Current Use Value of Medicine Plants in three 1 maya communities of the Yucatan

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Abstract

Twenty diseases were identified as being treated with herbal remedies, predominantly gastrointestinal issues (diarrhea, vomiting, stomachache, colitis, and dysentery) and chronic degenerative conditions (cholesterol, blood pressure, diabetes, hypertension). Cultural diseases (bad air, evil eye, fright, cold sweat) remain reported. Eighty plant species across 43 families were documented for medicinal purposes. The most culturally valued and frequently used species include rue (*Ruta graveolens*) with 0.42 UV and 43% FL, sour orange (*Citrus aurantium*) with 0.42 UV and 43% FL, oak (*Ehretia tinifolia*) with 0.39 UV and 39% FL, and Ts'uts'uk (*Diphysa yucatanensis*) with 0.36 UV and 36% FL. While the use of introduced plants is rising, native species still hold significance. Herbal medicine remains widely practiced, especially among individuals over 35, who possess the most knowledge. These Mayan communities in the Yucatan Peninsula are experiencing constant change, driven by diverse political and economic forces. The region's rich natural resources and significant tourist value contribute to the gradual abandonment of traditional plant medicine.

1. Introduction

Mexico's rich cultural and biological diversity is a testament to millennia of interaction between indigenous communities and their natural environment. This profound relationship has not only preserved but also enriched a wealth of traditional knowledge, particularly in the field medicine. The ongoing evolution and adaptation of this ancient wisdom are reflected in the dynamic nature of indigenous traditional medicine (Hérnandez-Ramírez et al., 2022; White-Olascoaga et al., 2013; Aparicio-Aparicio et al., 2021). Central to traditional medicine in Mexico is the extensive use of medicinal plants, which form the cornerstone of healthcare among diverse indigenous groups across various regions (Ávila-Uribe et al., 2016; Méndez et al., 2010; Zambrano et al., 2015). The use and understanding of these medicinal plants, known as "herbolaria", are deeply interwined with cultural beliefs and social dynamics within communities.

In recent years, there has been a growing recognition of the importance of quantitative approaches in studying medicinal plants. Methods such as use value indexes offer valuable insights into the relative significance and utilization of herbal resources (La Torre-Cuadros and Islebe, 2003; Paiva de Lucena et al., 2007). By integrating both qualitative and quantitative methodologies, researchers can comprehensively explore the multifaceted dimensions of traditional medicine, encompassing not only its practical applications but also its cultural and social significance.

Holistic studies that blend qualitative insights with quantitative analysis enable us to gain a deeper understanding of how traditional medicine shapes and reflects the cultural identity and social fabric of indigenous communities in Mexico. This approach not only facilitates the preservation of traditional knowledge but also contributes to the development of culturally sensitive healthcare practices that honor and respect the rich heritage of Mexico's indigenous peoples.

Several authors have documented that traditional knowledge is constantly evolving but warn that changes are occurring at an accelerated pace, even reaching the most remote communities (Vandebroek and Balick 2012; Voeks 2018). Some effects include the loss of the local language, shifts in subsistence activities, the abandonment of primary production and agricultural practices, the decline in the use and knowledge of medicinal plants, among others (Benz et al. 2000; Faust and Gabriel 2015;Maffi 2005; Reyes-García et al. 2013, Voeks 2018).

While the Yucatan Peninsula (PY) has been the focus of extensive research on medicinal plants, there are few studies that identify the processes of change or the loss of knowledge (Hopkings & Stepp 2012). Although the integration of quantitative methodologies to complement qualitative data has been somewhat limited, their importance cannot be overstated. Quantitative methods provide valuable insights into understanding processes of change, particularly in assessing the evolving value of traditional practices. By utilizing of indexes and other quantitative tools, researchers can effectively estimate the current usage and importance of traditional knowledge systems.

This integration of quantitative methods serves as a powerful auxiliary approach, enhancing our ability to grasp the nuances of cultural evolution and adaptation. By quantifying aspects of traditional practices, such as the use value of medicinal plants, researchers can gain deeper insights into how these practices are evolving over time. This holistic approach, combining qualitative and quantitative data, not only enriches our understanding of cultural dynamics but also provides practical insights for preserving and promoting traditional knowledge in a rapidly changing world.

Traditional knowledge is evolving, influenced by factors such as the global economy and political changes. This underscores the need for research that analyzes the shifts in the diverse sociocultural processes involved and updates information on medicinal plant knowledge, particularly in regions of great wealth like the Yucatan Peninsula.

The aim of this study was to assess the significance of medicinal plants within three Mayan-origin communities by capturing insights form traditional healers, patients, and community members across various age groups. By encompassing perspectives from multiple stakeholders, including both practitioners and recipients of traditional medicine, we sought to gain a comprehensive understanding of the role and value of medicinal plants within these communities. Qualitative and quantitative methods were used value indexes serving as indicators of change or loss of traditional knowledge. The study also aims to identify the factors contributing to the transformation of herbal medicine use in communities of the Yucatan Peninsula.

2. Methods

2.1 Study area

The study was conducted in three communities of the PY, Kantemó, Tigre Grande, and Kancabchen (FIGURE 1). These communities were selected based on the following criteria: 1) populations size between 150 and 600 inhabitants. 2) absence of specialized health services. 3) a predominant use of the Mayan language, with at least one traditional healer present in the community. Kantemó: It is located at 19° 42' 36" North latitude and 89° 02' 28" West longitude in the state of Quintana Roo, bordering the Chichankacab lagoon to the east. According to Miranda's (1963) vegetation classification, the predominant vegetation type is semi-deciduous medium dry forest (Anderson et al. 2005), with a warm sub-humid climate and summer rains. The community currently covers 1,226 hectares and has a population of 264 inhabitants (INEGI 2020; Palomino-Villavicencio and López-Pardo 2011). Kantemó is also known for its tourism services, particularly the "Bejkax ha" ecotourism center, which features tours of the “Cave of the Hanging Snakes”.

Kancabchen is located at 19.713889° North latitude and 88.861667° West longitude in the state of Quintana Roo. This *ejido* covers 13,215 ha (PHINA 2022), making it one of the largest *ejidos* in the municipality. The area has a warm sub-humid climate, with a vegetation consisting of semi-deciduous medium dry forest and medium statured tropical forest. The community has both an elementary school and high school, and its inhabitants are known for being the main lemon exporters in the municipality.

