Revista Etnobiología. Vol 18, Num. 3. Diciembre 2020. pp: 3-23 ISSNe 2448-8151; ISSN 1665-2703

Fecha de recepción: 30-junio-2020 Fecha de aceptación: 10-septiembre-2020

SOCIOECOLOGICAL BENEFITS OF A COMMUNITY-BASED RESTORATION OF TRADITIONAL HOME GARDENS IN GUERRERO, MEXICO

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ABSTRACT

Restoration of traditional agroforestry systems is gaining importance, as they provide viable and long-lasting solutions to the global socioecological crisis, especially in poor rural areas. In this study, we evaluated the motivation and socioecological benefits obtained from a community-based restoration project of traditional home gardens (THs); this was carried out by members of the Indigenous Non-Governmental Organization (INGO) Xuajin Me´phaa in the "La Montaña" region of Guerrero State, Mexico. We used 30 semi-structured interviews with farmers and field data collection of 30 THs (species abundance, diameter of woody species, the coverage area of non-woody species and alpha diversity index) and explored their ecological potential for promoting landscape connectivity. The main motivation for THs' restoration was food security and sovereignty. Most of reported species were used as food (39%), multipurpose issues (27%), spiritual needs (18%), medicine (11%), firewood (4%), and construction (1%). A total of 3,509 individuals belonging to 141 species were recorded, with an average of 23 ± 1 species and 117 ± 16 individuals per TH. The average alpha diversity index was high (H´=2.29 ± 0.11). Most of the total reported species were pollinated and dispersed by animals (91 and 57%, respectively). This paper highlights the various benefits of TH restoration projects in socio-ecologically fragile communities, especially when implemented through a community-based model.

KEYWORDS: food security, *La Montaña*, landscape connectivity, productive restoration, participatory action-research.

BENEFICIOS SOCIOECOLÓGICOS DE UNA RESTAURACIÓN COMUNITARIA DE HUERTOS TRADICIONALES EN GUERRERO, MÉXICO

RESUMEN

La restauración de sistemas agroforestales tradicionales está cobrando importancia, ya que proporciona soluciones viables y duraderas a la crisis socioecológica, especialmente en las zonas rurales pobres. En el presente estudio evaluamos la motivación y los beneficios socioecológicos obtenidos de un proyecto de restauración comunitaria de los huertos familiares tradicionales (THs), realizado por miembros de la Organización No Gubernamental

(ONG) ***Xuajin Me'phaa*** en la región de "La Montaña" del Estado de Guerrero (México). Realizamos 30 entrevistas semiestructuradas a propietarios y propietarias de traspatio; recopilamos información de la vegetación en 30 THs (abundancia y frecuencia de especies, diámetro de las especies leñosas, área de cobertura de las especies no leñosas e índice de diversidad alfa), y exploramos el potencial ecológico de los THs para promover la conectividad del paisaje. La principal motivación para la restauración de los THs fue la seguridad y soberanía alimentaria. Las especies halladas en los THs eran usadas como alimento (39%), para fines múltiples (27%), para satisfacer necesidades espirituales (18%), para medicina (11%), para leña (4%) y para construcción (1%). Registramos un total de 3.509 individuos pertenecientes a 141 especies, con un promedio de 23 ± 1 especie y 117 ± 16 individuos por TH. El índice medio de diversidad alfa fue alto (H'=2,29 $\pm$ 0,11). La mayor parte del total de las especies halladas eran polinizadas y dispersadas por animales (91 y 57%, respectivamente). En este estudio destacamos diversos beneficios que pueden obtenerse en proyectos de restauración de THs en comunidades socio-ecológicamente frágiles, especialmente cuando se ejecutan siguiendo un modelo comunitario.

PALABRAS CLAVE: Conectividad del paisaje, investigación-acción participativa, *La Montaña*, restauración productiva, seguridad alimentaria.

INTRODUCTION

All over the world, people are facing a serious socio-ecological crisis, which affects physical and economic access to food in terms of quantity and quality (food security [FAO, 2018]). The lack of food security and sovereignty lies on not just food production, but socioeconomic issues, including the purchasing power of wages, agricultural laws, cultural patterns, the resilience and biodiversity of production systems, climate effects, the sustainable use of ecosystems, genetic resources, etc.(FAO, 2018; 2019). Therefore, to provide viable and long-lasting solutions for this issue, as well as the degradation of ecosystem services in poor rural areas of developing countries, it is extremely necessary to promote productive systems that meet the ever-growing food demand while conserving biodiversity and being appropriate to the socioecological reality of each region.

In this sense, "productive restoration" proposes the use of culturally important multipurpose species that recovers soil productivity and helps to increase landscape connectivity, at the time it produces tangible goods for the local population through agroforestry and agroecology techniques (Altieri, 1999; Ceccon, 2013).

Home gardens are old-age agroforestry systems of subsistence crops to the farmer and their family (Viswanath *et al.,* 2019). They have been regarded as the agroecosystems that most imitate natural forests in terms of diversity and provide a wide range of ecosystem services (Mendieta and Rocha, 2007; Jose, 2009; Mattsson *et al.,* 2017), including mitigation and adaptation to climate change (Mbow *et al*., 2014).

In Mexico, home gardens are also result of a long history of management, since the pre-Columbian period; and play ecological, economic, and social functions (Vásquez-Dávila *et al.,* 2012; Moreno-Calles *et al.,* 2016a). They have also been the home of traditional processes of selection, domestication, diversification, and conservation of elements of flora and fauna, in close relationship with the preservation and enrichment of cultural values (Toledo and Barrera-Bassols, 2008). This is why they are also known as traditional home gardens (THs) and they may differ from one ethnic group to another in composition an structure (Berkes *et al.,* 2000; Toledo and Barrera-Bassols, 2008; Ruenes and Montañez, 2016). Mexico is home to 67 Indigenous ethnic groups (21% of population; CONAPO, 2016; SIC, 2019), and many of them maintain THs. However, most of the Mexican THs studies have been carried out in the southeastern, where the Mayan culture predominates (Vásquez-Dávila *et* *al.,* 2012; Moreno-Calles *et al.,* 2016a), while the THs from other ethnic groups are less known (Ordóñez-Diaz, 2018).

Guerrero is a state placed in Central Mexico and is the third poorest in the country (Forbes México, 2017). Its territory is divided into different regions, within which *La Montaña* stands out for its high levels of poverty (Balbuena-Ramírez *et al.,* 2018). Acatepec is an Indigenous municipality located in the *La Montaña* region and it is the third-poorest municipality in the Guerrero state: 97.6% of its total population was living in poverty by 2015 (CONEVAL, 2015). In addition, its landscape had suffered a constant and intense process of fragmentation due to conventional agricultural activities and firewood extraction by different Indigenous groups that have migrated to this area (Borda-Niño *et al.,* 2017a; Salgado *et al.,* 2017). This migration was result of territorial conflicts with neighboring municipalities that lasted through the beginning of this century (González, 2007).

