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Review

Aspects of Landscape and Pollinators—What is Important to Bee Conservation?

Gleiciani B. Patrício-Roberto * and Maria J. O. Campos

Departamento de Ecologia, UNESP—Univ Estadual Paulista, Campus Rio Claro, Avenida 24-A, 1515, Rio Claro, São Paulo 13506-900, Brazil; E-Mail: mjoc@rc.unesp.br

* Author to whom correspondence should be addressed; E-Mail: gleipatricio@gmail.com; Tel.: +55-19-3534-4964.

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Abstract: Pollinators, especially bees, are essential to terrestrial ecosystems. They ensure the maintenance of certain ecological processes, like superior plants' reproduction. In the past decades, agricultural intensification has caused extensive environmental changes, with major impacts on biodiversity, especially on the pollinators, which reflects the loss of fruits and seeds sets. Here, we review studies that elucidate the causes of decline of pollinators, consequences of landscape changes to agriculture and possibilities to bees' conservation. Many studies have related the loss of pollinators to changes in the landscape, such as the conversion of native forests into cultivated areas, which causes loss of important elements for bees (e.g., sources of pollen, nectar and oil, as well as varied nesting sites). Studies involving landscape ecology allow us to assess the effects of different farming practices over the richness and abundance of pollinators. Among the landscape elements performing positive influence on bees, the presence of remaining forests nearby cultivated areas proved to be a very important factor. Nevertheless, studies that evaluate all ground cover with a more integrated approach are still required to assess the effects of landscape context on the diversity and on the abundance of bees related to productivity of crops. Researches like these could provide specific data that strengthen the need for the conservation of different plants and animals, and could offer subsidies to propose necessary information for the execution of public and private policies, aimed at the conservation of the biodiversity.

Keywords: terrestrial ecosystems; remnant forests; cropped areas; fruit and seed sets

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1. Introduction

Pollinators are one of the key components of global biodiversity. They are essential to ecosystems and ensure the maintenance of ecological processes, including pollination, which is largely responsible for the reproductive success of most native and cultivated plants [1].

Insects represent the most significant group of pollinators. They participate in the pollination of a large number of plant species [2]. Bees, in particular, are the most specialized, because of their variety of morphological adaptations to collect, manipulate, transport and store pollen efficiently (e.g., different types of tongues, cubicula or scopa, among others) [3].

In addition to their morphological adaptations, bees have a foraging behavior that ranges from very generalist (species that visit a variety of flowering plants) to specialists (bees visiting one or a few plant species) [4]. This behavior makes these insects very important, both in the ecological perspective as well as in local broader economies, when considering their role in agricultural production.

Although no accurate data have been reported on the degree of the dependence of many plant species to their pollinators [5], it is estimated that 67% to 96% of the plants throughout the world rely on animals for transporting pollen. Regarding only the species located in the temperate zone, the dependence of plant species in relation to animals can reach 78%. In tropical regions, the plants depending on animals for pollination can account for up to 94% [6]. In Brazil, only Meliponini are responsible for around 40% to 90% of the pollination of native trees [7]. Although practically all wild plants rely on animal pollinators for their reproduction, studies about this interaction are rare. The majority of studies on the pollination are related to cultivated plants.

When considering the group of cultivated plants, the data attempting to express the dependency of crops to animal pollination are variable. It is estimated that close to a quarter of all food consumed by humans depends directly or indirectly on pollination by animals [8], and around 35% of the crop species are pollinated by this group [9]. By investigating only the European continent, the percentage of cultivated plant species dependent on pollination by animals is 84% [10], whereas in cultures located in tropical regions, this value can reach up to 70% of the crops [11].

Economically, the performance of pollinators (including groups of insects, birds and mammals) in the reproduction of cultivated plants is estimated at over a trillion dollars [12]. In 2005, the production of food entirely dependent on insects for pollination was estimated at €625 billion, about 39% of world production. The value of pollination services provided by bees, in this case, was estimated at €153 billion [13]. In Brazil, there is still lack information about the action of pollinators in many crops, making it difficult to estimate a value for this service [14].

Since the 90s, many species of pollinators disappeared from natural and agricultural areas [10,15–19]. Buchmann and Nabham (1996) pointed to this scenario in an article titled “The Pollination Crisis” [20]: the authors observed a reduction of 70% to 90% of the pollination, which provoked a decrease in the fruits and seeds sets of many native and cultivated species. This reduction occurred after huge and abrupt changes in the landscape, associated with the use of pesticides on crops, in the Sonoran Desert, Arizona.

Knowing that pollination is one of the most important ecological process for humans, especially for food production, the decrease in the number of pollinators on a global scale [21,22] mobilized the entire scientific community, making the Union Convention on Biological Diversity and the FAO (Food and Agriculture Organization) to create the International Pollinators Initiative, aiming to coordinate scientific research on conservation of pollinators [23].

2. General Aspects on Bees

Nowadays, it is estimated the existence of approximately 20,000 species of bees [24]. These insects exhibit several life habits, from solitary to highly social bees, which implies in a broad spectrum of habitats, because it involves different feeding and mating habits, besides varied nesting sites [24,25]. Regarding the use of food resources and nesting sites, groups of bees can be categorized into generalists or specialists. The specialist group, with specialist habits, often requires morphological and behavioral specialized adaptations. The pollen foraging offers good examples of this: bees, that gather pollen from plants with poricidal anthers, (e.g., Solanaceae) are capable of vibrate it through the vibration of thoracic muscles, promoting the release of pollen [24].