Tigre Grande is located at 19°42'36" North latitude and 89° 02' 28" West longitude in the municipality of Tzucacab, in the state of Yucatan. The area has a warm sub-humid climate with summer rains, and its vegetation consist primarily of medium statured tropical forest. The *ejido* covers 1,890 hecatres and has a population of 151 inhabitants, most of whom are speakers of the Mayan language (INEGI 2020; Zamora Crescencio et al. 2009), it is one of the smallest *ejidos* in the municipality. Self-subsistence agriculture is the primary productive system in the community, which has only elementary school.

The Yucatan Peninsula (PY) is in southeastern Mexico is a biotic province characterized by unique features, including karst geology. This landscape, originating from the Oligocene, is marked by soils of organic origin and varying soil types with minimal relief (Ayala Arcipreste 2001; Duno de Estefano et al. 2018). The predominant climate across the region is tropical sub-humid with summer rainfall and dry winter. The YP has elevations of less than 350 meters and rainfall ranging from 800 mm to 1500 mm, which supports the formation of plant associations such as semi-deciduous, deciduous and thorny tropical forest (Ibarra-Manriquez et al. 1995; Ibarra-Manriquez et al. 2002; Pérez-Sarabia et al. 2017). The region is home to about 2500 plant species, 680 of which are reported to be medicinal (Islebe et al. 2015; Dupuy Rada et al. 2015). Additionally, it has a high percentage of endemic tree species (72), representing 5.7% of the country’s endemism (Torrescano-Valle and Folan 2015). Culturally, the YP is known for the presence of the Mayan culture, with the contemporary Maya still preserving their language, customs and ancestral knowledge (Estrada-Belli 2011; Ramírez-Barajas and Calmé 2015).

2.2 Informants and interviews

The study was conducted between February and July 2022, during which extensive groundwork was laid. Prior to data collection, initial visits were made to the communities to establish rapport, identify key informants, and introduce the project. This proactive approach ensured the participation and engagement of community members, laying a solid foundation for the research. Informants were selected using methods proposed by Duarte (2004), Albuquerque (2006), and Aparicio-Aparicio (2021). Traditional physicians, *sobadores* (cures at the hands), J'men (Mayan priest), herbalists and midwives were considered as expert key informants. The study also included community members, particularly those aged 16 and 88, who are generally the most frequent users of medicinal plants or traditional medicine. Additionally, some experts did not self-identify as such, so villagers recognized by the community for their extensive herbal knowledge were also included (Bhattarai et al. 2010).

The semi-structured interviews were designed following the principles of the International Society for Ethnobiology ISE (ISE 2006), with the consent of the local authorities. Participants were fully informed about the objectives of the project and provided written consent (Martin 1995). The interview consisted of 24 semi-structured questions divided into three sections: 1) A record of diseases treated with herbal medicine, including parts of the plants used, identified properties, modes of use, and other ethnobotanical aspects (e.g., location, flowering time, fruiting); 2) Information on the location of useful plants and most common extraction areas; and 3) participants' perspectives on current herbalism and their experiences in the process of care and recovery. Additionally, observations of the informants' daily lives were conducted to understand their family and community roles, and to gather insights related to the valuation of flora and the identification of uses (Gómez García et al. 2016).

2.3 Botanical collection

Vegetation sampling was conducted using a modified version of Foster's (1995) methodology. Each plot, averaging 20 x 30 meters, was considered as the sampling unit. Botanical collections were made in 10 plots, guided by informants during walks. Photographs of useful species were taken during the sampling process, and unidentified species were collected for identification at the ECOSUR herbarium (ECO-CH-H).

2.4 Data analysis

Data analysis was carried out using a combination of qualitative and a quantitative approach to gain a comprehensive understanding of the use and significance of medicinal plants in the communities studied. A Spearman correlation was applied to assess the relationship between the age of informants and the number of medicinal plants the reported, using GraphPad Prism® v8.01. Prior to conducting the correlation analysis, a non-parametric Kolmogorov-Smirnov test was performed to ensure that the data met the assumptions of normality.

The data obtained from the interviews were analyzed using the informant consensus technique, which calculates the relative importance of each medicinal use of the plants based on the agreement among informants' responses (Bermúdez et al. 2005). The *Use Value* (UV) index was employed to express the importance of a species, calculated as the average number of uses mentioned per species divided by the total number of informants interviewed (Phillips and Gentry 1993):

$$VUs = \frac{\sum UVis}{\mathrm{ni}}$$

Where: UVis = is the number of uses mentioned (i) for each species (s). ni = total number of informants interviewed.

In addition to the UV index, other ethnobotanical indices were calculated to provide a nuanced understanding of the cultural significance of the plants. The *fidelity level* (FL) was determined to measure the degree of cultural acceptance of each plant species within the community, calculated as the percentage of informants who cited a specific medicinal use for a given species (Friedman 1986; Germosén-et al. 2017). Species that are cited with a frequency greater than or equal to 20% are considered significant from the point of view of cultural acceptance (Germosén-et al. 2017; Zambrano-Intriago et al. 2015), the value is obtained with the following formula:

$$FL = \frac{Np}{N} = x100$$

Where: Np = number of informants who mentioned a medicinal use for each species and N = number of uses mentioned for each plant.

The *Relative Popularity Level* (RPL) was used to assess how frequently a plant species is used, with values closer to one indicating higher popularity (Gheno-Heredia et al. 2011; Umair Muhammad et al. 2017). Finally, the *Rank Order of Priority* (ROP) was calculated to evaluate the correlation between FL and RPL, providing a prioritized list of medicinal plants based on their cultural importance.

The RPL and ROP value are calculated using the following formulae:

$$\frac{Iu}{Number\ of\ informants\ mentioning\ the\ use\ of\ a\ plant}$$

Where: Iu = number of aiments treated by a particular plant species.

$$ROP = FL\ x\ RPL$$

To further understand the diversity of medicinal plants and their significance in different locations, the floristic similarity among the 10 sampled plots was assessed using Jaccard's similarity coefficient. This index was calculated using the presence-absence data of species across the plots, with the analysis performed using the PAST software, version 4.11 (Hammer et al. 2001). The Jaccard index provided insights into the degree of species similarity between different plots, allowing for an understanding of the spatial distribution of medicinal plant knowledge within the communities.

