Agricultural management and local knowledge: key factors for the conservation of socio-ecosystems in the face of the pollinator world crisis

Manejo agrícola y conocimiento local: factores clave para la conservación de los socioecosistemas ante la crisis mundial de polinizadores

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Abstract
Background: Pollinators are key for the survival of a great percentage of angiosperm species and 75 % of production from cultivated species is expected to decrease in the absence of pollinators.
Questions: The goal of this study is to understand the role of agricultural management and local knowledge on pollination for the conservation of different insect species in communities where there is no direct tradition of pollinator management.
Study site: The study was conducted in central Mexico in a community with a traditional agroforestry system of semi-terraces called *metepantle*.
Methods: To estimate pollinator richness, we collected insects from the order Hymenoptera and Diptera as well as plants that were flowering on the borders of the *metepantle*. To evaluate local knowledge on pollination and its relation to agricultural management we performed semi-structured interviews.
Results: We found high pollinator richness for a temperate region. However, knowledge of biological pollination was scarce probably because the predominant crops are wind pollinated. Local knowledge on pollination and pollinators is not very extensive and varied in relation to the management of their *metepantle* and socioeconomic factors that influence the individual knowledge of people.
Conclusions: The structural and management characteristics of the traditional agricultural *metepantle* system promote holistic management that favors diversity and productivity of the agroforestry system while promoting local pollinator conservation.
Keywords: Agricultural system, local knowledge, pollination, pollinator richness, traditional management.

Resumen
Antecedentes: Los polinizadores son clave para mantener la sobrevivencia de las especies de angiospermas y se estima que la producción del 75 % de las especies cultivadas disminuiría en ausencia de polinizadores.
Pregunta: Comprender el papel que juegan el manejo agrícola y el conocimiento local sobre polinización para la conservación de diversas especies de insectos en comunidades donde no existe una tradición directa de manejo de polinizadores.
Sitio de estudio: Se realizó en la región central de México en donde se cultiva en un sistema agroforestal tradicional de semi-terrazas denominado metepantle.
Métodos: La riqueza de polinizadores se estimó mediante colectas mensuales de insectos de los órdenes Hymenoptera y Diptera, así como de las plantas que se encontraron en floración creciendo en los linderos del metepantle. Para evaluar el conocimiento sobre polinización y su relación con el manejo agrícola se aplicaron entrevistas semi-estructurada.
Resultados: La riqueza de polinizadores fue alta para una región templada. Sin embargo, el conocimiento sobre polinización biótica fue heterogéneo y escaso posiblemente porque los cultivos que dominan son polinizados por el viento. El conocimiento varió en relación con el manejo que realizan de su agroecosistema y con factores socioeconómicos que influyen sobre el conocimiento personal.
Conclusión: Las características estructurales y de manejo del sistema tradicional agrícola de metepantles promueven un manejo holístico que favorece la diversidad y productividad del sistema agroforestal al mismo tiempo que fomenta la conservación de los polinizadores.
Palabras clave: Conocimiento local, manejo tradicional, polinización, riqueza de polinizadores, sistemas agrícolas.

Pollinators are key elements for the maintenance of fruit and seed production in a great percentage of angiosperms (Garibaldi *et al.* 2014a, Ssymank *et al.* 2008). It has been estimated that yield of plant species cultivated in agricultural systems would decrease 75 % worldwide in the absence of pollinators (Ashworth *et al.* 2009). Reports of native pollinator loss and the collapse of *Apis mellifera* colonies have caused global concern. Thus, agricultural management practices that promote pollinator species abundance have been proposed (Garibaldi *et al.* 2014a). Many of these practices are currently used in traditional agroforestry systems and for their maintenance the local ecological knowledge that sustains them is crucial (Altieri & Trujillo 1987, Moreno-Calles *et al.* 2013, Roué *et al.* 2015).

A great diversity of insects such as bees, beetles, butterflies, flies, and some vertebrates like birds and bats, are recognized as pollinators. The majority of studies focus only on bees (Ssymank *et al.* 2008) due to their specialized feeding habits (exclusively on floral resource) and their connection to agriculture (Buchmann & Ascher 2005), but pollination may also depend on other animals. In temperate and humid environments or in periods when bees are little active, other insects with similar foraging patterns may be responsible for pollination (Ssymank *et al.* 2008, Rader *et al.* 2016). It is known that a greater richness and diversity of pollinators increases the quality of pollination ecosystem services (Garibaldi *et al.* 2014b, Rader *et al.* 2016) therefore conserving this diversity is fundamental to confront the global pollination crisis.

Pollinators are involved in the sexual reproduction of approximately 80 % of the terrestrial plants, and thus are responsible for the maintenance of plant biodiversity in all ecosystems (Garibaldi *et al.* 2014b, Rader *et al.* 2016). Furthermore, a great number of cultivated and wild resources for human food depend on these pollinators (Klein *et al.* 2007, Ashworth *et al.* 2009). Although most of the cultivated land on the planet is occupied by wind-pollinated cereals (60 % of the world's food production) (Ashworth *et al.* 2009), around 84 % of Europe's (Klein *et al.* 2007) and 85 % of Mexico's cultivated species (Ashworth *et al.* 2009) that depend on pollinators for sexual reproduction, would have a reduction in production if pollinator numbers diminished. In this context, a reduction or loss of local pollinators would affect food security and the diversity of everyday diet (Ashworth *et al.* 2009) with an estimated economic value of 153 billion Euros annually (Gallai *et al.* 2009).

Recent studies suggest that monospecific agricultural intensification is the main cause of native pollinator richness and abundance loss (Potts *et al.* 2010). This is because monospecific agricultural intensification entails land use change and the use of pesticides and herbicides that in combination reduce pollinator food resources and nesting space and may even lead to pollinator death by toxicity (Potts *et al.* 2010). Many management strategies have been proposed to increase insect survival such as the implementation of strips of wild vegetation within agricultural plots, the conservation of native vegetation fragments and an increment of agricultural heterogeneity (Garibaldi *et al.* 2014a, Kremen *et al.* 2002). At the plot level, several pollinator conservation strategies have been proposed: a reduction in agrochemicals, implementation of organic crops and crops that may add resources, conservation of wild plants intermixed with crops and a reduction of tillage (Garibaldi *et al.* 2014a). These practices promote resource availability for pollinators for long periods of time and maintain adequate nesting sites (Garibaldi *et al.* 2014a).

To conserve pollinators and promote sustainable strategies that take advantage of pollination, Roué *et al.* (2015) emphasize the need to understand local knowledge on pollination and its relation to agricultural management. Local knowledge about natural resources is acquired through cultural processes of social transmission and personal experimentation. This knowledge varies among the members of a community according to the individual idiosyncrasies that can change due to the influence of socio-economic processes such as the age of the people or their study level, as well as personal experience in the management of natural systems (Reyes-García *et al.* 2013). Some societies have attained great knowledge on the function and use of pollination and even associate pollination with cultural processes (Roué *et al.* 2015). However, in societies where there is no direct management of pollinators, such as apiculture or honey collection, knowledge on pollinators may vary between people and is rarely applied to agricultural management focused on increasing pollinator survival (FAO 2008). Management of biological diversity in agricultural systems, such as the use of polyculture farming and agroforestry systems are strategies that indirectly promote diversity and abundance of pollinators. In these cases, knowledge on pollination management can be integrated into a greater knowledge of ecosystem function (FAO 2008).

In the context of the world pollinator crisis, international organizations such as the International Pollinator Initiative (IPI) and the program for Food and Agriculture

Organization (FAO) on pollinator ecosystem services for sustainable agriculture have been created. Locally, national initiatives look to monitor pollinators and to establish programs for pollinator conservation in agricultural systems (FAO 2008). However, few programs evaluate the role of traditional ecological pollination knowledge as a strategy for the conservation of biological diversity of pollinators and their role in maintaining food security.