The socioecological critical situation mentioned above, led some members of the local INGO ***Xuajin Me´Phaa*** to carry out productive restoration of 200 THs through a community-based action, which emphasizes involving the entire community in the planning and management processes (Borda Niño *et al.,* 2017b). The project consisted mainly of the enrichment of existing THs with both native and non-native species, some desired by the THs owners, and some proposed by the IONG directors and UNAM academics, who also participated in the community-based project (Hernández-Muciño *et al*., 2018). This approach aims to harmonize views among all its participants as well as prevent conflict between parties (Menzel *et al.,* 2012). Although this project has started since 2014, its results were still not evaluated. Therefore, three years after, the present study aimed to analyze the motivation of ***Me´phaa*** people to participate in this project; to characterize the plant structure and composition in restored THs, and to

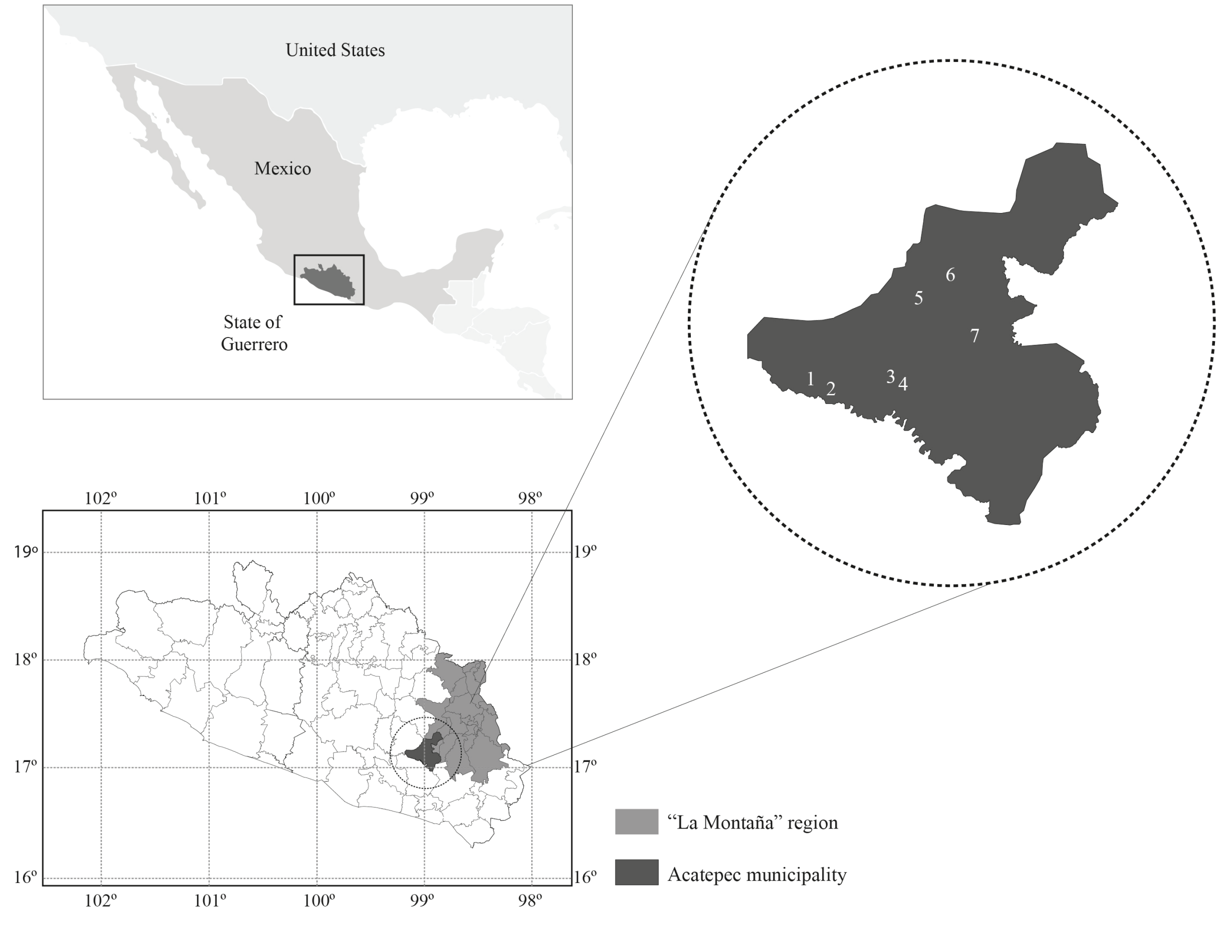

Figure 1. Location of study area. The numbers indicate the communities where we studied ***Me´phaa*** THs: 1) Plan de Gatica, 2) Escalerilla Zapata, 3) El Naranjo, 4) El Aguacate, 5) Alcamani, 6) Agua Tordillo, and 7) Xochitepec.

explore their ecological potential to promote landscape connectivity and biodiversity conservation.

METHODS

Study Site. The study was carried out during 2017 in the municipality of Acatepec, in the *La Montaña* region of Guerrero state, between 17º 00' and 17º 22' North latitude and 98º 49' and 99º 11' West longitude (Figure 1). This region has been populated by humans for approximately 2,000 years (Berrío *et al.,* 2006). It is currently home of Indigenous groups mostly engaged in subsistence agriculture like the "milpa", a traditional polyculture with corn, squash, and beans (Casas *et al.*, 1994).

Nearly 40% of the territory of Acatepec municipality is comprised of agricultural land, induced grasslands, bare soil, human settlements and roads; while 60% is composed by fragments of tropical deciduous forest and temperate forest. Most of these fragments (72%) was small (<21 ha) and considered as "open" by Borda-Niño *et al.* (2017a), due the intensive extraction of firewood.

The Indigenous Non-Governmental Organization (INGO) Xuajin Me'phaa, A.C. *Xuajin Me'phaa,* A.C. was created in 2002 by 13 communities of the region, with a staff of community technicians of ***Me'phaa*** origin (Hernández-Muciño *et al.,* 2018), an ethnic group also called *Tlapanecos* that originate from the central and southern area of Guerrero State, Mexico. Since 2008, they have been collaborating with the Regional Multidisciplinary Research Center of the National Autonomous University of Mexico (CRIM-UNAM, in Spanish), to achieving research and develop strategies that could improve the well-being of local people through a participatory action-research methodology (Ceccon, 2016; Borda-Niño *et al.,* 2017b; Hernández-Muciño *et al.,* 2018; Galicia-Gallardo *et al.,* 2019). One of the tangible results of this partnership was the project called "The forest of the grandparents (***Mbaá Yuskha*****,** in ***Me´phaa*** language): ***Me´phaa*** traditional home garden".