3. Results

3.1 Interviews

Interviews with community members revealed a total of twenty diseases frequently treated with herbal medicine. Grouped into five categories (Table 1) based on body systems proposed by Bhattarai (2010): respiratory, gastrointestinal, chronic degenerative, culture-linked diseases and others. The most commonly reported conditions included diabetes and gastrointestinal disorders, with chronic-degenerative diseases being cited by 22% of the informants and gastrointestinal issues by 21%. Cultural diseases, recongnized primarly by traditional doctors and older community members (Table 2), are those diseases not recognized by western medicine (Perreti 2010), for example: bad air (*mal aire*), evil eye (*mal de ojo*), fright (*susto*) and cold sweat (*sudor frío*).

Table 1
Main diseases according to informants (traditional practitioners and patients).

Body system (categories)	Diseases treated with plants	Percentage of incidence
Chronic degenerative	Cholesterol, blood pressure, diabetes, hypertension.	38%
Gastrointestinal	Diarrhea, vomiting, stomachache, colon pain, dysentery.	36%
Respiratory	Cough, flu, asthma, catarrh, pneumonia.	14%
Diseases linked to culture	Evil eye (*mal de ojo*), gastrointestinal blockage (*empacho*), fright (*susto*), bad air (*mal aire*), clogged blood (*pasmo en sangre*), umbilical beat (*cirro o tip'te*).	7%
Others	*Calentura* (fever), Kidney stones.	5%

*The diseases were grouped by body system (Bhattarai 2010) and according to the diseases described by the informants.

The analysis showed a positive and significant correlation between the age of informantsand the number of medicinal plants they cited, underscoring the role of older individuals as key repositories of traditional knowledge within the community. The values found were Kantemó < 0.01 r = 0.6196, P = 0.0105, Tigre Grande < 0.1000, r = 0.858 0.0004; and Kancabchen < 0.0001, r = 0.75 (Fig. 2).

3.2 Testimonials

Regarding the perspective of the inhabitants in relation to current herbal medicine, some of the testimonies of the informants are quoted:

"The kids nowadays, they don't care about plants, they don't like to make their medicine, out of laziness more than anything else" (Don Mariano Catzin, 63 years old, *Sobador*, traditional healer who treats dislocated bones and performs massages to alleviate muscles)."

"Before you didn't see advertisements for medicines on television, now you see them everywhere, that makes it easier for people to buy medicines, even if it is more expensive than making a tea" (Doña Fernanda, 70 years old, herbalist).

"Those who migrate from childhood to work in Cancun to Playa, get used to the city and forget what they learned as children, that is what happened to my daughter, she forgot many preparations, medicines, but she has also learned others with the plants they find" (Doña Balvina, 62 years old, housewife).

3.2 Botanical identification

A total 80 medicinal plants were recorded and identified, which were grouped into 43 botanical families (Table 2) at the three sites. The Lamiaceae family was best represented with eight species, followed by Fabaceae (6), Malvaceae and Euphorbiaceae (5). Apocynaceae and Asteraceae each contributed four species. Within the list of medicinal plants, it was found that: *Pilocarpus racemosus* Vahl, *Byrsonima bucidaefolia* standl, *Critonia aromatisans* (DC.) R.M. King & H. Ro, *Ceiba schottii*, *Diphysa yucatanensis* Hanan-Alipi & M. Sousa and *Croton chichenensis* Lundell were identified as endemic to the Yucatan Peninsula. Regarding the sources of these plants, 65% of the informants reported gathering them from their plots or orchards, 21% from *milpa* (traditional cornfields), and 14% from the surrounding tropical forest.

3.3 Use Value Index

The use value (UV) and fidelity level (FL) indices were used to quantify the importance and cultural acceptance of each medicinal plant species reported by the communities. UV reflects to the number of different uses assigned to a plant, while FL indicates the extent of cultural acceptance, or how highly a plant is valued within the community. Among the species Ts’uts’uk (*Diphysa yucatanensis*), sour orange (*Citrus aurantium*), roble (*Ehretia tinifolia*) and rue (*Ruta graveolens*) had UVs above 0.35. Notably, sour orange and rue are species introduced during the colonial period (Table 2). Figure 3 illustrates the UV values across the three communities, showing three levels of importance: high (FL ≥ 20%), medium (19.3–6.6%) and low (4.9–1.6%). More than half of the species exhibited a FL value of 100% indicating strong cultural acceptance.

Table 2
Use value, fidelity level, Relative popularity level and Rank order of priority index for medicinal plants in three Mayan communities of the Yucatan Peninsula.

