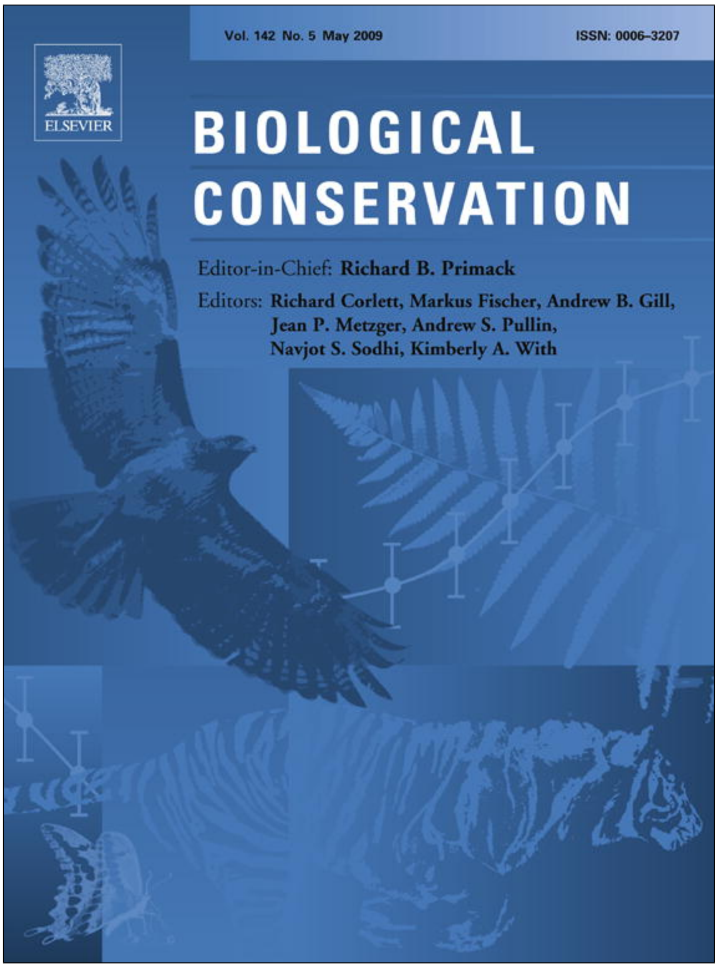
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Pollinator-dependent food production in Mexico

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ABSTRACT

Animal pollination is one of the essential services provided by ecosystems to humans. In the face of a potential worldwide pollination crisis it is important to assess which countries may be more vulnerable in order to prioritize pollinator conservation efforts. The poverty level, the population density and the level of pollinator dependence for food provisioning are key aspects to identify vulnerable countries. We evaluate these aspects and determine the level of human food provisioning dependence on pollinators in Mexico, a developing and highly populated country. The diversity of crop species in Mexico is exceptionally high. Nearly 85% of fruit and/or seed consumed species depend to some degree on pollinators for productivity. Overall, pollinator-dependent crops generate larger income but cover a lower cultivated area and produce less volume compared to non-pollinator-dependent crops. Volume per unit area, however, as well as revenue per unit area, is much higher for pollinator-dependent crops. Native wild pollinators also play a key role in fruit or seed production of Mexican domesticated plant species and in the reproduction of many useful wild species. Thus, assuring free pollination services is particularly important in Mexico as the livelihood of a large proportion of the population exclusively and directly depends on ecosystem services for subsistence. Feasible conservation strategies involve the payment of environmental services to *Ejidos* (communal land tenure systems) making efforts to protect or restore plant resources and native pollinators, and the creation of new protected natural areas, which ensures food provision, mating and nesting sites for pollinators.

1. Introduction

Animal pollination is one of the essential services provided by ecosystems to humankind (Costanza et al., 1997; Allen-Wardell et al., 1998; Kearns et al., 1998; Ricketts et al., 2008). Animal pollinators are responsible for the sexual reproduction of more than 80% of the terrestrial vascular plants, including most crop species (Buchmann and Nabham, 1996). Therefore, by affecting sexual reproduction, pollinators play a key role in the maintenance of plant diversity in terms of species number, genetic variation and richness of functional groups (Costanza et al., 1997; Balvanera et al., 2001; Diaz et al., 2006; Fontaine et al., 2006), thus contributing ultimately to ecosystem services linked to plant diversity (Mittlelbach et al., 2001; Diaz et al., 2006).