The project was accepted and carried out by members of the INGO for three main reasons: i) agroforestry practices are successful alternatives within the small scale production scheme, ii) the project integrated management practices compatible with their traditional knowledge, iii) such practices employed techniques consistent with the friendly use of natural resources and a collective concern about the currently degradation of natural resources in their region (Hernández-Muciño *et al.,* 2018).

Firstly, they carried out a participatory planning to locate where the THs would be restored and to choose the species that would be produced within the nurseries (Borda-Niño *et al.,* 2017b). CRIM-UNAM partners trained via workshops the technicians from the INGO in soil and water conservation, integrated livestock management, production of vegetables using plastic tunnels, and agroforestry systems. Subsequently, the INGO acquired and distributed some materials such as seedlings of plant species (selected by the INGO members in the planning phase), agricultural tools, materials for building irrigation infrastructure, and fences for enclosing farmed livestock and delimiting THs areas.

Assessing the Motivation for THs Restoration. We carried out 30 semi-structured interviews in seven communities with the goal of understanding the ***Me´phaa***´s motivation for restoring the THs. We asked *what do you have your TH for? Why have you been planting in your TH*? The interviews required translators since few interviewees spoke Spanish. As an indirect mechanism to identify other motivations, we asked them about the use(s) given to each species. We organized their responses into six categories: food, spiritual (as ornamental, for festivals and beliefs), medicine, construction, firewood and multipurpose. We presented the use of each species in the table of species found within the 30 THs, together with its origin status, pollination and dispersal syndrome (Annex 1).

We asked extra questions depending on the interviewees' answers in order to determine if they were reaching their goals or not; we asked about the periods in which plant species could be harvested for food, as well as which products from their THs could be sold by the time of the study.

Assessing Plant Composition and Structure of the Restored THs. We chose 30 ***Me´phaa*** THs from seven communities to evaluate the composition and plant structure. The choice was made based on the availability of their owners to participate on the day of the visit. We did not consider seasonal food plants (vegetables), because they had been harvested by the time of the field visit. In each TH we measured the area and identified the species based on existing floristic lists from the region (Allen, 1945; Maas and Chatrou, 1995; Serviss *et al*., 2000; Hammel *et al*., 2003, 2014; Fonseca and Medina-Lemos, 2012; León, 2014; Martínez and Fonseca, 2017). We also measured the diameter at breast height of woody species and the coverage area of the non-woody species.

To determine the importance of each species in the THs, we calculated the Relative Importance Value Index (RIVI%; McIntosh, 1978) for each species using the following formula:

$$\text{RIVI\%} = \frac{\text{relative abundance} + \text{relative frequency} + \text{relative dominance}}{3} * 100$$

Where:

$$\text{Relative abundance} = \frac{\text{abundance of species } i}{\text{total abundance of all species}} * 100$$

$$\text{Relative frequency} = \frac{\text{frequency of species } i}{\text{total frequency of all species}} * 100$$

$$\text{Relative dominance} = \frac{\text{dominance of species } i}{\text{total dominance of all species}} * 100$$

Dominance was calculated differently for woody and non-woody plants. For non-woody species, dominance was the coverage area, calculated as the area of an ellipse (A):

$$A = \pi \, \mathrm{a} \, \mathrm{b}$$

Where:
a= length of ellipse semi-major axis
b= length of ellipse semi-minor axis
For woody species, the basal area (BA) was used to represent dominance. It was calculated using the following formula:

$$BA = \left(\frac{DBH}{2}\right)^2$$

Where: DBH= diameter of breast height
We determined the alpha diversity (H´) of each community using the Shannon Diversity Index (Shannon and Weaver, 1963):

$$\mathrm{H}' = \sum_{i=1}^{n} pi \, \ln pi$$

Where:

$$pi = \frac{\text{number of individuals of species } i}{\text{total number of individuals of all species}}$$

A non-parametric Spearman (rho) correlation analysis was conducted between alpha diversity (Shannon Diversity Index) and the years that the INGO has supported THs owners with seedlings. Finally, we calculated the Pielou (J´) Evenness Index to estimate the alpha diversity uniformity of each community (Pielou, 1969):

$$J' = \frac{\mathrm{H}'}{\mathrm{H}' max}$$

Where:

H´= Shannon Diversity Index
H´ max= natural logarithm of S
S= number of species

Exploring the Potential of the Restored THs to Promote Landscape Connectivity and Biodiversity Conservation. We looked up the origin status (autochthonous or allochthonous), and the pollination and dispersal syndromes of each species recorded in the 30 THs (Annex 1). For this purpose, we used the information available in the species sheets (http://www.conabio.gob.mx/institucion/proyectos/resultados/J084_Fichas%20de%20Especies.pdf.) and the *EncicloVida* platform (http://enciclovida.mx) created by the Mexican National Biodiversity Commission (CONABIO, in Spanish), as well as literature references. We also considered the presence of the species in the surrounding native forest fragments as native species in the context of *circa situm* conservation (Boshier *et al.,* 2004).

Additionally, we analyzed the potential of THs to promote biodiversity conservation in a fragmented landscape of the study by comparing the indices of alpha diversity (H´) from woody species found in the THs versus those found by Borda-Niño (2013) in patches of native vegetation of Acatepec municipality. This information was organized by altitudinal intervals: i) lowest interval (520–1071 m.a.s.l., tropical deciduous forest, ii) medium interval (1072–1606 m.a.s.l., pine-oak forest), and iii) highest interval (1607–2606 m.a.s.l., coniferous forest [Table 2]).

RESULTS AND DISCUSSION

Motivation for THs Restoration. ***Me´phaa*** people were initially nomadic (González, 2007) until the municipality of Acatepec was founded in 1285. Since then, they have managed THs through many generations; as new families were formed through marriage they received land to build their house, which they then surrounded with a home garden. The interviewees replied that their ancestors always had THs around their homes, that is why the project was called "The forest of the grandparents (***Mbaá Yuskha*****,** in ***Me´phaa*** language): ***Me´phaa*** traditional home garden" (Figure 2). When interviewees arrived at their current residence, 13% of the plots that were converted to THs was used for conventional agriculture, and 87% was part of the forest. At the THs early age, they hosted just a few trees, land was quite vulnerable to erosion as it was on sloping terrains and had received agrochemicals.

