née	-	-	X	X	X	-	-	-	-	X	X	-
Garryaceae												
Garrya laurifolia Hartw. ex Benth.	-	-	-	X	X	X	X	X	-	X	-	-

Annex 2. Cont.

Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Lamiaceae												
Clinopodium macrostemum (Moc. & Sessé ex Benth.) Kuntze	-	-	-	-	-	-	-	-	-	X	-	-
Salvia aff. *fruticosa* Mill.	-	-	-	-	-	-	-	-	X	-	-	-
S. cinnabarina M. Martens & Galeotti	-	X	-	X	X	-	-	-	-	X	X	X
S. macrophylla Benth.	-	-	-	-	-	-	-	-	-	X	-	-
S. melissodora Lag.	X	X	-	-	X	X	X	X	-	-	X	-
S. mexicana L.	-	-	-	-	-	X	-	-	-	-	-	-
S. stolonifera Benth.	-	-	X	-	-	-	-	-	-	-	-	-
Lauraceae												
Litsea glaucescens Kunth	X	-	-	X	X	X	-	-	-	X	-	-
Lythraceae												
Cuphea cyanea DC.	-	X	-	X	X	-	-	-	-	X	-	-
Oleaceae												
Fraxinus purpusii Brandegee	-	-	-	-	-	-	X	X	-	-	-	-
Onagraceae												
Fuchsia encliandra Steud.	-	X	X	X	X	-	-	-	-	X	-	-
Polygalaceae												
Monnina xalapensis Kunth	X	-	-	X	X	X	-	-	-	X	-	-
Rhamnaceae												
Ceanothus caeruleus Lag.	X	-	-	-	X	-	-	-	-	-	-	-
Rhamnus serrata Humb. & Bonpl. ex Willd.	X	X	-	X	X	-	-	-	X	-	-	X
Rosaceae												
Cercocarpus macrophyllus C.K. Schneid.	-	-	-	X	X	X	-	-	X	-	-	-
Malacomeles denticulata (Kunth) G.N. Jones	X	-	-	-	X	X	-	-	X	X	X	-
Prunus serotina subsp. *capuli* (Cav.) McVaugh	-	-	-	X	-	-	-	-	-	X	-	-
Rubus trilobus Moc. & Sessé ex Ser.	-	-	-	-	-	-	-	-	-	X	X	-
Vauquelinia australis Standl.	-	-	-	-	-	-	-	-	-	-	X	-
Rubiaceae												
Bouvardia longiflora (Cav.) Kunth	-	-	X	-	X	-	X	X	X	X	X	-
B. ternifolia (Cav.) Schltdl.	X	-	-	X	X	-	-	-	X	X	-	-
Chiococca pachyphylla Wernham	-	-	-	-	X	-	-	-	-	-	-	-

Annex 2. Cont.