Currently, land-use change, biotic invasions, and climate change are factors that severely alter the diversity, structure, distribution, and functioning of ecosystems (Saunders et al., 1991; Sala et al., 2000). Land-use change, especially the destruction and fragmentation of habitats through the expansion of agricultural, pastureland, and cities boundaries, are the main driving forces of current biodiversity loss (Sala et al., 2000). The loss of biodiversity has, in turn, large impacts on ecosystem processes, ecosystem services, and therefore on human well-being (Diaz et al., 2006). The effects of anthropogenic activities on pollinator diversity have received much attention of research during the last decades (Buchmann and Nabham, 1996; Allen-Wardell et al., 1998; Richards, 2001; Vergara, 2002; Kevan, 2004; Ghazoul, 2005; Winfree et al., 2009). Local extinctions due to anthropogenic disturbances have been reported for some pollinator species of bees, hoverflies (Biesmeijer et al., 2006) and butterflies (Maes and VanDick, 2001). Specifically, several examples of pollinator diversity and/or abundance decline have been documented to be caused by agriculture intensification (Kremen et al., 2002; Perfecto et al., 2003; Morandin and Winston, 2005; Harvey and Gonzalez-Villalobes, 2007; Winfree et al., 2009), habitat loss (Klein et al., 2003; Chacoff and Aizen, 2006; Ricketts et al., 2008; Winfree et al., 2009), alien species introduction (Morales and Maizen, 2002; Goulson, 2003) and pesticide use (Kevan, 1975; Kevan et al., 1997; Kearns et al., 1998; Parra-Tabla et al., 1998; Winfree et al., 2009).

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Despite the evidence on pollinator losses, Ghazoul (2005) recently argued that the loss of certain pollinator species may not necessarily affect crop yields or wild fruit production in plant species that are wind or mostly self-pollinated or if they are insured against specific pollinator losses by a diverse array of pollinators. Nevertheless, the growing available evidence focused on crop species shows that not only self-incompatible crops but also self-compatible and even self-pollinated crops decrease their fruit/seed production and/or quality and crop stability when pollinator abundance and/or diversity are reduced (e.g. Calzoni and Speranza, 1998; Klein et al., 2003; Blanche and Cunningham, 2005; Morandin and Winston, 2005; Olschewski et al., 2006). Also, at the community level, it was experimentally demonstrated that seed production is negatively affected by decreased pollinator diversity (Fontaine et al., 2006). Therefore, in most cases documented decreases in pollinator diversity contribute to the loss of pollination service (e.g. Kremen et al., 2002; Ricketts et al., 2004; Larsen et al., 2005; but see Chacoff et al., 2008).

It was recently shown that human reliance on animal pollination food production in a global context is high: nearly 75% of the main crop species rely on pollinators for fruit or seed set (Klein et al., 2007). However, there is an opposite trend in terms of volume crop production: 60% of global food volume comes from 18 non-pollinator-dependent crop species and 35% from pollinator-dependent crops (5% unevaluated; Klein et al., 2007). Thus, although animal pollinators may be irrelevant for the few staple food crops producing the largest volume of food, they do play a key role in provisioning diversity of food crops and therefore supply vital nutrients for human subsistence (Klein et al., 2007; Gallai et al., 2008). Such diversification of human diet, which implies the consumption of many different fruits, seeds and vegetables, is essential for maintaining a healthy nutritional status, improving children's growth rate, and consequently enhancing human well-being (WHO Report, 1990; MEA, 2005).

Pollination service decline can have short and long term consequences for human well-being. Short term consequences are basically related to decreased food provisioning (e.g. Kearns et al., 1998; Cincotta and Engelman, 2000; Steffan-Dewenter et al., 2005), whereas long term consequences are indirectly related to the cascading effects of plant diversity decrease (Cincotta and Engelman, 2000; Biesmeijer et al., 2006; Fontaine et al., 2006), affecting other ecosystem services such as air and water purification, nutrient cycling, disease control, among others (Mittlelbach et al., 2001; MEA, 2005; Balvanera et al., 2006). Both short and long term consequences of pollination services decline will be severe for human population, especially among the subsistence farmers. The rural poor and traditional societies face the most serious and immediate risks as they exclusively and directly rely on wild pollinators for crop production, wild species exploitation and on other ecosystem services derived from plant diversity (Allen-Wardell et al., 1998; Cincotta and Engelman, 2000; MEA, 2005; Diaz et al., 2006). Overall, pollination service declines will be felt disproportionately by the world's poor who cannot substitute free ecosystem services with alternative services purchased in the local and global market (Partap et al., 2001; MEA, 2005; Diaz et al., 2006).

In this context it is crucial to learn which countries are more vulnerable to the pollination crisis in order to prioritize pollinator conservation strategies. Simple and useful factors to identify vulnerable countries are the poverty level, the population density and the level of animal pollination dependence for food provisioning (MEA, 2005). Information of a country's poverty level and population density is relatively easy to obtain from annual censuses; however, a great gap of information exists on the degree of animal pollination dependence for food production.