Mexico has a high diversity of pollinators (around 2000 bee species, Quezada-Eúan & Ayala-Barajas 2010) that consists mainly of solitary bees (Michener 2000, Michener *et al.* 1994). Thus, it is important to understand the traditional knowledge on pollination and its relationship to agricultural management, and the role it plays in conservation of this ecosystem service. In this study we analyze insect pollinator species richness in an agroforestry terrace system. We also document local knowledge on pollination and pollinators and their relationship to agricultural production and management. We hypothesized that pollinator knowledge would be heterogeneous and vary in relation to the socioeconomic characteristics of the interviewed people and the importance of pollinators on the production of food in the agroforestry system.

Materials and Methods

Study site. Our study was conducted from May to October 2016 at a rural community in the ejido El Rosario in Tlaxcala, central Mexico (Figure 1), which is at an elevation of 2,714 m asl. on foothills of a mountainous area. The predominant vegetation is a mixed forest of *Pinus* spp. and *Quercus* spp. in lower areas and firs (*Abies* sp.) in higher areas. The climate is temperate with rainy summers and occasional frosts. Land use is mainly agricultural, although they also coordinate a Forest Management Plan for the extraction of wood. The community received an award from the Mexican government for best forest management practices in 2014 (Premio Nacional al Mérito Forestal).

Agriculture in this community is carried out through a traditional agroforestry system called *metepantle* (González-Jacome 2016), which involves the use of semi-terraces in which cultivation areas follow the inclination of the mountain slope. The mountain slope is slightly modified with the construction of ditches and raised edges or borders that surround the semi-terraces and help retaining moisture while preventing erosion (Figure 2).
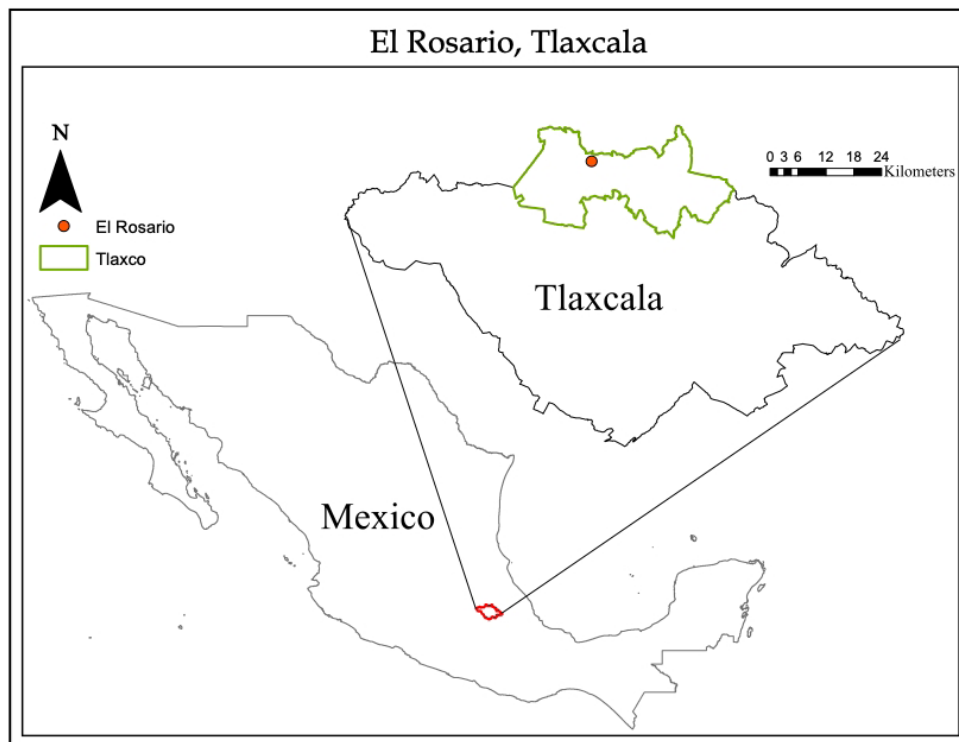
Figure. 1. Location of El Rosario in the municipality of Tlaxco in the state of Tlaxcala, central Mexico.

Figure. 2. *Metapantles* in El Rosario, Tlaxcala. Farming plots with ditches (A) for moisture retention and borders (B) where trees and *Agave* grow are observed. Elevated crop fields in semi-terraces (C) are in the center of the image.

Some species like *Juniperus deppeana* Steud, *Buddleja americana* L*., Agave salmiana* Otto ex Salm-Dyck or fruit trees like the native *Prunus capuli* Cav. and *Crataegus mexicana* DC. or introduced fruit trees like *Prunus persica* (L.) Batsch are encouraged to grow on the elevated borders that surround the *metepantle* (Altieri & Trujillo 1987, Moreno-Calles *et al.* 2013). In addition to be a source of resources, the vegetation that grows on these borders helps to retain soil and moisture, increases organic matter in the system and works as a living fence between fields. It also protects crops from the wind and regulates pests (Altieri & Trujillo 1987, González-Jacome 2016). *Metepantles* form an agricultural matrix of semi-terraces, ditches, borders and large extensions of corridors formed by elevated ground that are a reservoir of diversity and resources for the local population of wild animals and pollinators.

The main crops of the system are maize, barley, oats, wheat, beans (*Phaseolus vulgaris* L*.*) and faba beans (*Vicia faba* L.). These are mixed with other crops and useful wild plants conforming a polyculture. Because the local soils are poor, these crops are annually rotated for allowing soil nutrient content recovery (Altieri & Trujillo 1987).

The *metepantle* system has been slowly changing because local farmers are starting to incorporate elements of mechanized commercial agriculture. The introduction of machinery has eliminated some sites of natural high borders to facilitate the entry of tractors (González-Jacome 2016). With tractors, agrochemicals like glyphosate and urea are being implemented and local crop varieties are being substituted for commercial hybrids. In the short term, an increase in productivity has been reported but many farmers affirm that agrochemicals are impoverishing soils in the long run (Altieri & Trujillo 1987). They also state that agrochemicals are expensive and have to be used every season, while natural organic fertilizers last up to five years and promote moisture retention (Altieri & Trujillo 1987).

Data collection. Collections to calculate pollinator richness of insects of the orders Hymenoptera (bees) and Dip-

tera (flies) were carried out monthly between July and October 2016. The insect collections were performed at the center of four different *meteplantle* plots each containing the essential *metepantle* elements (border, ditch and semi-terrace). Two of the four plots were near the forest, at a distance of approx. 100 m (J and P plot) and two of them were far from it, around 1 to 2 km (C and S plot). Between the plots there was an approximate distance of 1 to 2 km. Following LeBuhn *et al*. (2003) and Westphal *et al*. (2008) we used around 30 pan traps per plot from 9 am to 2 pm during two days per month. The pan traps were painted in three different colors, yellow, blue and white and were placed alternately covering the entire plot. In addition, an entomological net was used to capture insects from both Hymenoptera and Diptera orders along the borders of each *metepantle* during the same hours and days that the pan traps were placed. The collected insects were preserved in alcohol and then dried for identification. To identify available pollinator nutrition resources, we collected all plants that were flowering on the elevated borders of the *metepantles* except for plants belonging to the family Poaceae. Collected insects were identified to the lowest possible taxonomic level and deposited at the National Insect Collection (Colección Nacional de Insectos del Instituto de Biología de la Universidad Nacional Autónoma de México). Plants were identified to genus level but not always at the species level. Therefore, the morphospecies concept was used.

To evaluate knowledge on local pollination and its relationship to agricultural management a semi-structured interview was conducted (Russell-Bernard 1995) to farmers of the community aging between 27 and 88 years old with variable education level. Insects collected in the area were showed to the farmers and we asked if they knew the insects and to provide any local names. They were also asked to name any wild or harvested plants that grow on the borders of the *metepantle*. From these interviews, a list of plants cultivated in the region was assembled and the degree of local agricultural production dependence on biological pollination was calculated following Ashworth *et al*. (2009).

Data analysis. Pollinator species richness and composition was calculated from the Hymenoptera collections. We compared species richness between plots and census using a contingency chi-square analysis. Species composition and temporal variation between plots was analyzed using Principal Coordinate Analysis (PCO). To determine if differences of Hymenoptera richness between plots was a consequence of other variables (such as distance between natural vegetation to plots, level of modernization in agricultural plots, or number of flowering species) we used a log-linear regression with a Poisson distribution.

