

Can the use of medicinal plants motivate forest conservation in the humid mountains of Northern Oaxaca, Mexico?

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Abstract

Background. Non-timber forest products are being integrated into conservation strategies. Their relevance for obtaining medicinal plants is frequently cited as a reason to conserve forests.

Question. Can the use of medicinal plants motivate forest conservation?

Study site and dates. The study was conducted in Santiago Camotlán, Distrito Villa Alta, Oaxaca, a humid mountainous area in the Sierra Norte of Oaxaca, Mexico, from August 2011 to May 2013.

Methods. Ecological Land Units were characterized, and the relative importance of medicinal plants was evaluated. The ethnobotanical methods included participatory mapping, open interviews, semi-structured interviews and free lists with local healers, as well as members of 17 systematically selected households. Medicinal plant species, and plants considered characteristic for an Ecological Land Unit by local specialists, were collected during plant walks with both healers and experts on the territory. For each species, a newly proposed Knowledge, Use and Perception Index based frequency of mention in free lists, frequency of use and perceived importance was calculated.

Results. Local people divided their territory primarily by physical geographic characteristics and utilization. Nine units were distinguished: village and roads, home gardens, pastures, cultivated fields (maize, beans, sugar cane and coffee), cloud forest, semi-evergreen tropical forest and evergreen tropical forest, secondary vegetation ("acahuales"), and riparian vegetation. The most important medicinal plants were *Salvia microphylla*, *Lippia alba* and *Artemisia absinthium*, all cultivated in home gardens; weedy vegetation provided the majority of all medicinal plants. Individuals interested in preserving medicinal species transplanted them into a home garden.

Conclusion. For people in the study area, the presence and use of medicinal plants was not a decisive reason for forest conservation.

Key words: Ecological Land Units, home gardens, Knowledge, Use and Perception Index, tropical forest, wild plant collection.

Resumen

Antecedentes. Los productos forestales no maderables están siendo integrados en las estrategias de conservación. Su relevancia para la obtención de plantas medicinales se cita frecuentemente como una razón para conservar los bosques.

Pregunta. ¿El uso de plantas medicinales puede motivar la conservación de bosques?

Sitio y años de estudio. El estudio se llevó a cabo en Santiago Camotlán, Distrito Villa Alta, Oaxaca, en un área montañosa húmeda de la Sierra Norte de Oaxaca, México, de agosto 2011 a mayo 2013.

Métodos. Se caracterizaron unidades ambientales y se evaluó la importancia relativa de las plantas medicinales. Los métodos etnobotánicos incluyeron mapeo participativo, entrevistas abiertas, entrevistas semi-estructuradas y listados libres con curanderos, así como miembros de 17 hogares seleccionados sistemáticamente. También se recolectaron en caminatas botánicas, plantas medicinales con curanderos y plantas consideradas características de cada unidad ambiental por conocedores del territorio. Para cada especie se calculó un índice nuevo, de Conocimiento, Uso y Percepción, basado en frecuencia de mención en listados libres, frecuencia de uso e importancia percibida.

Resultados. La gente local dividió su territorio principalmente por características geográficas, físicas y utilización. Se distinguieron nueve unidades: pueblos y caminos, huertos familiares, potreros, campos de cultivo (maíz, frijol, caña de azúcar y café), bosque de niebla, bosque tropical semiperenne y bosque tropical perenne, vegetación secundaria ("acahuales") y vegetación riparia. Las plantas medicinales más

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importantes fueron *Salvia microphylla*, *Lippia alba* y *Artemisia absinthium*, todas cultivadas en huertos familiares. La vegetación herbácea secundaria proporcionó la mayoría de las plantas medicinales. Los individuos interesados trasplantaron las especies medicinales en sus huertos como medida de preservación. **Conclusión.** Para la población del área de estudio, la presencia y uso de plantas medicinales no fue una razón decisiva para la conservación de bosques.

Palabras clave: bosque tropical, huertos familiares, Índice de Conocimiento, Uso y Percepción, recolección de plantas silvestres, Unidades Ambientales.



Worldwide, tensions and synergies between the conservation of biological and cultural traits, sustainable use of resources, food security and health of rural communities is widely discussed (Cunningham 2001, Ladio 2006, Rockström *et al.* 2009). One recent focus is the distribution, management and conservation of non-timber forest products, particularly edible and medicinal plants. They are among the most important resources in terms of quantity and value to rural people, often second only to firewood, and the nutrition and health of millions of people depend on them (Schippmann *et al.* 2002, Hamilton 2004). Studies of the management and conservation of forests necessarily include the role of local perceptions and regulations, conservation of sacred sites and the influence of local leaders, both political and spiritual (Byers *et al.* 2001, Colding & Folke 2001, Tiwari *et al.* 2010).

“Medicinal plants” is usually the category with the largest number of known useful species in ethnobotanical surveys. Globally, about 10 % of the total flora is thought to have medicinal uses (Schippmann *et al.* 2002). In Mexico, Caballero & Cortés (2001) published the results of a literature review and counted 2,140 species, about 7 % of the total flora, but their list is probably still incomplete. Many medicinal plants are gathered from wild populations.

Often, studies on medicinal plant conservation are focused on documenting the impact of gathering, attempting to determine an amount that would be sustainable (van Andel & Havinga 2008, Kandari *et al.* 2012). Others analyze species at risk and propose conservation measures. Some try to identify priority species for conservation based on their characteristics or local importance (Albuquerque & Oliveira 2007, Oliveira *et al.* 2007, Kisangau *et al.* 2011). Few studies report on the perspective of the local users or their own conservation measures.

The exact vegetation type that provides the medicinal plants is not frequently investigated, and results of the few existing studies appear to differ among regions and cultures. Some studies in Africa, Asia and South America show that most medicinal plants grow in conserved forests (Brazil, caatinga – Albuquerque 2006, Tanzania - Kitula 2007, Ethiopia - Kandari *et al.* 2012, Argentina - Molares & Ladio 2012). This is reinforced by some local beliefs that plants from wild vegetation are more effective (Kandari *et al.* 2012, Molares & Ladio 2012). Sometimes spiritual-religious reasoning is involved (Lulekal *et al.* 2008, Megersa *et al.* 2013). Based on these studies, some authors propose to integrate these species into local conservation strategies (WHO *et al.* 1993, Balick & Cox 1996, Schippmann *et al.* 2002, Hamilton 2004).

However, studies in Mexico and some other regions point to human-influenced vegetation as the most important source of medicinal plants (Oaxaca - Frei *et al.* 2000, Mexico – Caballero & Cortés 2001, Chiapas - Stepp & Moerman 2001, Surinam - Van On *et al.* 2001, Nepal - Rokaya *et al.* 2012). Thus, in Mexico, the importance of less disturbed vegetation as a source of medicinal plants requires more detailed study. Cunningham (2001), after working with people whose conservation of vegetation was motivated more by religious beliefs than ecological reasons, asked whether people really conserve habitats because useful plants grow there, or rather for other reasons.

This investigation asks whether the value of medicinal plants for local people (in a broad sense, not necessarily monetary) can motivate conservation of their forests. This includes where people obtain their medicinal plants, if they use plants from forests, if these medicinal plants are important for them, and if their use is currently or potentially important enough to motivate the conservation of forests. This knowledge is essential to design forest policy that is locally appropriate.

The study area was particularly suitable for this study because it has only been under strong external cultural influence since the 1990s. Moreover, it has extensive well-conserved natural vegetation and a functioning system of traditional medicine as well as a local government op-

Author contributions:

All authors collaborated in conceiving and designing the study, as well as in the analysis of the data; they reviewed the various versions of the paper. MPN did the field work and the interviews, collected and identified the plants (some with the help of colleagues indicated in the paper), and wrote the first Spanish-language version of the paper. HV wrote the English version.

erating under communal norms. The concept of Ecological Land Unit *sensu* Sayre *et al.* (2014) used in this study refers to an “area with a distinct bioclimate, landform, lithology and land cover”, land cover meaning vegetation or manmade surfaces (such as roads). Thus, human action and organization is an integral part of the concept (Boege 2000, Paredes-Flores *et al.* 2007, Urquijo & Bocco 2011).

Materials and methods

Overview. Ecological Land Units were circumscribed based mainly on local criteria. Then, we identified the local medicinal plants and the vegetation types where they were obtained. We assigned a value to the plants based on frequency of mention in free-lists, recent use and perception of value, obtained in structured interviews. These data were then put into perspective with the results of in depth interviews with healers, experts on the territory and the general population on uses, motivations and conservation.

The study area. Santiago Camotlán is located in a relatively remote part of northern Oaxaca, Mexico, in the eastern part of a mountainous region called Sierra Norte or Sierra de Juárez. It is both a community and municipality within the District of Villa Alta, Figure 1, with elevations between 600 and 2,000 m and frequent steep slopes. The municipal seat is 1,400 m above sea level, Figure 2. Average annual temperatures vary from 16 to 26 °C, that is, climate ranges from temperate to tropical. Climate maps (INEGI 2005) distinguish five climate types within two major divisions. A large part has very high year-round rainfall, up to 4,000 mm/yr (semitropical-humid, 49 % of the area, tropical humid, 33 %) and the rest has less rain (around 1,500 mm/yr) and a dry winter season (tropical humid, 11 %, temperate humid, 7 % and semitropical humid, 0.1 %). The region has one small permanent river, the Cajonos, and several seasonal ones; it is part of the Papaloapan river basin. Soils are highly variable and derive from both volcanic and sedimentary material (Centeno-García 2004) and form acrisols, cambisols, lithosols, phaeosols, luvisols, nitisols and regosols. The most common soil type is humic acrisol, rich in organic matter, but quite acid and infertile (Alfaro-Sánchez 2004, INEGI 2005).