Species	Common name	Family	Medicinal use	Affected	UV	FL %	RPL	ROP
Diphysa yucatanensis	Ts´ uts´ uk	Fabaceae	*I, *VI	kids	0.607	51	0.31	15.99
Citrus aurantium	Naranja agria/Pak'al	Rutaceae	*III, *IV,*XXXI	kids, adults	0.426	85	0.36	30.52
Ehretia tinifolia	Roble	Boraginaceae	*I, *XII, *III	kids, adults	0.393	71	0.28	19.74
Ruta graveolens	Ruda	Rutaceae	*XII, XXXIII, *I, *II	all	0.393	79	0.31	24.66
Momordica charantina L.	Cundeamor/Lal much	Curcubitaceae	*XVI, IV, *X	kids, adults	0.311	79	0.25	19.41
Psidium guajava L.	Guayaba	Myrtaceae	*III,IV	adults	0.279	47	0.13	6.17
Tradescantia spathacea Sw.	Maguey morado	Commelinaceae	*I, *VI,* II	kids	0.262	88	0.23	20.08
Bunchosia swartziana Griseb	Siipche'	Malpighiaceae	X, *XIX, *XVI	kids, adults	0.262	63	0.16	10.25
Hamelia patens Jacq	K'anaam	Rubiaceae	VIII, *XXXIV	adults	0.246	73	0.18	13.22
Mentha citrata Ehrh.	Hierba buena	Lamiaceae	V, *III, *XXI,VII	kids, adults	0.230	79	0.18	14.17
Piper auritum	Hoja santa	Piperaceae	*XIX, *X	kids	0.230	57	0.13	7.49
Mentha piperita	Menta	Lamiaceae	*I, VIII, XX, XXI	all	0.230	79	0.18	14.17
Parthenium histerophorus	Altaniza	Asteraceae	VIII, *III, V	all	0.230	79	0.18	14.17
Manilkara zapota (L)	Zapote	Sapotaceae	XXXIX	women	0.197	92	0.18	16.53
Piscidia piscipula (L.) Sarg.	Ja'bin	Fabaceae	IV,*XVI	all	0.197	67	0.13	8.74
Chenopodium ambrosoides	Epazote	Chenopodiaceae	XXIX, *I	all	0.197	100	0.20	19.67
Melissa officinalis	Toronjil	Lamiaceae	*III, V	all	0.180	82	0.15	12.07
Clinopodium brownei (Sw.) Kuntze	Polejo	Lamiaceae	*I, *XII, *VI	kids, adults	0.164	80	0.13	10.49
Plectranthus amboinicus (Lour.) Spreng	Oregano grueso	Lamiaceae	*III, V	all	0.164	80	0.13	10.49
Ocimum basilicum L.	Albahaca	Lamiaceae	IV,*XV	adults	0.164	80	0.13	10.49
Mosannona depressa (Baill.) Chatrou	Elemuy	Annonaceae	*XVI,*III,*XVI,*XIV	adults	0.164	100	0.16	16.39
Spondias purpurea	Ciruela	Anacardiaceae	IV, *X	kids	0.164	60	0.10	5.90
Nicotiana tabacum L.	Tabaco	Solanaceae	*lll,VII, *XVII	all	0.131	100	0.13	13.11
Aloe vera	Sábila	Liliaceae	XXI, VIII	all	0.131	88	0.11	10.04
Bursera simaruba (L.) Sarg	Chacaj	Burseraceae	IX	all	0.115	86	0.10	8.43
Cecropia peltata L.	Guarumbo	Urticaceae	XXXIII,*XVI,	all	0.115	100	0.11	11.48
citrus aurantifolia	limón	Rutaceae	*XII,*III	all	0.115	100	0.11	11.48
Bougainvillea xbuttiana	Bugambilia	Nyctanaceae	*X	kids	0.115	100	0.11	11.48

Species	Common name	Family	Medicinal use	Affected	UV	FL %	RPL	ROP
Brosimum alicastrum Sw. ssp. Alicastrum	Ramón	Moraceae	IX, VIII	all	0.098	83	0.08	6.83
Senna.ssp	Xkan lol	Fabaceae	*I	kids	0.098	100	0.10	9.84
Cedrela odorata L.	Cedro	Meliaceae	XVI	all	0.098	100	0.10	9.84
Punica granatum L.	Granada	Punicaceae	XXXV	all	0.098	67	0.07	4.37
Bauhinia divaricata L.	Pata de vaca	Fabaceae	*XII	all	0.066	75	0.05	3.69
Jatropha gaumeri Greenm	Pomolché	Euphorbiaceae	XXXIII	all	0.066	75	0.05	3.69
Parmentiera aculeata (kunth) Seem	Pepino kat	Bignonaceae	*XVI	all	0.066	100	0.07	6.56
Tithonia diversifolia (Hemsl.) A. Gray	Árnica	Asteraceae	IX	all	0.066	100	0.07	6.56
Allium schoenoprasum	cebollina	Amarillidaceae	*XV	all	0.066	100	0.07	6.56
Bixa orellana L.	Achiote	Bixaceae	VIII	all	0.066	100	0.07	6.56
Zingiber officinale Roscoe	Genjibre	Zingiberaceae	VIII, *XV	all	0.066	100	0.07	6.56
Anthurium sclechtendalii	Boobtunich	Araceae	*IV, *XXIV	all	0.066	100	0.07	6.56
Cymbopogon citratus (DC.) Stapf	Zacate limón	Poaceae	*IV	all	0.066	100	0.07	6.56
Moringa oleifera	Moringa	Moringaceae	X, *IV	all	0.066	100	0.07	6.56
Critonia aromatisans (DC.) R.M. King & H. Rob	Chiople	Asteraceae	V	all	0.049	100	0.05	4.92
Asclepias curassavica L.	Pool kuts	Apocynaceae	XXXIII	all	0.049	100	0.05	4.92
Croton chichenensis Lundell	Xiquim burro	Euphorbiaceae	XI	all	0.049	100	0.05	4.92
Urera baccifera (L.) Gaudich. ex Wedd	Ortiga	Urticacea	*III, *XXXII, XXIX	all	0.049	100	0.05	4.92
Artemisia bulgaris L.	Si´sim	Asteraceae	*XXIV	all	0.049	100	0.05	4.92
Morinda citrofolia L.	Noni	Rubiaceae	*XIII	all	0.049	100	0.05	4.92
Zea mayz L.	Elote	Poaceae	*IV	all	0.049	100	0.05	4.92
Plantago major L.	llantén	Plantaginaceae	*XXXVI	all	0.033	100	0.03	3.28
Cissampelos pareira L.	Xpetetum	Menispermaceae	*VI	kids	0.033	100	0.03	3.28
Thevetia ahouai (L.) A. DC.	Huevo de perro	Apocynaceae	*XV	all	0.033	100	0.03	3.28
Ceiba schottii	Pochote	Malvaceae	II,	kids	0.033	100	0.03	3.28
Justicia spicigera	Riñonina	Acanthaceae	II	kids	0.033	100	0.03	3.28
Pilocarpus racemosus Vahl	Tamkasche		*XV	all	0.033	100	0.03	3.28
Petiveria alliacea L	Payche	Phytolaccaceae	*III, IV, *XXXII	all	0.033	100	0.03	3.28
Enriquebeltrania crenatifolia/krugiodendron	Chintok		VII	kids	0.033	100	0.03	3.28
Mimosa pudica L.	Dormilona	Fabaceae	XXXIII	all	0.033	100	0.03	3.28
Manihot esculenta	Yuca	Euphorbiaceae	I,VI	kids	0.033	100	0.03	3.28
Cordia dodecandra DC.	Ciricote	Boraginaceae	IV	all	0.033	100	0.03	3.28