Scientific name	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10	P11	P12
Sapindaceae												
Dodonaea viscosa Jacq.	-	X	-	-	X	X	X	X	X	-	-	-
Scrophulariaceae												
Castilleja tenuiflora Benth.	-	-	-	-	-	-	-	-	-	-	X	-
Lamourouxia rhinanthifolia Kunth	-	-	-	X	-	-	-	-	-	-	-	-
Penstemon roseus (Cerv. ex Sweet) G. Don	X	-	-	-	-	-	-	-	-	-	X	-
Solanaceae												
Cestrum anagyris Dunal	-	-	-	-	X	-	-	-	-	X	-	-
Solanum cervantesii Lag.	-	-	-	-	-	-	-	-	-	X	-	-
S. lanceolatum Cav.	X	X	-	-	-	-	-	-	-	-	X	X
Verbenaceae												
Lantana camara L.	X	X	-	X	X	X	-	-	X	X	-	-
No determinated												
n.d. 1	-	-	-	-	-	-	-	-	X	-	-	-
n.d. 3	-	-	-	-	-	-	-	-	-	X	-	-
n.d. 4	-	X	-	-	-	-	-	-	-	-	-	-
n.d. 5	-	-	-	-	-	-	-	-	-	-	X	-
Agavaceae												
Agave potatorum Zucc.	-	-	-	-	X	-	-	X	-	-	-	X
Arecaceae												
Brahea dulcis (Kunth) Mart.	-	-	-	-	X	-	X	X	-	-	X	X
Asparagaceae												
Beaucarnea gracilis Lem.	-	-	-	-	X	-	-	-	-	-	-	-
Dasylirion serratifolium (Karw. ex Schult. f.) Zucc.	-	-	-	-	-	-	-	-	X	-	-	-
Bromeliaceae												
Hechtia aff. *sphaeroblasta* B.L. Rob.	X	-	-	-	-	-	-	-	X	-	-	X
Nolinaceae												
Nolina longifolia (Karw. ex Schult. f.) Hemsl.	X	-	-	-	X	-	-	-	-	-	-	-
Smilacaceae												
Smilax moranensis M. Martens & Galeotti	-	-	-	-	X	-	-	-	-	-	-	-
Total species in fragment	27	29	12	39	63	23	17	19	20	39	30	18

Annex 3. List of useful species of seasonally dry oak forest in three municipalities of the Mixteca Alta region, Oaxaca, Mexico.

SPECIES	**USE TYPE**											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**T**
Cupressaceae												
Juniperus flaccida Schltdl.	X	X	X	X		X	X	X	X	X	X	10
Anacardiaceae												
Rhus schiedeana Schltdl.		X	X			X		X	X	X		6
R. standleyi F.A. Barkley		X	X	X		X	X	X		X	X	8
Apiaceae												
Arracacia aegopodioides (Kunth) J.M. Coult. & Rose		X	X		X	X		X		X		6
Apocynaceae												
Asclepias notha W.D. Stevens		X	X			X		X	X	X	X	7
Aquifoliaceae												
Ilex discolor var. *tolucana* (Hemsl.) Edwin ex T.R. Dudley		X	X			X		X	X	X		6
Asteraceae												
Ageratina calophylla (Greene) R.M. King & H. Rob.		X	X			X	X	X	X	X		7
A: petiolaris (Moc. ex DC.) R.M. King & H. Rob.		X	X	X	X	X	X	X	X	X		9
Archibaccharis serratifolia (Kunth) S.F. Blake		X	X	X				X	X	X		6
Baccharis conferta Kunth		X	X		X	X		X	X	X		7
B. serrifolia DC.		X	X		X	X		X		X		6
Bidens ostruthioides (DC.) Sch. Bip.		X	X		X	X		X	X	X		7
B. pilosa L.			X			X		X	X	X		5

1= agricultural; 2= fuel; 3= edible; 4= construction; 5= domestic; 6= entertainment; 7= tools; 8= medicinal; 9= ornamental; 10= livestock; 11= others; T= different uses total

Annex 3. Cont.

SPECIES	USE TYPE											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**T**
Critonia hebebotrya DC.		X	X			X	X	X	X	X		7
Dahlia merckii Lehm.			X			X		X	X	X		5
Perymenium discolor Schrad.		X	X			X		X	X	X		6
P. mendezii DC.			X		X	X		X	X	X		6
Pittocaulon praecox (Cav.) H. Rob. & Brettell						X	X	X	X	X		5
Roldana barba-johannis (DC.) H. Rob. & Brettell		X	X	X	X	X		X	X	X		8
R. oaxacana (Hemsl.) H. Rob. & Brettell		X				X		X	X	X		5
Rumfordia floribunda DC.					X	X		X	X	X		5
Senecio callosus Sch. Bip.		X	X			X		X	X	X	X	7
Stevia lucida Lag.		X	X			X		X	X	X		6
Tagetes lucida Cav.		X	X			X		X	X	X	X	7
Verbesina virgata Cav.		X			X	X		X	X	X		6
Vernonia karvinskiana DC.			X			X		X	X	X	X	6
Vernonia sp.		X		X		X	X		X	X		6
Viguiera rhombifolia (B.L. Rob. & Greenm.) S.F. Blake			X		X	X		X	X	X		6
Berberidaceae												
Berberis moranensis Schult. & Schult. f.	X	X	X			X	X			X		6
Betulaceae												
Alnus jorullensis Kunth	X	X	X	X	X		X	X	X	X	X	10
Bignoniaceae												
Tecoma stans (L.) Juss. ex Kunth		X	X			X		X	X	X	X	7
Boraginaceae												
Lithospermum calycosum (J.F. Macbr.) I.M. Johnst.			X			X		X	X	X		5
Ericaceae												
Arbutus xalapensis Kunth		X	X	X	X	X	X	X	X	X	X	10
Arctostaphylos pungens Kunth		X	X			X		X	X	X		6
Chimaphila maculata (L.) Pursh		X				X		X	X	X		5