THs owners began to plant species that they obtained mainly locally; 83% of the species that were introduced came from areas closed to the THs, from neighbors as gifts and barter, from the forest patches, and also from the INGO nursery, while maintaining some others that

Figure 2. Pictures of some of the THs studied. The two above belong to Alcamani and the two below to Plan de Gatica.

naturally regenerated inside the THs (17% of the species). Introduction of seedlings was not the only restoration strategy implemented, the participants also built water and soil conservation trenches. In fact, they elaborated their own spatial and temporal planning for their home garden, manipulating the patterns and processes of ecological succession to produce a desired species composition and structure (Borda-Niño *et al.*, 2017b; consult Aguirre [2018] to see vertical structures of vegetation found in ***Me´phaa*** THs). To date, they have been participating in training workshops about agroforestry and agroecological techniques, microtunnel production, composting, soil, water, flora, and fauna conservation. They said they had restored their THs "for the family to eat healthy, to not spend money and to sell".

We detected a preference for edible species over the non-edible species; 39% of the species were used as food. Interviewees had introduced animals with the same purpose: 90% of them housed chickens, 50% pigs, and 17% goats. Pigs and goats were eaten just once or twice per year, so the vast majority of animal food in the THs was chicken meat and eggs. From what the interviewees said, we inferred that their main source of food comes from their THs (fruits, tubers, vegetables, eggs, and chickens). They also cultivated maize (*Zea mays*) and beans (*Phaseolus vulgaris*) in their "milpa" plots, and sporadically bought packaged dry soup, chilli, cheese, and eggs in the community store. The animal food produced in THs was mostly restricted to chicken meat and eggs, which has been proposed as the best source of nutrients after breast milk (Surai and Sparks, 2000); therefore, it could be considered that THs provide valuable nutrients to their holders.

After food resources, *multipurpose* was the second most important use for adding plants to ***Me´Phaa*** THs (27%), followed by *spiritual* use (18%) to decorate the house, the church and for religious festivities and beliefs. Eleven percent of the species were used as a *medicine*, 4% for *firewood* and 1% for *construction*. Hence, the motivation to restore the traditional home gardens of ***Me´phaa*** people from *La Montaña* were to satisfy various material and spiritual needs. Nevertheless, their main motivation was food security. The priority of one category of *species-use* as above others has been explained in other studies by the socio-economic level of the owners (Castiñeiras *et al.,* 2002) and the ethnic identity (Neulinger *et al.,* 2012). Among the ***Me´phaa*** people, the priority for food security could be explained by the almost hundred percent of poverty found in the Acatepec municipality, linked to the high percentage of people (40.5%) that suffer hunger within Guerrero State (CONEVAL, 2015). ***Me´phaa*** communities in La Montaña have been widely recognized with high level of social lag and marginalization; they do not have access to health services, schools, paved roads, telecommunications, or processed food (CONEVAL, 2015; Ceccon 2020).

Interviewees reported that some plant species cultivated within the THs allowed them to have food all year round: vegetables were harvested from May to September, and some edible fruits species, such as bananas (*Musa* spp. L.), lime (*Citrus aurantifolia* Christm) and papaya (*Carica papaya* L.) are available throughout the year. This sustainability in the food supply could be explained by the diversified production, which is the basis of production in THs and other agroforestry systems (Mendieta and Rocha, 2007). Our results support previous findings that emphasize food security as THs main function in poor areas (Torquebiau, 1992; Sunwar *et al.,* 2006; Gasco, 2008; Galhena, 2013; Moreno-Calles, 2016a). Nevertheless, THs have also been highlighted as providers of cultural services (Calvet-Mir *et al.,* 2012, Moreno-Calles, 2016b). Some studies have reported cases in which ornamental use was more prevalent than food use in some Mexican THs (Rico-Gray *et al.,* 1990; Bautista *et al.,* 2016). In *La Montaña*, the *spiritual* use (as ornamental, for festivals and beliefs) was the third most important category of use reported among the interviewees (18%). This result could be explained by the ***Me´phaa*** people's strong cultural roots, and a deep sense of identity and resistance, perhaps encouraged by their long exposure to land conflicts, and violence that have exacerbated their poverty status (González, 2007) and has turned them to be the most organized ethnic group in the area in terms of religious festivities and productive associations (Nicasio, 2003).

Commercialization was not the main interest of the interviewees to restore their THs, but a secondary. As they responded in the interviews, they restored their THs "for the family to eat healthy, to not spend money and to sell". At the moment of the present study, just a few individuals generated food surpluses for exchange and commercialization. The scarce food surplus available in the THs to market might be influenced by a combination of factors: the average young age of the THs (11 years); the short period of being restored (3 years), and the clear identified needs of these communities which were food and water security, medicine and multipurpose species to strengthen autonomy and domestic organization instead of looking for agribusiness systems (Hernandez-Muciño *et al.*, 2018).

Plant Composition and Structure of the Restored THs. The number of species hosted in home gardens has been explained by various socioecological factors, such as agroecology, geography, the size of home gardens, and traditional culture (Kumar and Nair, 2004; Ruenes and Montañez, 2016). In ***Me´Phaa*** THs, a high number of species and individuals were found in small areas (464.5 ± 59 m^2 per home garden): 23 ± 1 species and 117 ± 16 individuals per home garden, and 2658 ± 74 individuals/ha. In fact, the total number of species recorded in ***Me´phaa*** THs (141) was higher than the average (122 species) found by Moreno-Calles *et al.* (2016a) in a meta-analysis of 95 local studies of THs from Mexico. Our results suggests that the high richness of species and individuals might be the outcome of an intensive exchange of species and propagules among local neighbors (aspect mentioned by interviewees), a consequence of the very high social capital (8.8 from 10) found in the study region by Galicia-Gallardo *et al.* (2019), which means that the ***Me´Phaa*** people based their relationships on trust and reciprocity (Ostrom and Ahn, 2003).

The value of the RIVI% in ***Me´phaa*** THs was determined by the interests that people had in a given species; generally, owners planted more individuals of species whose products they were interested in selling or exchange in addition to self-consumption. The non-woody and woody species with the highest RIVI were edible: banana (*Musa* spp. L., 55%) and mango (*Mangifera indica* L., 16%), respectively (Figure 3).

