How does urbanization affect perceptions and traditional knowledge of medicinal plants?

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Abstract

Background: Use and knowledge of medicinal plants play an essential role in community health in rural Mexico. They are part of the local inheritance and constitute an economic alternative. Nevertheless, knowledge of their use has declined due to factors like accelerated urbanization processes. Some authors have proposed that by reducing natural spaces, urbanization generates changes which will impact recognition, use and management of natural resources. We evaluate how urbanization affects knowledge, use and perception of medicinal plants in a Biosphere Reserve in Mexico.

Methods: Using a mixed methodology including quantitative and qualitative analyses, we generate a list of medicinal plants, methods of preparation, prevalence of illness, and use.

Results: 210 medicinal plants were identified. The more urbanized community used greater number of introduced plants; whereas the less urbanized used and had more knowledge about wild plants. One of the factors explaining these differences was occupation. People who work outdoors have greater knowledge of wild plants. The more urbanized community knew and used more introduced species.

Conclusions: This can lead to a loss of knowledge of use and management of wild species, with implications for the conservation of biocultural heritage. Substitution of native by introduced plants shows disinterest and disuse, which could be reflected in their ecosystems.

Background

Traditional knowledge of the use and management of natural resources is a reflection of the relationship between human communities and their physical, biotic, and cultural environment over time[1,2]. This relationship is mediated by the cultural, economic, and ecological context, making it dynamic and versatile[3,4]. These changes can modify traditional knowledge, such that it grows, remains the same, or erodes[3]. This can affect how elements of nature are used and managed, as well as practices, customs, beliefs, and ideas[5,6] at both the individual and group levels[4]. Consequently, there is a consensus that biodiversity conservation implicitly involves traditional knowledge[7,8].

Some studies have shown that processes associated with modernization negatively affect the degree and depth of knowledge of natural resources; increasing level of education, migration, and urbanization are related to loss of ability to recognize, name, use, and manage plant resources[9,10,11]. Urbanization is a complex economic process that entails social and environmental change that occur over short time periods and often modify cultural patterns[6,12]. This process sometimes generates innovations in the culture that, in association with the acquisition of prestige, motivate the displacement of patterns of social behavior and organization[13]. At the same time, urbanization leads to drastic changes in people's lifestyle, perception, and sociability[14,15], which can directly affect the use and management of natural resources.

In particular, urbanization can affect people's knowledge of medicinal plants (which involves recognizing, naming, using, and managing species in that use category). It has been hypothesized that urban communities, by having increased access to medical services, may abandon or reduce their use of medicinal plants to treat some illnesses and ailments. In addition, this loss of knowledge and abandonment of use could be due to a decrease in agricultural, agroforestry, and forested areas, since urbanization reduces the areas for medicinal plant collection. At the same time, the processes of urbanization bring with them devaluation of and discrimination against traditional knowledge.

Some authors have suggested that the decreased contact between the people and their natural environment results in societies that are more tolerant to the progressive loss of biodiveristy[16]. Therefore, the management and transmission of traditional knowledge to new generations is crucial for the prevention of biodiversity loss[16].

The use of medicinal plants is one of the elements of traditional knowledge that, because it is linked directly to health, is particularly sensitive for local communities[17]. It is estimated that 80% of the population in developing countries use those resources for primary care[18]. Their use persists in rural and urban areas as a result of the transmission of knowledge, mostly in verbal form and between generations[19]. At the same time, the lack of access to public health services in rural areas incentivizes the use of medicinal plants[20,21].

Despite their importance, knowledge of medicinal plants is subject to several threats due to, among other factors, urbanization[22,23], since the processes of economic development lead to the loss of wild vegetation and the reduction of the area dedicated to traditional agriculture, and with that, cultural modification[24]. Land use change leads not only to the destruction of habitat of a variety of medicinal plants, but also impacts the degree of knowledge of their management and uses. When medicinal plants no longer exist in the natural environment, the reflection on their use is also lost between one generation and the next[11,25,26]. Consequently, the use and management of medicinal plants could be modified by a reduction in the areas of collection and propagation, reluctance and decrease in their use, as well as the perception of incompatibility between traditional and western medicine[17].

The general panorama of the effects of urbanization on the traditional knowledge of medicinal plants requires more research in order to clarify how certain factors associated with urbanization (access to official health services, migration, changing economic activities, etc.), affect their use in traditional communities. It is important to document these processes in bioculturally megadiverse countries with a long tradition of use of medicinal plants and that currently face a scenario of loss of associated biocultural heritage due to, among other processes, urbanization.

The processes that deteriorate biocultural heritage are notorious in Mexico, one of the five most diverse countries worldwide[27], and where about 6,000 species of medicinal plants are used, of which at least 4,000 are collected from forests and jungles[28]. Despite this grand biocultural legacy, which is the result of

thousands of years of interaction between diverse cultures and their environments[29], there are currently challenges that urgently need to be met. The country faces a public health emergency due to the obesity and diabetes epidemics, in addition to other diseases associated with sedentary lifestyle and increasing urbanization[30]. In addition, it is 43rd out of 194 countries in the rate of urbanization, with 80.2% of its inhabitants living in cities[31]. At the same time, it is ranked fifth worldwide in rates of deforestation[32], and land use change, including urbanization, has led to the destruction of ecosystems that harbor biodiversity, including species of medicinal plants.

For these reasons, this study evaluates the knowledge of medicinal plants possessed by inhabitants of two communities with differing degrees of urbanization. At the same time, we explored the relationship between urbanization and the number of native and introduced species people knew, as well as sociocultural factors that influence species richness of medicinal plants used, comparing the relationships within and between communities.

This work was based on the premise that urbanization changes patterns of knowledge and use of medicinal flora, such that we expected inhabitants of the more urbanized community to know fewer species of medicinal plants and highlight introduced species, and that purchase would be the mode of acquisition of medicinal plants; all of which would warn of a loss of the knowledge of medicinal flora in this community. In contrast, we expected the less urbanized community to have more knowledge of local medicinal species, prefer native and wild species, and more frequently collect them.

Methods

Description of the study area

The study was carried out near the border of the Sierra de Huautla Biosphere Reserve (*Reserva de la Biosfera Sierra de Huautla*; REBIOSH), in the state of Morelos, Mexico (Figure 1). The reserve was decreed in 1999, has an area of 59,030 hectares, and is covered almost entirely by Tropical Dry Forest (TDF)[33,34], which is characterized by trees with an average height of 10 m that lose their leaves during the dry season[35]. The total population within the reserve is 25,356 inhabitants[36] in rural communities with high marginalization indexes due to little access to health, transportation, and education services and limited employment opportunities[37].

There are 939 species of vascular plants reported in the area, of which 602 (56%) are used by the community to meet health, food, and shelter needs, among other uses[33]. About 400 species (66%) are medicinal plants that can be used to help resolve some health issues, since there are no public health services in 60% of the communities[33,38].