Annex 3. Cont.

SPECIES	USE TYPE											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**T**
Comarostaphylis discolor (Hook.) Diggs		X	X			X		X		X	X	6
C. polifolia (Kunth) Zucc. ex Klotzsch		X	X	X		X		X		X	X	7
Fabaceae												
Acacia tequilana S. Watson		X	X			X		X		X		5
Brongniartia mollis Kunth		X	X	X		X		X	X	X	X	8
Calliandra grandiflora (L'Hér.) Benth.		X	X		X	X			X	X		6
Coursetia polyphylla Brandegee		X	X	X		X			X	X		6
Desmanthodium ovatum Benth.			X			X		X	X	X		5
Desmodium sp.		X	X			X		X	X	X		6
Diphysa occidentalis Rose		X	X	X	X	X	X	X	X	X		9
Eysenhardtia polystachya (Ortega) Sarg.		X	X	X	X	X		X	X	X		8
Leucaena diversifolia (Schltdl.) Benth.		X	X	X		X		X		X		6
Lysiloma acapulcense (Kunth) Benth.		X	X	X	X	X		X	X	X	X	9
Phaseolus anisotrichos Schltdl.			X			X		X	X	X		5
Rhynchosia discolor M. Martens & Galeotti			X		X			X	X	X		5
Vachellia farnesiana (L.) Wight & Arn.		X	X	X		X	X	X	X	X	X	9
V. pennatula (Schltdl. & Cham.) Seigler & Ebinger		X	X	X		X	X	X	X	X	X	9
Fagaceae												
Quercus acutifolia Née	X	X	X	X		X	X	X		X	X	9
Q. candicans Née	X	X		X		X	X	X	X	X		8
Q. castanea Née	X	X	X	X		X	X	X	X	X		9
Q. crassifolia Bonpl.	X	X	X	X	X	X	X	X	X	X		10
Q. deserticola Trel.	X	X		X	X	X	X	X	X	X	X	10
Q. dysophylla Benth.	X	X	X	X	X	X	X	X		X		9
Q. laeta Liebm.		X	X	X	X	X	X	X		X	X	9
Q. laurina Bonpl.	X	X	X	X		X	X	X	X	X		9

Annex 3. Cont.