Species	Common name	Family	Medicinal use	Affected	UV	FL %	RPL	ROP
Hibiscus poeppigii (Spreng)	Tulipan de monte	Malvaceae	*III	all	0.033	100	0.03	3.28
Plectranthus hadiensis	vaporub	Lamiaceae	*VIII	all	0.033	100	0.03	3.28
Kalanchoe integra	Belladona	Crassulaceae	*XV	all	0.016	100	0.02	1.64
Tabernaemontana amygdalifolia Jacq	Utsu'peek'	Apocynaceae	XXXVII	kids	0.016	100	0.02	1.64
Guazuma ulmifolia Lam	pixoy	Malvaceae	*IV	all	0.016	100	0.02	1.64
Annona muricata	Guanabana	Annonaceae	*IV	all	0.016	100	0.02	1.64
Cocos nucifera L.	Coco	Arecaceae	*IV	all	0.016	100	0.02	1.64
Helicteres baruensis Jacq	Tsutup	Malvaceae	IV, *XXX	all	0.016	100	0.02	1.64
Hibiscus rosa-sinensis L.	Tulipan	Malvaceae	XXXVIII	all	0.016	100	0.02	1.64
Persea americana Mill	Aguacate	Lauraceae	XI	all	0.016	100	0.02	1.64
Ocimum campechianum Mill	Kakaltuun	Lamiaceae	*VIII	all	0.016	100	0.02	1.64
Capsicum chinense	Chile habanero	Solanaceae	*XVIII	all	0.016	100	0.02	1.64
Catharanthus roseus	Vicaria blanca	Apocynaceae	*IV	women	0.016	100	0.02	1.64
kalanchoe daigremontiana Raym.	Mala madre	Crassulaceae	*XV	all	0.016	100	0.02	1.64
Curcuma longa	Curcuma	Zingiberaceae	*III	women	0.016	100	0.02	1.64
Agave americana	Henequen	Agavaceae	*XXI	women	0.016	100	0.02	1.64
Byrsonima bucidaefolia standl	sakpaj	Malpighiaceae	*IV	all	0.016	100	0.02	1.64
Phyllanthus amarus Schumach. & Thonn	Pich ojo		*I	kids	0.016	100	0.02	1.64
Byrsonima crassifolia	Nance/Chi'	Malpighiaceae	*IV	all	0.016	100	0.02	1.64
Cnidoscolus aconitifolius (Mill) I.M. Johnst	Chaya de monte	Euphorbiaceae	*III, XXIX	all	0.016	100	0.02	1.64
Arrabidaea floribunda (Kunth) Loes	Ek´kiix	Bignonaceae	XXXV,*III	Women	0.016	100	0.02	1.64
Aristolochia maxima Jacq	Guaco	Aristolochiaceae	VIII	all	0.016	100	0.02	1.64

UV = Use value; FL = Fidelity level. The diseases are cited according to the definition given by the interviewees, *culture-associated diseases: Evil eye *mal de ojo* (I), Diabetes (XVI), umbilical beat *cirro* or *tip'te* (XXXI), bad air *mal viento* (II), Lice (XVII), gastrointestinal blockage *empacho* (XXXII), Colic (III), skin burn for *chechem -Metopium brownei-* (XVIII), Fever (XXXIII), Diarrhea (IV), Scabies (XIX), Sore throat (XXXIV), Vomit (V), Covid-19 (XX), Inflammation (XXXV), Cold sweat *sudor frío* (VI), clogged blood *pasmo en sangre* (XXI), Asthma (XXXVI), frignt *susto* (VII), Fibroids (XXII), Apraxia (XXXVII), Dry cough (VIII), Vaginal infection (XXIII), Cancer (XXXVIII), cough with phlegm (IX), Thrush (XXIV), Rash (X), Urinary infection (XI), pregnancy pain (XXVI), headache (XII), pain in wounds (XXVII), rheumatism (XIII), dry eyes (XXVIII), pain in the ear (XIV), wounds (XXIX), kidney stones (XV), early birth (XXX).

The cultural significance of each medicinal plant species was assessed using the Relative Popularity Level and Rank Order of Priority (ROP) indices. RPL measures the frequency of use and overall popularity of a species, while ROP evaluates the correlation between Fidelity Level (FL) and RPL, offering insights into the cultural importance of each plant. An ROP value exceeding 20 generally indicates species with a high FL, typically above 50. Table 3 lists the five most popular species, each cited by more than ten informants, which are considered culturally significant. These species include *Diphysa yucatanensis*, used to treat conditions like the evil eye and cold sweat;

Momordica charantina for diabetes; *Ehretia tinifolia* for diarrhea and rash; *Ruta graveolens* for a variety of ailments, including the evil eye, colic, and headaches; and *Citrus aurantium*, commonly used for colic and vomiting.

3.3 Herbal diversity in the orchards

Herbal diversity was assessed by collecting plants from ten plots, with four in the Kantemó and six in Kancabchen. Unfortunately, due to political issues, sampling could not be conducted in Tigre Grande. The Jaccard index was used to compare species diversity among the plots. The analysis revealed the highest similarity between plots 2 and 10 (IJ = 0.409) and between plots 2 and 6 (IJ = 0.406). In contrast, the lowest similarity was observed between plots 3 and 7 (IJ = 0.192) and between plots 5 and 8 (IJ = 0.15), indicating less than 20% similarity in species diversity between these plots (Appendix 2).

4. Discusion

Inhabitants perceive herbal medicine as the primary resource for treating common diseases within their communities. The most frequently mentioned conditions were chronic-degenerative diseases, cited by 22% of informants, followed by gastrointestinal diseases, mentioned by 21%. Culturally associated diseases, reported by 7% of respondents, are conditions typically treated by herbalists or traditional doctors. These findings align with the results of Vázquez et al. (2011), who identified diarrhea, colic, cough, dysentery, and stomach pain as the predominant ailments in rural communities.

Diabetes emerged as one of the most commonly reported diseases across the three communities, affecting 38% of the interviewed population, particularly the elderly. This finding is consistent with Alvarado-Osuna et al. (2001), who reported that 75% of the Otomí indigenous people in Yosphí and El Rincón, Querétaro, suffer from diabetes mellitus and hyperlipidemia. Juárez-Ramírez et al. (2014) further highlight that in Mexico, health disparities are most evident in chronic-degenerative diseases, disproportionately affecting indigenous adults. This trend is attributed to dietary shifts in indigenous and rural populations, with increased consumption of industrialized foods in recent decades, coupled with inadequate health and sanitation services (Ferrari et al. 2004). Additionally, diarrhea and vomiting were frequently reported, mirroring findings from other indigenous regions in Colombia, Chile, and Argentina, as documented by Molares and Ladio (2009) and Castillo et al. (2012).