We selected two communities—El Limón de Cuauchichinola (ELC) (within the REBIOSH) and Tepalcingo (TGO; in the area of influence of the REBIOSH)— which differ in their degree of urbanization (Table 1). ELC was founded in 1900 by a migrant population, and in 1929 was consolidated as an *ejido* (a mode of

collective community-based land ownership in Mexico). ELC has a population of 129 and has a public primary school and local government house. A portion of its youth and adult population emigrate temporarily to the United States in search of employment opportunities. TGO is the municipal seat of the municipality of the same name and has a population of 23,209 inhabitants. It was founded in 1272 by native tribes, but it was not until 1869 that it was considered a municipality of Morelos. This community acts as a hub of distribution and trade in the region, and it is visited by people from different communities of southern Morelos to buy and sell products, which also makes it a destination for people who have migrated from other neighboring communities.

Table 1. Demographic data for the communities of El Limón de Cuauchichinola (ELC) and Tepalcingo (TGO).

Community /location	Number of inhabitants / Nº homes	Economic activities	Services	Average education (years)
ELC / 18°31'51" North latitude, 98°56'15" West longitude, (1,259 masl), 28.5 km from municipal seat	129 / 37	Seasonal agriculture, Extensive livestock rearing, gathering of non-timber forestry products	37 homes in the community, all occupied, of which only 28 have electricity, running water, and public sewer lines. Public primary school and once monthly brigade offering free medical appointments.	5.1
TGO / 18°35'47" North latitude, 098°50'237" West longitude (1,160 masl). Municipal seat.	12,053 / 3674	Functions as a center for commerce and distribution of products and has approximately 370 different services, among which small shops and are the most frequent.	2,382 homes have electricity, running water, and public sewer lines. Has education, public healthcare and private medical practices, as well as wellness programs and public transportation.	7.62

The urbanization indicators that we used were the economic activities, availability of healthcare services, and average level of education. The socioeconomic data were obtained from the 2010 census[36] and the National Statistical Directory of Economic Units (*Directorio Estadístico Nacional de Unidades Económicas*)[39]. ELC is less urbanized than Tepalcingo, since its inhabitants depend almost exclusively on primary sector activities (Table 1, Figure 2). In contrast, TGO is a more urbanized community, since its inhabitants mainly work in the tertiary sector, such as commercialization and services (Table 1, Figure 3).

Stratified Random Sampling

In order to analyze the existence of an urbanization gradient that could impact knowledge of medicinal plants, we did stratified random sampling, differentiating regions within each community following the sampling design proposed by Pagaza[9]. In both communities, two regions were defined: central and peripheral. The central region referred to the area where the community's administrative services were concentrated, while the periphery was defined as the areas near zones of agriculture, agroecosystems, and wild vegetation.

Free listing and semi-structured interviews

We used free listing to document the number of medicinal plant species known by the inhabitants of each community, with 28 and 77 people in ELC and TGO respectively[40,41]. With the same people we did a semi-structured interview[40] in order to collect personal data (name, age, sex, occupation, and birthplace), as well as data with respect to medicinal plants, including their use, methods of preparation, parts used, method of acquisition (collection or purchase), conditions for which they are used, and if they have consulted with specialists in medicinal plants or traditional medicine. Saturation or redundancy of information was used to determine when the appropriate sample size was reached[42], and a non-parametric t test for unbalanced data was used in order to avoid biases in the results due to the difference in the total number of interviews per community.

Structured interview

Using information from the stratified random sampling, we located 16 key informants (7 in ELC and 9 in TGO), who were recognized for their experience in the management of medicinal plants. We carried out structured interviews with these informants to obtain detailed information about the species of medicinal plants used, frequent ailments, plant parts used, method of acquisition, and opinions and perceptions concerning the persistence or erosion of the knowledge and use of medicinal plants[40].

Ethnobotanical walks

To determine the taxonomic identities of the species recounted, both in the listing and in the structured interview, we carried out six ethnobotanical walks[43] in zones of wild and secondary vegetation, as well as agroecosystems in both communities (4 in TGO and 2 in ELC). The botanical specimens were collected

and identified and deposited in the “HUMO” herbarium at the Center for Research in Biodiversity and Conservation (*Centro de Investigación en Biodiversidad y Conservación*, CIByC-UAEM).

Quantitative analysis of information

In order to determine whether there were differences in the knowledge of medicinal plants between the two communities, we analyzed the results of the free listing and semi-structured interviews with a Wilcoxon’s W test for samples with asymmetrical distribution. This analysis was done for the total number of species named, and separately for the number of native, introduced, and wild species mentioned. The differences were evaluated between communities, regions, occupations, sex, and birthplace of the interviewee. The analyses were done in SPSS software, version 24.0[44].

Using the data from the free listing and the semi-structured interviews, we constructed a database with 16 variables that considered the socioeconomic information and degree of knowledge of medicinal plants in the interviewed populations of the two communities. In order to characterize the differences in knowledge of medicinal plants depending on the degree of urbanization within and between the communities, we did a discriminant function analysis using SPSS software, version 24.0[44].

Qualitative analysis of information

We did a qualitative analysis of the information from the interviews with key informants in order to characterize the ideas, comments, and perceptions associated with knowledge of medicinal plants. This approach from the social sciences guides the research question, allowing the deep exploration of the modifications of knowledge of medicinal plants from the perspective of people from the localities which have broad experience with their management[45]. This methodology is based on the notion that reality is socially constructed, and that people therefore give meaning to social and natural phenomena according to their perceptions of the world[46,47,48]. The interviews from the two communities were transcribed and codified using the program ATLAS.ti version 7.5[49], organizing the information according to the perceptions of the key informants into four coded categories: treatment preferences, teaching-learning, availability of medicinal plants, and problems. The codification of the information consisted in an exploratory line-by-line reading and selection of particular data in order to reduce the information into a format that was manageable for analysis and interpretation. We also created a perception map linking the responses obtained and enumerating the responses that were similar among interviewees[50,51,52,53]. This map was included because it serves as a graphical summary of the different perceptions and to structure the narrative of the results and discussion.

Results

In the two communities studied, we recorded a total of 269 common names of medicinal plants, which correspond to 217 species, of which 148 (68%) are native to Mexico, 79 (36%) are naturally distributed in the study area, and 69 (31%) are introduced. The total richness is grouped into 70 botanical families, and

the families with the largest number of species were Fabaceae, (28 species), Asteraceae (21), Lamiaceae (11), Solanaceae (9), and Malvaceae (8).

Differences in the degree of knowledge of medicinal plants by community

In ELC, 95 species of medicinal plants were mentioned, distributed in 46 botanical families, of which 73 are native to Mexico, 39 are considered part of the Tropical Dry Forest (51%), and 22 are introduced (Figure 4). In TGO, 175 species of medicinal plants were named, which are distributed in 71 botanical families, 115 are native to Mexico (66%), 60 species are introduced (34%), and 58 Tropical Dry Forest species were identified (Figure 4).