The municipality includes large tracts of little-disturbed forests that harbor animals such as jaguar, tapir and monkeys (Contreras-Díaz & Pérez-Lustre 2008). Forest types consist of cloud forest, semi-evergreen tropical forest and evergreen tropical forest (illustrations in Supplemen-

Figure 1. Map showing the location of the study area.

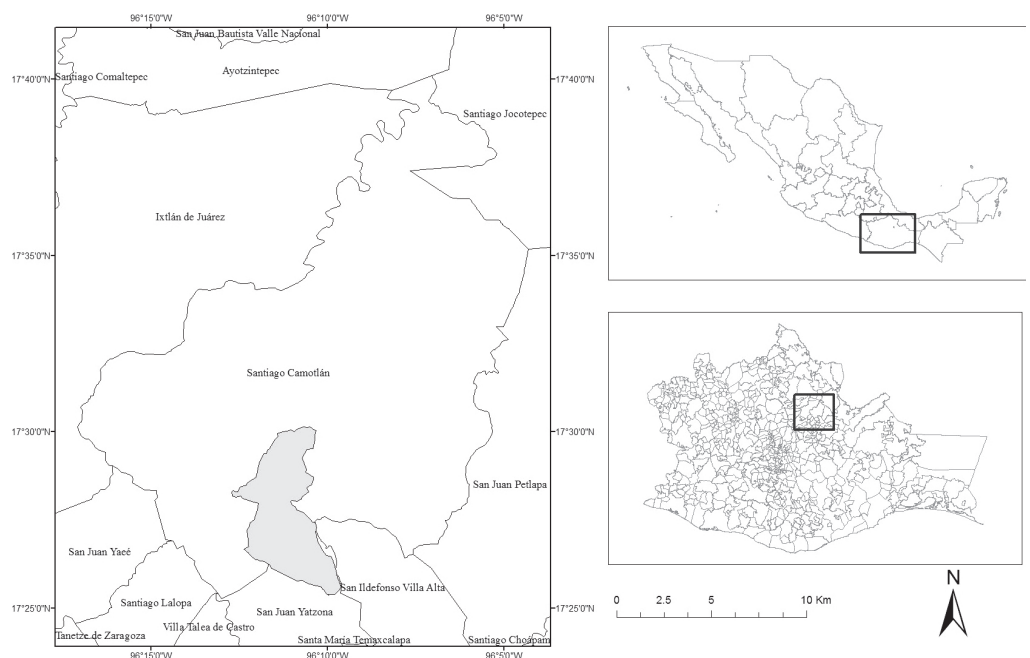


Figure 2. Landscape surrounding Santiago Camotlán, Oaxaca, Mexico.



tary Material 1), and the area is considered a priority area for conservation (Torres-Colin 2004, (DOF 2007, Arriaga-Cabrera 2009) but is not yet formally protected. The village received payments for environmental services for conserving its cloud forests. Secondary vegetation included cultivated areas (maize, beans, coffee and sugarcane), pastures (mainly for cattle) and regrowth shrub and forestland, the acahuals. The urban areas had roadside vegetation and home gardens.

At the time of the study, the community had a population of less than 900 individuals (IMSS 2013); the livelihoods of most people were based on agriculture and cattle ranching. There was some commerce and services. Zapotec, Chinantec and Mixe ethnic groups were represented in the population. The main indigenous language was Zapotec (De Ávila-Blomberg 2004) but most people spoke Spanish as their first language. Land ownership was communal, but customary rights to certain plots of land existed. There were municipal, agrarian and church authorities; important decisions were made in community assemblies that still functioned in this region (INAFED 2010).

A rural government clinic had a permanent nurse and a visiting physician. The community also had a traditional doctor, several healers with different specialties (bonesetter, midwife, and specialists for other illnesses). There was very little medicinal plant commerce in the community (only one very occasional itinerant vendor), and every medicinal plant collected was used locally.

Classification and description of the Ecological Land Units (August 2011-September 2012). The project was presented and consent obtained first from the municipal and agrarian authorities, and then from the community in an assembly. In this assembly, we also solicited consensus proposals of people considered experts on the history and the territory of the community; the result was a group of five men and two women, who agreed to participate.

In order to characterize and delimit the Land Units, the identified experts were asked in a meeting to draw their territory on a large sheet of paper (about 60 × 60 cm) and to include important reference points (participative mapping, Figure 3). Then, the study area was circumscribed by a polygon based on coordinates of a local community development plan (ECOPRODES

In individual meetings, the experts on territory were interviewed in depth (Sheil *et al.* 2002)

With the help of these experts, two routes were drawn which, according to them, covered all

The second group was a sample of the general population. We selected every 10th family on a list maintained by the local clinic, which was the most accurate list of the population available; the total was 20 families. Three declined to participate, and so the population sample comprised 17 families. Each family member was asked individually if he or she wished to participate. We interviewed 48 people over 8 years old: 16 males and 32 females of 72 possible family members. This age limit was chosen, because previous research has shown that children from this age onward have a basic knowledge of the domain environment (e.g., Zarger 2002, Setalapharik & Price 2007). They were interviewed alone and care was taken that they did not discuss the interviews before their turn by taking along another person who talked to them while they waited. Some family members were away at that moment (they were not included), but some also declined.

First, both groups were asked the same questions: Which medicinal plants do you know (free list)? Where do they grow? Which medicinal plants did you use in the last year? Which medicinal plants do you consider most important?

Then, the plants mentioned in the interviews were collected with the help of the healers. They were identified and deposited in the same way as the plants collected for the description of the vegetation. The collections included both spontaneous and cultivated plants; 14 well-known cultivated plants were not collected but identified in the field and are indicated in the species list (Appendix). We also observed and documented the presence and absence of the medicinal species in the different Ecological Land Units. Further information on their distribution was obtained from the healers.

Importance is a diffuse term that can include economic relevance, use value, cognitive salience, position in a cultural domain and others. In ethnobotanical studies, a number of indices are employed, depending on the aim of the study (Phillips 1996, Hoffman & Gallaher 2007). For example, cognitive salience may be measured with the number and position of species in free lists (Reyes-García *et al.* 2006). Informant consensus or ratings may be used to analyze cultural significance (Lozada *et al.* 2006, Molaes & Ladio 2009); the number of uses a species has, or the number of illnesses treated in the case of medicinals (Phillips & Gentry 1993a,b, Phillips 1996, Albuquerque *et al.* 2007) can measure use value. However, for the individual person, "importance" may include aspects of all of these factors (economic and social).

As we wished to integrate the perspective of the studied population (Byg & Balslev 2001) and actual (as opposed to historical) use, we created an index based on the three sets of data obtained in the interviews: known medicinal plants (K), plants used in the last year (U) and plants perceived as important (P). Each mention on each list gave the species one point, for a maximum of three points.

The question on "plants used in the last year" may be considered controversial; people are often not very good at recalling events past the last 1-2 weeks accurately (Stepp 2010). Bernard *et al.* (1984) revised the literature on informant accuracy in remembering past events and commented "Be warned that the sum of all these reports can be very depressing to the behavioral scientist who relies on recall and report in lieu of more expensive forms of data collection such as participant observation or direct observation". He goes on to show that a large portion of answers to surveys are wrong; often people answer what they consider socially desirable or convenient. However, in our experience, illness was an outstanding event in our study area (not as common as Stepp (2010), reported for his study group in Chiapas) which people remembered. While some inaccuracy is inevitable, we do believe that the answers to this question reflect actual use better than mere knowledge of a plant as medicinal.

The sum of these points, the Knowledge, Use and Perception Index (KUPI), reflected its relative importance. The Appendix lists the species with the KUPI for the two groups of interviewees, the healers and the general population. Please note that the index values or points are specific for this study and depend on the number of interviews. For comparative studies, the value would have to be divided by the number of participants. Then we integrated the results for the general population and the specialists - which we initially had separated - because we found that the most important species and the habitats from which they were obtained were similar in both populations. For example, *Salvia microphylla* was listed as a medicinal plant by 41 of the 55 interviewees (48 of the general population and 7 healers); 27 had used it in the last year and 21 felt it was an important medicinal plant. This results in 89 index points for the "Sum KUPI".

Additionally, both the healers and the general population were asked about the conservation of medicinal plants in open interviews. We inquired what conservation meant for them, if they were interested in continuing access to medicinal plants and if they had done anything to assure their survival in the community. We also asked if they had noted any changes in the availability of these plants, both spontaneous and cultivated, during their lifetime.

Results

Classification of the Ecological Land Units. The most important local criterion for land classification was climate. Local people divided the land into two large types, "tierra caliente" (hot land, in Zapotec: "Yuú baá") and "tierra fría" (cold land; in Zapotec: "Yuú ziaág"). "Tierra fría" ranged from 1,300 to 2,000 m above sea level, and included the main community and the cloud forest areas, as well as two sacred sites, Las Cruces and La Cumbre. These sites were used for religious petitions and therefore called petition sites ("sitios de pedimento"). "Tierra caliente" covered more area than "tierra fría", and elevation ranged from 600 to 1,300 m. People subdivided these general types into units, which were named for geographical features, like creeks and rivers, land use or historical events. Only a few places had names based on dominant plant species, such as a part of the tropical forest dominated by the palm *Chamaedorea tepejilote*, named "tepejilotal".