The findings demonstrate that the use of medicinal plants remains a crucial aspect of healthcare in the three Maya communities of Kantemó, Tigre Grande, and Kancabchen in the Yucatán Peninsula. Informants identified 82 plant species from 43 families with medicinal uses. Of these, 5 species are used for treating chronic-degenerative diseases, 27 for gastrointestinal issues, and 13 for culturally associated ailments. These results are consistent with Zamora et al. (2009), who documented 79 medicinal plant species in southern Yucatán, and Anderson et al. (2005), who reported 261 species with medicinal uses in the central-western Yucatán Peninsula, although their study primarily focused on the knowledge of traditional healers.

Over the past decade, quantitative methods have become valuable tools for assessing the extent of knowledge and detecting changes in traditional knowledge within rural and indigenous populations (Benz et al. 2000; Camou-Guerrero et al. 2008; Jorand 2008; La Torre-Cuadros and Islebe 2003). The findings of this study align with those of Camou-Guerrero et al. (2008) in Chihuahua, La Torre-Cuadros and Islebe (2003) in Quintana Roo, and Santiago Martínez (2018) in Oaxaca, where variations were observed in the number of species and their reported uses. These differences may stem from factors such as the level of knowledge about local flora in each region and the extent to which this knowledge is still actively practiced.

In the three communities, 82 medicinal plant species were identified, with five species showing particularly high use values: *Ehretia tinifolia* (0.3934), *Momordica charantina* (0.3115), *Ruta graveolens* (0.3934), *Citrus aurantium* (0.4262), and *Diphysa yucatanensis* (0.6066). Gómez et al. (2016) classify these values as high, indicating that these species have a broad range of medicinal applications. Additionally, species such as guava (*Psidium guajava*), purple maguey (*Tradescantia spathacea*), *Siipche* (*Bunchosia swartziana*), and *K'anaan* (*Hamelia patens*) also hold significant herbal use value in the communities, each serving various medical purposes. According to Camou-Guerrero et al. (2008), UV values between 0.01 and 0.06 are considered low, typically indicating less frequent use. However, Gómez García and Toscano (2006) caution that the UV index might introduce bias if the diverse medicinal applications of a single species are not adequately considered.

The plant species used to treat diabetes in Kantemó, Tigre Grande, and Kancabchen exhibit high UV values, particularly *Momordica charantina* and *Bunchosia swartziana*. However, the highest UV values were recorded for species used to address conditions affecting the broader population, including culturally significant ailments. For instance, *Diphysa yucatanensis* (0.60) and *Ehretia tinifolia* L. (0.39) are employed to treat cold sweats, the evil eye, and evil winds, reflecting their strong cultural and medicinal importance.

The Fidelity Level (FL) index helps identify plant species that are highly valued by the community, while the Relative Popularity Level (RPL) and Rank Order of Priority (ROP) indices provide additional insights into the popularity and cultural significance of these species. Notably, the most highly preferred species differ from the most popular ones, with popularity often aligning with high UV values. While FL can sometimes overestimate a species' importance, ROP offers a more nuanced adjustment. For example, *Citrus aurantium* has an FL of 85 but achieves the maximum ROP of 30, indicating high values across the UV, RPL, and ROP indices. This species is both popular and widely used in all three communities. Conversely, *Diphysa yucatanensis* has the highest UV (0.60) among all species, yet its FL is only 50, lower than species like *Nicotiana tabacum* (UV = 0.13), which has an FL of 100. Nevertheless, *Diphysa yucatanensis* has the highest RPL (0.31) and one of the highest ROP values (15), underscoring its cultural significance. Employing multiple indices allows for a balanced assessment of species that might otherwise be overvalued or undervalued.

The findings regarding useful plant species in the study area align with those of Gómez et al. (2016), who identified 91 species across 51 families, with bitter orange, rue, basil, pennyroyal, and lemon balm being particularly significant. These species were also highly valued by the inhabitants in the present study. Additionally, the use of bitter melon (*Momordica charantia* L.) for treating diabetes aligns with the findings of Toscano (2006). This study integrates both botanical and cultural aspects, utilizing a qualitative methodology that was well-suited for deeply exploring the meaning and importance of medicinal plants within the context of therapeutic herbal medicine.

The data from the three communities reveal a nuanced distribution of herbal knowledge, with older individuals, particularly women, serving as the primary custodians and users of herbal remedies. Informants aged 45 to 80 years demonstrated the most extensive knowledge of plant species, while younger individuals were familiar with fewer species. These findings are consistent with those of Ávila-Uribe et al. (2016), who reported that older adults (65 to 95 years) in central Mexico possess more extensive knowledge of medicinal plants. Similarly, Carbajal-Esquivel et al. (2012) highlighted the significant role of older adults, especially women, in preserving and using ethnobotanical knowledge within indigenous communities. The positive correlation between age and herbal knowledge was strong across the three communities (Fig. 2). Although younger people possess less knowledge, it is noteworthy that they continue to seek out and use medicinal plants.

Hopkins and Stepp (2012) highlight the significance of researching medicinal plants not only to identify effective remedies but also to understand the factors that contribute to the conservation, transformation, or loss of this knowledge. In the present study, the analysis of 10 backyards (plots) revealed a total of 55 plant species, making these areas the most common source of medicinal plants. This prevalence may be attributed to the proximity of backyards to residences, which allows for easy cultivation of commonly used herbaceous plants. These findings are consistent with Paredes-Flores et al. (2007), who noted that useful flora is often found within garden spaces. Similarly, White-Olascoaga et al. (2013) reported that family agroecosystems are the primary sites for collecting medicinal plants. The data from the three communities indicate that while some medicinal plants are collected from natural systems, family plots or gardens remain the preferred locations for cultivation and collection.