The Wilcoxon's W test showed significant differences between the communities (ELC vs. TGO) at all levels of the analysis (total number of species mentioned, number of native, introduced, and wild species) of knowledge of medicinal plants. The region factor showed differences between the center and periphery of the two communities in the total number of species, number of native species, and number of wild species, but not the number of introduced species. With respect to sex, women mentioned more introduced species than men (W = 1,314, p= 0.002), with no differences in the total, native, or wild species (Table 2). With respect to occupation, people that worked in the field mentioned more wild species than homemakers (W = 704, p= 0.016). There were no significant differences when comparing among birthplaces (Table 2).

Table 2. Results of Wilcoxon's W test of differences in knowledge of medicinal plants between communities (ELC = El Limón de Cuauchichinola; TGO = Tepalcingo). Bold text indicates significant differences ($P < 0.01$).

mmunity		Region		Occupation		Sex		Birthplace	
TOTAL NUMBER OF SPECIES NAMED									
C	TGO	Center	Periphery	Rimary activities	Homemakers	Female	Male	In the study communities	In other communities in Morelos
.885.50		**2278.00**		612.00		1568.50		763.00	
0.003		**0.0399**		0.3921		0.2111		0.2682	
TOTAL NUMBER OF NATIVE SPECIES NAMED									
.212.50		**2209.00**		656.50		1923.50		811.50	
0.0460		**0.0123**		0.1099		0.2265		0.5113	
TOTAL NUMBER OF INTRODUCED SPECIES NAMED									
2080.50		2680.50		489.50		**1314.00**		797.50	
0.0001		0.5876		0.2336		**0.0024**		0.4279	
TOTAL NUMBER OF WILD SPECIES NAMED									
2050.00		**2243.50**		**704.00**		1960.00		827.00	
0.0001		**0.0220**		**0.0166**		0.1417		0.6067	

Knowledge of medicinal plants and urbanization gradient

The discriminant function analysis showed that people's knowledge of medicinal plants is affected by urbanization. As shown in Table 3, the first two functions explain 92% of the variation, with the first explaining 77.2% and the second 14.8%. The grouping of the interviewees in discriminant function 1 is statistically significant, which is also confirmed by the canonical correlation value and Wilk's lambda. Figure 5 shows that the interviewees are distributed along an urbanization gradient, in which the periphery of ELC is shown in the yellow oval on the left hand side of the graph, followed by interviewees from the central zone of ELC (red oval). Next, the distribution of the interviewees from the periphery of TGO (gray oval) and from the center of TGO (black oval) are interspersed with each other. The most important variables in Function 1 (Table 4) were: the age of the informants, the number of species collected, the number of native species mentioned, and the number of wild species reported. These all had a negative sign, which means that people located toward the right hand side of the graph (TGO) had on average lower age, referred to a lower number of species collected, and therefore native and wild species were in the minority, in contrast to people located on the left hand side of the graph (ELC). At the same time, the variables with positive values were the number of species purchased, domesticated and introduced species. This means that interviewees that were located on the right hand side of the graph

reported, on average, purchasing a larger number of species of medicinal plants, which are mostly domesticated species, and in many cases are exotic or introduced plants.

Table 3. Autovalues and Wilk's Lambda from the discriminant functions analysis, using as a grouping variable the center and periphery regions of each study community.

Function	Autovalue	% variance	Cumulative %	Canonical Correlation
1	1.081	77.2	77.2	0.721
2	0.208	14.8	92.0	0.415
Test of functions	**Wilk's Lambda**	**Chi-squared**	**df**	**Sig.**
1 a 2	0.358	98.658	42	0.000
2	0.745	28.301	26	0.344

Table 4. Relative importance of the variables studied in the first two discriminant functions.

Standardized Canonical Discriminant Function Coefficients		
Variable	Funtion	
	1	2
Sex	-0.1002	-0.0953
Age	**-3.1193**	6.4347
Birthplace	-0.1734	0.1926
Ocupation	0.3962	0.3197
Number of species	-0.7418	-0.6630
Number of native species	**-1.4697**	-0.0436
Number of introduced species	0.7278	-0.6194
Number of wild TDF species	**-1.2784**	0.3881
Number of domesticated species	**1.0076**	-1.0529
Number of ruderal species	-0.1274	-0.1139
Number of herbaceous species	-0.0989	-0.1353
Number of ruderal and herbaceous species	-0.3304	0.0692
Number of species collected	**-1.7439**	-0.5615
Number of species purchased	**1.0749**	-0.0085
	0.3174	-0.1511

*Bold text indicates the most important variables in the discriminant function.

Table 5 shows that 61.3% of the total interviewees are correctly classified according to degree of urbanization assigned to each community. In this sense, the majority of interviewees were correctly classified as from the periphery of ELC (77.8%), followed by inhabitants of the center of TGO (63.9%), then the periphery of TGO (56.1%) and finally, the center of ELC (45.5%).

Table 5. Classification of interviewees according to the urbanization gradient in the study communities. The data show raw and percentage values[35,38].

Comunidad	Predicted Group Membership				Total
	Tepalcingo Center	Tepalcingo Periphery	El Limon Center	El Limon Periphery	
Tepalcingo Center	23	13	0	0	36
Tepalcingo Periphery	15	23	2	1	41
El Limon Center	1	3	5	2	11
El Limon Periphery	4	0	0	14	18
Tepalcingo Center	63.9%	36.1%	0%	%0	100%
Tepalcingo Periphery	36.6%	56.1%	4.9%	2.4%	100%
El Limon Center	9.1%	27.3%	45.5%	18.2%	100%
El Limon Periphery	22.2%	0%	0%	77.8%	100%

*61.3% of original grouped cases correctly classified.

Perceptions and qualitative analysis of knowledge of medicinal plants in different urbanization contexts

In ELC, seven key informants were interviewed—two men and five women between 54 and 73 years of age. Most of these people were born in the community and their occupation was in the primary sector (agriculture, livestock, gathering) and in the home. These people preferred to use medicinal plants to cure illness, since these are abundant in their communities and are a free alternative for the treatment of many ailments. However, they mentioned that if use of these plants does not lead to improvement, or with specific conditions such as bites/stings or severe illness, they must travel to another more urban community to seek treatment at a health clinic because those services are not available in the community, which involves higher costs.

The majority of the interviewees learned to use medicinal plants directly from family members or by observing their use by other people. However, none of the people had transmitted their own knowledge to others, and in ELC interviewees mentioned that knowledge of medicinal plants is being lost since inhabitants prefer the speed of allopathic medicine. The key informants from ELC did not consider traditional medical practitioners, however, the population recognizes them and eventually consults them on their knowledge of medicinal plants, such that they do play an important role in the less urbanized community that lacks permanent healthcare services (Figure 6).

In TGO, nine key informants were interviewed—five women and four men, between the ages of 39 and 72, that hold diverse occupations, from the home to traditional medicine practitioners. The majority preferred to use only medicinal plants to treat illness, since they are unfamiliar with the substances used in allopathic medicine, while the remaining informants preferred to combine traditional medicine with allopathic medicine.