Soil ("tierra") was classified based on color and texture. There were two main types suitable for agriculture: red and black soil. People knew the plants that grow in "tierra caliente" and "tierra fría", as well as in these two soil types. They differentiated several landforms, especially "llanos" (flat areas), "cerros" (hills and mountains) and "lomas" or "hoyancas" (ridges).

The population distinguished the following seven ecological land units: villages and roads, pastures, home gardens, cultivated fields, secondary vegetation ("acahuales"), riparian vegetation, and forests ("tierra caliente" and "tierra fría"). For this work, we used the classification outlined above but divided the forests into three types according to our observations: cloud forest (tropical montane rain forest, which correspond to the "bosques de tierra fría"), semi-evergreen tropical forest and evergreen tropical rainforest (which correspond to "bosques de tierra caliente", but were not differentiated by local people). Figure 4 gives an overview of the spatial

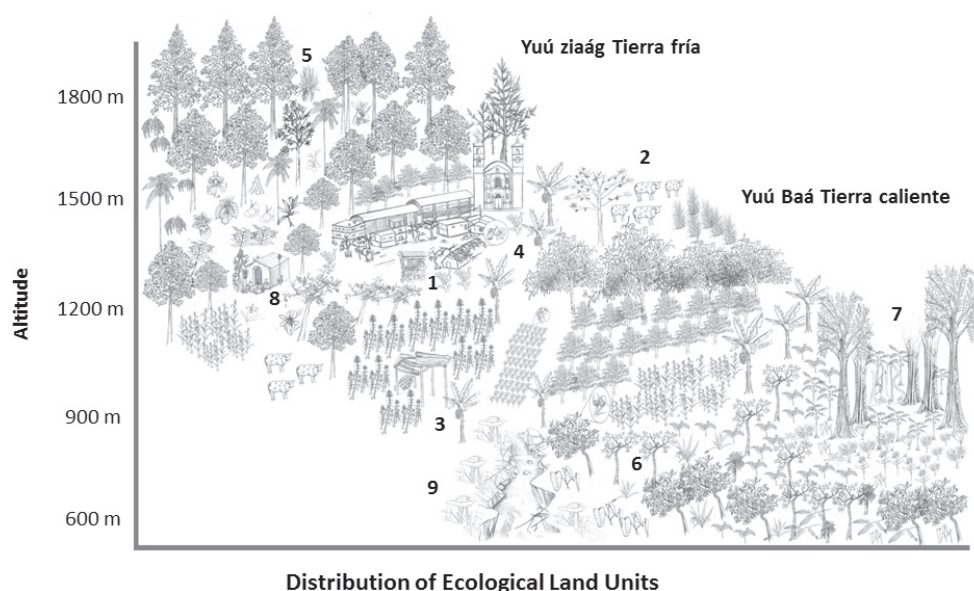


Figure 4. Distribution of the Ecological Land Units by altitudinal gradient. (1) Village and roads, (2) Pastures, (3) Cultivated fields, (4) Home gardens, (5) Cloud forest, (6) Semi-evergreen tropical forest, (7) Evergreen tropical forest (8) Secondary vegetation derived from cloud forests (acahuales), (9) Riparian vegetation.

arrangement of the vegetation types and Table 1 describes each ecological unit by its climate, soil type, management, useful products, indicator species and medicinal plants. Representative photographs of each ecological unit can be found in Supplementary Material 1.

The medicinal plants. Sixty medicinal plant species named in the free lists were registered and identified (Appendix 1). The most important plant families were Asteraceae, Lamiaceae, Rutaceae, Urticaceae and Verbenaceae. The most important species were *Salvia microphylla* (mirto) (89 KUPI index points), *Lippia alba* (pitona) (59), *Artemisia absinthium* (hierba maestra) (46), *Eupatorium* sp. (juquelite) (36), *Ruta graveolens* (ruda) (31), *Tanacetum parthenium* (Santa María) (30), *Verbena litoralis* (verbená) (27), *Aloe vera* (sábila) (26), *Matricaria recutita* (manzanilla) (22) and *Urtica chamaedryoides* (chichicastle) (22). Of these 10 most important species, five were introduced plants, cultivated in the home gardens.

Figure 5 shows the ten most important medicinal plants for each Ecological Land Unit, ordered by the combined importance index (KUPI) for both groups of interviewees. Table 2 shows the ten most important species, separate for the healers and the general population (the full data are available in the Appendix).

The main source of the most important medicinal species was the home garden. Species that grew in other types of secondary vegetation - pastures, fields and acahuales - followed. Few medicinals were obtained from forests or less disturbed vegetation. People attributed this to the fact that the forests were far away and difficult to get to in case of necessity - they preferred to have their medicinal plants at hand, though the cloud forest was, in fact, quite easy to reach. The most important species from forests, all native, were *Dichaea neglecta* (espinazo de culebra) (4 KUPI index points), *Liquidambar styraciflua* (llavito) (2), *Equisetum myriochaetum* (cola de caballo) (3), *Pinguicula moranensis* (cuangracia gruesa) (1), *Peperomia peltilimba* (cuanyia) (5) and *Quercus elliptica* (encino rojo) (1). However, they were not of sufficient interest to merit consideration when contemplating changes in land use.

While most medicinal plants had a relatively low importance value, the relevance of mirto, *Salvia microphylla*, used for stomachache, diarrhea, indigestion, "susto" (the syndrome) and menstrual pain, was striking and unexpected, but coincided with general observations. We also observed that personal interest influenced perceived importance. For example, the bonesetter felt that *Sida rhombifolia*, used for bone fractures, was very important, while the general population focused on species used to treat conditions "that the doctor doesn't attend" (culturally defined syndromes) and common ones, particularly digestive tract disorders.

Table 3 shows the motives and activities people reported for conserving medicinal plants. Motives were mainly those mentioned above - people wanted to have easy access to plants that were important for them, such as those used to treat culturally defined syndromes, "susto" and "mal de ojo" (e.g., *Dichaea neglecta*, espinazo de culebra, and *Pityrogramma calomelanos*, ocopetillo), which grow in the cloud forest, or *Pilea microphylla* (cuangracia) which grows near houses. The main conservation activities were transplanting and leaving them undisturbed during general agricultural work; both took place only in secondary vegetation.

People had observed that several species had become less common, particularly cloud forest medicinal plants, for example, *Equisetum myriochaetum* (cola de caballo), *Magnolia dealbata* (súchil), *Quercus elliptica* (encino) and *Valeriana candolleana* (bejuquito de la disipela delgada). The main reason given was deforestation for cattle pasture. The healers and some other people had tried to transplant the forest species *Equisetum myriochaetum* (cola de caballo) and *Pinguicula moranensis* (cuangracia gruesa) without success and expressed certain concern about maintaining these species in their natural habitat. They had not, however, taken any concrete action in this direction, such as convincing assemblies. Some populations of cultivated plants, such as *Gardenia jazminoides* (gardenia) and *Artemisia absinthium* (hierba maestra), had also decreased. People would like to grow *Citrus medica* (cidra) and *Citrus limetta* (lima de ombligo), but only one garden owner had been successful. On the other hand, some species had expanded. *Aloe vera* (sábila) had been introduced to the region about five years earlier, and could now be found in almost every home garden. *Pteridium* sp. (ocopetate), a weedy plant that colonizes cultivated fields and old fields, had increased considerably.