Medina et al. (2018) suggest that the declining use of medicinal plants could be attributed to the increasing availability of patent medicines. However, the inaccessibility of health systems and the limited provision of pharmaceuticals in some areas may be driving a renewed interest in traditional herbal remedies. It is possible that enhanced government focus and widespread health campaigns have strengthened the public health system's role in treating chronic diseases in the three communities, potentially contributing to the reduced reliance on medicinal plants for conditions like diabetes.

The testimonies collected in this study not only provide a semi-quantitative perspective on the use and significance of medicinal plants but also reveal shifts in health perceptions and practices within the communities. According to Jorand (2008), these changes are largely due to the fragmentation and restriction of plant use within household groups. García de Alba et al. (2012) further note that urbanization and industrialization have increasingly limited the practice of herbal medicine, relegating knowledge that requires experience and skill in its use and management. The interviews conducted in this research identified three primary factors contributing to the decline of herbal knowledge:

1) Changing Generational Attitudes: Younger generations show less interest in traditional plant-based remedies, reflecting broader cultural shifts in health practices. Notably, recognition of expertise in herbal medicine varies, with only one informant self-identifying as a traditional herbalist, while in other communities, such recognition comes from communal acknowledgment.

2) Accessibility and Promotion of Commercial Medicines: The widespread availability and aggressive marketing of commercial pharmaceuticals offer a convenient, though often costlier, alternative to plant-based treatments. This has impacted the traditional use of herbal medicine.

3) Migration from Rural to Urban Areas: Migration to urban areas leads to a transformation in knowledge and lifestyle, with individuals often abandoning traditional practices in favor of the more accessible health options available in cities."

5. Conclusions

Medical herbalism remains a cornerstone of traditional medicine, yet knowledge about it is often fragmented and imprecise. In the communities of Kantemó, Tigre Grande, and Kancabchen, medicinal plants continue to play a crucial role in treating diseases, particularly chronic-degenerative conditions such as diabetes and hypertension, as well as gastrointestinal issues like diarrhea and vomiting. Although medicinal plants are still collected from natural environments, there is a growing preference for cultivating them in Maya home gardens, which supports in situ conservation and the sustainable use of these plants. The indices of use value and cultural importance proved effective as both quantitative and qualitative measures of herbal knowledge, helping to identify the most frequently used and culturally significant plants. This study found that while native species remain highly valued, introduced species are gaining increasing recognition and use.

While some authors, such as Leonti (2022), have criticized the use of ethnobotanical indices for their limited statistical rigor and perceived lack of informative value, the data presented in this study demonstrate that these indices, when combined with statistical analysis, can yield meaningful insights. The ethnobotanical indices used here effectively complemented the statistical tools, providing valuable information on the use and cultural significance of medicinal plants, the current perceptions of herbal medicine in the region, and the increasing use of introduced species. This study supports the argument that the concurrent use of statistical methods and ethnobotanical indices can be both practical and informative when their respective strengths are fully leveraged.

The economic and political shifts in the communities of the Yucatán Peninsula have significantly impacted the use and disuse of natural resources, leading to a gradual loss of traditional knowledge. Traditional Maya medicine is inherently dynamic, continuously adapting to global changes—whether beneficial or detrimental. This study provides crucial insights into the evolving practices of herbal medicine in the region, confirming a transformation in how these practices are applied. There is an urgent need to update ethnobotanical studies in the Yucatán Peninsula to better understand the shifting worldviews and to develop strategies aimed at preserving the biocultural heritage that has been a hallmark of the Maya civilization for millennia. Efforts should be made to recover and document traditional knowledge, particularly that which has been lost over time but remains essential for the treatment of various diseases.

Some authors strongly criticize the use of ethnobotanical indices (Leonti 2022), arguing that they have few statistical elements and provide little information. However, the data presented here include statistical analysis and the use of ethnobotanical indices; both complement and provide relevant information about the use and value of medicinal plants, the current use and perception of herbal medicine in the region, and the detection of the more frequent use of introduced species. We can argue that the simultaneous use of statistical tools and ethnobotanical indices is possible and useful if the strengths of both tools are utilized.

The economic and political changes occurring in the communities of the Yucatan Peninsula influence the use and disuse of natural resources, and various changes are reflected in the loss of knowledge. Traditional Maya medicine is constantly changing, is dynamic, and adapts to global changes, which can be positive or not. This work provides relevant data on how the use of herbal medicine in the region has changed and allows us to confirm that there is a transformation in practice. There is currently a strong need to update ethnobotanical studies in the region to understand how worldviews are changing to develop strategies to preserve the biocultural heritage that has distinguished the Maya area for millennia. It is possible to recover traditional knowledge of the use of medicinal plants, especially those that have been lost over time and are indispensable for treating diseases.

Declarations

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56. Appendice
57. Appendice 1 Jaccard index between the orchards of the Mayan communities of Kantemó (S1, S2, S3, S4) and Kancabchen