Mexico is a high-populated country (103 million people; INEGI, 2005) where nearly 50% of its population lies below the poverty line (Torres, 2001). The livelihoods of a large quantity of people rely strongly on the free provision of pollination services for food supply. In addition, Mexico is one of the world's most important centers of plant domestication where populations of wild crop relatives and domesticated cultivars coexist (Harlan, 1975; Bye and Linares, 2000). Wild crop relatives represent crucial reservoirs of potentially transferable useful genes into cultivars to improve their quality and productivity (Smith et al., 1992; Maxted et al., 2007). In this regard, native pollinators may contribute to the maintenance of plant genetic resources through pollen flow between wild crop relatives and closely related cultivated plant populations (e.g. Ellstrand et al., 1999; Papa and Gepts, 2003).

The aim of our study was to evaluate human food provisioning dependence on pollinators in Mexico. Our study was directed to analyze information on cultivated plant species, particularly those domesticated or semi-domesticated in Mexico, their different uses and parts used. Special attention was directed to plant species whose fruits or seeds are consumed by humans, considering information on the cultivated area, volume produced, yield crop value, and the level of pollinator dependence. Also, our study aimed to comparing those variables between pollinator-dependent and non-pollinator-dependent crop species in order to identify more productive and/or more rentable type of crops. Following the FAO crop categorization, we analyzed diversity of crop species and the level of pollinator dependence within the categories. We highlight the importance of pollinator-dependent crop species and of the use of wild plant species of Agavaceae and Cactaceae, two particularly representative plant families of Mexico. Finally, our study identifies gaps of information, and defines some management strategies for pollination services conservation in Mexico.

2. Methods

We generated a list of the currently cultivated plant species in Mexico from the National agricultural census conducted by SAGARPA (Secretaría de Agricultura, Ganadería y Pesca, 2002) and from other studies on ethnobotany and processes of domestication of Mexican plants (Harlan, 1975; Colunga et al., 1986; Hernández-Xolocotzi, 1993; Casas et al., 1996, 2001; Casas and Barbera, 2002). This list includes cultivated plant species used as food, forage, medicine, ornamental, textile, or as raw material for several industrial products. We identified crop species domesticated in Mexico and other plant species currently managed by Mexican people. Managed or semi-domesticated plant species are defined as wild populations subjected to some type of human practice without significant perturbations of their habitats and directed to maintain or increase in situ the availability of their useful products (Casas et al., 2007). We searched for the uses of domesticated and semi-domesticated plant species. In the case of plant species whose fruits or seeds are consumed by humans we searched for information (SAGARPA, 2002) on the cultivated area (ha), volume (metric tonnes, mt) produced and yield value (U$S). We further classified these species as: cereals, fruits, nuts, oil bearing cops, pulses, spices, stimulants, and vegetables, following FAO crop categories (http://www.fao.org/waicent/faostat/agricult/). This categorization helps visualizing and comparing crops with different nutritional attributes: while all crops within a category can be taken as potential substitutes for one another, this is not possible between categories (e.g., a fruit cannot be substituted by a spices).

Information on the degree of animal pollinator dependence for fruit or seed production was obtained by searching the published literature of each plant species in electronic databases