Records of Diptera were used only to quantify insect diversity not to analyze richness and composition. Diptera were not either used for interviews since their feeding habits cannot be easily classified as pollination.

Species richness of the plants that were flowering along the plots was calculated in the same way and compared between plots using contingency chi-square analysis. A Principal Coordinate Analysis (PCO) was conducted with presence-absence data to assess variation in plant composition between plots and census.

To analyze local pollination knowledge patterns, we used a Principal Components Analysis (PCA) to evaluate the relationship between variables associated with pollination knowledge (number of species and the nesting sites mentioned), variables related to socioeconomic status (age, education level), and variables related to *metepantle* agricultural management related to pollination (farming of crops that depend on pollination, knowledge of plants growing on the borders of the *metepantle*). The significance of the relation between variables was estimated by means of a log-linear regression with a Poisson distribution.

Results

Pollinator collection and richness. A total of 43 morphospecies from the order Hymenoptera from 22 genera and five families were collected (Supplementary material 1). The family with the greatest number of species was Halictidae (15 species from five genera) followed by Apidae (14 species from nine genera) (Table 1). The most frequently collected species was *Apis mellifera* followed by *Lasioglossum* (*Evylaeus*) sp., *Anthophora marginata* and two species of the genus *Bombus* sp. (Figure 3 and 4). We identified 20 morphospecies from the order Diptera (Supplementary material 2). The most frequently collected family was Syrphidae in which the most collected genera were *Eristalis* and *Syrphus*.

Collected pollinator species richness was between 22 and 26 morphospecies per plot. This figure did not change along the four censuses ($\chi^2 = 9.38$, $p = 0.40$). Although there were no differences between plots ($\chi^2 = 71.97$, $p = 1$), morphospecies composition changed with seasonality (Figure 5). The October morphospecies composition (Figure 5 yellow points) differed from that of July through September.

Table 1. Families, number of genera and morphospecies from the orders Hymenoptera and Diptera colected in four *metepantles* of El Rosario, Tlaxcala.

Family	Genera	Morphospecies
Order Hymenoptera		
Andrenidae	4	9
Apidae	9	14
Colletidae	1	2
Halictidae	5	15
Megachilidae	3	3
Total	**22**	43
Order Diptera		
Tachinidae	5	5
Syrphidae	3	5
Tabanidae	2	3
Calliphoridae	1	2
Tephritidae	1	1
Heleomyzidae	1	1
Tanypezidae	1	1
Asilidimorpha	1	2
Total	**15**	20

Species richness per plot did not vary in relation to the richness of plants flowering on the borders of the *meteplantle*, plot distance from the forest, or agricultural modernization of the *meteplantle* plots such as tractor or pesticide use.

Composition of the wild plants living on the borders of the metepantle that were flowering. The total richness of flowering plants living on the borders of the *metepanltes* was 89 morphospecies belonging to 64 genera and 27 families. The family that showed the greatest richness of morphospecies was Asteraceae with 22 genera and 34 morphospecies and was notably richer than the rest of the collected families (Supplementary material 3). Most of these plants are considered weeds and only some of them are considered useful.

There were no significant differences in composition of plants flowering on the borders of the *metepantles* between plots ($\chi^2 = 90.32$, $p = 1$). However, there was certain variation in the temporal composition of the collected plant species in plot C and J between July and October. The rest of the plots maintained a similar composition (Figure 6).

Recorded Metepantle crops and the importance of pollination for the agroecosystem. Poaceae and Fabaceae fol-lowed by Solanaceae and Cucurbitaceae are the families most mentioned in the crops of the *meteplantle*. All the people interviewed mentioned growing corn and second-ly, the crops most referred to were, barley, fava beans and fruit trees. Chilacayotes (*Cucurbita ficifolia* Bouché), to-matoes and alberjón (*Pisum sativum* L.) were mentioned in at least 20 % of the interviews (Figure 7).

Most of the interviewed people (70 %), cultivate the four cereals (maize, barley, oats and wheat), which are wind pollinated. Cultivated species that depend on biotic pollination up to some degree were used by 34 % of the interviewed farmers (Figure 7, based on the classification of Ashworth *et al.* 2009).

Socio-demographic characteristics of the interviewed farmers. All the interviewed people worked primarily as farmers and on occasions worked on activities of the sec-ondary sector of the economy. Only one person interviewed was a professional who also worked in agriculture. Another person was a forest ranger that also farmed his own fields. Interviewed farmer's age spanned 22 to 88 years old with a mean of 63.3. Formal education varied from 0 to 15 years (university) with a mean of 4.5 years (incomplete elementa-ry school). Age and level of education were negatively cor-related ($r = -0.787$ $p < 0.05$), level of education decreased with age. Since few women are dedicated to agriculture,

only one woman was interviewed. Of the interviewed people, 76 % were born in and were living in the community.

Local knowledge on pollination and pollinators. Based on the list of insects that interviewed people know, the species most commonly identified (80 %) was the one locally called *jicote* which is a species of the genus *Bombus* and the one locally called *colmenas* which corresponds to *Apis mellifera*. Using photographs and specimens of the morphospecies collected at the *metepantles* we were able to corroborate that people correctly identified *jicotes*. *Apis mellifera* was frequently confused with flies from the genus *Eristalis*. The third best-identified group (23.3 %) was the so-called *clalizos* that belong to the genus *Anthophora*. It is the only species of solitary bees that is recognized and has a local name. Its unique characteristic is a striped abdomen and they are known for having a painful sting. They are robust bees that are slow and nest and eat near the farming plots.

Six of the thirty interviewed farmers mentioned "mountain bees" and described them as thin, black insects that build cone-shaped nests with little honey on hillside trees. It seems that the description fits a species of wasp, however this could not be confirmed because they do not inhabit agricultural areas and thus were not collected.

Of interviewed farmers, 90 % were familiar with the nesting site of one or more species. The highest number of identified nesting places by the interviewed farmers was

four. The most mentioned species was *A. mellifera* and its beehives that are known to nest in manmade hives for apiculture as well as *Agave* plants and old tree trunks. The second most mentioned species were *jicotes* that make small social nests in the ground or in holes found in houses. Less understood was that *clalizos* make small tunnels in the ground with individual cells or that "mountain bees" make cone-shaped hives on forest trees.

Of interviewed people, 93 % knew the function of pollinators landing on flowers, 66.7 % said that this was related to the use of flower nectar, 46 % associated this action with pollen while some people mentioned both functions. The majority referred to pollen and nectar as a food source. However, some people also said that these resources were for making honey and that pollen was used to construct honeycombs. Only five interviewees (16.7 %) recognized biological pollination as an ecological process, two of them learned this in school and knew the term "pollination" and "pollinator", the rest understood this process empirically. Four of the interviewed people used terms related to pollination but two of them did not know their exact meaning. Only 13.3 % recognized wind pollination. In general, knowledge on pollination is related with the management of hybrid cultivars.

There is a consensus among interviewed farmers on a greater abundance of pollinators during the rainy season due to a spike in flowering. However, 80 % of the inter-
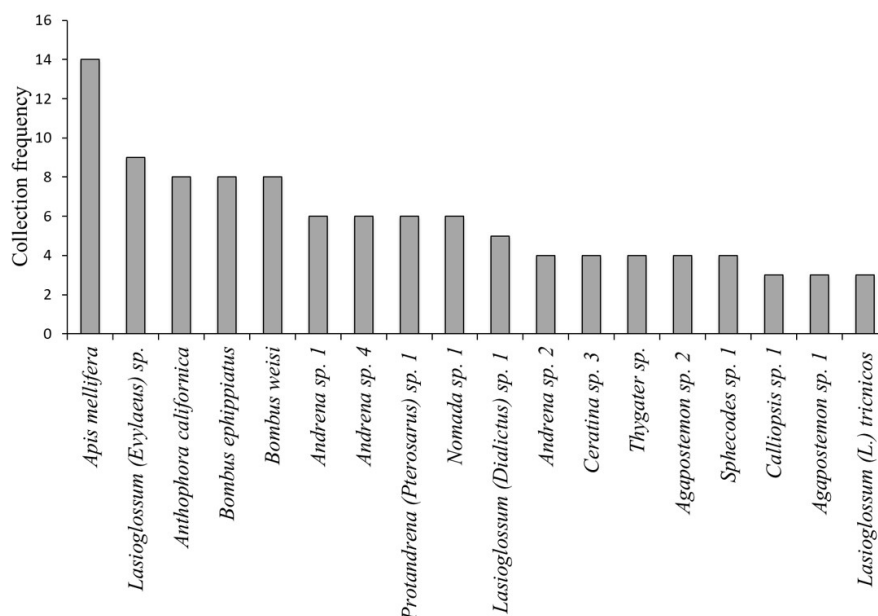
Figure 3. Bee species (Hymenoptera Order) collected with greater frequency. Of the 43 species only the ones that were collected at least three times are shown.