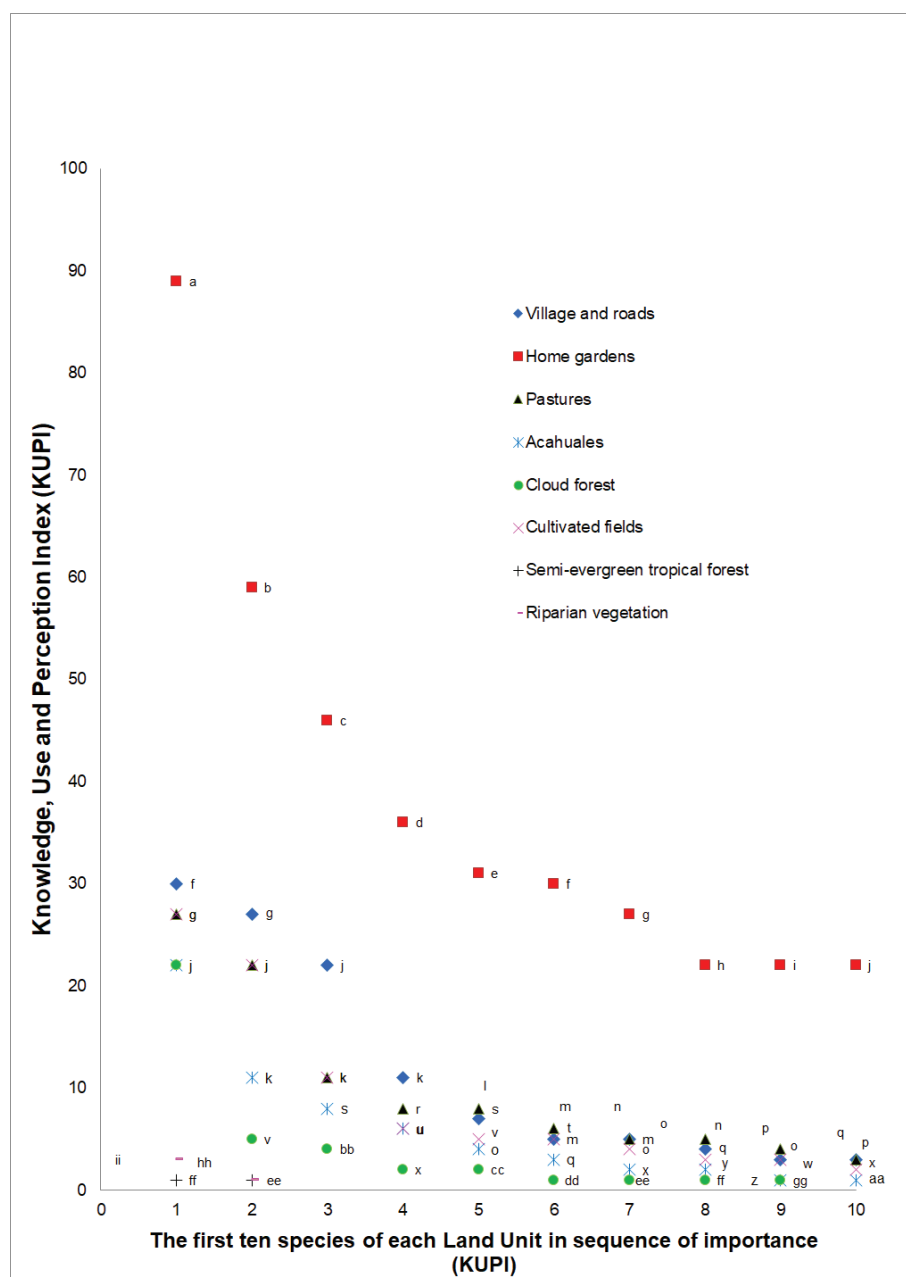


Figure 5. The most important medicinal species of each Ecological Land Unit, ordered by their importance index value. The evergreen tropical forest is not represented, as it had very few medicinal species. a: *Salvia microphylla* (mirto), b: *Lippia alba* (pitona), c: *Artemisia absinthium* (hierba maestra), d: *Eupatorium* sp. (juquelite), e: *Ruta graveolens* (ruda), f: *Tanacetum parthenium* (Santa María), g: *Verbena litoralis* (verbena), h: *Aloe vera* (sábila), i: *Matricaria recutita* (manzanilla), j: *Urtica chamaedryoides* (chichicastle delgado), k: *Bacopa procumbens* (susto de suelo), l: *Pilea microphylla* (cuangracia delgado), m: *Oenothera rosea* (flor rosa), n: *Cuphea aequipetala* (flor morada), o: *Sida rhombifolia* (malvarisco), p: *Psidium guineense* (huesina), q: *Malva parviflora* (malva), r: *Citrus sinensis* (naranja), s: *Persea americana* (aguacate), t: *Citrus aurantiifolia* (limón), u: *Ocimum micranthum* (huele a relleña), v: *Peperomia peltimbba* (cuanyia), w: *Borreria suaveolens* (riñonina), x: *Liquidambar styraciflua* (llavito), y: *Boehmeria caudata* (tlaca), z: *Plantago major* (llante), aa: *Calea urticifolia* (cuanshia), bb: *Dichaea neglecta* (espinazo de culebra), cc: *Pityrogramma calomelanos* (ocopetatillo), dd: *Odontosoria schlehtendalii* (susto de lumbré), ee: *Pinguicula moranensis* (cuangracia gruesa), ff: *Quercus elliptica* (encino), gg: *Magnolia dealbata* (súchil), hh: *Passiflora* sp. (susto de trompa de víbora), ii: *Equisetum myriochaetum* (cola de caballo).

Table 1 Description of the Ecological Land Units recognized in this study. The information includes location, products, indicator species (based on interviews; not necessarily dominant) and examples of medicinal species growing in the unit.

Ecological Land Unit	Description	Species
1. Village and roads Location: "Tierra fría"	This is mainly the urban area, divided into four barrios, Loma Linda, Melchor Ocampo, San Martín and Magnolias. Vegetation grows on the waysides, vacant lots, walls, etc.	Indicators: <i>Lopezia racemosa</i> , <i>Rhynchospora radicans</i> , <i>Polygonum capitatum</i> Useful products: medicinal and edible plants Medicinals: <i>Pilea microphylla</i> , <i>Oenothera rosea</i> , <i>Sida rhombifolia</i>
2. Pastures Location: "Tierra fría" and "Tierra caliente"	Local people distinguish two types – natural and induced grassland. For the second type, forest was cleared and mostly exotic forage species were planted	Indicators: <i>Paspalum paniculatum</i> , <i>Eleusine indica</i> Useful products: medicinal and edible plants, mainly fruit trees and spinach-type plants ("quelites") Medicinals: <i>Polygala glochidata</i> , <i>Plantago major</i> , <i>Lepidium virginicum</i>
3. Home gardens Location: "Tierra fría"	In Mexico, "solar", "huerto" and "jardín" are usually more or less synonymous. However, in the study area people distinguished "solar" (area near the house with fruit trees and animals such as chicken, ducks and turkeys, sometimes some maize, coffee or beans), "huerto" (a small vegetable garden) and "jardín", a part near the house with mainly ornamentals, but also some medicinals	Indicators: <i>Persea americana</i> , <i>Allium tuberosum</i> , <i>Sechium edule</i> Useful products: Multiuse plants, edibles and plants with both ornamental and medicinal use Medicinals: <i>Psidium guajava</i> , <i>Ruta graveolens</i> , <i>Melothria pendula</i>
4. Cultivated fields Location: "Tierra fría" and "Tierra caliente"	Maize, bean and sugarcane fields as well as coffee plantations. Maize can be associated with climbing beans and squash; the fields often contain non-crop edible plants. Sugarcane is restricted to the areas with tropical climate. Maize and bean cultivars are different for tropical and temperate areas	Indicators: <i>Zea mays</i> (several cultivars, white, yellow, black), <i>Phaseolus vulgaris</i> (several cultivars: black (sacuan), cuarenteno (one with a soft testa and one with a thick testa) and climbing (enredador), <i>Coffea arabica</i> , <i>Saccharum officinarum</i> Useful products: Edible plants (the main cultivated ones, but also spinach-like wild-growing vegetables and fruit), medicinal and animal forage plants Medicinals: <i>Ocimum micranthum</i> , <i>Castilleja arvensis</i> , <i>Parietaria pensylvanica</i>
5. "Acahuals" Location: "Tierra fría" and "Tierra caliente"	This is the vegetation on fallow fields or plantations, that is, secondary vegetation or regrowth; it may be herbaceous in the beginning and later shrubby or forest-like. It may be derived from various forest types. Farmers say that during the first and second year, these areas are dominated by some Asteraceae and ferns. After that, woody succession starts, and after about 30 years the area has species similar to those it had before clearing the forest. Currently, <i>Pteridium</i> sp. is dominating many of these areas and may delay succession	Indicators: <i>Heliocarpus donnell-smithii</i> , <i>Ipomoea</i> sp., <i>Mimosa albida</i> Useful products: firewood, edible plants ("quelites"), medicinals, wood for fences and construction, mushrooms Medicinals: <i>Cecropia obtusifolia</i> , <i>Ricinus communis</i> , <i>Heliotropium angiospermum</i>
6. Cloud forest Location: "Tierra fría"	This is the forest of the "tierra fría". Characteristic families are Melastomataceae, Orchidaceae, Bromeliaceae and many species of ferns	Indicators: <i>Liquidambar styraciflua</i> , <i>Oreopanax xalapensis</i> , <i>Bejaria aestuans</i> Useful products: edibles, medicinals, ornamentals, firewood, wood, mushrooms Medicinals: <i>Dichaea neglecta</i> , <i>Pinus chiapensis</i> , <i>Magnolia dealbata</i>
7. Semi-evergreen tropical forest Location: "Tierra caliente"	This is the main forest of the tropical areas, "tierra caliente". The characteristic families are Araceae, Fabaceae, also ferns and fungi	Indicators: <i>Inga vera</i> , <i>Inga jinicuil</i> , <i>Manilkara zapota</i> Useful products: edibles, medicinals, ornamentals, wood, firewood, mushrooms, fibers for basketry Medicinals: <i>Quercus elliptica</i> , <i>Passiflora</i> sp., <i>Urtica chamaedryoides</i>
8. Evergreen tropical forest Location: "Tierra caliente"	The evergreen tropical forest of the community is restricted to a remote and inaccessible area. It has very large trees, epiphytes and climbing vines; the main families are Araceae, Arecaceae, Lauraceae, Rubiaceae, Orchidaceae, together with abundant ferns, mosses and fungi. Only a few people go there to collect the immature edible inflorescences of the tepejilote palm	Indicators: <i>Chamaedorea tepejilote</i> , <i>Chamaedorea pinnatifrons</i> Useful plants: edibles Medicinals: None
9. Riparian vegetation Location: "Tierra fría" and "Tierra caliente"	This is the vegetation that grows near creeks and rivers	Indicators: <i>Xanthosoma sagittifolium</i> , <i>Heliconia</i> spp. Useful products: edibles (mainly "quelites") and medicinals Medicinals: <i>Equisetum myriochaetum</i> , <i>Peperomia peltatilimba</i> , <i>Pinguicula moranensis</i>

Table 2. The ten most important species of the healers and of the general population, according to the KUPI index. KUPI = M + U + I where M-plants known, U-plants used in the last year, I-plants considered important. Habitat: 1-Village and roads, 2-Pastures, 3-Home gardens, 4-Cultivated fields, 5-Acahuals, 6-Cloud forest, 7- Semi-evergreen tropical forest, 8- Evergreen tropical forest, 9-Riparian vegetation. For the full table, see the Appendix.