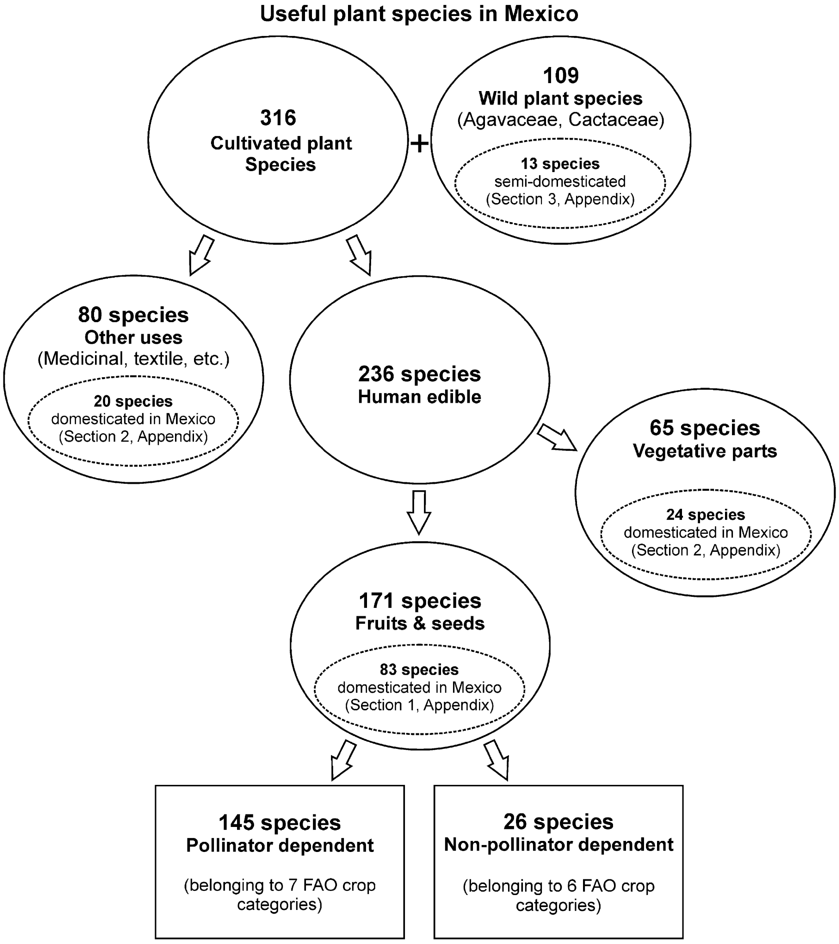

Fig. 1. Summary of uses, domestication and pollinator dependence for useful plant species in Mexico. The two major groups contain cultivated (i.e., crops) and wild (Agavaceae, Cactaceae) plant species. Cultivated plants are divided by their uses. Cultivated human edible species are differentiated by the parts consumed. Detailed information regarding whether the species are pollinator-dependent or non-dependent is given for fruit and seed-consumed species. Smaller, short-dashed ovals give the number of semi-domesticated and domesticated species in Mexico within the total number of species given in the larger ovals.

such as ISI web of science and Scopus. If information was not available, we contacted colleagues working with the species. When no source of information was available we used indirect means to distinguish pollinator-dependent crop species: plant species with complex, showy flowers and rewards were considered to be mainly animal pollinated. The list of currently useful wild Agavaceae and Cactaceae species was obtained from Gentry (1998) and Casas and Barbera (2002), respectively. When information was available, we tabulated the level of yield (fruit or seed set) dependence on pollinators following Klein's et al. (2007) categorization: *Essential*: pollinator absence produce a reduction of >90% of crop production compared with pollinator presence, *High*: between 40% and 90% of reduction in absence of pollinators, *Modest*: between 10% and <40% of reduction and *Little*: >0–10% of reduction. Non-pollinator-dependent crop species were considered those cited in original papers as anemophilous, autonomous self-pollinated, parthenocarpic, or those classified by Klein et al. (2007) as *No increase*: no yield increase with animal-mediated pollination. We compared the relative production in terms of area and yield value between pollinator-dependent and non-pollinator-dependent crops with ANOVA after log-transforming the data to meet homogeneity assumptions. A similar analysis was conducted within each of the categories defined by FAO (fruits, nuts, oil bearing crops and pulses). We show back-transformed data on figures.

3. Results

3.1. Crop species

A total of 316 plant species were identified as commonly cultivated In Mexico: 236 of them used as human food (including beverages), and 80 species are cultivated for a variety of uses including textile, ornamental, fodder, medicinal, and for manufacturing industrial products (Fig. 1; Supplementary Table). Humans consume the fruits and/or seeds of 171 crop species and the vegetative parts of other 65 species. Nearly 85% of fruit or seed consumed species depend, to some degree, on pollinators for successful fruit/seed production, whereas nearly 15% of these crop species are non-pollinator-dependent (Fig. 1; Supplementary Table). From these 171 species, we assessed precise information on the degree of dependence on pollinators for 108 fruit or seed-producing crops. More than 60% of these crops fall within the *Essential*, *High*, and *Modest* dependence levels whereas 23% and 15% belong to the *Little* and *No increase* categories, respectively (Fig. 2a). For the remaining 63 fruit or seed-producing crop species we were only able to determine whether they are pollinator-dependent or non-pollinator-dependent by their flower morphologies and by using bibliographic information. Most of these species are pollinator-dependent, but the level of dependence is unknown (Fig. 2a).