The community with the highest diversity (H´) and evenness (J´) of plant species was El Naranjo (H´ = 3.54 ± 0.13; J´= 0.86, respectively; Table 1), while the community with the lowest diversity (H´) and evenness of plant species (J´) was Xochitepec (H´ = 1.79 ± 0.44; J´= 0.46 respectively), the closest community to the town. In this case, the town makes it more accessible, making it more feasible for the THs owners to sell surplus products, which could encourage increased dominance of marketable products, such as banana, pineapple, papaya, and coffee, reducing the alpha diversity. These results agree with studies that have shown that the proximity to markets and sources of employment generally reduces the biodiversity and increases dominance of specific species to be sell (Kehlenbeck and Maass, 2003; Landreth and Saito, 2014).

The average alpha diversity index recorded in ***Me´Phaa*** THs was high (H´=2.29 ± 0.11) and this variable was positively correlated with the years each THs started to receive seedlings from the INGO (rho = 0.3844, $p \leq 0.05$). Hence, diversity might have been promoted to a certain extent by INGO restoration project, through the propagation in nurseries of seedlings from different species (some of them not traditionally used) that were delivered to the THs owners.

Potential of the Restored THs to Promote Landscape Connectivity and Biodiversity Conservation. Native plants are widely recognized as key elements of the landscape ecological interactions; nonetheless, some allochthonous species can assume new roles in ecological processes that are important to maintain the integrity and functionality of the forest (Williams, 1997; Davis *et al.,* 2011). Moreover, non-natives species have been part of our lives, landscapes, and civilizations for a long time as they have had great socio-economic importance (Altieri, 1999; Kendle and Rose, 2000).

Me´phaa THs owners hosted in their THs more allochthonous (52%) than autochthonous (48%) species. This could be a consequence of ***Me´phaa*** THs owners and their families realizing that non allochthonous species provide suppling services such as food and medicine,

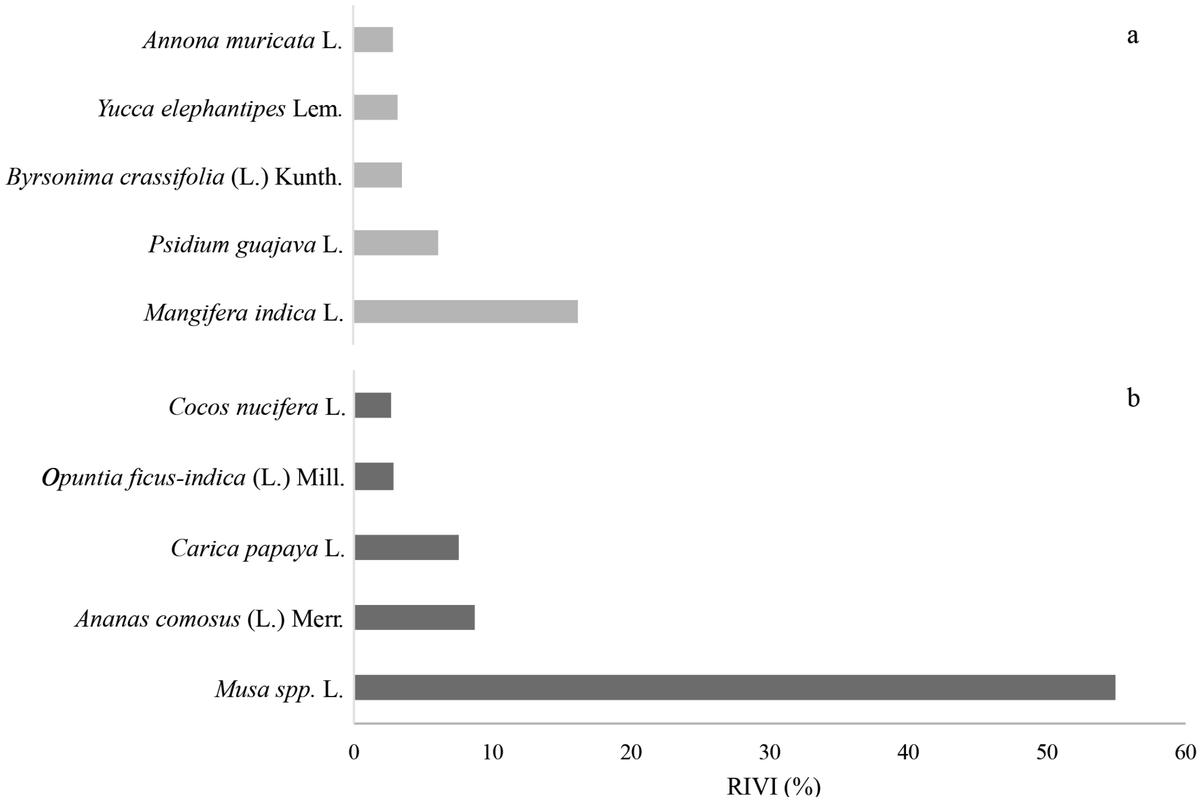

Figure 3. Relative Importance Value Indices (RIVI%) of the highest-ranked woody species (a-light gray) and non-woody species (b-dark grey) in ***Me´Phaa*** THs.

but also aesthetic, spiritual, educational and recreational ones (Aguirre, 2018). Despite the complicated and limited access to external species due to geographical isolation, ***Me´phaa*** people have a high degree of communication and social cohesion (Galicia-Gallardo *et al*. 2019) that could be encouraging them to share knowledge and propagules from either allochthonous and autochthonous species ancestrally or recently incorporated within their THs (Aguirre, 2018). Additionally, as a result of the workshops implemented in the project, THs owners accepted some allochthonous and non-traditionally used species that were suggested for academics and INGO directors based in their benefits for human health and for environmental services such as pollination (see Aguirre, 2018). In this vein, ***Me´phaa*** THs are contributing to agrobiodiversity conservation by maintaining crop varieties through many generations and introducing new ones, perpetuating, thereby, processes of selection and domestication of species, as has occurred historically in traditional agroforestry systems (Toledo and Barrera-Bassols, 2008).

Ninety-one percent of the total amount of species was pollinated by animals (zoophily), and 9% by the wind (anemophily); whilst 57% of them were dispersed by animals (zoochory), 32% by gravity (barochory), and 11% by wind (anemochory). Zoophily increases the extent of pollen dispersal among more distant trees that are less likely to

Table 1. Shannon Diversity Index (H´) and Pielou Evenness Index (J´) of the THs studied in each community, in Acatepec municipality.