Figures

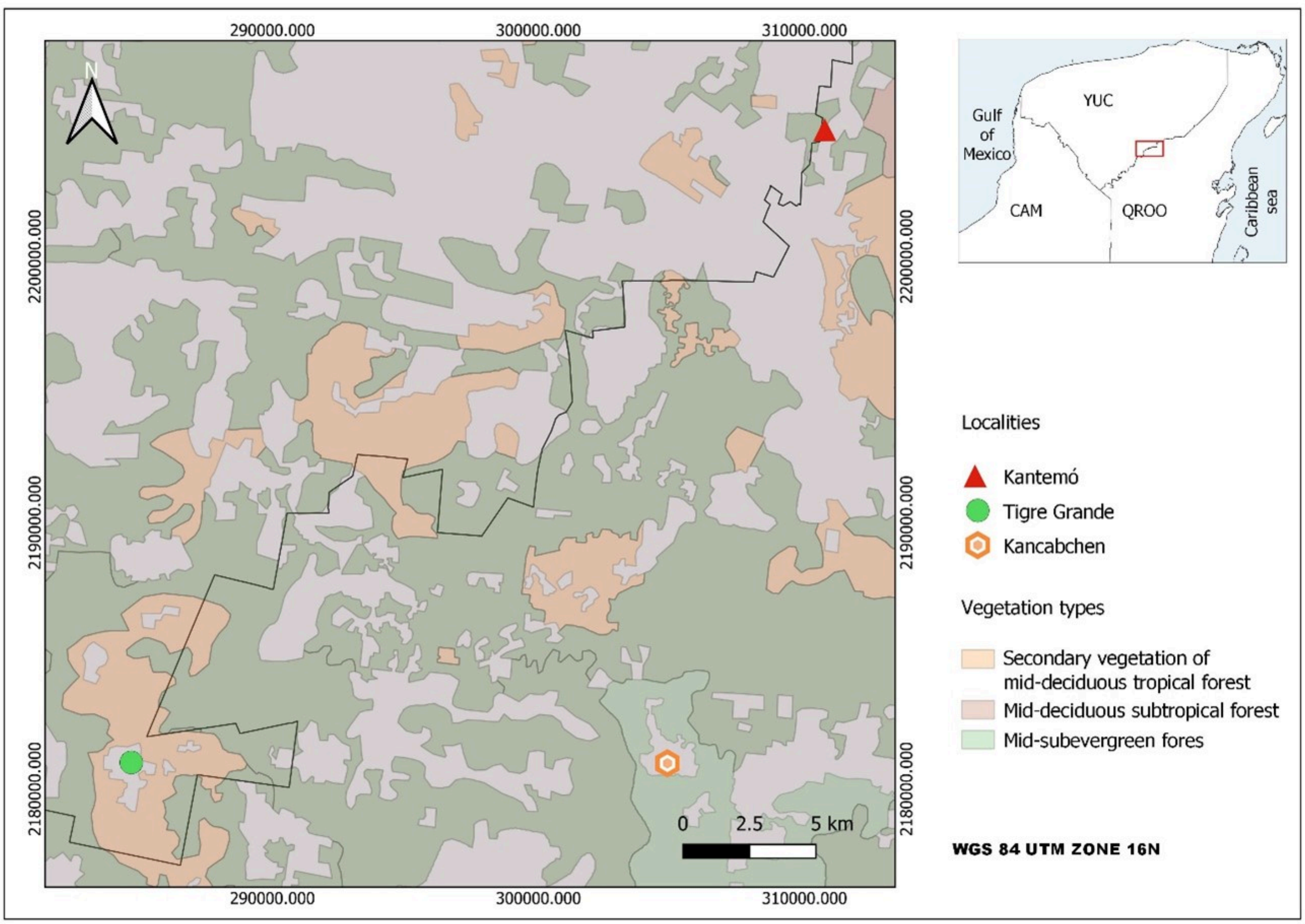

Figure 1

Location map of the three Yucatan Peninsula communities studied.

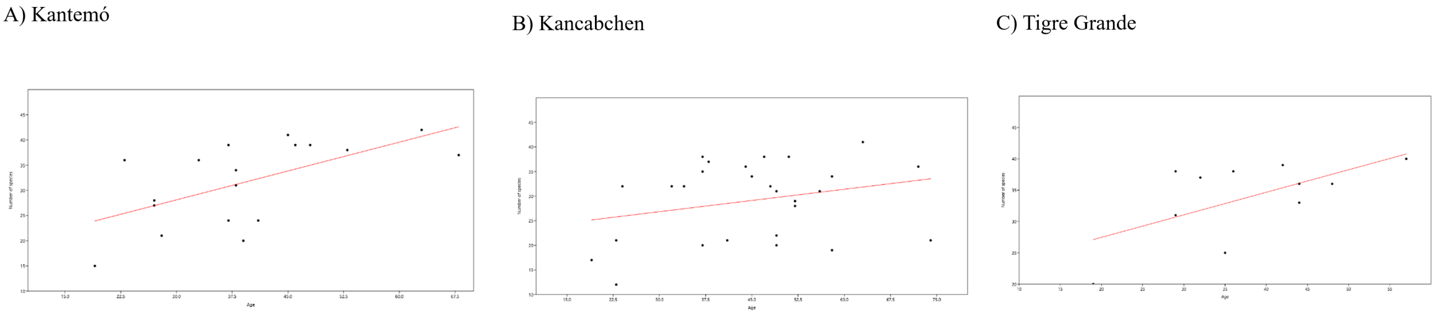

Figure 2

Correlation between the age of the informant and the number of medicinal plants known.

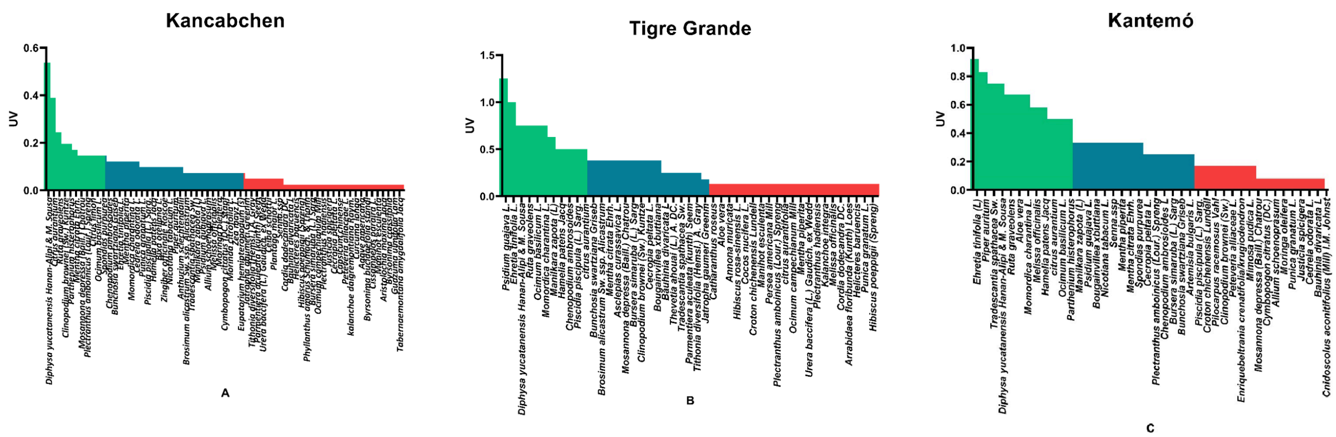

Figure 3

Use value index of the medicinal species in three communites of Yucatan Península. Green = high importance, blue = medium importance, pink = low importance.

Supplementary Files

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- Appendice1MooArguelloetal.2024.docx