The informants learned about the use of medicinal plants from a family member or by observing others, and several are transmitting that knowledge to their children, although many are not interested in learning, leading them to consider that knowledge of the use of medicinal plants is being lost in their community. In addition to the lack of interest in learning about these resources, they mention that another factor relevant to the loss of knowledge is the fact that these plants are disappearing and that the clinic physicians advise their patients against using medicinal plants. However, they also mention that one characteristic that has helped to maintain this knowledge is that the use of medicinal plants is a free alternative for those that do not have money to buy allopathic medications. They also mention that medicinal plants are most available in surrounding patches of native vegetation. Additionally, they commented that at the local market they could acquire many varieties of medicinal plants from other regions and even other countries.

Most of the interviewees said they attend health clinics only when their condition does not improve with natural treatments or when they are suffering from a serious illness. In addition, the use of medicinal plants for these informants was a source of supplementary income for their families, although the number of patients has decreased in recent years due to the increase in the availability of allopathic medicines in the community. However, thanks to the confidence that the community has in their abilities, they continue to provide their services:

"…the thing is that people lose confidence in the doctors, because they say one thing, then they want to treat you for something else… I had pain from an infection I had, and the doctor checked me out and said it was my gall bladder, that I needed an operation, but I didn't listen to him, I took some herbs I prepared and now I'm fine…but it takes time, and nowadays people don't want to be healed, they want everything quick, and I tell them that if they want to heal, they have to take the treatment for at least a month…" Key informant from TGO (Figure 6).

Discussion

The importance of Tropical Dry Forest (TDF) in the provision of medicinal plants

The region where the study communities are located provides a considerable percentage of the medicinal plants that are sold in Mexico[54], which indicates the importance of these resources in the culture and economy of the inhabitants of this natural reserve, as well as the contribution of the Tropical Dry Forest (TDF) to the treatments used in and the general persistence of the practice of traditional medicine. In this study, we recorded a total of 217 species of medicinal plants, which correspond to 72.33% of the flora reported for the region by Maldonado-Almanza[38]. TDF is the dominant vegetation type providing medicinal plants to the Sonora Market (*Mercado de Sonora*) in Mexico City, which is one of the most important markets for medicinal plants in Latin America[54]. Thus, TDF is of great environmental, social, and economic importance in the conservation of these resources[28,55,56,57].

This percentage indicates that both communities possess a large amount of knowledge about medicinal plants due to the role they play in health and the local population's need for viable and low-cost healthcare options. This can be explained by the fact that only 40% of the communities within the reserve have permanent public healthcare installations, like in TGO, while the inhabitants of less urbanized communities, like ELC, must invest time and money in traveling to the municipal seat to receive these services[4,33,58]. It is possible that these differences in access to healthcare also reflect asymmetry in knowledge of medicinal plants between the two communities.

Medicinal plants are the most important use category among the useful plants of Mexico[59] and the second most important among the group of species considered Non-Timber Forest Products (NTFPs) [60]. This importance is reflected by the number of ailments and treatments for which these plants are used by different local cultural groups[59].

The most represented botanical families in this study contain a large variety of useful secondary compounds in leaves, stems, bark, flowers, and fruits, in addition to being some of the most represented families in this type of vegetation[59,61]. Species such as *Amphipterygium adstringens* (Schltdl.) Standl., *Eysenhardtia polystachya* (Ortega) Sarg., *Haematoxylum brasiletto* H. Karst., and *Crescentia alata* Kunth had the highest importance and frequency of use, which is consistent with other studies from the study area and TDF more generally[28,38,57,62].

Urbanization negatively affects the level of knowledge of locally distributed medicinal plants

In contrary to our expectation, in this study we identified that the most urbanized community had greater overall knowledge of medicinal plants (TGO 175 spp. vs. ELC 95 spp.). This result was observed for different criteria which are fundamental for analyzing the degree of knowledge of medicinal plants[11], such as the number of species mentioned, the number of native species, and the number of wild species (Table 2). This is probably related to the fact that TGO has a long history as a hub of regional distribution of medicinal plants and because it is the location of a market dating back to prehispanic times, in which merchants from all over the country gather to sell NTFP including crafts, medicinal plants, seasonal foods, utensils, beverages, etc. [63,64,65]. This fair generates commercial relationships and reinforces symbolic and cultural aspects, which contribute to adaptation and innovation in traditional health practices as well as foment knowledge of medicinal plants among mestizo and semi-urban populations[9,58,66,67]. Such events, Vandebroek & Balick[68] point out, allow relatively urbanized communities to maintain a large amount of knowledge of medicinal plants due to demographic and historical dynamics that often buffer the loss of this knowledge.

This dynamic of exchange of medicinal resources through the fair in TGO may also explain the increased use of species that are purchased or introduced in this community. As a consequence, in the more urbanized community of TGO, the number of introduced and domesticated species was a significant component of the medicinal plants known by the interviewees. In contrast, in the less urbanized community of ELC, native TDF plants and wild plants were more frequently mentioned and used. This is

consistent with research by Blair that mentions that in moderately urbanized contexts, there is increased presence of useful plants, though these tend to be introduced[69]. In addition, a number of authors have proposed that in contemporary tropical pharmacopeias, people prefer introduced species to complement their therapeutic repertoir[70,71], and in some cases, it is traditional medicine practitioners and local healers that promote and maintain introduced species within these communities[72,73,74]. This demonstrates the importance of valuing the knowledge and use of wild species and native domesticated species. At the same time, we found that there is greater knowledge of medicinal plants among ELC inhabitants and that this knowledge is centered on native and wild TDF species. This occurs because the lesser degree of urbanization results in closer proximity to wild vegetation, which favors the recognition and use of natural resources in daily life and delays the negative consequences of urbanization processes that tend to reduce human contact with their natural surroundings[11].

Variables that influence the degree of knowledge of medicinal plants

The degree of knowledge of medicinal plants differed between the two communities (Table 2) and was affected mainly by socioeconomic variables and the age of the interviewees, the way in which they acquired medicinal plants (collection or purchase), and the number of native, introduced, wild, and domesticated plants they named (Table 4). This agrees with the assertion of Rangel de Almeida and collaborators, who explained that geographic proximity among communities is a crucial factor for their similarity in botanical knowledge[73], as occurs in our study area, where both communities are surrounded by the same type of vegetation. These differences are expressed in the type and source of the resources that are known to each group. In ELC, the people with the most knowledge of the local flora were those that work in the primary sector. In contrast, in TGO, although there was a great deal of knowledge of medicinal plants, they were most knowledgeable about exotic and domesticated plants, and tended to work in the tertiary sector. These results agree with previous findings from other investigations, in which a lower level of local botanical knowledge was related to non-agricultural employment and decrease in activities related to extraction of natural resources[11].