COMMUNITY	H´	J´
El Naranjo	3.54 ± 0.13	0.86
Plan de Gatica	3.05 ± 0.13	0.74
Agua Tordillo	2.93 ± 0.13	0.74
El Aguacate	2.75 ± 0.19	0.74
Alcamani	2.23 ± 0.54	0.55
Escalerilla Zapata	2.06 ± 0.33	0.52
Xochitepec	1.79 ± 0.44	0.46

be related (Ceccon and Varassin, 2014), contributing to increase inter- and intra-specific genetic variability and the flexibility of species to adapt to climatic variability and diseases (Ellstrand and Elam, 1993). Zoochory increases native trees regeneration and species diversity through the dispersion of propagules among surrounding fragments (Ceccon, 2013). These finding suggest a potential role of THs to promoting the connectivity of the landscape (Perfecto and Vandermeer, 2010).

For autochthonous species, 89% were pollinated by animals, and 11% by the wind. Regarding their dispersion, most of the species (63%) were dispersed by animals, 23% by gravity and only 14% by the wind. For allochthonous species, 93% were pollinated by animals, and 7% by the wind; while 52% were dispersed by animals, 40% by gravity, and 8% by the wind (Figure 4).

THs are surrounded by forest fragments of *Quercus* and *Pinus* above 1 000 m and *Selva Baja Subcaducifolia* below that altitudinal level (Borda-Niño *et al.* 2017b). They can provide food and habitat for insects, birds, reptiles, and mammals, so they can serve as stepping stones among fragments along the landscape, supporting the conservation of species, diversity and the generation of an interactive network of organisms in agricultural landscapes, which are common in developing countries as Mexico (Reis *et al.,* 2003; Montagnini, 2006; Uezu *et al.,* 2008; Flores-Ramírez and Ceccon, 2014). In this study, the direct effects of the THs' plant composition and structure on the environmental services at landscape scale were not assessed. Nonetheless, research on the specific effect of ***Me´phaa*** THs in the landscape heterogeneity and connectivity is already underway.

Native forest fragments decline in diversity with elevation, whilst THs do not (Table 2). The indices of alpha diversity (H´) of woody species found in the THs of the medium (1072–1606 m.a.s.l.) and highest (1607–2606 m.a.s.l.) altitudes were higher than those found in the

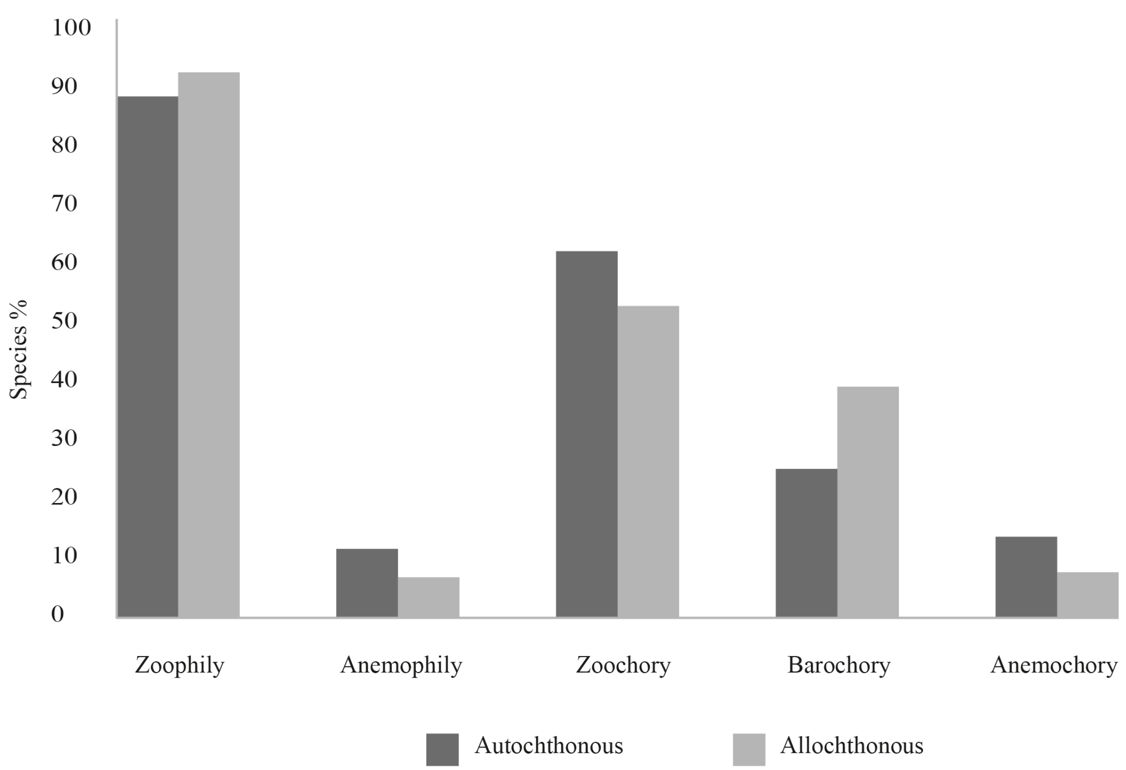

Figure 4. Percentage of autochthonous (dark) and allochthonous (light) species belonging to each pollination syndrome (zoophily, anemophily) and dispersal syndrome (zoochory, anemochory, barochory) found in the ***Me´Phaa*** THs.

open temperate forest fragments (pine-oak forest and coniferous forest) belonging to the same altitudes within the study region (Borda-Niño *et al.,* 2017a, Table 2). In contrast, at the lowest altitude (520–1071 m.a.s.l.), the patches of tropical deciduous forest surpassed the THs in diversity (H´). This result could be explained by the significant negative correlation between the alpha diversity of wild plant communities and altitude (Wang *et al.,* 2003; Borda-Niño, 2013). However, in the case of human-managed systems such as THs, species diversity might be driven by both environmental and social factors, as mentioned above. Hence, ***Me´phaa*** THs might be contributing to the maintenance of biodiversity at low and medium altitudes, while increasing it at higher altitudes where forest biodiversity is often low.

CONCLUSIONS

Traditional home gardens in *La Montaña* showed a complex composition and structure that were influenced by socioecological factors, such as food security, spiritual beliefs and festivities, and environmental features.

The production within restored THs is contributing to achieving food security and sovereignty for the ***Me´phaa*** people, ensuring the availability, access, and stability of the food supply throughout the year, as well as the freedom to produce their own food through culturally-appropriate methods and systems. In addition, restored THs might be enhancing the connectivity and ecological integrity of landscapes affected by intensive land-use.

The successful restoration of the ***Me´phaa*** THs highlight the result of a dialogue of knowledge (since the planning and all phases of the project) between the local population and the scientific community in the construction of a socially sustainable and collective environmental paradigm, a process that might stimulate changes in the relationship between local inhabitants and the ecological systems of the region. It was important to firmly consider the exercise of community participation in decision making, respecting the ancestral knowledge of the local population, their organization, and autonomy.