Figure 4. Some of the species collected more frequently: (A) *Bombus ephippiatus*, (B) *Bombus weisi*, (C) *Lasioglossum* (Evylaeus) sp. and (D) *Anthophora marginata*.

viewed farmers considered that pollinator abundance is decreasing and 91.7 % of them attributed this to the use of pesticides and agrochemicals. Another cause of pollinator loss that was mentioned was a reduction in apiculture due to the presence of Africanized bees.

None of the interviewed farmers considered that pollinators negatively affected their crops. In fact, 90 % consider pollinators important. Of these, 50 % considered them important mainly because of honey production and 28 % because they provide some benefit to plants. In this last category, 75% of people interviewed mentioned that these benefits to plants are related to reproduction and 20 % considered pollinators important because they are local wild fauna.

Of the interviewed farmers, 20 % mentioned hummingbirds as pollinators because of their association to flowers. Only three people mentioned butterflies. They were described by their colors (yellow, white and spotted) and because of their migration patterns in October and November. Of interviewed farmers, 50 % mentioned flies but none distinguished the species at a morphological level, nor did they clearly identify their role as pollinators.

Patterns that determine local knowledge on pollinators. The results from the principal components analysis ex-

plained 67.4 % of the total variation (PC1 = 43.2 %, PC2 = 24.2 %). The distribution of knowledge on pollinators and nesting sites was related to management activities of the *metepantle* that are linked to pollination and to socioeconomic aspects of the interviewed people (Figure 8). The greatest eigenvalue of the first component (PC1) was the number of recognized pollinators; the second greatest was the number of mentioned nesting sites followed by the number of wild plants mentioned that grow on the borders of the *meteplantle*. In the second component (PC2) the highest value was the mention of crops that depend on pollination. On both components, age and scholarship level were also important variables in the distribution of knowledge of both components (Table 2).

Knowledge is distributed on a gradient from right to left (Figure 8), where people on the right were those that identified more pollinators, more plants that flowered on the *metepantle* borders and more nesting sites. They also mentioned that their crops require biological pollination. These people were the oldest (more than 60 years old) and the ones with lower scholarship level. People situated at the left side of the graph were younger (40 years old or younger) and had a higher scholarship level but recognized less pollinators and nesting sites. The exceptions
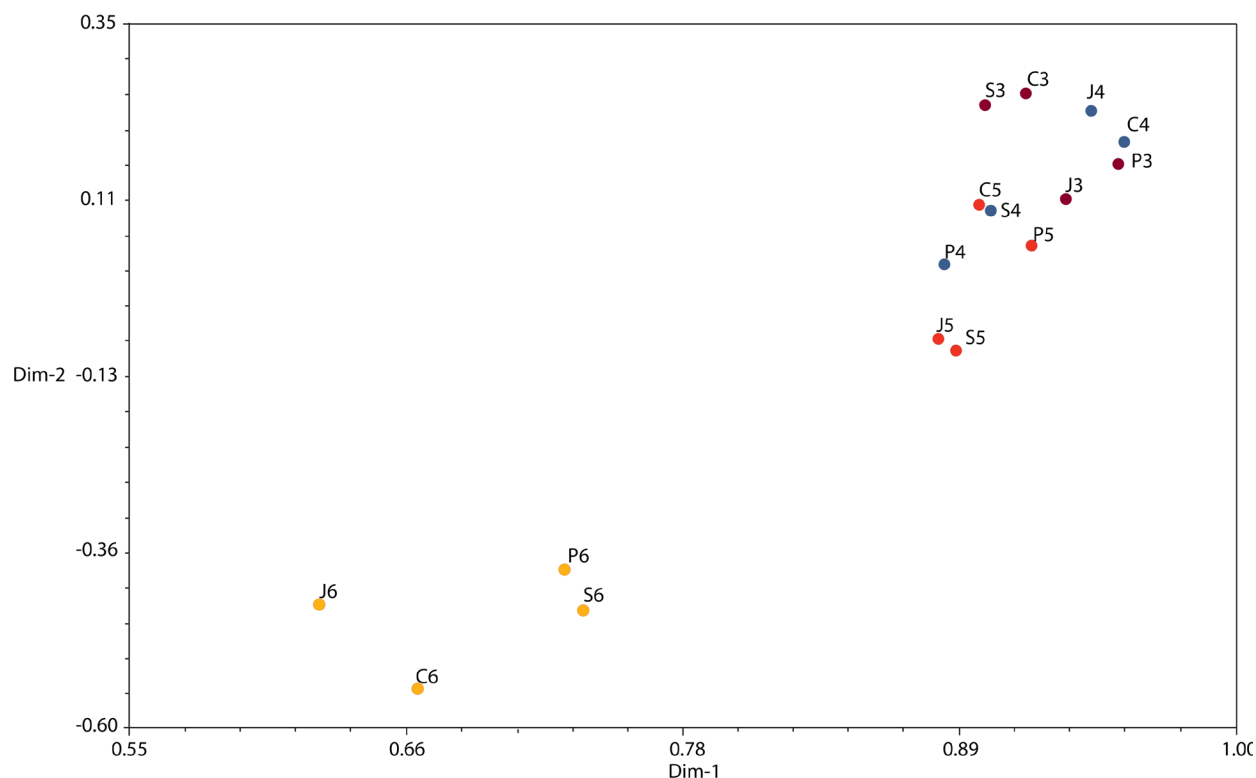
Figure 5. Principal Coordinate Analysis (PCO) for variation in collected bee species composition in the four plots during the four months of the collection. The letter corresponds to the plot where bees were collected. Number indicate month of plant collection. July (3), August (4), September (5) and October (6).

were farmer 19 and farmer 15 who had greater knowledge on pollinators, were between 55 and 60 years old but had a higher study level than people within this group. These two people named a greater number of wild plants growing on the borders of the *meteplantle* and farmed species that require biotic pollination. One of them is the community forest ranger and the other was the only female farmer interviewed.

To evaluate if the variables used for the PCA had a significant relationship, we performed a log-linear regression between the social and management variables and the pollinator knowledge. The only variable that had a significant relationship with pollinator knowledge (number of identified pollinators) was the number of identified plants that grow on the borders of *metepantles* ($\chi^2 = 3.812$, $p = 0.05$) more pollinators were identified when more plants were identified (Table 3).

Discussion

Biotic pollination is a key ecosystem service for agricultural productivity maintenance and food security. In the face of a possible "pollinator crisis" it is important to document traditional ecological knowledge on pollination and understand the mechanisms that determine the recognition of this biological process and its relationship with the manipulation of agroforestry systems. In communities where there is no direct manipulation of pollinators, agroforestry management and diversity maintenance of wild and cultivated plants will largely determine the capacity of the system to preserve enough resources that will favor diversity and permanence of native pollinators.

Insect diversity of the metepantle agroforestry system. Even though we did not collect bees along the entire year, but only during the rainy season when there are more available floral resources, the recorded bee richness (43 morphospecies belonging to 22 genera and 5 families) may be considered high for an agricultural environment with temperate climate. The bee fauna of temperate mountainous areas in central Mexico although not as rich as that of xeric areas in the northeast of the country, has a considerable diversity (*e.g.*, Hinojosa-Díaz 2003). In another mixed crop system with a temperate climate in Huejotzing, Pue-

Table 2. Principal Component Analysis (PCA) Eigenevalues. Eigenvalues that contribute more to each component are in bold.