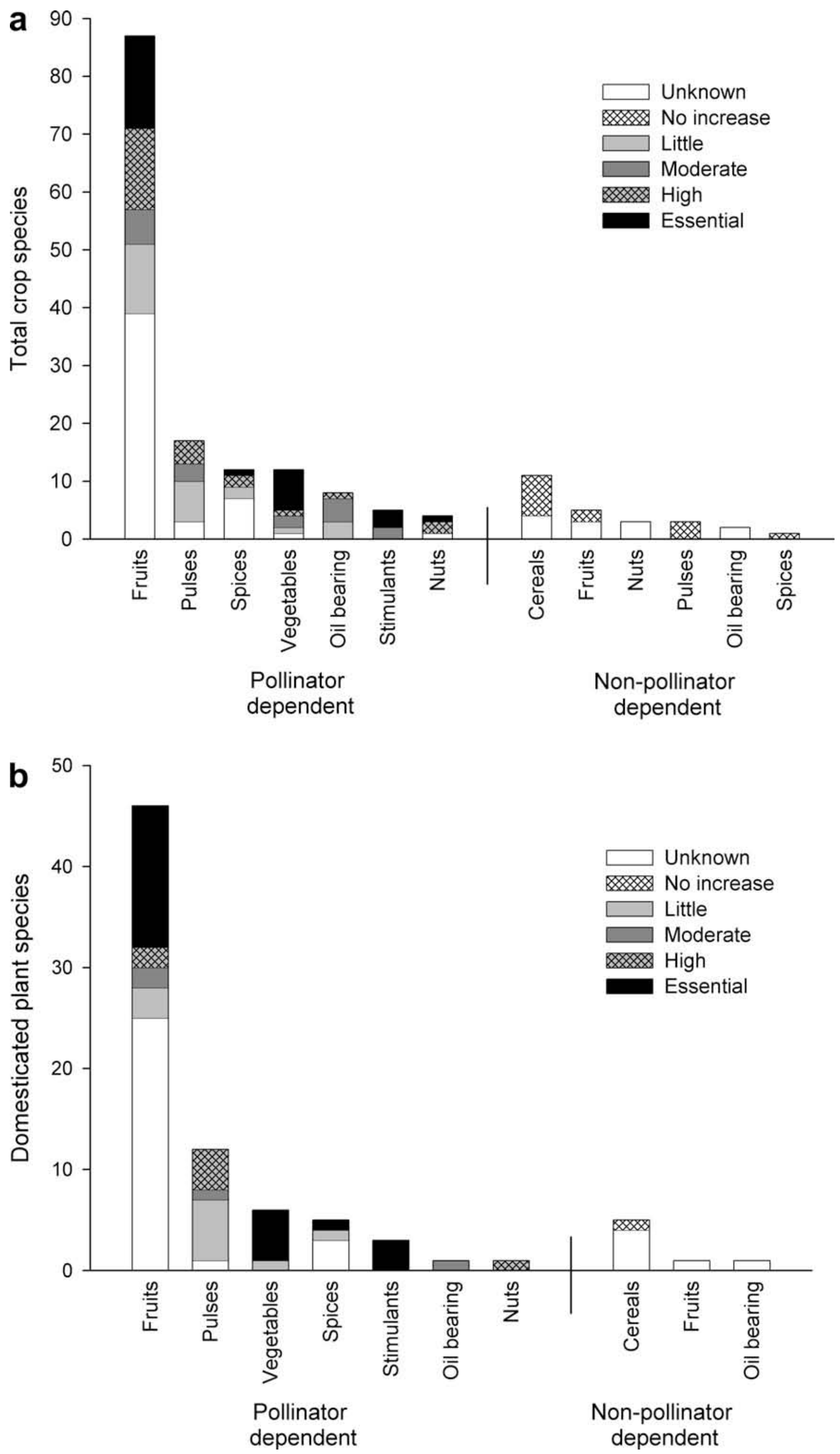

Fig. 2. Pollinator dependence levels following Klein's et al. (2007) categorization for (a) total Mexican crop species and (b) for Mexican domesticated species. Plant species with human edible fruits/seeds are exclusively considered. Colors and texture represent different crop categories following FAO definitions.

Information on the cultivated area, total volume produced, and yield value was available for 70% (99 species) of pollinator-dependent and 85% (22 species) of non-pollinator-dependent crop species (Supplementary Table). In decreasing number of species, fruits, pulses and spices categories represent more than 70% of Mexican cultivated crop species whose fruits and seeds are human food (Fig. 2a). Within each FAO crop category, on average, 80% of crop species are pollinator dependent (Fig. 2a). All vegetables and stimulants are pollinator-dependent crops, whereas cereals are entirely non-pollinator-dependent crops (Fig. 2a). As expected, essential and high pollinator dependence yield production was found in most of the species within fruits, vegetables, and nuts crop categories (Fig. 2a).

At the country level, non-pollinator-dependent crops cover a much greater cultivated area than pollinator-dependent crops (Table 1). This greater area is mostly due to the traditional and particularly high incidence of wind-pollinated corn crops throughout Mexico (Table 2; Supplementary Table). Also, non-pollinator-

Table 1
pollinator-dependent and non-pollinator-dependent crop species in Mexico. Absolute and relative values at the country level: cultivated area (ha 10^5); volume (metric tonnes 10^5), yield value (U$S 10^8), volume per hectare (mean metric tonnes/ha) and yield value per Ha (mean U$S/Ha). Data from Mexican census SAGARPA (2002).