Healers species	KUPI	Habitat	General population species	KUPI	Habitat
1 <i>Salvia microphylla</i>	14	3	1 <i>Salvia microphylla</i>	75	3
2 <i>Lippia alba</i>	9	3	2 <i>Lippia alba</i>	50	3
3 <i>Tanacetum parthenium</i>	8	3	3 <i>Artemisia absinthium</i>	41	3
4 <i>Artemisia absinthium</i>	5	3	4 <i>Eupatorium</i> sp.	31	3
5 <i>Eupatorium</i> sp.	5	3	5 <i>Ruta graveolens</i>	25	3
6 <i>Ruta graveolens</i>	6	3	6 <i>Tanacetum parthenium</i>	22	3
7 <i>Aloe vera</i>	5	3	7 <i>Aloe vera</i>	21	3
8 <i>Verbena litoralis</i>	7	1,2,3,4	8 <i>Verbena litoralis</i>	20	1,2,3,4
9 <i>Persea americana</i>	4	2,3,4,5,6	9 <i>Matricaria recutita</i>	19	3
10 <i>Sida rhombifolia</i>	4	1,2,3,4,5	10 <i>Urtica chamaedryoides</i>	19	1,2,3,4,5,6,7

Local people were particularly interested in multiuse plants - especially those that were not only medicinal, but also edible. Those species, such as llavito, encino, súchil and huesina, were actively managed because they had other uses, not for their medicinal properties. Several women observed that the use of herbicides on roadsides, "acahuals" and fields had reduced the populations of wild medicinal plants. Both men and women noted that the expansion of cattle ranching had had the same effect, particularly on weedy medicinals. Another relevant detail was the belief that sacred sites should not be disturbed - this would have a negative impact on the efficiency of religious petitions.

Discussion

Classification of the Ecological Land Units. The traditional climate, vegetation and soil classifications in the study region were similar to those of nearby areas inhabited by Mixes and Chinantecs, though there were some differences in the complexity at the highest level. For example, Martin (1993) reports that in neighboring areas people distinguished "tierra caliente", "tierra fría" and "tierra templada" (temperate land). The same author reports five Chinanteco categories for the same mountain region: hot and humid, hot and dry, temperate and humid, temperate and dry, and cold. However, the Zapotecs in the Southern Mountains (Sierra Sur) of Oaxaca distinguish only cold-humid and hot-dry climate types (Luna-José 2006, Luna-José & Rendón-Aguilar 2012). There are two possible explanations: 1. Zapotecs, in general, recognize fewer climate types, and 2) a more complex classification had been lost in the study community due to the cohabitation of several ethnic groups for which Spanish is the lingua franca, possibly causing loss of vocabulary.

The local population classified vegetation into seven categories, mainly based on use or management type. A classification reported from the Isthmus Zapotecs and Mixes was similar in its criteria; the population distinguished village, home gardens, roadsides, maize fields, coral, pasture, coffee plantation, forest and mountains (Frei *et al.* 2000). However, other studies report the use of physiognomy and dominant species in naming vegetation. Luna-José (2006) and Luna-José & Aguilar (2012) indicate that the Zapotecs of the Sierra Sur classify vegetation by its physiognomy and degree of disturbance, and the Mixes and Chinantecs of the Sierra Norte use physiognomy, habitat and composition of the flora (Martin 1993). Another criterion, reported from Ethiopia, is density of the vegetation (Megersa *et al.* 2013). No unifying principle could be identified for classifying vegetation in the region.

Local empirical soil classifications in central and southern Mexico usually consider texture, color, consistency, moisture retention, ease of agricultural work, fertility and salinity (Ortiz-

Table 3. Conservation activities of the population of Santiago Camotlán, Oaxaca.

Reasons for conserving medicinal plants	1. Because the plant heals; it is very efficient; it heals conditions that the medical doctor can't treat (culture-bound syndromes); alleviates common ailments such as those of the digestive tract 2. Because it has many uses, particularly as food
Conservation activities <i>ex situ</i>	Wild plants are transplanted to home gardens (by both men and women)
Conservation activities <i>in situ</i>	Women ask that herbicides not be applied to certain sites Men spare certain plants when weeding Sacred sites (La Cumbre and Las Cruces) are not disturbed as that could lower their effectiveness as petition sites

Solorio & Gutiérrez-Castorena 2001). This was confirmed in our study area: the farmers of Camotlán recognized soils by color, texture and their potential for agriculture. Martin (1993) reports similar criteria for the nearby Mixes and Chinantecos.

Medicinal plants. Our index was useful for differentiating those species that were important in everyday life, according to the local population, from those that were used only occasionally. We suggest that other criteria frequently used in indices, such as simple numbers of use reports (which may be historical) or number of uses, are less accurate for this purpose, though they may be correlated (see, for example, Tardío & Pardo-de-Santayana 2007). The results clearly showed that relatively few species dominated the medicinal plant needs, both of the general population and the healers.

Most medicinal plants were obtained from secondary vegetation, particularly home gardens. This contrasts with results from regions outside of Mesoamerica, such as Patagonia, the Caatinga of Brazil, the Himalayas and some parts of Africa (Albuquerque 2006, Adnan & Hölscher 2012, Kandari *et al.* 2012, Molares & Ladio 2012). However, it coincides with the results of Frei *et al.* (2000) for Isthmus Zapotecs and Mixes, and other parts of Mexico and the world (Stepp & Moerman 2001, Stepp 2004, Rokaya *et al.* 2012). None of the medicinal species obtained from forests was sufficiently important to motivate forest conservation.

This could be due to several factors. We suggest that ordinary people only self-medicate with medicinal plants for well-known and recurrent conditions - and have the plants they need for this at hand. If they have more serious or rare complaints, they either consult the clinic with its Western-style medicine, or the traditional healers. These healers, particularly the traditional doctor, knew many more plants than those listed here, and obtained some of them from forests; the sites of these species were sometimes kept secret. However, the rarity of this type of events, and the lack of political power of the healers, did not allow translation of this need into conservation measures.

Most medicinal plants in Camotlán were native, though the proportion of introduced plants was considerable, particularly among the most important species (as mentioned, five of the ten most important species were introduced, see the species list in the Appendix). The same observation has been made in most places where this question has been studied (Mexico, Argentina, Mozambique, Brazil (Estomba *et al.* 2006, Coelho-Ferreira 2009, Bruschi *et al.* 2011), with very few exceptions (de Almeida *et al.* 2010). This shows that people regularly use their own surroundings for their medicinal plant needs, but adopt new plants rapidly (see the *Aloe* example) if they satisfy a need. All of the introduced species grew near houses, as elsewhere (Albuquerque & Oliveira 2007, Almeida *et al.* 2010).

Conservation in the sense of scientists or the urban population was a foreign concept to most community members. Only those that have been in contact with external agents, like people with a function in the local government, had a concept of species conservation, mainly because of payments for environmental services that the community received (and which has led to a ban on felling trees, but did not influence access to medicinal plants). However, the interviewees did have a concept of caring for their forests. As mentioned above, altering the sacred sites

was considered particularly damaging; this has also been reported elsewhere (Colding & Folke 2001). However, this factor only applies to relatively small areas.

Most people observed decrease in some species and increase in some other useful species. For example, one useful citrus fruit (cidra) from the gardens was disappearing, probably because of climatic inadaptation, but sábila (*Aloe*) was increasing. Susto de trompa de víbora (*Passiflora*) from the cloud forest had lost populations. It was mainly specialists who were somewhat concerned about the disappearance of important plants - those considered important for treatment of serious illnesses or had multiple purposes. However, they did not actively conserve them (apart from trying to transplant them). Megersa *et al.* (2013) reported a similar phenomenon in Ethiopia.

People did not associate the habitat of the medicinal plants with their efficacy as has been reported from Patagonia, Argentina, where plants growing in undisturbed vegetation were considered to have better medicinal properties (Molares & Ladio 2012). The value of a medicinal plant was determined by the rapidity of patient response and by the number of ailments it could be used for. Active conservation was only observed for multipurpose species where other uses were perceived to be more important, like food or fuel. We suggest that food use as a driver of conservation should be explored further.

Our study shows that medicinal plant use does not necessarily motivate forest conservation. Perhaps this was partly due to particular circumstances in our study area: the humid vegetation possibly does not contain as many medicinal plants as arid vegetation types (see, for example, Argueta-Villamar 2009); a traditional medical system that emphasizes herbaceous plants and uses few barks and roots (Argueta-Villamar 2009; also see the suggestion of Albuquerque (2006) that barks and roots are more important in semiarid vegetation types); and acceptance of the services offered by the local clinic, which reduced demand. If one of these circumstances had been different, the outcome could have been different also.

Based on our study, in Santiago Camotlán, Oaxaca, Mexico, secondary vegetation harbored the most important medicinal plants. Of the natural vegetation, only cloud forests provided a few of these species. The level of use and importance of plants from conserved forests was low. The conservation of medicinal plants in their natural habitat was not a subject of much interest for the local population, or a factor in decisions on land use. There were, however, differences in perception and interest within the population. Conservation of some sites was motivated by religious beliefs.