Complementary to these differences in traditional botanical knowledge (Table 2), our findings reveal overlap in the knowledge of medicinal plants. This can be explained by the existence of an urbanization gradient, as well as by the fact that the method of analysis compared intrinsic differences between regions within each study community (Figure 4). These overlaps occur in the majority of the regions that were designated, but are particularly frequent between residents of the central and peripheral regions of TGO. This may be due to family dynamics, since many people inherit plots of land from their parents which are found on the outskirts of these communities. In contrast, in ELC, homes tend to be situated on large plots of land that house the entire extended family, including children and even grandchildren. Therefore, the difference in knowledge of medicinal plants of the inhabitants of this less urbanized community could be due to the complex dynamic of migration and establishment of people from different communities.

On the other hand, the differences in knowledge of medicinal plants could also be due to the occupation of the interviewees. While homemakers in TGO apparently mentioned a large number of medicinal plants, these were mostly purchased and introduced, which could be due to their openness to commerce, since they are the member of the family that tends to attend markets to sell farm and other products (Table 6). On the other hand, the people whose occupation was in the primary sector used more wild, collected, and domesticated native species. This is consistent with findings of Beltrán-Rodríguez and collaborators with respect to the idea that agriculture and livestock husbandry contribute to ethnobotanical knowledge, unlike those who work in commerce or service industries, which know more introduced species[57].

Table 6. Average number of species mentioned by occupation.

	TGO		ELC	
Occupation	Average	Standard deviation	Average	Standard deviation
Primary sector	7.66	3.01	10.06	4.93
Homemaker	10.625	6.13	9.53	6.38

While it has been reported that people who work in the tertiary sector and who have higher economic income may have more knowledge of medicinal plants, it has also been observed that a considerable proportion of that knowledge is of introduced species[73,75], which suggests that westernization and urbanization tend to homogenize local knowledge and diminish the biocultural richness of rural communities, putting at risk knowledge of medicinal plants and their natural environment[76]. The dominant culture legitimizes certain types of knowledge and practices deemed valid and desirable[77]. With the understanding that culture and knowledge are flexible and dynamic, it is well known that some traditional practices are devalued by the dominant culture, which leads to transformation and erosion of experiences and knowledge of the management of the landscape and its resources[78]. For this reason, it is fundamentally important to preserve the knowledge and practices associated with the management of the natural environment, since they would disappear if there is no longer a relationship between human communities and natural elements, leading to the erosion of knowledge associated with natural resources[11,25], the abandonment of their use[54] and their progressive loss[16].

Threats to the continuity of use of medicinal plants in the urbanization gradient

The increasing urbanization of TGO promoted by regional migration of inhabitants from ELC to this community, as well as the constant flux of migrants between TGO and the United States of America could negatively affect the consumption of medicinal or other useful plant species in the region in both localities, which could contribute to the destabilization of traditional identity paradigms[79]. In some studies, it has been shown that this effect can lead to cultural change, which modifies the knowledge and perception of medicinal and edible plant resources[10,17,68,80].

The preference for the use of medicinal plants as a preventative method in ELC may respond to the fact that inhabitants must invest more time and money to travel to another community to receive healthcare services. On the other hand, those who do have public healthcare services must attend monthly to avoid being denied service. These dispositions may act as social coercion mechanisms that promote the devaluation of traditional therapies by official healthcare systems, which has negative implications for the appreciation and knowledge of medicinal plants[17,67,81].

In the case of ELC, it is losing the transmission of knowledge of medicinal plants, probably due to the migration of young people. Since this transmission depends on the collective memory of the communities, there is increasing tolerance of the progressive loss of knowledge of plant resources[16,79]. It is important to mention that the key informants from ELC do not consider themselves traditional medicine practitioners, despite possessing a large body of knowledge of medicinal plants. This may imply that they do not consider it important to transmit their knowledge to others, generating a process of colonization of the native epistemologies. This involves the dispossession and devaluing of knowledge and of the cultural foundations of indigenous, mestizo, and rural communities by the imposition of hegemonic models in multiple aspects of community life, in particular, healthcare[82,83,84].

The loss of this knowledge, according to interviewees, is mainly due to the speed with which allopathic medicines work, and the pressure exerted by the healthcare system to disincentivize the use of medicinal plants. Both factors could result in the disuse of local resources, and therefore, disinterest in conserving them. Pérez-Nicolás and collaborators have suggested that medicinal plants cannot be use to foment forest conservation[85]. However, the case of the Flora Sanctuary *Orito Ingi Ande* in Colombia is an example that this is possible, since in 2008 the government and indigenous community agreed to conserve the biodiversity, including many medicinal plants, and the associated traditional knowledge[86]. It is therefore important to find mechanisms that allow synergy between traditional and western healing systems. This could maintain traditional knowledge and positive valorization of natural resources, playing a positive role in the communities and the conservation of their surroundings[67,87].

In TGO, traditional practices had an important presence in daily life and in symbolic aspects of community life. This is reflected by the knowledge possessed by its inhabitants of medicinal plants, and we therefore found a larger number of key informants that consider themselves traditional medicine practitioners. Although in both communities traditional practices are used to improve health, the cultural processes are very dynamic due to interaction with other cultures[77].

In TGO, people receive economic benefits from the use of medicinal plants, be it by collecting them, using them in traditional medicine, or using them as a cheaper alternative to allopathic medicine. This coincides with the assertion by Shackleton and collaborators that NMFPs are vital components for local use as well as for sale in local and regional economies[88].

The inhabitants of TGO invest less time and money to visit a health clinic and use a wider variety of forms of treatment than in ELC. We consider that having access to more healthcare options in TGO

allows people to try different healing methods. In the case of ELC, it may be that since there are fewer options for treatment and lower income, in addition to a strong effect of coercion by health policies, the value of knowledge of medicinal plants decreases, with negative repercussions for their use.

Characterizing and attempting to explain complex phenomena in depth, such as the effect of urbanization on knowledge of medicinal plants, requires an interdisciplinary approach. This research highlights the value and utility of knowledge that is maintained in rural communities about their surroundings, evidencing the implications for the conservation of local flora, specifically species with medicinal uses.

Conclusions

Knowledge of medicinal flora is diverse and dynamic, and can often be eroded by sociocultural processes like urbanization. This study shows the complexity of the phenomenon, since communities with a higher degree of urbanization can be a catalyst for the acquisition of a new set of knowledge, treatments, and forms of preparation. However, these innovations can be detrimental to the use of native flora, local knowledge systems, and their mechanisms of transmission. In this study, while the less urbanized community recognized a lower number of medicinal plants, these were mostly native plants distributed in the surrounding vegetation. This could maintain links with and dependency on the local forest, which could stimulate conservation of important areas of Tropical Dry Forest. Strong threats to the use of medicinal plants are evident due to complex processes, such as migration and contradictory public policy, which can erode biocultural heritage of traditional peoples.

Declarations

Ethics approval and consent to participate.

Not applicable.

Consent for publication.

Not applicable.