ACKNOWLEDGEMENTS

The data in this paper was obtained through informed consent of the Indigenous Non-Governmental Organization ***Xuajin Me´Phaa*** members and inhabitants of the communities ***Me´Phaa*** from the *La Montaña* region, State of Guerrero. The authors are grateful for their participation and hospitality. This study was supported by the master´s fellowship provided by National Council for Science and Technology (CONACYT) and the Program to Support Research Projects and Technological Innovation (PAPIIT) IN300615 and IN300119. We also

Table 2. Comparative values of the Shannon Diversity Index (H´) average (± standard error) of tree species from native vegetation patches (obtained from Borda-Niño 2013) and from traditional home gardens (THs) per community within the lowest (520–1071 m.a.s.l.), medium (1072–1606 m.a.s.l.) and highest (1607–2606 m.a.s.l.) altitudinal ranges in Acatepec municipality.

	ALTITUDINAL RANGES (M.A.S.L)		
	LOW 520–1071	MEDIUM 1072–1606	HIGH 1607–2606
Native patches[a]	H´=2.8 ± 0.24	H´= 1.8 ± 0.09	H´=1.5 ± 0.20
Escalerilla Zapata	H´=2.34 ± 0.13		
Plan de Gatica	H´=2.09 ± 0.12		
El aguacate	H´=2.30 ± 0.06		
El Naranjo	H´=2.48 ± 0.14		
Alcamani		H´=2.48 ± 0.17	
Xochitepec		H´=2.02 ± 0.23	
Aguatordillo			H´=2.27 ± 0.12

[a]Source: Borda-Niño, 2013

thank Fredy Vargas for the photographs of the home gardens.

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Annex 1. List of species found within the THs with their respective uses (U: A= food, F= firewood, M= medicine, O= spiritual, P= post, S= shade, C= construction); their status of origin (E: AU=autochthonous, AL=allochthonous); their pollination syndrome (P: ZO=zoophily, AN=anemophily), and dispersal syndrome (D: ZO=zoochory, AN=anemochory, AU=barochory).

COMMON NAME	SCIENTIFIC NAME	U	E	P	D
**	*Clethra lanata* M.	*	AU	ZO	AU
Aguacate**	*Persea americana* Mill.	A, P	AU	ZO	ZO
Algodón silvestre**	*Cochlospermum vitifolium* (Willd.) Spreng	O	AU	ZO	ZO
Almendro	*Terminalia catappa* L.	A	AL	ZO	ZO
Amapola**	*Pseudobombax ellipticum* (Kunth.) Dugan.	O	AU	ZO	AN
Amate**	*Ficus sp.*	M, P, S	AU	ZO	ZO
Bambú	*Bambusa textilis*	C	AL	AN	AU
Bugambilia morada	*Bougainvillea glabra* Choisy.	O, M	AL	ZO	AU
Cacahuananche	*Gliricidia sepium* (Jacq.) Kunth.	A, P, F	AU	ZO	AU

Annex 1. Cont.

COMMON NAME	SCIENTIFIC NAME	U	E	P	D
Cacao	*Theobroma cacao* L.	A	AL	ZO	ZO
Café	*Coffea arabica* L.	A	AL	ZO	ZO
Camote chino	*Ipomoea* sp.	F	AL	ZO	AU
Caña	*Saccharum officinarum* L.	A	AL	AN	ZO [1]
Capulin**	*Prunus serotina* (Cav.) McVaugh	F	AU	ZO	ZO
Carambola	*Averrhoa carambola* L.	A	AL	ZO	ZO
Cempazuchitl	*Tagetes erecta* L.	O	AU	ZO	AN [1]
Cilantro	*Coriandrum sativum* L.	A	AL	ZO [3]	AU
Chaya	*Cnidoscolus aconitifolius* (Mill.) I.M.Johnst.	A	AU	ZO [2]	AU [1]
Chayote	*Sechium edule* (Jacq.) Sw.	F	AU	ZO	ZO
Chía	*Salvia hispanica L*	F	AU	ZO	ZO
Chicozapote	*Manilkara zapota* (L.) P.Royen	A, P	AU	ZO	ZO
Chile	*Capsicum sp.*	A	AU	ZO [1]	ZO
Chirimoya	*Annona cherimola* Mill.	A, P, S	AU	ZO	ZO
Ciruela**	*Spondias purpurea* L.	A, P	AU	ZO	ZO
Colorín**	*Erythrina americana* Mill.	A, P	AU	ZO	ZO
Consuelda	*Symphytum officinale* L.	M	AL	ZO	AU
Copa de oro	*Allamanda cathartica* L.	O	AL	ZO	AN [4]
Copal**	*Bursera simarruba* L.	M	AU	ZO	ZO
Croton	*Codiaeum variegatum* (L.) Rumph. EX A. Juss.	O	AL	ZO	AU
Cuatololote**	*Andira inermis* (W.Wright) DC.	M	AU	ZO	ZO
Cuaulote**	*Guazuma ulmifolia* Lam.	F, C	AU	ZO	ZO
Cupataiste	*Theobroma* sp.	F	AU	ZO	ZO
Durazno	*Prunus persica* (L.) Stokes.	A	AL	ZO	ZO
Encino amarillo**	*Quercus glaucescens* Bonpl.	F, P, S	AU	AN	ZO[5]
Encino blanco**	*Quercus scytophylla* Liebm.	F, P, S	AU	AN	ZO[5]
Encino rojo**	*Quecus elliptica* Née.	F, P, S	AU	AN	ZO
Epazote	*Dysphania ambrosioides* (L.) Mosyakin. EX Clemants	A, M	AU	AN	AU
Flor de avatar	-	O	AL	ZO	-
Flor de aretillo	*Fuchsia regia* (Vand. EX Vell.) Munz.	O	AL	ZO	ZO
Flor de mayo**	*Plumeria rubra* L.	O	AU	AN	AN
Flor de Moises	*Nerium oleander* L.	O	AL	ZO	AN
Flor de pascua	*Euphorbia pulcherrima* Willd. ex Klotzsch.	O	AU	ZO [1]	AU [1]
Floripondio**	*Brugmansia arborea* (L.) Steud.	O	AL	ZO	AU
Fresa	*Fragaria* sp.	A	AL	ZO	ZO
Frijol	*Phaseolus vulgaris* L.	A	AU	ZO [6]	AU
Geranio	*Pelargonium sp.*	O	AL	ZO	AN
Gordolobo	*Verbascum thapsus* L.	M	AL	ZO	AU
Granada	*Punica granatum* L.	A	AL	ZO	AU

Annex 1. Cont.