Variables	PC1	PC2
Nesting sites mentioned	**0.68**	0.12
Number of identified plants growing on the *metepantles* borders	**0.67**	0.50
Scholarship level	**-0.67**	**0.61**
Age	**0.68**	**-0.62**
Number of identified pollinators	**0.75**	0.18
Mention of crops dependent on pollination	0.45	**0.64**

bla, México, only 28 species of bees were reported (Vergara 2002). In a citrus plantation of Argentina only 22 species of bees were reported (Chacoff & Aizen 2006) while 40 bee species were reported in watermelon plantations of California (Kremen *et al.* 2002). Twenty fly morphospecies of the order Diptera that belonged to eight different families were collected. Fly pollinators have very diverse life histories and most of them consume floral resources only at the adult life stage. This makes it difficult to establish the identity of the species and at what life stage they are pollinating. Still, they are the most important group of pollinator insects after the order Hymenoptera (Ssymank *et al.* 2008). Thus, our record of their presence was important because they can be the dominant pollinators of temperate, high altitude or high latitude environments (Ssymank *et al.* 2008). During our collection, we observed a great abundance of some species of the genera *Eristalis* and *Syrphus* that both belong to the Syrphidae family. Of the species in this family, 40 % have larvae that feed on aphids. Thus, they are important in the management of crop pests (Ssymank *et al.* 2008), a problem that many of the interviewed farmers seem to have.

It has been found that when forests are near agricultural plantations, there is an increase in floral resources and native pollinator within crop sites (Chacoff & Aizen 2006, Garibaldi *et al.* 2014b, Kremen *et al.* 2002, Bailey *et al.* 2014). However, the *metepantle* system practiced by the community of El Rosario, with its system of borders and berms surrounding and connecting plots, is maintaining a matrix where a great richness of wild and cultivated trees, shrubs and herbs can provide sufficient floral resources to keep a high diversity of pollinators. This may be the reason why forest distance to the J and P plots (10 m approx.) did not produce differences in species pollinators richness compared to plots far from the forest (1 to 2 km approx.). Further, morphospecies bee composition only changed relative to seasonality because of short periods of active behavior at different moments of the year (Buchmann & Ascher 2005). It has been documented that the richness and diversity of plants in agricultural border systems can serve as biological corridors for the movement of animals, increasing the functional connectivity of rural landscapes (Burel 1996). The smaller the distance between islands of vegetation, an increase is observed in the richness of animal species that survive in regions with anthropogenic activity. (Estrada *et al.* 1997, Estrada & Coates-Estrada 2001).

Bees have varying flight ranges depending on their lifestyle (solitary or social) and size, in species of the tribe Meliponini (in the American tropics) the flight range for foraging activity from the nest can be around 2 km, while for smaller bees such like *Lasioglossum* they can still fly beyond 100 m from their nests (Roubik 1989). Considering that the *metepantle* system includes areas suitable

Table 3. Results of the log-lineal analysis that show significance between the relationships of socioeconomic and *metepantle* management variables and pollinator knowledge variables (number of identified pollinators and number of nesting sites mentioned).

Variables	Number of pollinators		Number of nesting sites	
	p	χ^2	*p*	χ^2
Age	0.278	1.177	0.181	1.789
Scholaship level	0.261	1.264	0.248	1.335
Number of identified plants growing on the *metepantles* borders	0.051[*]	3.812	0.245	1.353
Mention of crops dependent on pollination	0.260	1.271	0.26	1.271
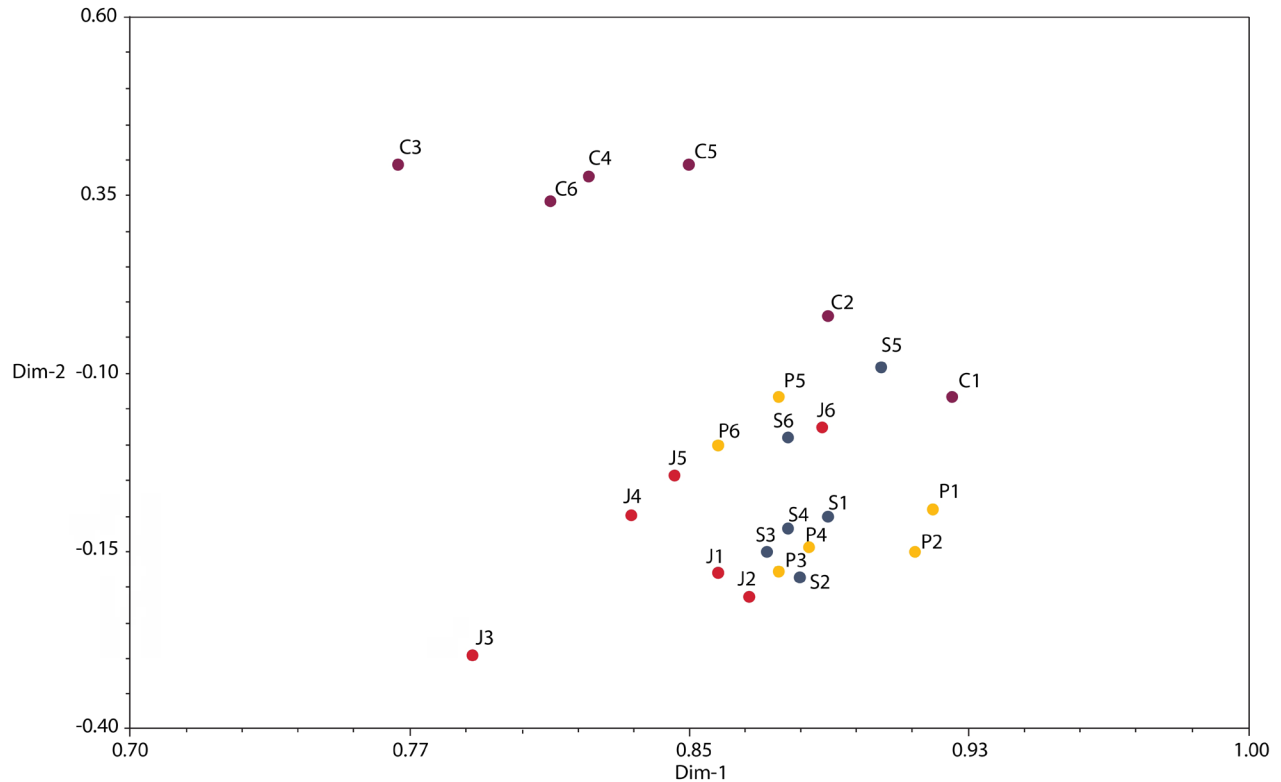
Figure 6. Principal Coordinate Analysis (PCO) where variation in the composition of the plants flowering on the *metepantle* borders is shown. The letter corresponds to the plot where plants were collected. Number indicate month of plant collection. May (1), June (2), July (3), August (4), September (5) and October (6).

for bee nesting and that the flight capacities for most bee species exceeds a few hundred meters while foraging, the wild plants of the borders and the crops are almost certainly to be within full reach of most bee species here found.

The use of tractors within the *metepantle* is uncommon because passing through its borders and berms represents a physical limitation. The use of agrochemicals is among the main drivers of pollinator diversity loss (González-Varo *et al.* 2013), but as we observed, there is low use of agrochemicals in the community. Of the 22 genera of collected bees, 14 of them were species that are known to nest mainly in the ground (Wilson & Carril 2016). We consider that the small degree of modernization of the *metepantles* and the biological characteristics of borders and berms will remain a good nesting and refugee sites where bees may be protected outside of the forest.

Local knowledge on pollination and pollinators. Considering that we found 43 different morphospecies of bees, interviewed farmers identified only a small fraction. The most frequently mentioned species were bees, they were also the most frequently collected species and they are

large and noisy. Such is the case of the European bee *A. mellifera*; "*jicotes*" referring to the genus *Bombus* and *clalizos* of the genus *Anthophora*. The exception was *L.* (*Evylaeus*) sp. that had a high frequency of collection but was poorly recognized by the interviewed farmers because they are very small (3.5 to 8 mm) and hard to observe (Michener 2000). *Apis mellifera* was mistaken on occasions for the fly *Eristalis* sp. The foraging patterns of *Eristalis* sp. are similar to those of *A. mellifera* than those of other flies (Golding & Edmunds 2000). Large flies of the order Diptera that were collected were not identified by the interviewed people and were only recognized as countryside fauna and not as floral visitors.