	Pollinator-dependent crops	Non-pollinator-dependent crops	Total
Area (ha) 10^5	49 (33%)	101 (67%)	150
Metric tonnes 10^5	220 (38%)	355 (62%)	575
Yield value (U$S) 10^8	50 (54%)	43 (46%)	93
Metric tonnes/ha (±1 SD)	11 ± 2.20	5.34 ± 2.18	16.34
U$S/ha (±1 SD)	3480 ± 748	1732 ± 562	5212

dependent crops produce higher overall volumes than pollinator-dependent crops (Table 1). However, considering only crop categories containing both, pollinator-dependent and non-dependent species (fruits, nuts, oil bearing crops, and pulses), pollinator-dependent crops cover a greater area and produce a higher volume than non-pollinator-dependent, except for the nuts category (Table 2). The overall income generated by non-pollinator-dependent crops is of considerable smaller amount compared to that obtained from pollinator-dependent crops (Table 1), similarly to that observed within each crop category, except nuts (Table 2). More specifically, in terms of productivity, pollinator-dependent crops produce significantly more volume ($F_{[1;104]} = 13.02$, $P < 0.001$; Table 1), and profits per hectare ($F_{[1;104]} = 1.11$, $P = 0.005$; Table 1) than non-pollinator-dependent crops. Comparisons of volume and profits per hectare between pollinator-dependent and non-pollinator-dependent crops within the same crop category were never statistically significantly different. However, pollinator-dependent crops tend to produce more volume and profits per hectare than non-pollinator-dependent crops within each crop category (Table 2). Fruits category showed the contrary trend, as a result of the particularly high volumes produced by the heavy-per-unit parthenocarpic pineapple crop (Supplementary Table). Independently of pollinator dependence, the most productive categories per unit area are fruits, oil-bearing crops and vegetables; whereas the most profitable categories per unit area are fruits, vegetables and spices (Table 2).

3.2. Domesticated and wild species

Most of Mexican domesticated and semi-domesticated plant species (68%) are consumed for their edible fruits or seeds, whereas only a few species (32%) are useful for their edible vegetative parts or have many other uses (e.g., textile, ornamental, etc.; Fig. 1). Overall, most domesticated and semi-domesticated plant species depend on animal pollinators for fruit or seed production (Fig. 2b). We assessed accurately the level of dependence on pollinators for 46 fruit/seed-producing domesticated species. Nearly 75% of these plant species are within the categories of *Essential* to *Modest* pollinator-dependence, whereas 25% of them belong to the *Little* and *No increase* categories (Fig. 2b). For 37 fruit or seed-producing domesticated species we were only able to determine whether they are pollinator-dependent or non-pollinator-dependent by their flower morphologies and by using bibliographic information. Most of these species are pollinator-dependent, but the level of dependence is unknown (Fig. 2b). Therefore, most of the domesticated and semi-domesticated plant species are used as human food and depend on pollinators for production. Most of domesticated species belong to fruits and pulses crop categories (Fig. 2b). Within the fruit category, 95% of species are pollinator dependent, while domesticated nuts, spices, pulses, stimulants and vegetables are all pollinator dependent. All cereals, on the contrary, are non-pollinator-dependent (Fig. 2b). The contribution of pollinators to the reproduction of wild plants used by humans also has alimentary and economic importance in Mexico. For instance, most Cactaceae and Agavaceae species depend on animal pollination for successful reproduction as it is revealed from the studies cited in Supplementary Table and by considering the complex morphology and reward offered by flowers. A total of 116 native cacti species in Mexico are commonly consumed as food or beverages, or are used as medicine or ornamental plants (Supplementary Table). Most of these species are gathered in the wild (i.e., non-cultivated, Fig. 3). Similarly, from the native Agavaceae species that are commonly used or consumed, most of them are non-cultivated and gathered in the wild (Fig. 3).

4. Discussion

The diversity of crop species in Mexico is exceptionally high (316 species); overall this country has 20% more crop species than 15 countries of the European Union altogether (264 crop species; Williams, 1994, 2002). More than a half of the currently cultivated plant species in Mexico are crops whose fruits or seeds are consumed by humans and more than 80% of these crops depend in some degree on pollinators for efficient production. This high proportion of pollinator-dependent crops is similar to that observed at the continental (European Union 84%; Williams, 1994) and global scales (74%; Klein et al., 2007). Most of food production volumes in Mexico, however, derive from non-pollinator-dependent crops, pattern that agrees with the global trend recently reported by Klein et al. (2007). In the case of Mexico, the higher volume of food production by non-pollinator-dependent crops is essentially due to

Table 2
Pollinator-dependent (D) and non-pollinator-dependent (N) crop species in Mexico. Absolute and relative values for each FAO crop categories (fruits, nuts, oil bearing crops, pulses spices, stimulants, vegetables, cereals): cultivated area (ha 10^5); volume (metric tonnes 10^5), yield value (U$S 10^8), volume per hectare (mean metric tonnes/ha) and yield value per hectare (mean U$U/ha). *P* values represent ANOVA's results from comparisons between pollinator-dependent and non-pollinator-dependent crops belonging to the same crop category. Within parentheses is the number of crops for each crop category. Data from Mexican census SAGARPA (2002).