Availability of data and materials

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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Author´s contributions

CAG-Gathered and analyzed theoretical information, applied and analyzed interviews and made all necessary field work, analyzed quantitative and qualitative results and helped to produce the perceptions map, JB- constructed theoretical and methodological frameworks, analyzed quantitative information LBR- Revised manuscript and analyzed quantitative information, CL- Revised manuscript and was fundamental in the urbanization theoretical construction and in identifying the studied localities, HCB- Revised the manuscript and strengthened methodology, AlMC- Revised the manuscript and provided integrated and useful insights on results analyses and interpretations, JASH- Revised the manuscript and provided integrated and useful insights on results analyses and interpretations, XLM- constructed theoretical and methodological frameworks, analyzed qualitative information and elaborated responses maps.

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Figures

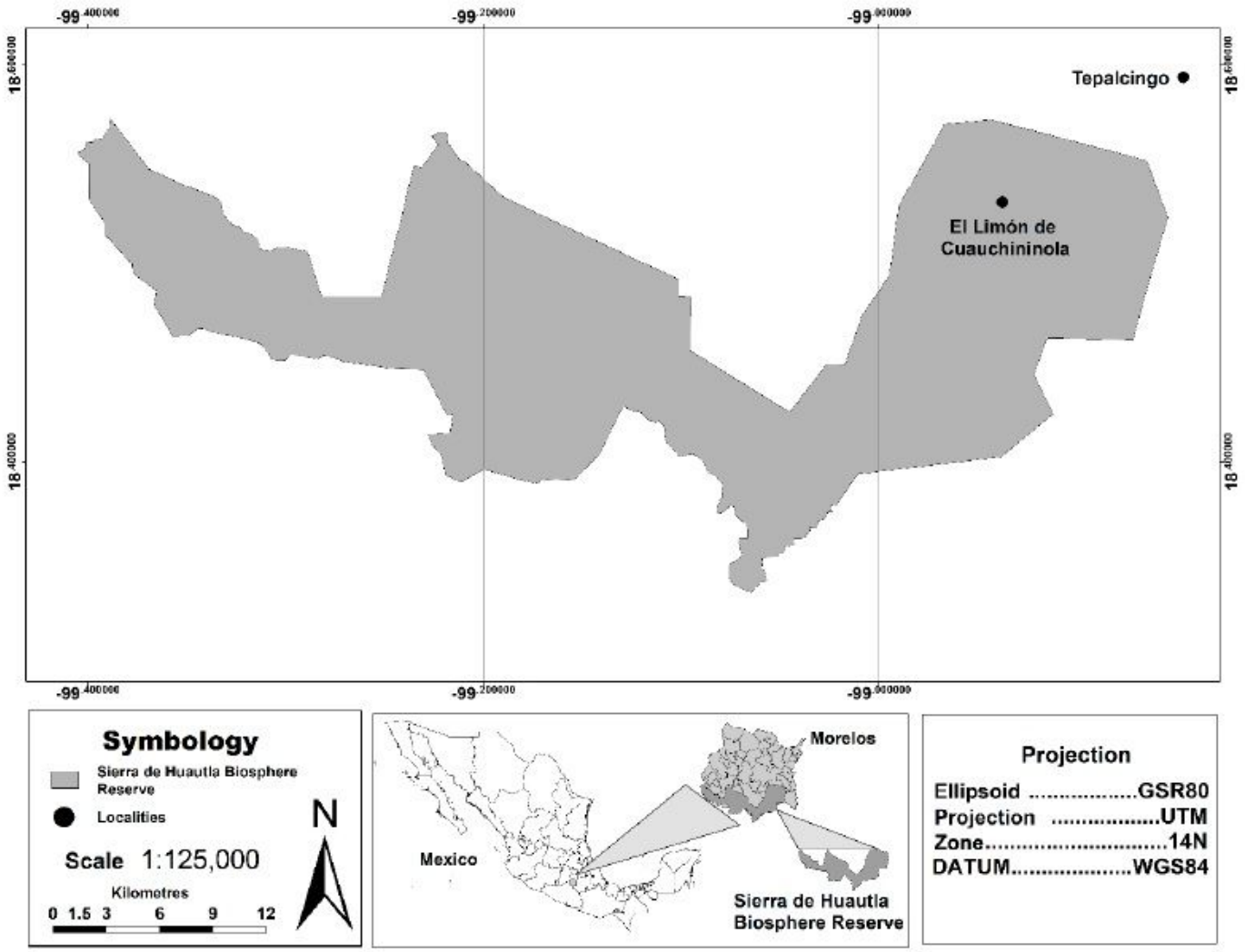

Figure 1

Sierra de Huautla Biosphere Reserve (Reserva de la Biósfera Sierra de Huautla; REBIOSH) and location of the study localities.

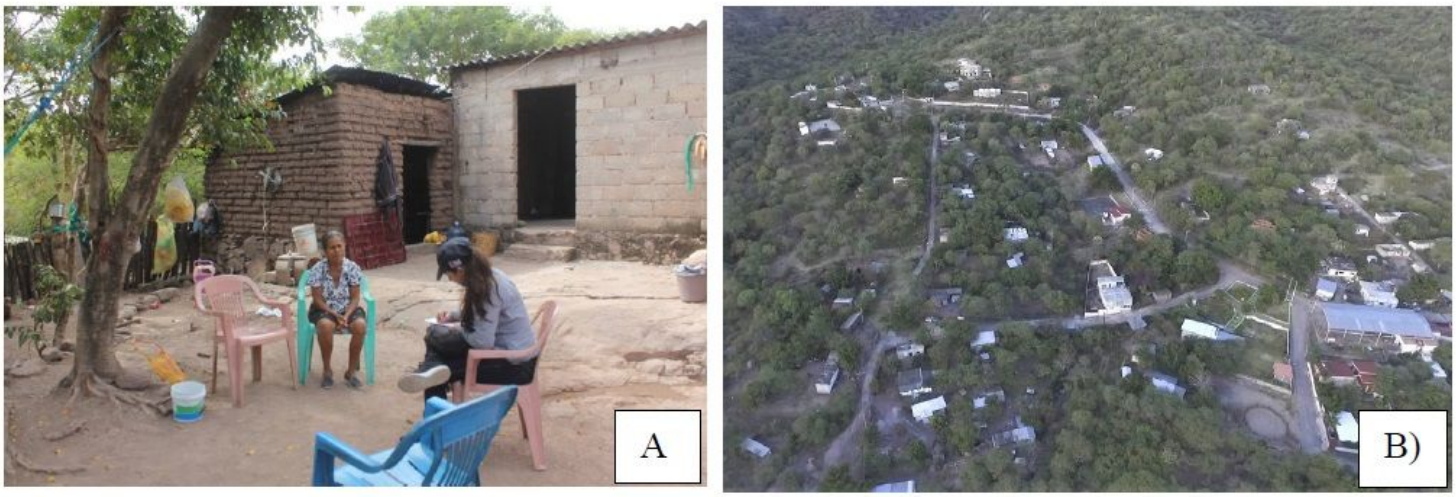

Figure 2

Community of El Limón de Cuauchichinola. A) Interview with community members; B) General panorama of the community. Photos: A) C. Arjona; B) Nextia multimedia.