SPECIES	USE TYPE											
	1	2	3	4	5	6	7	8	9	10	11	T
Q. liebmannii Oerst. ex Trel.	X	X	X	X	X	X	X	X	X	X		10
Q. obtusata Bonpl.	X	X		X		X	X	X	X	X		8
Q. rugosa Née	X	X		X	X	X	X	X	X	X	X	10
Garryaceae												
Garrya laurifolia Hartw. ex Benth.		X	X	X	X		X	X		X		7
Gentianaceae												
Halenia brevicornis (Kunth) G. Don			X					X	X	X		4
Lamiaceae												
Clinopodium macrostemum (Moc. & Sessé ex Benth.) Kuntze			X		X	X		X	X	X		6
Lepechinia caulescens (Ortega) Epling			X			X		X	X	X		5
Salvia cinnabarina M. Martens & Galeotti			X			X	X	X	X	X		6
S. coccinea Buc'hoz ex Etl.			X			X		X	X	X		5
S. fruticulosa Benth.		X	X			X	X	X	X	X		7
S. macrophylla Benth.		X	X		X	X		X	X	X		7
S. melissodora Lag.		X	X			X		X	X	X		6
S. mexicana L.			X			X		X	X	X		5
S. polystachia Cav.			X			X		X	X	X		5
S. stolonifera Benth.			X			X		X	X	X		5
Lauraceae												
Litsea glaucescens Kunth		X	X		X	X	X	X	X	X		8
Lythraceae												
Cuphea aequipetala Cav.			X			X		X	X	X		5
C. cyanea DC.		X	X			X		X	X	X		6
Malpighiaceae												
Galphimia glauca Cav.		X	X			X	X	X	X	X	X	8
Malvaceae												
Robinsonella cordata Rose & Baker f.		X	X			X			X	X		5
Onagraceae												
Fuchsia encliandra Steud.			X	X		X		X	X	X		6

Annex 3. Cont.

SPECIES	USE TYPE											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**T**
Orobanchaceae												
Conopholis alpina Liebm.		X	X	X		X		X	X	X		7
Passifloraceae												
Passiflora karwinskii Mast.			X			X			X	X		4
Polygalaceae												
Monnina xalapensis Kunth	X	X		X		X		X	X	X		7
Rhamnaceae												
Ceanothus caeruleus Lag.		X	X			X	X	X	X	X		7
Rhamnus sp.		X	X	X		X		X	X	X		7
Rosaceae												
Cercocarpus macrophyllus C.K. Schneid.		X	X	X	X	X	X		X	X	X	9
Malacomeles denticulata (Kunth) G.N. Jones		X	X	X	X	X	X	X	X	X	X	10
Prunus serotina Ehrh.		X	X	X			X	X	X	X	X	8
Rubus trilobus Ser.		X	X			X	X	X	X	X		7
Vauquelinia australis Standl.		X	X	X	X	X	X	X		X		8
Rubiaceae												
Bouvardia longiflora (Cav.) Kunth			X			X		X	X	X		5
B. ternifolia (Cav.) Schltdl.			X			X		X	X	X		5
Hintonia latiflora (Sessé & Moc. ex DC.) Bullock		X	X		X			X	X	X		6
Santalaceae												
Phoradendron galeottii Trel.	X	X	X			X		X	X	X		7
P. lanceolatum Engelm. ex A. Gray	X	X	X			X		X	X	X		7
Sapindaceae												
Dodonaea viscosa Jacq.		X		X	X	X		X	X	X		7
Scrophulariaceae												
Penstemon isophyllus B.L. Rob.			X			X		X	X	X		5
P. roseus (Cerv. ex Sweet) G. Don			X			X		X	X	X		5
Solanaceae												
Cestrum nitidum M. Martens & Galeotti						X		X	X	X		4

Annex 3. Cont.

SPECIES	USE TYPE											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**T**
Solanum cervantesii Lag.		X	X			X		X	X	X		6
S. lanceolatum Cav.		X	X		X	X	X	X	X	X	X	9
Verbenaceae												
Lantana hispida Kunth		X	X	X		X	X	X	X	X		8
Calochortaceae												
Calochortus barbatus (Kunth) J.H. Painter		X	X			X		X	X	X		6
Iridaceae												
Sisyrinchium angustissimum (B.L. Rob. & Greenm.) Greenm. & C.H. Thomps.			X	X		X			X	X		5
Melanthiaceae												
Schoenocaulon tenue Brinker			X	X	X	X		X	X	X		7
Orchidaceae												
Dichromanthus cinnabarinus (La Llave & Lex.) Garay			X			X			X	X		4
TOTAL SPECIES	16	76	93	41	34	99	37	97	93	106	24	