	Fruits		Nuts		Oil bearing		Pulses		Spices		Stimulants	Vegetables	Cereals
	D (87)	N (5)	D (4)	N (3)	D (8)	N (3)	D (17)	N (3)	D (12)	N (1)	D (5)	D (12)	N (11)
Area (Ha) 10^5	10.5	1.29	0.04	0.52	1.7	0.1	24.2	1.68	1.58	0.04	8.6	2.5	97.6
Metric tonnes 10^5	112	30	0.54	0.68	3.46	0.15	20.37	2.88	14.8	0.05	17.5	51	321
Yield value (U$S) 10^8	19.35	6.78	0.06	1.14	0.3	0.06	9.33	1	5.68	0.04	3.1	12.2	34.2
Metric tonnes/Ha (±1 SD)	8.50 (6.59)	20.10 (17.22)	19.83 (36.19)	0.47 (0.73)	24.61 (59.92)	0.75 (0.91)	4.73 (5.42)	2.4 (1.86)	3.85 (3.50)	1.45	1.37 (1.15)	24.28 (15.75)	2.76 (1.44)
P value	0.10		0.06		0.51		0.49		–		–	–	–
U$S/Ha (±1 SD)	4 634 (9 104)	6 463 (2 354)	1 556 (750)	833 (1203)	684 (718)	434 (300)	1 656 (2 895)	769 (743)	1 594 (1 056)	1 130	517 (278)	5 295 (718)	470 (218)
P value	0.69		0.37		0.58		0.62		–		–	–	–

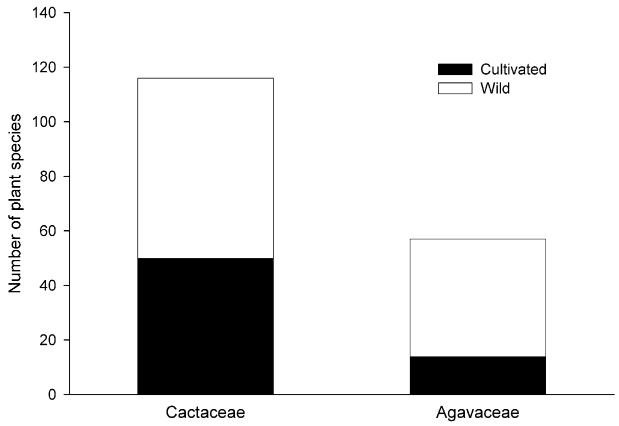

Fig. 3. Proportion of useful wild and cultivated species of Agavaceae and Cactaceae in Mexico.

the much larger area of land assigned to these crops. When examining the relative volumes of food production per unit area, pollinator-dependent crops produce twice as much volume as non-pollinator-dependent crops. Thus, on average, less area of land is required for producing a metric tonne of a pollinator–dependent crop. In economic terms, pollinator-dependent crops in Mexico are more profitable: pollinator-dependent crops produce on average twice as much income per hectare as non-pollinator-dependent crops. A similar trend, with even larger differences, was recently found at the global scale (Gallai et al., 2008). Therefore, pollinators seem to be important in Mexico and globally, not only for contributing to human nutrient balance by providing food diversity, but also for maximizing food volume production and incomes per hectare of land. Surprisingly, although most of crop species within the fruit category are pollinator dependent, there is a substantial number of species for which the level of dependence is still unknown (Fig. 2a). More work should be oriented in determining the dependence level of this diverse category.

Mexico is one of the world's most important centers of plant domestication (Harlan, 1975; Bye and Linares, 2000), containing populations of many wild crop relatives, which represent important socio-economic resources. Wild crop relatives' populations are reservoirs of likely useful genes; therefore, native pollinators can play a key role contributing to gene flow between cultivated species and their wild crop relatives. An example is the case of Mexican *Cucurbita* crops, where several species have been domesticated and are basic subsistence crops for rural people (Lira, 1988). All *Cucurbita* species are highly dependent on animal pollination; thus native pollinators may be key actors in maintaining their genetic diversity and production stability (Canto-Aguilar and Parra-Tabla, 2000; Montes-Hernandez and Eguiarte, 2002). As for *Cucurbita* species, most of Mexican domesticated and semi-domesticated plant species produce edible fruits and seeds, and their successful production depends on pollinators. Because these native plant species share evolutionary history with their native pollinators through mutualistic relationships, it is reasonable to assume that native wild pollinators should achieve more efficient pollination service than managed introduced pollinators. In this study we found no information on the level of pollinator dependence for more than one third of Mexican domesticated species, particularly within the fruits and spices categories (see also National Research Council, 2007). Future research should be oriented to determine the level of pollinator dependence fruit production in these historically vital plant species. Remarkably, most of the widely used Cactaceae and Agavaceae species are wild, non-cultivated, implying that these species depend almost exclusively on wild pollinators for their sexual reproduction. Wild plant food diversity is used for poor people as insurance and coping mechanism, providing alternative sources of food in the face of increasing economic or market uncertainty (MEA, 2005). This is a key issue, as it highlights that wild pollinator services can be particularly important for the livelihood of poor people. This assessment contrasts with Ghazoul's (2007) argument that wild pollinator services are only valuable if they are relevant to crop production. Contrary to this view, we consider that more dimensions need to be taken into account (social, cultural, economical, ecological, etc.) in the evaluation of pollination services to fully determine the impact of wild pollinators for human well-being.