It is likely that the appearance of the insects influenced the degree of identification on behalf of the farmers. The appearance hypothesis proposed by De Lucena *et al.* (2007) suggests that the appearance of plants, depending on how conspicuous they are, will determine their value and use as a resource. "Apparent" plants are woody and dominate late successional stages. "Non-apparent" plants are herbaceous or are only found at early successional stages making them harder to find. In the case of bees,

larger ones could be more conspicuous, easier to find and could be considered more "apparent". In this study, the best recognized bees were those collected with greater frequency, possibly because they are the most abundant, because they have longer activity periods or simply because they were easier to collect. In most cultures, pollinator conspicuity influences their recognition (FAO 2008).

On the other hand, knowledge on pollinator behavior and their nesting requirement is usually greater when pollinators are near the places where people live and work (FAO 2008). In this case, many of the interviewed farmers (90 %) knew the nesting place of *A. mellifera* because people have, at one time, practiced apiculture in manmade hives near their houses or places of work. Additionally, people recognized the formation of hives from which honey can be obtained. However, the nesting sites of "clalizos" (*Anthophora* sp.) in which tunnels are formed in the ground in the shape of individual cells called "cantaritos" (meaning little vases) were also recognized. The nesting sites of *Bombus* sp. that nest in the ground and form small colonies were recognized too. It is interesting that the people that know the nesting sites for more species were also the ones able to distinguish between social and solitary species. This implies empirical ecological knowledge on the life cycles of these organisms.

Knowledge on the process of pollination is very heterogeneous. Most farmers (93 %) know that floral visitors, mainly bees, land on flowers to obtain nectar as a food resource as well as for other uses in the colony. They also know that they cover themselves in a yellow powder that comes from flowers (pollen). Of this 93 %, only nine interviewed people know their role in plant reproduction. Other studies have shown that knowledge on pollination is linked to knowledge acquired from agricultural activities and crop requirements rather than observation in non-agricultural contexts (FAO 2008). Something similar occurs in this study. Knowledge on pollination was greater in relation to crops like maize, and even though maize is wind-pollinated, farmers clearly recognized the role of pollinators in the formation of hybrid varieties. Similarly, the process of biotic pollination to produce hybrid fruit trees was also recognized. Only five interviewed farmers recognized the ecological process of biotic pollination, and of these, two learned it in school and three understood it empirically.

In the Bolivian Amazon, pollinator visits to Brazil nut trees (*Bertholletia excelsa* Bonpl.) are considered harmful by local people because they think that these visits can cause flowers to fall off and reduce nut production (FAO 2008). In New Zealand, few agriculturists consider pollinator activity to be important (FAO 2008). However, at our study site, the general perception of pollinators is good, and they are not considered to harm crops. Some recognized that they are beneficial, and they are considered important for being part of the local fauna. This indicates that they perceive wild pollinator diversity as a positive attribute.
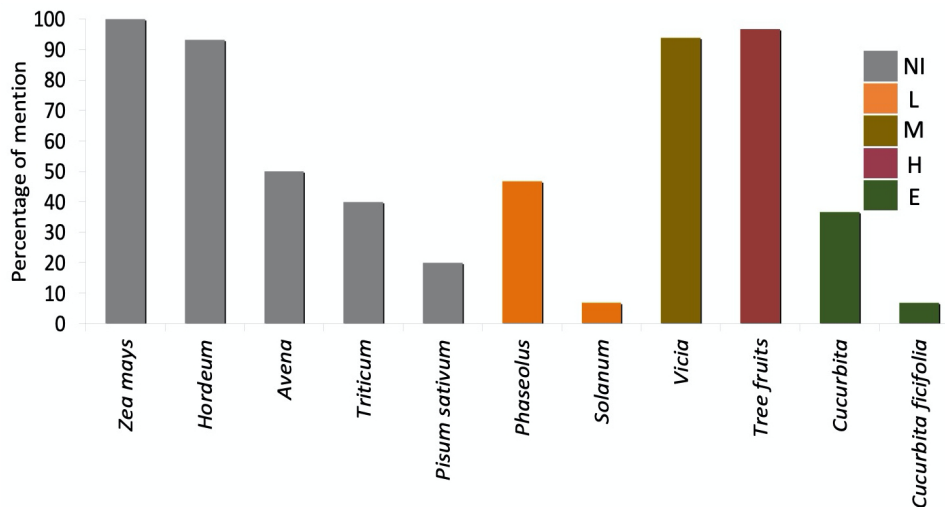

Figure 7. Mention percentage of the crops cultivated by the interviewed farmers. The degree of dependence on biotic pollination of each crop following Ashworth *et al.* 2009 is shown: E: essential (the absence of pollinators results in a > 90 % decrease in fruit production), H: high (the absence of pollinators results in 40 - 90 % decrease in fruit production), M: moderate (10 - 40 % decrease in fruit production) and L: low (0 - 10 % decrease in fruit production), NI: no increment (fruit production does not increase in the presence of pollinators).

Local distribution of knowledge and its relationship with the agroforestry system. Local knowledge on natural resources is not always equally distributed among the members of a community. Its variation may be related to socioeconomic and environmental factors (Reyes-García *et al.* 2013). Few studies have documented local knowledge on pollinators, and none have been carried out in our study region. Some performed by the FAO (2008) in Bolivia, New Zealand and South Africa show that knowledge on pollinators greatly varies among the members of the same community. In the Mesoamerican region, we only found three studies carried out in the south-central portion of Mexico. The local knowledge about different species of bees (Solís & Casas 2019) and stingless bees (Apidae: Meliponini) (Reyes-González *et al.* 2014) has been reported in the state of Michoacán and the Cuicatec region of the Tehuacán-Cuicatlán Valley. A loss of local knowledge on the management of stingless bees is reported associated with socioeconomic differences between the inhabitants of the region (Reyes-González *et al.* 2020). The degree of knowledge on pollination in this study was dependent on two aspects. One of them was the socioeconomic characteristics of the interviewed farmers and the other one was management regarding the types of crops used and the plants maintained on the borders of the *metepantles*. The people who recognized more pollinator insects and nesting sites were the oldest, with a lower scholarship level, that use crops dependent on pollination and that mentioned the most species of plant that grow on the borders of their sowing plots.

According to our results, knowledge on pollination could be related to accumulate agricultural management experience. Younger farmers may have not acquired yet such knowledge and experience to recognize pollinators even though they are dedicated to agriculture (Reyes-García *et al.* 2013). Another important aspect may be a person's observation ability. In this context, we saw that the people who recognized more pollinators were the same ones that were also able to mention more species of plants that grow on the borders of the *metepantle* and that they are known to be important floral resources for pollinators. This was the most important variable related to knowledge of pollinator insects, which means that people also observe pollinators that visit these plants.