People and healers were most interested in conserving multi-purpose plants that were easily accessible, preferably cultivated in gardens; this, of course, is a form of conservation. A few species that could not be cultivated and thus would have to be conserved in their natural habitat existed, but they were not high-priority species.

This means that conservation strategies based on medicinal plants as non-timber forest products cannot be recommended universally, but have to be analyzed on a case-by-case basis. In our study area, the three main factors influencing the use of medicinal plants (vegetation type, demand and the characteristics of the traditional medicine) were not favorable for forest plants. The influence of these factors may be different in other parts of Mexico and the world. Perhaps in the future, when we have better data on the usefulness of local floras, their relationship with their environment, and characteristics of traditional medical systems, we will be able to make predictions.

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Literature cited

- Adnan M, Hölscher D. 2012. Diversity of medicinal plants among different forest-use types of the Pakistani Himalaya. *Economic Botany* **66**: 344–356. DOI: 10.1007/s12231-012-9213-4
- Albuquerque UP. 2006. Reexamining hypotheses concerning the use and knowledge of medicinal plants: a study in the Caatinga vegetation of NE Brazil. *Journal of Ethnobiology and Ethnomedicine* **2**: 30. DOI: 10.1186/1746-4269-2-30
- Albuquerque UP, Medeiros PM, Almeida ALS, Monteiro JM, Freitas Lins Neto EM, Melo JG, dos Santos JP. 2007. Medicinal plants of the caatinga (semi-arid) vegetation of NE Brazil: A quantitative approach. *Journal of Ethnopharmacology* **114**: 325–354. DOI: 10.1016/j.jep.2007.08.017
- Albuquerque UP, Oliveira RF. 2007. Is the use-impact on native caatinga species in Brazil reduced by the high species richness of medicinal plants? *Journal of Ethnopharmacology* **113**: 156–170. DOI: 10.1016/j.jep.2007.05.025
- Alfaro-Sánchez G. 2004. Suelos. In: García-Mendoza AJ, Ordóñez Díaz M de J, Briones-Salas M., eds. *Biodiversidad de Oaxaca*. México, D.F.: Universidad Nacional Autónoma de México, Instituto de Biología, Fondo Oaxaqueño para la Conservación de la Naturaleza-World Wildlife Fund, 55–65.
- Almeida C de FCBR, Ramos MA, Amorim ELC, Albuquerque UP. 2010. A comparison of knowledge about medicinal plants for three rural communities in the semi-arid region of northeast of Brazil. *Journal of Ethnopharmacology* **127**: 674–684. DOI: 10.1016/j.jep.2009.12.005
- Argueta-Villamar A. 2009. Introducción. Atlas de las plantas en la medicina tradicional mexicana. In: Argueta A, ed. *Biblioteca Digital de la Medicina Tradicional Mexicana*. <www.medicinatradicional-mexicana.unam.mx/intro_atlas.html> (accessed March 4, 2017)
- Arriaga-Cabrera L. 2009. Regiones prioritarias y planeación para la conservación de la biodiversidad. In: Dirzo R, González R, March JJ, eds. *Capital Natural de México, vol II: Estado de Conservación y Tendencias de Cambio*. México, D.F.: Comisión Nacional para el Conocimiento y Uso de la Biodiversidad, 433–457.
- Balick MJ, Cox PA. 1996. *Plants, People, and Culture: the Science of Ethnobotany*. New York: Scientific American Library, 1–228. ISBN: 0-7167-5061-9.
- Bernard HR. 1984. The problem of informant accuracy: the validity of retrospective data. *Annual Review of Anthropology* **13**, 495–517.
- Boege E. 2000. *Protegiendo lo Nuestro: Manual para la Gestión Ambiental Comunitaria, Uso y Conservación de la Biodiversidad de los Campesinos Indígenas de América Latina*. Serie Manuales de Educación y Capacitación Ambiental 3. México, D.F.: Instituto Nacional Indigenista, Programa de las Naciones Unidas para el Medio Ambiente - Red de Formación Ambiental para América Latina y el Caribe, 1–180. ISBN: 968-7913-08-8
- Bruschi P, Morganti M, Mancini M, Signorini MA. 2011. Traditional healers and laypeople: A qualitative and quantitative approach to local knowledge on medicinal plants in Muda (Mozambique). *Journal of Ethnopharmacology* **138**: 543–563. DOI: 10.1016/j.jep.2011.09.055
- Byers BA, Cunliffe RN, Hudak AT. 2001. Linking the conservation of culture and nature: A case study of sacred forests in Zimbabwe. *Human Ecology* **29**: 187–218. DOI: 10.1023/A:1011012014240
- Byg A, Balslev H. 2001. Diversity and use of palms in Zahamena, eastern Madagascar. *Biodiversity and Conservation* **10**: 951–970. DOI: 10.1023/A:1016640713643
- Caballero J, Cortés L. 2001. Percepción, uso y manejo tradicional de los recursos vegetales en México. In: Rendón-Aguilar B, Rebollar-Domínguez S, Caballero-Nieto J, Martínez-Alfaro M, eds. *Plantas, Cultura y Sociedad: Estudio sobre la Relación entre Seres Humanos y Plantas en los Albores del Siglo XXI*. México, D.F.: Universidad Autónoma Metropolitana-Unidad Iztapalapa y Secretaría de Medio Ambiente, Recursos Naturales y Pesca, 79–100. ISBN: 970-654-782-7
- Centeno-García E. 2004. Configuración geológica del estado. In: García-Mendoza AJ, Ordóñez-Díaz M de J, Briones-Salas MA. eds. *Biodiversidad de Oaxaca*. México, D.F.: Universidad Nacional Autónoma de México, Instituto de Biología, Fondo Oaxaqueño para la Conservación de la Naturaleza-World Wildlife Fund, 29–42. ISBN: 9703220452
- Coelho-Ferreira M. 2009. Medicinal knowledge and plant utilization in an Amazonian coastal community of Marudá, Pará State (Brazil). *Journal of Ethnopharmacology* **126**: 159–175. DOI: 10.1016/j.jep.2009.07.016
- Colding J, Folke C. 2001. Social taboos: “Invisible” systems of local resource management and biologi-

- cal conservation. *Ecological Applications* **11**: 584–600. DOI: 10.1890/1051-0761(2001)011[0584:STISOL]2.0.CO;2
- Contreras-Díaz R, Pérez-Lustre M. 2008. Etnoecología de mamíferos silvestres y los zapotecos del municipio de Santiago Camotlán, Villa Alta, Oaxaca. *Etnobiología* **6**: 56–67.
- Cunningham AB. 2001. *Applied Ethnobotany: People, Wild Plant Use, and Conservation*. London: Earthscan, 1-300. ISBN: 13:978-1-85383-697-8
- De Ávila-Blomberg A. 2004. La clasificación de la vida en las lenguas de Oaxaca. In: García-Mendoza AJ, Ordóñez Díaz M de J, Briones-Salas M., eds. *Biodiversidad de Oaxaca*. México, D.F.: Universidad Nacional Autónoma de México, Instituto de Biología, Fondo Oaxaqueño para la Conservación de la Naturaleza-World Wildlife Fund, 481–539. ISBN: 9703220452
- DOF [Diario Oficial de la Federación]. 2007. *Acuerdo por el que se establecen las Reglas de Operación del Programa de Conservación para el Desarrollo Sostenible (PROCOCODES) anteriormente Programa de Desarrollo Regional Sustentable (PRODERS)*. In: DOF 28122007. <www.dof.gob.mx/nota_detalle.php?codigo=5011893&fecha=28/12/2007> (accessed March 1, 2015).
- ECOPRODES [Ecología y Producción para el Desarrollo Sustentable]. 2011. *Plan de desarrollo local*. Comunidad de Santiago Camotlán, Distrito Villa Alta, Oaxaca.
- Estomba D, Ladio A, Lozada M. 2006. Medicinal wild plant knowledge and gathering patterns in a Mapuche community from North-western Patagonia. *Journal of Ethnopharmacology* **103**: 109–119. DOI: 10.1016/j.jep.2005.07.015
- Frei B, Sticher O, Heinrich M. 2000. Zapotec and Mixe use of tropical habitats for securing medicinal plants in México. *Economic Botany* **54**: 73–81. DOI: 10.1007/BF02866601
- Hamilton AC. 2004. Medicinal plants, conservation and livelihoods. *Biodiversity and Conservation* **13**: 1477–1517. DOI: 10.1023/B:BOC.0000021333.23413.42
- Hoffman B, Gallaher T. 2007. Importance indices in ethnobotany. *Ethnobotany Research and Applications* **5**: 201–218. DOI:10.17348/era.5.0.201-218
- IMSS [Instituto Mexicano del Seguro Social]. 2013. *Unidad Médica Rural No. 139 del Instituto Mexicano del Seguro Social*. Regimen Oportunidades. Santiago Camotlán, Distrito Villa Alta, Oaxaca, Mexico: IMSS Oportunidades.
- INAFED [Instituto Nacional para el Federalismo y el Desarrollo Municipal]. 2010. *Enciclopedia de los Municipios y Delegaciones de México*. <www.inafed.gob.mx/work/enciclopedia/EMM20oaxaca/index.html> (accessed May 8, 2018)
- INEGI [Instituto Nacional de Estadística y Geografía]. 2005. *Prontuario de información geográfica municipal de los Estados Unidos Mexicanos*. Santiago Camotlán, Oaxaca. Clave geoestadística 20457. México, D.F.: INEGI.
- Kandari LS, Phondani PC, Payal KC, Rao KS, Maikhuri RK. 2012. Ethnobotanical study towards conservation of medicinal and aromatic plants in upper catchments of Dhauliganga in the central Himalaya. *Journal of Mountain Science* **9**: 286–296. DOI: 10.1007/s11629-012-2049-7
- Kisangau DP, Herrmann TM, Lyaru H, Hosea K, Cosam J, Mbwambo Z, Masimba P. 2011. Traditional knowledge, use practices and conservation of medicinal plants for HIV/AIDS care in rural Tanzania. *Ethnobotany Research and Applications* **9**: 43–57. DOI: 10.17348/era.9.0.43-57
- Kitula RA. 2007. Use of medicinal plants for human health in Udzungwa Mountains Forest: a case study of New Dabaga Ulongambi Forest Reserve, Tanzania. *Journal of Ethnobiology and Ethnomedicine* **3**: 7. DOI: 10.1186/1746-4269-3-7
- Ladio A. 2006. Los desafíos actuales de la Etnobotánica. *Boletín Latinoamericano y del Caribe de Plantas Medicinales y Aromáticas* **5**: 27.
- Lozada M, Ladio A, Weigandt M. 2006. Cultural transmission of ethnobotanical knowledge in a rural community of northwestern Patagonia, Argentina. *Economic Botany* **60**: 374–385. DOI: 10.1663/0013-0001(2006)60[374:CTOEK]2.0.CO;2
- Lulekal E, Kelbessa E, Bekele T, Yineger H. 2008. An ethnobotanical study of medicinal plants in Mana Angetu District, southeastern Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **4**: 10. DOI: 10.1186/1746-4269-4-10
- Luna-José AL., Rendón-Aguilar B. 2012. Traditional knowledge among Zapotecs of Sierra Madre del Sur, Oaxaca. Does it represent a base for plant resources management and conservation? *Journal of Ethnobiology and Ethnomedicine* **8**: 24. DOI: 10.1186/1746-4269-8-24
- Luna-José AL. 2006. *Conocimiento y cuantificación de los recursos vegetales en diez comunidades de la Sierra Madre del Sur, Oaxaca*. MSc. Thesis. Texcoco: Colegio de Postgraduados.
- Martin G. 1993. Ecological classification among the Chinantec and Mixe of Oaxaca, México. *Etnoecología* **1**: 14–31.
- Megersa M, Asfaw Z, Kelbessa E, Beyene A, Woldeab B. 2013. An ethnobotanical study of medicinal plants in Wayu Tuka District, East Welega Zone of Oromia Regional State, West Ethiopia. *Journal of Ethnobiology and Ethnomedicine* **9**: 68. DOI: 10.1186/1746-4269-9-68