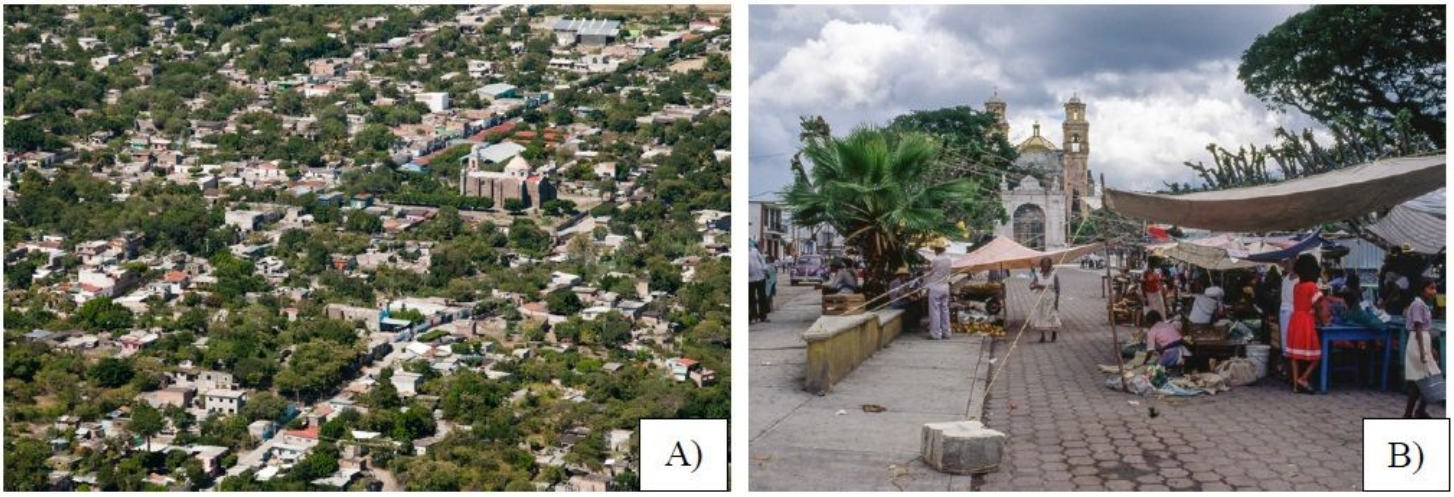

Figure 3

A) General overview of the community of Tepalcingo; B) Commercial activities in the center of the community. Photographs: A) Sistema de Archivos Compartidos UAEM-3Ríos.

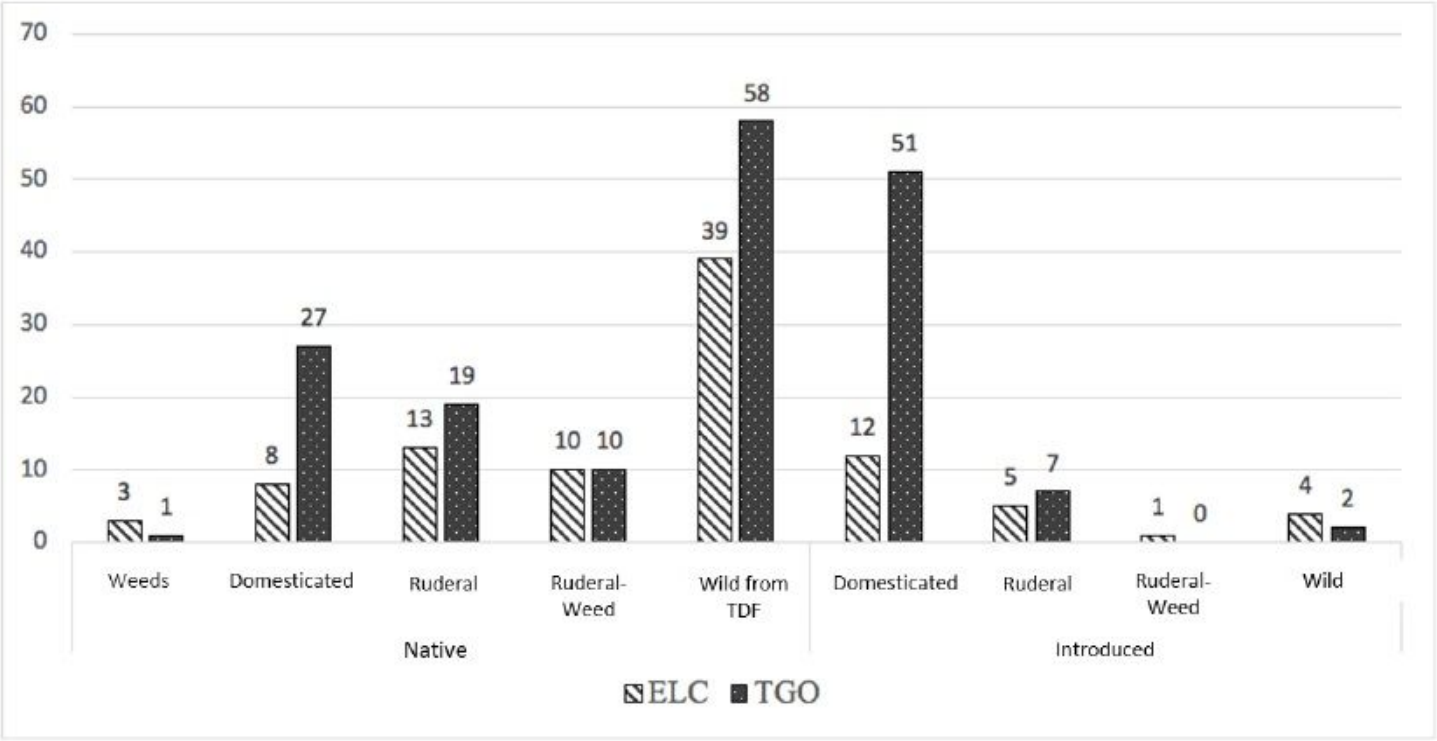

Figure 4

Number of species mentioned in each community, categorized by plant origin and degree of management.