COMMON NAME	SCIENTIFIC NAME	U	E	P	D
Grasena	*Dracaena sp.*	O	AL	ZO	AU
Guamuchil	*Pithecellobium dulce* (Roxb.) Benth.	F, S	AU	ZO	AU
Guanábana	*Annona muricata* L.	A	AU	ZO	ZO
Guapinol**	*Hymenaea courbaril* L.	A	AU	ZO	ZO
Guayaba ácida**	*Psidium acutangulum* Mart. Ex DC	A	AU	ZO	ZO
Guayaba dulce	*Psidium guajava* L.	A	AU	ZO	ZO
Heliconia	*Heliconia latispatha* Benth.	O	AL	ZO	AU
Hierba santa	*Piper auritum* Kunth.	A, M	AU	ZO [7]	ZO
Hierbabuena	*Mentha spicata* L.	M	AL	ZO	ZO
Higuerilla**	*Ricinus communis* L.	M	AL	ZO [9]	AU [8]
Huaje**	*Leucaena leucocephala* (Lam.) De Wit	A	AU	ZO	AU
Huizache	*Acacia farnesiana* (L.) Willd.	F, S	AU	ZO	AU
Ilama	*Annona diversifolia* Donn. SM.	A	AU	ZO	ZO
Izote	*Yucca elephantipes* Baker.	A	AU	ZO	AN [10]
Jacaranda	*Jacaranda mimosifolia* D.Don	S, P	AL	ZO	AN
Jamaica	*Hibiscus sabdariffa* L.	A	AL	ZO	AU
Jengibre	*Zingiber officinale* Rosc.	A, M	AL	ZO	AU
Jinicuil**	*Inga jinicuil* G. Don.	A	AU	ZO	ZO
Jitomate	*Solanum lycopersicum* L.	A	AU	ZO	ZO
Limón agrio	*Citrus aurantifolia* (Christm.) Swingle.	A, P, F	AL	ZO	ZO
Limón dulce/lima	*Citrus sp.*	A, P, F	AL	ZO	ZO
Maguey	*Agave* sp.	M	AU	ZO	AU
Malanga	*Colocasia esculenta* (L.) Schott	A	AU	ZO	AU
Mamey	*Pouteria sapota* (Jacq.) H. E. Moore & Stearn.	A	AU	ZO	ZO
Mandarina	*Citrus reticulata* Blanco.	A	AL	ZO	ZO
Mango	*Mangifera indica* L.	A	AL	ZO	ZO
Manzana	*Malus domestica* Borkh.	A	AL	ZO	ZO
Maracuyá	*Passiflora edulis* Sims	A	AL	ZO	ZO
Marañón	*Anacardium occidentale* L.	A, M	AL	ZO	ZO
Moringa	*Moringa oleifera* Lam.	A	AL	ZO	ZO
Muena	*Calathea* sp.	O	AL	ZO	AU
Nanche**	*Byrsonima crassifolia Kunth.*	A	AU	ZO	ZO
Naranja	*Citrus × sinensis* Osbeck.	A	AL	ZO	ZO
Níspero**	*Eriobotrya japonica* (Thund.) Lindl.	A	AL	ZO	ZO
Noni	*Morinda citrifolia* L.	M	AL	ZO	ZO

Annex 1. Cont.

COMMON NAME	SCIENTIFIC NAME	U	E	P	D
Nopal	*Opuntia* sp.	A	AU	ZO	AU
Oreja de elefante	*Alocasia odora* (G.Lodd) Spach.	O	AL	ZO[12]	AU
Palma areca	*Areca catechu* L.	O	AL	ZO	AU
Palma de coco	*Cocos nucífera* L.	A	AL	ZO	AU
Palo de Neem	*Azadirachta indica* A.Juss.	M	AL	ZO	ZO
Palo Guarumbo**	*Cecropia obtusifolia* Bertol.	M	AU	ZO	ZO
Papa voladora	*Dioscorea bulbifera* L.	A	AU	ZO [11]	AU
Pápalo/pepeza	*Porophyllum ruderale (Jacq.) Cass.*	A	AU	ZO	AN
Papaya	*Carica papaya* L.	A	AU	ZO	ZO
Parota	*Enterolobium cyclocarpum* (Jacq.) Griseb.	F, P, S	AU	ZO	ZO
Pata de cabra**	*Bauhinia divaricata* L.	O	AU	ZO	ZO
Pata de Venado**	*Bauhinia ungulata* L.	O	AU	ZO	ZO
Piña	*Ananas comosus (*L.) Merr.	A	AL	ZO	AU
Pino**	*Pinus* sp.	F, P, S	AU	AN	AN
Pistache	*Pistacia vera* L.	A	AL	ZO	AU
Plátano**	*Musa* sp.	A	AU	ZO	ZO
Pumarosa	*Syzygium jambos* (L.) Alston.	A, P, F	AL	ZO	ZO
Rambután	*Nephelium lappaceum* L.	M,F	AL	ZO	ZO
Roble amarillo	*Tabebuia chrysantha* (Jacq.) S.O.Grose.	S,P	AU	ZO	AN
Roble rosado	*Tabebuia rosea* (Bertol.) Bertero ex A.DC.	S, P	AU	ZO	AN
Rosal	*Rosa* spp.	O	AL	ZO	ZO
Sábila	*Aloe vera* (L.) Burm.F.	M	AU	ZO	AU
Sauce	*Salix* sp.	P, S ,C	AL	AN	AN
Sauco**	*Sambucus nigra* L.	M, F	AU	ZO	ZO
Tabachín	*Delonix regia* (Bojer ex Hook.) Raf.	S,O	AL	ZO	AU
Tamarindo	*Tamarindus indica* L.	A	AL	ZO	ZO
Tejuruco**	*Genipa americana* L.	A	AU	ZO	ZO
Tlachicón**	*Curatella americana* L.	F, P, S	AU	ZO	ZO
Toronja	*Citrus x paradisi* Macfad.	A	AL	ZO	ZO
Tulipán	*Hibiscus rosa-sinensis* L.	O	AL	ZO	AU
Vaporub	*Plectranthus Tomentosa* Forssk.	M	AL	ZO	ZO
Yaca	*Artocarpus heterophyllus* Lam.	A	AL	ZO	ZO
Yuca	*Manihot esculenta* Crantz.	A	AL	ZO	ZO [10]
Zacate de limón	*Cymbopogon citratus* (DC.) Stapf.	A	AL	AN [1]	AU
Zapote blanco	*Casimiroa edulis* La llave & Lex.	M	AU	ZO	ZO