Finally, the type and diversity of crops sowed in plots also influenced knowledge on pollination. In this case, older people with lower study level were the ones that
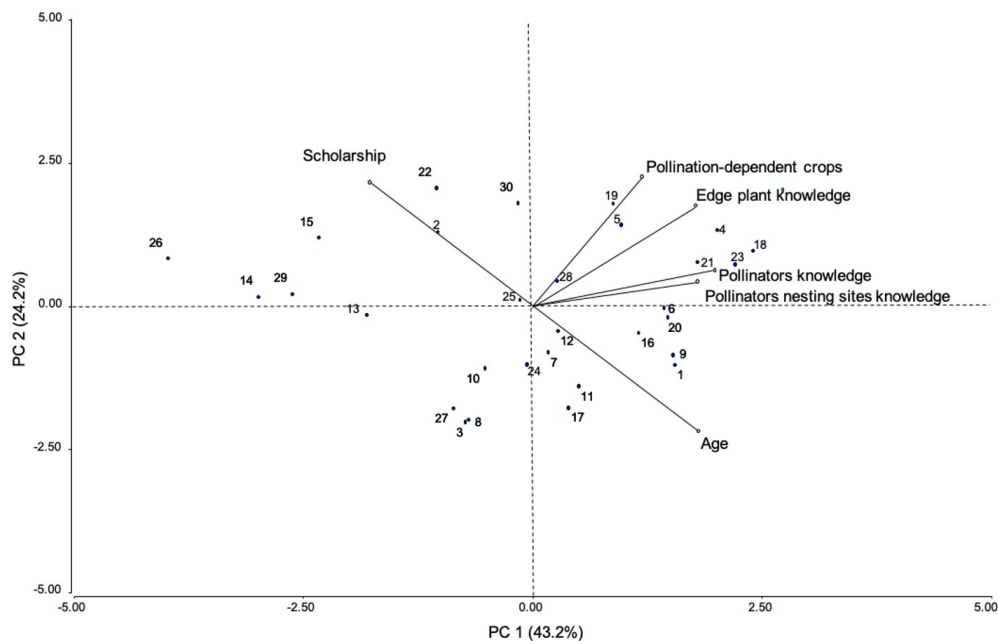
Figure 8. Principal Components Analysis (PCA). The distribution of the 30 interviewed people (represented with numbers) is shown. They are distributed according to their knowledge on pollinators (measured as number of recognized pollinators, and number of nesting sites mentioned) in relation to socioeconomic variables (scholarship level and age), and aspects of pollination related to *metepantle* management (measured as the mention of having crops that depend on biological pollination and the number of identified plants growing on the borders of the *metepantles* that flowered and consequently produced resources for pollinators)

sowed crops, such as zucchini, that depend more on biotic pollination and thus observed pollinator visits with greater frequency. Younger farmers with a higher education level usually prefer to sow crops, such as barley, that have greater commercial value (it is sold for beer production) and do not depend on biological pollination but rather on wind pollination. It is common for scholarship level to influence knowledge on biological and natural resource attributes (Bruyere *et al.* 2016). Less diversified commercial agriculture that may put native bee communities at risk and reduce knowledge on pollination is frequently related to higher scholarship levels (Klein *et al.* 2007, Kremen *et al.* 2002).

The value of biotic pollination for the metepantle agricultural system. Eleven species of crops (mainly cereals) are cultivated in the *metepantles* of the community of El Rosario. All the interviewed farmers mentioned that they farm maize and, in a lower percentage, barley, oats and wheat. As occurs at a global level (Ashworth *et al.* 2009), cereals occupy the greatest area of land. However, cereals depend on wind for pollination and thus biotic pollination is not as important for agricultural productivity of half of the crops in the *metepantles*. However, other crops promoted by the community and a large percentage of the interviewed people, depend in some measure on biotic pollination. The absence of pollinators would cause a moderate reduction in the production of *V. faba* (10 - 40 %) but a high reduction (40 - 90 %) in the production of fruit trees that grow on the edges of the *metepantles*. The rest of the species cultivated by less than 50 % of the interviewed people were *Solanum lycopersicum* L. (tomato), *Phaseolus vulgaris* (beans), *Cucurbita* sp. (zucchini) and *Cucurbita ficifolia* (figleaf gourd) which depend on biotic pollination. These last two even have strict dependency on pollination. According to Ashworth *et al.* (2009) even though crops that depend on biotic pollination do not occupy great areas of land in Mexico, they occupy a greater volume per area unit and thus their presence in the *metepantle* systems may promote the conservation of native pollinators in this region.

The degree of dependence of crops on biotic pollination greatly determines the degree of knowledge people have on this biological process as well as the vulnerability of the agricultural system (Klein *et al.* 2007, Ashworth *et al.* 2009). As proposed by Roué *et al.* (2015), knowledge that is linked to experience and personal observation can be identified more easily considering agricultural management and the population's ecosystem knowledge.

Local knowledge on pollination and pollinators among the population of El Rosario, Tlaxcala, is heterogeneous and is related with agroecosystem management and socioeconomic variables. However, pollinator richness was high for an agricultural environment in temperate region, pollinator recognition and knowledge on biotic pollination was scarce probably because the predominant crops are wind pollinated.

The structure and the management strategies of the traditional agricultural system *metepantle* favored high pollinator richness. The plant abundance of the borders of the *metepantles* form a matrix that functions providing corridors for the movement of pollinators with enough floral resources for them. The reduced modernization of this agricultural system allows us to assume that border system will remain as a refuge site for pollinators. Practically all the management strategies recommended by Garibaldi *et al.* (2014a) to promote pollinator diversity and abundance in agricultural systems, such as the maintenance of strips of wild vegetation between agricultural fields, landscape heterogeneity and a reduction in the use of agrochemicals and machinery were used in the *metepantles*. Although these traditional practices are not directly focused on pollinator management, they promote a holistic management that favors diversity and productivity of the agroforestry system while promoting local pollinator conservation through the protection of nesting sites and floral food resources through natural vegetation on the borders of the *metepantle*.

Acknowledgements

Compliance with Ethical Standards:

Based on the code of ethics of the International Society of Ethnobiology, permission to conduct this research was requested under the terms in which the community indicated us. To request permission, we attend a community assembly to explain the scope of the project. Subsequently, the interviewees orally authorized their agreement to answer our questions. People were informed about the interest of the first author to publish her research and to carry out her bachelor thesis. No personal data has been published in this investigation.

Supplementary material

Supplemental data for this article can be accessed here: https://doi.org/10.17129/botsci.2659

Literature cited

Altieri M, Trujillo J. 1987. The agroecology of corn production in Tlaxcala, Mexico. *Human Ecology* **15**: 189-220. DOI: https://doi.org/10.1007/BF00888380

Ashworth L, Quesada M, Casas A, Aguilar R, Oyama K. 2009. Pollinator-dependent food production in Mexico. *Biological Conservation* **142**: 1050-1057. DOI: https://doi.org/10.1016/j.biocon.2009.01.016

Bailey S, Requier F, Nusillard B, Roberts SPM, Potts SG, Bouget C. 2014. Distance from forest edge affects bee pollinators in oilseed rape fields. *Ecology and Evolution* **4**: 370-380. DOI: https://doi.org/10.1002/ece3.924

Bruyere B, Trimarco J, Lemungesi S. 2016. A comparison of traditional plant knowledge between students and herders in northern Kenya. *Journal of Ethnobiology and Ethnomedicine* **12**: 1-10. DOI: https://doi.org/10.1186/s13002-016-0121-z

Buchmann S, Ascher J. 2005. The plight of pollinating bees. *Bee World* **86**: 71-74. DOI: https://doi.org/10.1080/0005772X.2005.11417316

Burel F. 1996. Hedgerows and their role in agricultural landscapes. *Critical Reviews in Plant Sciences* **15**: 169-190. DOI: https://doi.org/10.1080/07352689.1996.10393185

Chacoff N, Aizen M. 2006. Edge effects on flower-visiting insects in grapefruit plantations bordering premontane subtropical forest. *Journal of Applied Ecology* **43**: 18-27. DOI: https://doi.org/10.1111/j.1365-2664.2005.01116.x

De Lucena R, Araújo E, De Albuquerque U. 2007. Does the local availability of woody Caatinga plants (Northeastern Brazil) explain their use value? *Economic Botany* **61**: 347-361. DOI: https://doi.org/10.1663/0013-0001(2007)61[347:DTLAOW]2.0.CO;2

Estrada A, Coates-Estrada R. 2001. Bat species richness in live fences and in corridors of residual rain forest vegetation at Los Tuxtlas, Mexico. *Ecography* **24**: 94-102. DOI: https://doi.org/10.1034/j.1600-0587.2001.240111.x

Estrada A, Coates-Estrada R, Meritt DA. 1997. Anthropogenic landscape changes and avian diversity at Los Tuxtlas, Mexico. *Biodiversity and Conservation* **6**: 19-43. DOI: https://doi.org/10.1023/A:1018328930981

FAO [Food and Agriculture Organization of the United Nations]. 2008. *Rapid Assessment of Pollinator's Status: a contribution to the international initiative for the conservation and sustainable use of pollinators*. Rome: FAO pp.112 http://www.fao.org/uploads/media/raps_2.pdf (accessed January 23, 2019)