- Molares S, Ladio A. 2009. Ethnobotanical review of the Mapuche medicinal flora: Use patterns on a regional scale. *Journal of Ethnopharmacology* **122**: 251–260. DOI: 10.1016/j.jep.2009.01.003
- Molares S, Ladio A. 2012. Mapuche perceptions and conservation of Andean *Nothofagus* forests and their medicinal plants: a case study from a rural community in Patagonia, Argentina. *Biodiversity and Conservation* **21**: 1079–1093. DOI: 10.1007/s10531-012-0241-2
- Oliveira RF de, Lins Neto EMF, Araújo EL, Albuquerque UP. 2007. Conservation priorities and population structure of woody medicinal plants in an area of caatinga vegetation (Pernambuco State, NE Brazil). *Environmental Monitoring and Assessment* **132**: 189–206. DOI: 10.1007/s10661-006-9528-7
- Ortiz-Solorio CA, Gutiérrez-Castorena M del C. 2001. La etnoedafología en México una visión retrospectiva. *Etnoecológica* **1**: 44–62.
- Paredes-Flores M, Lira-Saade R, Dávila-Aranda P. 2007. Estudio etnobotánico de Zapotitlán Salinas, Puebla. *Acta Botánica Mexicana* **79**: 13–61. DOI: 10.21829/abm79.2007.1037
- Phillips O. 1996. Some quantitative methods for analyzing ethnobotanical knowledge. In: Alexiades MN, Sheldon JW, eds. *Selected Guidelines for Ethnobotanical Research: A Field Manual*. Bronx, NY: New York Botanical Garden, 171–197. ISBN: 978-0-89327-404-7
- Phillips O, Gentry AH. 1993a. The useful plants of Tambopata, Peru: I. Statistical hypotheses tests with a new quantitative technique. *Economic Botany* **47**: 15–32. DOI: 10.1007/BF02862203
- Phillips O, Gentry AH. 1993b. The useful plants of Tambopata, Peru: II. Additional hypothesis testing in quantitative ethnobotany. *Economic Botany* **47**: 33–43. DOI: 10.1007/BF02862204
- Reyes-García V, Huanca T, Vadez V, Leonard W, Wilkie D. 2006. Cultural, practical, and economic value of wild plants: a quantitative study in the Bolivian Amazon. *Economic Botany* **60**: 62–74. DOI: 10.1663/0013-0001(2006)60[62:CPAEVO]2.0.CO;2
- Rockström J, Steffen W, Noone K, Persson Å, Chapin FS, Lambin EF, Lenton TM, Scheffer M, Folke C, Schellnhuber HJ, Nykvist B, de Wit CA, Hughes T, van der Leeuw S, Rodhe H, Sörlin S, Snyder PK, Costanza R, Svedin U, Falkenmark M, Karlberg L, Corell RW, Fabry VJ, Hansen J, Walker B, Liverman D, Richardso K, Crutzen P, Foley JA. 2009. A safe operating space for humanity. *Nature* **461**: 472–475. DOI: 10.1038/461472a
- Rokaya MB, Münzbergová Z, Shrestha MR, Timsina B. 2012. Distribution patterns of medicinal plants along an elevational gradient in central Himalaya, Nepal. *Journal of Mountain Science* **9**: 201–213. DOI: 10.1007/s11629-012-2144-9
- Sayre R, Dangermond J, Frye C, Vaughan R, Aniello P, Breyer S, Cribbs D, Hopkins D, Nauman R, Derrenbacher W, Wright D, Brown C, Convis C, Smith J, Benson L, Paco VanSistine D, Warner H, Cress J, Danielson J, Hamann S, Cecere T, Reddy A, Burton D, Grosse A, True D, Metzger M, Hartmann J, Moosdorf N, Dürr H, Paganini M, DeFourny P, Arino O, Maynard S, Anderson M, Comer P. 2014. *A New Map of Global Ecological Land Units — An Ecophysiological Stratification Approach*. Washington DC: Association of American Geographers, 1–46. ISBN: 978-0-89291-276-6
- Schippmann U, Leaman DJ, Cunningham AB. 2002. Impact of cultivation and gathering of medicinal plants on biodiversity: global trends and issues. In: FAO. *Biodiversity and the Ecosystem Approach in Agriculture, Forestry and Fisheries*. Proceedings. 1–21. ISBN 92-5-104917-3
- Setalapharik C, Price LL. 2007. Children's traditional ecological knowledge of wild food resources: a case study in a rural village in Northeast Thailand. *Journal of Ethnobiology and Ethnomedicine* **3**: 33. DOI: 10.1186/1746-4269-3-33
- Sheil D, Puri RK, Basuki I, van Heist M, Saefuddin, Rukmiyati, Sardjono MA, Samsedin I, Sidiyasa KD, Chrisandini, Permana E, Angi EM, Gatzweiler F, Johnson B, Wijaya A, eds. 2002. *Exploring Biological Diversity, Environment, and Local People's Perspectives in Forest Landscapes: Methods for a Multidisciplinary Landscape Assessment*. Bogor, Indonesia: Center for International Forestry Research (CIFOR), 1–93. ISBN: 979-8764-88-9. DOI: 10.17528/cifor/001021
- Stepp JR. 2004. The role of weeds as sources of pharmaceuticals. *Journal of Ethnopharmacology* **92**: 163–166. DOI: 10.1016/j.jep.2004.03.002
- Stepp JR. 2010. Informant use recall technique in ethnobotany. In: Albuquerque UP, Hanazaki N, eds. *Recent Developments and Case Studies in Ethnobotany*. Recife, Brasil: Sociedade Brasileira de Etnobiologia e Etnoecologia, 103–111. ISBN: 8577167119, 9788577167111
- Stepp JR, Moerman DE. 2001. The importance of weeds in ethnopharmacology. *Journal of Ethnopharmacology* **75**: 19–23. DOI: 10.1016/S0378-8741(00)00385-8
- Tardío J, Pardo-de-Santayana M. 2007. Cultural importance indices: A comparative analysis based on the useful wild plants of Southern Cantabria (Northern Spain). *Economic Botany* **62**: 24–39. DOI: 10.1007/s12231-007-9004-5
- Tiwari BK, Tyngsong H, Lynser MB. 2010. Forest management practices of the tribal people of Meghalaya, North-East India. *Journal of Tropical Forest Science* **22**: 329–342.
- Torres-Colin R. 2004. Tipos de vegetación. In: García-Mendoza AJ, Ordóñez Díaz M de J, Briones-Salas

- M. eds. *Biodiversidad de Oaxaca*. México, D.F.: Universidad Nacional Autónoma de México, Instituto de Biología, Fondo Oaxaqueño para la Conservación de la Naturaleza-World Wildlife Fund, 105–117. ISBN: 970-32-2045-2
- Urquijo PS, Bocco G. 2011. Los estudios de paisaje y su importancia en México, 1970-2010. *Journal of Latin American Geography* **10**: 37–63. DOI: 10.1353/lag.2011.0025
- van Andel T, Havinga R. 2008. Sustainability aspects of commercial medicinal plant harvesting in Suriname. *Forest Ecology and Management* **256**: 1540–1545. DOI: 10.1016/j.foreco.2008.06.031
- Van On T, Quyen D, Bich LD, Jones B, Wunder J, Russell-Smith J. 2001. A survey of medicinal plants in BaVi National Park, Vietnam: methodology and implications for conservation and sustainable use. *Biological Conservation* **97**: 295–304. DOI: 10.1016/S0006-3207(00)00125-7
- WHO [World Health Organization], IUCN [International Union for Conservation of Nature and Natural Resources], WWF [World Wide Fund for Nature], eds. 1993. *Guidelines on the Conservation of Medicinal Plants*. Gland, Switzerland: World Health Organization, World Conservation Union, World Wide Fund for Nature, 1-38. ISBN 2-8317-0136-8
- Zarger R. 2002. Learning the environment. In: Lancy DF, Bock JC, Gaskins S. Lanham, MD, eds. *The Anthropology of Learning in Childhood*. Landham MD: Altamira Press, 341-369. ISBN: 0759113238

APPENDIX 1.