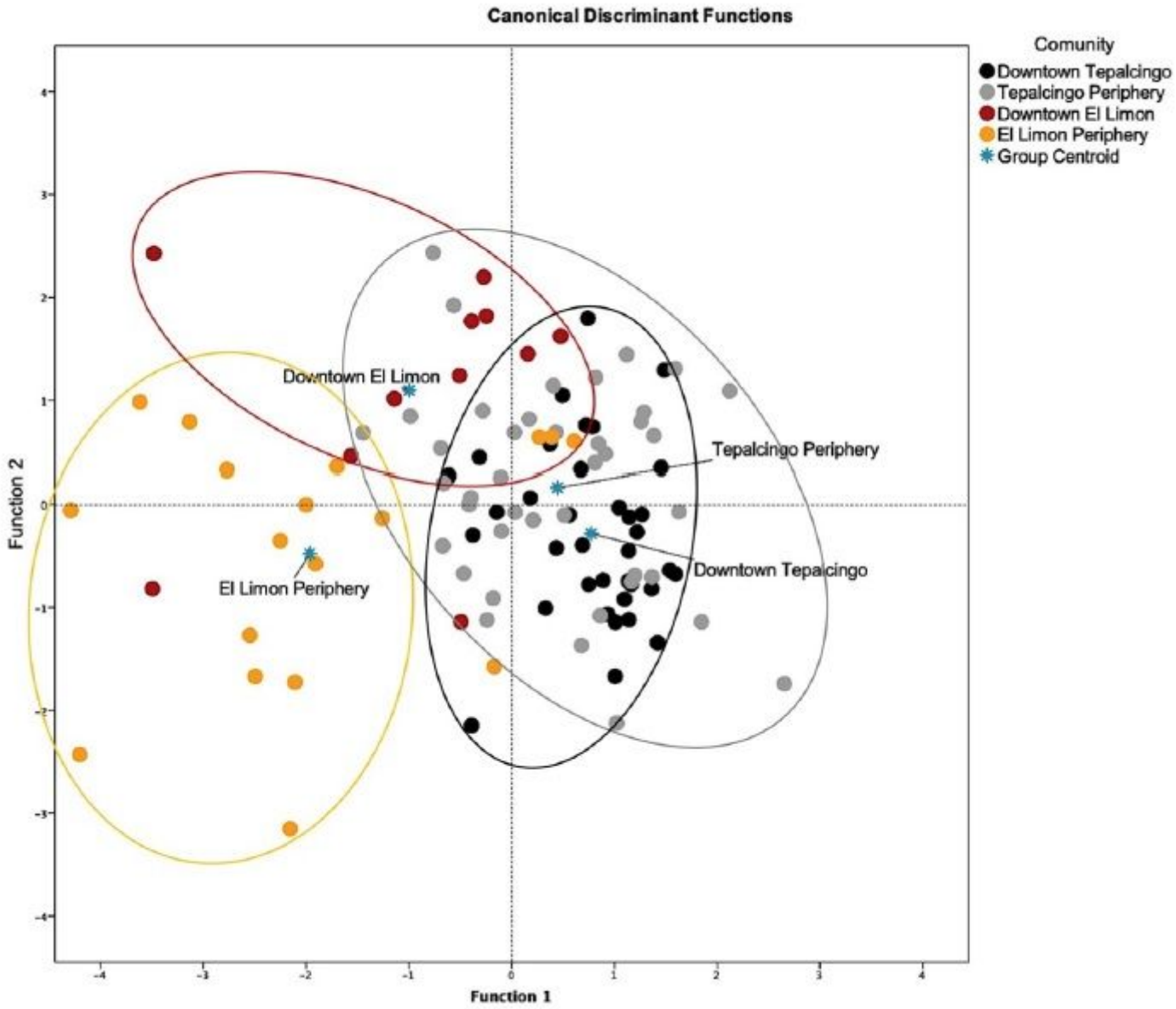

Figure 5

Distribution of interviewees according to degree of urbanization

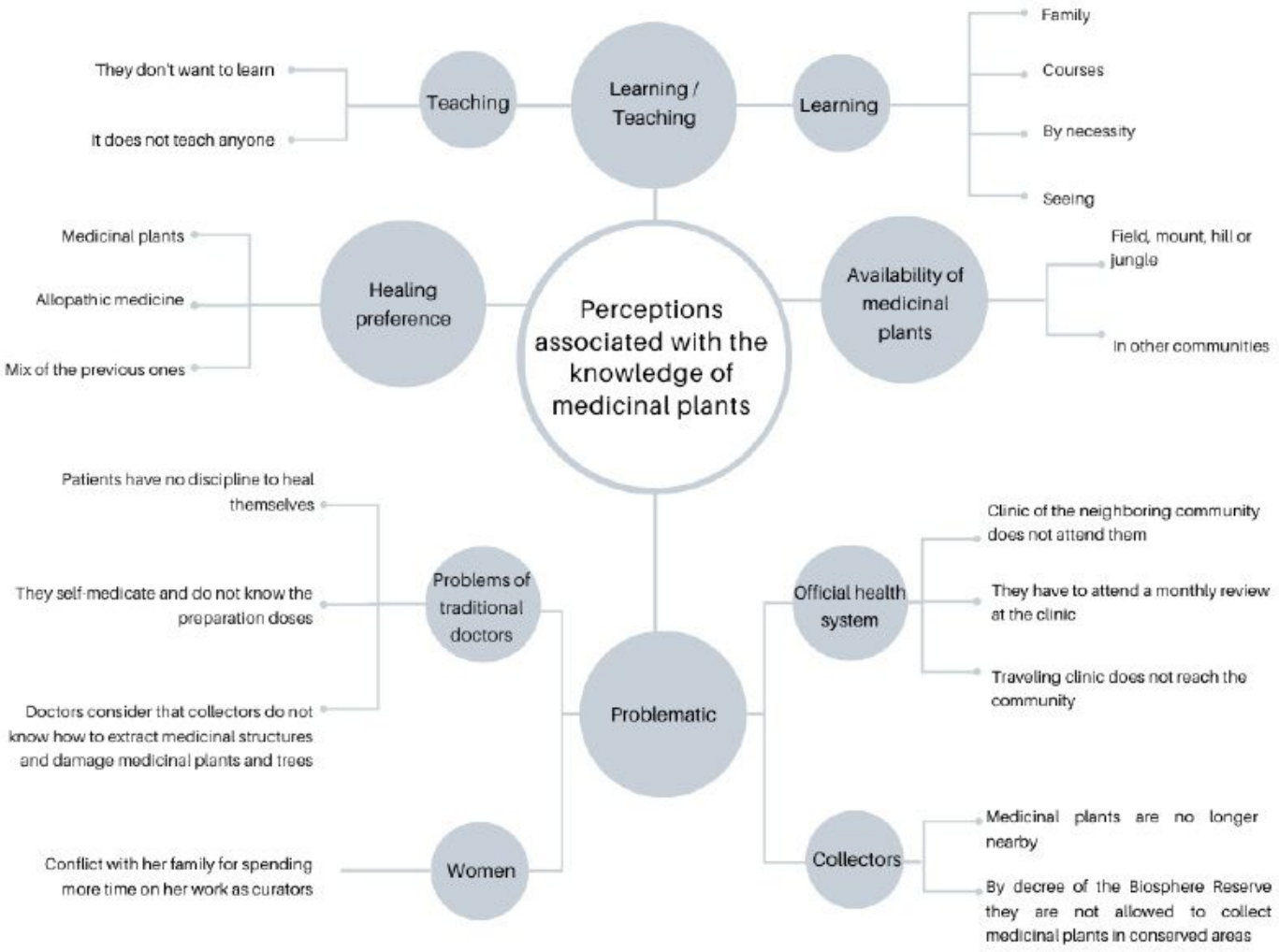

Figure 6

Perception map based on interviews with key informants from ELC and TGO.