Gallai N, Salles J, Settele J, Vaissière B. 2009. Economic valuation of the vulnerability of world agriculture confronted with pollinator decline. *Ecological Economics* **68**: 810-821. DOI: https://doi.org/10.1016/j.ecolecon.2008.06.014

Garibaldi L, Carvalheiro L, Leonhardt S et al. 2014a. From research to action: Enhancing crop yield through wild pollinators. *Frontiers in Ecology and the Environment* **12**: 439-447. DOI: https://doi.org/10.1890/130330

Garibaldi L, Steffan-dewenter I, Winfree R, Aizen M, Bommarco R, Cunningham S, Kremen C, Carvalheiro L. 2014b. Honey Bee Abundance. *Science* **339**: 1608-1611. DOI: https://doi.org/10.1126/science.1230200

Golding YC, Edmunds M. 2000. Behavioural mimicry of honeybees (Apis mellifera) by droneflies (Diptera: Syrphidae: Eristalis spp.). *Proceedings of the Royal Society B: Biological Sciences* **267**: 903-909. DOI: https://doi.org/10.1098/rspb.2000.1088

González-Jacome A. 2016. Sistemas agrícolas en orografías complejas: las terrazas de Tlaxcala. *In*: Moreno-Calles A, Casas A, Toledo V, Vallejo-Ramos M, eds. *Etnoagroforestería en México*. México: Universidad Nacional Autónoma de México, pp 111–144. ISBN 9786070281648

González-Varo JP, Biesmeijer JC, Bommarco R, Potts SG, Schweiger O, Smith HG, Steffan-Dewenter I, Szentgyörgyi H, Woyciechowski M, Vilá M. 2013. Combined effects of global change pressures on animal-mediated pollination. *Trends in Ecology and Evolution* **28**: 524-530. DOI: https://doi.org/10.1016/j.tree.2013.05.008

Hinojosa-Díaz I. 2003. Abejas silvestres (Hymenoptera: Apoidea) del declive sur de la sierra del Chichinautzin, Morelos, México. *Folia Entomologia* **42**: 1-20.

Klein A, Vaissière B, Cane J, Steffan-Dewenter I, Cunningham S, Kremen C, Tscharntke T. 2007. Importance of pollinators in changing landscapes for world crops. *Proceedings of the Royal Society B: Biological Sciences* **274**: 303-313. DOI: https://doi.org/10.1098/rspb.2006.3721

Kremen C, Williams N, Thorp R. 2002. Crop pollination from native bees at risk from agricultural intensification. *Proceedings of the National Academy of Sciences* **99**: 16812-16816. DOI: https://doi.org/10.1073/PNAS.262413599

LeBuhn G, Griswold T, Minckley R, Droege S, Roulston T, Cane J, Messinger O. 2003. *A Standardized Method for Monitoring Bee Populations-the Bee Inventory (BI) Plot*. Draft. http://online.sfsu.edu/beeplot/pdfs/Bee%20Plot%202003.pdf (accessed July 5, 2016)

Michener C. 2000. *The Bees of the World*. Maryland: Johns Hopkins University Press. ISBN: 9780801885730

Michener C, McGinley R, Danforth B. 1994. *The Bee Genera of North and Central America* (Hymenoptera: Apoidea). Washington: Smithsonian Institution Press. ISBN 1-56098-256-X

Moreno-Calles A, Toledo V, Casas A. 2013. Los sistemas agroforestales tradicionales de México: Una aproximación biocultural. *Botanical Sciences* **91**: 375-398 DOI: https://doi.org/10.17129/botsci.419

Potts S, Biesmeijer J, Kremen C, Neumann P, Schweiger O, Kunin W. 2010. Global pollinator declines: Trends, impacts and drivers. *Trends in Ecology and Evolution* **25**: 345-353. DOI: https://doi.org/10.1016/j.tree.2010.01.007

Quezada-Eúan J, Ayala-Barajas R. 2010. Abejas nativas de México. La importancia de su conservación. *Ciencia y Desarrollo* **36**: 8-13

Rader R, Bartomeus I, Garibaldi LA, Garratt MPD, Howlett BG, Winfree R, Cunningham SA, Mayfield MM, Arthur AD, Andersson GKS, Bommarco R, Brittain C, Carvalheiro LG, Chacoff NP, Entling MH, Foully B, Freitas BM, Gemmill-Herren B, Ghazoul J, Griffin SR, Gross GL, Herbertsson L, Herzog F, Hipólito J, Jaggar S, Jauker F, Klein AM, Kleijn D, Krishnan S, Lemos CQ, Lindström SAM, Mandelik Y, Monteiro VM, Nelson W, Nilsson L, Pattemore DE, Pereira NDO, Pisanty G, Potts SG, Reemer M, Rundlöf M, Sheffield CS, Scheper J, Schüepp C, Smith HG, Stanley DA, Stout JC, Szentgyörgyi H, Taki H, Vergara CH, Viana BF, Woyciechowski M. 2016. Non-bee insects are important contributors to global crop pollination. *Proceedings of the National Academy of Sciences of the United States of America* **113**: 146-151. DOI: https://doi.org/10.1073/pnas.1517092112

Reyes-García V, Guèze M, Luz A, Paneque-Gálvez J, Macía M, Orta-Martínez M, Pino J, Rubio-Campillo X. 2013. Evidence of traditional knowledge loss among a contemporary indigenous society. *Evolution and Human Behavior* **34**: 249-257. DOI: https://doi.org/10.1016/j.evolhumbehav.2013.03.002

Reyes-González A, Camou-Guerrero A, del-Val E, Ramírez MI, Porter-Bolland L. 2020. Biocultural Diversity Loss: the Decline of Native Stingless Bees (Apidae: Meliponini) and Local Ecological Knowledge in Michoacán, Western México. *Human Ecology* **48**: 411-422. DOI: https://doi.org/10.1007/s10745-020-00167-z

Reyes-González A, Camou-Guerrero A, Reyes-Salas O, Argueta A, Casas A. 2014. Diversity, local knowledge and use of stingless bees (Apidae: Meliponini) in the municipality of Nocupétaro, Michoacan, Mexico. *Journal of Ethnobiology and Ethnomedicine* **10**: 47. DOI: https://doi.org/10.1186/1746-4269-10-47

Roubik D. 1989. *Ecology and Natural History of Tropical 8ees*. Cambridge: Cambridge University Press. ISBN 0-521-42909-9

Roué M, Battesti V, Césard N, Simenel, R. 2015. Ethno-ecology of pollination and pollinators. Knowledge and practice in three societies. *Revue d'ethnoécologie*. **7**. DOI: https://doi.org/10.4000/ethnoecologie.2229

Russell-Bernard H. 1995. *Métodos de Investigación en Antropología*. Walnut Creek: AltaMira Press. ISBN 0-8039-5245-7

Solís L, Casas A. 2019. Cuicatec ethnozoology: traditional knowledge, use, and management of fauna by people of San Lorenzo Pápalo, Oaxaca, Mexico. *Journal of Ethnobiology and Ethnomedicine* **15**: 1-16. DOI: https://doi.org/10.1186/s13002-019-0340-1

Ssymank A, Kearns C, Pape T, Thompson F. 2008. Pollinating flies (diptera): A major contribution to plant diversity and agricultural production. *Biodiversity* **9**: 86-89. DOI: https://doi.org/10.1080/14888386.2008.9712892

Vergara CH. 2002. Bees floral visitors in a mixed orchard in central Mexico. *Crop Research-Hisar* **24**: 113-116. ISSN 0970-4884

Westphal C, Bommarco R, Carré G, Lamborn E, Morison N, Petanidou T, Potts SG, Roberts SPM, Szentgyörgyi H, Tscheulin T, Vaissiére BE, Woyciechowski M, Biesmeijer C, Kunin WE, Settele J, Steffan-Dewenter I. 2008. Measuring Bee Diversity in Different European Habitats and Biogeographical Regions. *Ecological Monographs* **78**: 653-671. DOI: https://doi.org/10.1890/07-1292.1

Wilson J, Carril O. 2016. *The Bees in your Backyard: A Guide to North America's Bees*. New Jersey: Princeton University Press. ISBN: 9780691160771