List of the medicinal species cited in the interviews: Scientific name, family, common name, Ecological Land Unit, origin (native/introduced) and value of the Knowledge, Use and Perception Index.

The species are ordered by their value of the Knowledge, Use and Perception Index from most to least important. Ecological Land Units: 1-Village and roads, 2-Pastures, 3-Home gardens, 4-Cultivated fields, 5-Acahuales (secondary vegetation), 6-Cloud forest, 7- Semi-evergreen tropical forest, 8- Evergreen tropical forest, 9-Riparian vegetation. Origin: N-Native, I-Introduced, U-Unknown. KUPI: Knowledge, Use and Perception Index. An asterisk * indicates the cultivated species (n=14) that were not collected but identified in the field.

KUPI = M + U + I

M-plants known

U-plants used in the last year

I-plants considered important

Sum KUPI - sum of healers + general population, used for Fig. 5, and for ordering the species list.

Num.	Species	Family	Common name	Ecological Land Unit	Origin	Sum KUPI	KUPI Healers	KUPI General population
1	<i>Salvia microphylla</i> Kunth	Lamiaceae	mirto	3	N	89	14	75
2	<i>Lippia alba</i> (Mill.) N. E. Br. ex Britton & P. Wilson	Verbenaceae	pitona	3	N	59	09	50
3	<i>Artemisia absinthium</i> L.	Asteraceae	hierba maestra	3	I	46	05	41
4	<i>Eupatorium</i> sp.	Asteraceae	juquelite	3	N	36	05	31
5	<i>Ruta graveolens</i> L.	Rutaceae	ruda	3	I	31	06	25
6	<i>Tanacetum parthenium</i> (L.) Sch. Bip.	Asteraceae	santa María	3	I	30	08	22
7	<i>Verbena litoralis</i> Kunth	Verbenaceae	verbena	1,2,3,4	N	27	07	20
8	<i>Aloe vera</i> (L.) Burm. f.*	Xanthorrhoeaceae	sábila	3	I	26	05	21
9	<i>Matricaria recutita</i> L.*	Asteraceae	manzanilla	3	I	22	03	19
10	<i>Urtica chamaedryoides</i> Pursh	Urticaceae	chichicastle	1,2,3,4,5,6,7	N	22	03	19
11	<i>Mentha spicata</i> L.*	Lamiaceae	hierbabuena	3	I	14	02	12
12	<i>Mecardonia procumbens</i> (Mill.) Small	Plantaginaceae	susto de suelo	1,2,3,4,5	N	11	02	09
13	<i>Citrus sinensis</i> (L.) Osbeck*	Rutaceae	naranja	3	I	08	-	08
14	<i>Rosmarinus officinalis</i> L.*	Lamiaceae	romero	3	I	08	05	03
15	<i>Persea americana</i> Mill.*	Lauraceae	aguacate	2,3,4,5,6	N	08	04	04
16	<i>Pilea microphylla</i> (L.) Liebm.	Urticaceae	cuangracia delgada	1,3	N	07	03	04
17	<i>Ocimum basilicum</i> L.*	Lamiaceae	albahácar	3	I	06	03	03
18	<i>Ocimum micranthum</i> Willd.	Lamiaceae	huele a rellena	1,2,3,4,5	N	06	01	05
19	<i>Citrus aurantifolia</i> (Christm.) Swingle*	Rutaceae	limón	2,3	I	06	-	06
20	<i>Mentha pulegium</i> L.*	Lamiaceae	poleo	3	I	06	03	03
21	<i>Artemisia ludoviciana</i> Nutt.*	Asteraceae	estafiate	3	N	05	01	04
22	<i>Origanum majorana</i> L.*	Lamiaceae	orégano	3	I	05	-	05
23	<i>Oenothera rosea</i> L'Hér. ex Aiton	Onagraceae	flor rosa	1,2,3,4	N	05	-	05
24	<i>Cuphea aequipetala</i> Cav.	Lythraceae	flor morada	1,2	N	05	-	05
25	<i>Pilea pubescens</i> Liebm.	Urticaceae	hojas redondas	1	N	05	-	05
26	<i>Pilea pumila</i> (L.) A. Gray	Urticaceae	hojas alargadas		N	05	-	05
27	<i>Valeriana candolleana</i> Gardner	Caprifoliaceae	bejuquito de la disipela delgada	1,5,6	N	05	-	05
28	<i>Prunus persica</i> (L.) Batsch*	Rosaceae	durazno	3	I	05	01	04

29	<i>Peperomia peltilimba</i> C. DC.	Piperaceae	cuanyia	3,6,9	N	05	02	03
30	<i>Dichaea neglecta</i> Schltr.	Orchidaceae	espinazo de culebra	6	N	04	-	04
31	<i>Sida rhombifolia</i> L.	Malvaceae	malvarisco	1,2,3,4,5	N	04	04	-
32	<i>Bougainvillea glabra</i> Choisy*	Nyctaginaceae	bugambilia	3	I	03	-	03
33	<i>Equisetum myriochaetum</i> Schltdl. & Cham.	Equisetaceae	cola de caballo	9	N	03	02	01
34	<i>Fraxinus uhdei</i> (Wenz.) Lingelsh.	Oleaceae	fresno	3	N	03	02	01
35	<i>Citrus limetta</i> Riso	Rutaceae	lima	2,3	I	03	-	03
36	<i>Malva parviflora</i> L.	Malvaceae	malva	1,2,3,4,5	I	03	01	02
37	<i>Borreria suaveolens</i> G. Mey.	Rubiaceae	riñonina	1,3,5	N	03	03	-
38	<i>Psidium guineense</i> Sw.	Myrtaceae	huesina	1,2,3	N	03	-	03
39	<i>Sambucus nigra</i> subsp. <i>canadensis</i> (L.) Bolli	Adoxaceae	sauco	3	N	03	-	03
40	--	--	cuanree	1,2,5	U	02	-	02
41	<i>Pityrogramma calomelanos</i> (L.) Link	Pteridaceae	Ocopetatito	1,3,6	N	02	-	02
42	<i>Allium tuberosum</i> Rottler ex Spreng.	Liliaceae	cebollina	3	I	02	02	-
43	<i>Liquidambar styraciflua</i> L.	Altingiaceae	llavito	4,5,6	N	02	02	-
44	<i>Litsea glaucescens</i> Kunth	Lauraceae	laurel	5,6	N	02	02	-
45	<i>Boehmeria caudata</i> Sw.	Urticaceae	tlaca	1,2,5	N	02	-	02
46	<i>Citrus medica</i> L.	Rutaceae	cidra	3	I	01	-	01
47	<i>Pinguicula moranensis</i> Kunth	Lentibulariaceae	cuangracia gruesa	6,9	N	01	01	-
48	--	--	cuansini	1,2,3,4,5	D	01	01	-
49	<i>Quercus elliptica</i> Née	Fagaceae	encino	6,7	N	01	01	-
50	<i>Odontosoria schlechtendalii</i> (C. Presl) C. Chr.	Lindsaeaceae	susto de lumbre	6	N	01	01	-
51	<i>Passiflora</i> sp.	Passifloraceae	susto de trompa de víbora	7	N	01	-	01
52	<i>Solanum nigrescens</i> M. Martens & Galeotti	Solanaceae	hierba mora	2,3	N	01	-	01
53	<i>Piper auritum</i> Kunth	Piperaceae	hierba santa	2,3,4	N	01	-	01
54	<i>Plantago major</i> L.	Plantaginaceae	llante	1,2,3,4,5	I	01	-	01
55	<i>Parietaria pensylvanica</i> Muhl. ex Willd.	Urticaceae	paletaria	1,3,4	N	01	01	-
56	<i>Lippia graveolens</i> Kunth	Verbenaceae	salvia de castilla	3	N	01	01	-
57	<i>Sedum praealtum</i> A. DC.	Crassulaceae	siempre viva	3	N	01	-	01
58	<i>Magnolia dealbata</i> Zucc.	Magnoliaceae	súchil	5,6	N	01	01	-
59	<i>Calea urticifolia</i> (Mill.) DC.	Asteraceae	cuanshia	1,5	N	01	01	-
60	<i>Tithonia diversifolia</i> (Hemsl.) A. Gray	Asteraceae	árnica	3	N	01	01	-