Although scarcely recognized, pollinator extinction may constitute one of the major threats for human well-being in the near future (Kevan and Phillips, 2001; MEA, 2005). The World Health Organization recommends 400 gr per capita and per day of fruits and vegetables in order to have a healthy nutrition (WHO, 1990). Particularly, fruits, vegetables, and stimulants are the most pollinator-dependent crop categories in Mexico, and therefore the most vulnerable ones to pollinator declines. At the world scale, these same three crop categories will not suffice the current consumption level in a scenario of pollination crisis (Gallai et al., 2008). Thus, the poor and rural people face the most immediate risks as they exclusively and directly rely on ecosystem services (e.g. Allen-Wardell et al., 1998; Cincotta and Engelman, 2000; MEA, 2005). Mexico is one of the most populated countries in the world and nearly half of its population lies below the poverty line (Torres, 2001). Therefore, conserving pollinators in Mexico is a priority to assure free pollination services for food diversity provisioning and for maintaining plant diversity and their associated benefits for the livelihood of a large quantity of people. Moreover, pollinators serve as food provision insurance not only to the country where they occur but also to other countries that import their crops, typically the developed and industrialized countries (Deutsch and Folke, 2005; Gallai et al., 2008). For example, Mexico is the main provider of fresh vegetables and fruits to the United States (SAGARPA, 2002). Also, the high demand of fruits, vegetables, and stimulants in Europe needs to be supplied by many other countries (Gallai et al., 2008). Therefore, pollinator decline could have also serious consequences in countries or regions where fruits, vegetables and stimulant crops are commonly imported (Gallai et al., 2008).

As far as we know, this is the first study to assess the pollination dependence of a country's main crops production, thus comparative analyses between countries are not possible at this time. Habitat loss and fragmentation seem to be the main factor determining decrease of pollinator richness and abundance at the global scale (e.g. National Research Council, 2007; Taki and Kevan, 2007; Winfree et al., 2009). The high rates of forest fragmentation in Mexico (Trejo and Dirzo, 2000) can thus represent a serious threat to the pollinator fauna and thus to the pollination service (e.g. Quesada et al., 2004; Aguilar et al., 2006). Documenting the geographical extent of pollinators' declines and promoting research on pollination ecology is a research priority (National Research Council, 2007). Research results should help to establish bases for designing pollinator conservation policies in the Mexican legislation, thus having precise information at the country level is indispensable. Here we found that pollinators are essential for 12% of the total crops used as human food in Mexico; a larger proportion compared to the global scale where 7% of the crops obligatory require pollinators for production (Gallai et al., 2008).

Developing plans for in situ maintenance and conservation of native pollinators and plant genetic resources through the *Ejidos* system is a high priority for sustainable use of natural resources in Mexico. *Ejidos* (managed by *ejidatarios*) are one of the two types of communal land tenure systems in Mexico. Members of this system have the capacity to allocate and enforce their own rights to resources under a communal scheme. In 1992 the law was modified and today *ejidatarios* can claim individual parcels or transfer ownership of their lands (Waman, 2001). This change has increased risks on the country's ecosystems because the communal property rights system has acted as a protective shell for ecologically sound productive practices (Toledo, 1996; Alcorn and Toledo, 1998).

The conservation practices for native pollinators should be accompanied by new conceptions of land use management by local rural people, such as avoiding the use of pesticides, ceasing the destruction of bat caves, and ensuring habitat connectivity for the pollinators (National Research Council, 2007). One possible mechanism to accomplish this strategy is to develop a program for the payment of environmental services to those *Ejidos* or individuals making efforts to protect or restore plant resources and native pollinators. The creation or improvement of protected natural areas will offer greater availability and diversity of food source for pollinators throughout the seasons, as well as mating and nesting sites, which will result in a higher diversity of native pollinators. This chain of events would improve pollination services in croplands and would guarantee the maintenance of plant diversity, contributing to the overall conservation of Mexican's biological megadiversity and therefore to the conservation of worldwide ecosystem services.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2009.01.016.

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