Regardless of the life habits of bees to establish themselves in a region, it is necessary to have ideal conditions to nesting sites (comprising pre-existing cavities, deadwood trunks, banks, under ground galleries), specific materials for nest building (leaves, oils and resins) and proper feeding sites (sources of pollen and nectar) [24]. These resources must also be accessible inside the home range or the ray of flight of each species [26], because a foraging bee uses the landscape according to the flight ability, which is influenced by the body size [27,28]. Solitary bees with small body size, for example, depend on habitat characteristics immediately near their nesting sites (about 250 m to 500 m) [29–31] and have little flexibility to adapt to changes in the environment [32]. Bees with large body size, like *Bombus*, flies in larger landscape scales, of up to six kilometers [27,28]. Although they can fly long distances from the location of the nest looking for their needs [33], they usually fly in distances with an average of 300 m radiuses from their nests [34].

3. The Role of Wild and Exotic Bees on Pollination

Wild bees are responsible for the majority of pollination of native plants, so the preservation of natural habitats is extremely important to their maintenance. In addition, many species of cultivated plants are also pollinated by wild bees, which often are their exclusive pollinators [14]. In Brazil, passion fruit plant depends exclusively on the pollination of a native species (*Xylocopa* sp.) for fruit formation [35–39] and, despite being considered the world's largest producer, this country has low productivity due to the deficit of these bees in cultivated areas [40]. In another study using 41 crops from the six continents, was verified a positive increase in fruit set after the visits of wild pollinators, twice bigger when compared to the pollination made by honeybees [41].

Native bees, which in general are specialists, and can be solitary, are present in a fewer number in nature. Because of this they are not sufficient to ensure the pollination of large cultivated areas. The introduction of exotic bees (e.g., *Apis mellifera* L.) may have contributed to the decline of wild pollinators, because they are generalists and highly competitive, besides their great adaptability in disturbed habitats [14]. However, in a scenario with few pollinator species, exotic bees, mainly *A. mellifera* L., can play this role. In some solanaceous crops, these honeybees presented a flying adaptation in which they release the pollen by grasping the tip of the anther's cone and flying up and down, shaking the flower [42,43]. In these cases, the pollination by *A. mellifera* L. could increase the weight of fruits, if compared to those fruits formed without bee pollination [42].

The combination of the visit of exotic with native bees in the flowers was also positive for sunflower and in most 41 crops (used in a study around the world), increasing the fruit and seed set [41,44], showing that visits from wild bees associated with honeybees were the best fitting model for fruit formation [41]. So, in a scenario where there is a finding of a crescent decline of pollinators, mainly native species, interspecific interactions of native bees and honeybees, in particular, *Apis mellifera* L., are important to maintain the supply of food for humans and preserve natural habitats [14].

The anthropic introduction of bees in a particular region can cause ruptures in plant-pollinator interactions, established co-evolutionarily, but not necessarily in a negative way. Studies using molecular techniques are able to determine the origin of species in the area and certainly can contribute to the understanding of evolution in plant-pollinator interactions, providing important data for the conservation of this group [45].

4. The Causes and Consequences of the Decline of Pollinators

Since the diversity and abundance of bees ensure the pollination and maintains the plant diversity of ecosystems [27], researchers and government agencies throughout the world have been focusing research efforts to avoid the extinction of these pollinators [1,15–19,46–48].

In environments with few pollinators, such as the Oceanic Islands, the disappearance of a single species, mainly the specialists bees, can exert a strong impact on local biodiversity [15]. When the pollinator's decline is observed for generalist species, the impact on plant community can be even greater [15,20]. During the period between 1990 and 1995 the loss of honeybees in North America was so abrupt that native and cultivated plant species showed significant reduction (from about 70% to 90%) in fruit set and number of seeds [20].

In 1993, Heywood predicted a loss of more than 20,000 plant species worldwide in the next decades, and it would be due to the expected decline of co-dependent pollinators [49]. The decline of pollinators in the regions of Great Britain and the Netherlands was demonstrated through the comparison of many articles surveying pollinators, published during the periods before and after 1980. This decline occurred in species richness of bees (except *Apis mellifera*) of 52% in Great Britain and 67% in the Netherlands. In this study, it was also observed that the decline of species of plants and their specialist pollinators was greater than the decline observed for generalist species [50], which usually tolerate more changes in landscape than the specialist ones. The causes of the decline of generalist species use to be different, and as reported on literature, the most important is the use of pesticides, which can cause the death of entire colonies [51]. To anticipate the consequences of environmental change on plant-pollinator interactions, it is necessary to understand several aspects involved in the distribution of species, such as the way they respond to patterns of landscape structure and management, besides the foraging and nesting behavior, among others [52,53].

Since 1945, more natural areas were converted to agricultural areas than in the period from the 13th and 19th centuries together [54]. According to this document, the agricultural systems cover a quarter of the Earth's land surface. Many important pollinator species have been reported to be highly sensitive to the loss of nesting sites and to pesticides in general, which defines its presence or absence in areas with different management. The loss of features provided by ecological processes, caused by the agriculture intensification depends on the spatial scale at which these practices occur [55]. The land management on a large spatial scale can determine the presence of various species of pollinators, the size of their populations and their trophic interactions, structure and dynamics of communities in a field [56]. Within this context, the changes in the landscape and biotic and abiotic alterations in fragmented areas may result in a decreased abundance and loss of genetic variability for some species, in addition to the disappearance of others [57,58].

In past decades, the agricultural intensification caused extensive environmental changes, such as the conversion of natural areas in cultivated ones and, more recently, the conversion of these cultivated areas, until then diversified, into large homogeneous areas of crops with a single species and few natural forests. In Europe, the impacts of these changes, at different scales (local and landscape) on biodiversity were very large, especially on the pollinators [59,60]. The changes in landscape also affected the bees of US—a survey study on bee related to the landscape modifications of over 140 years, conducted in northeastern, found a slight decrease in the abundance and richness of native bees, except to the genus *Bombus,* which declined drastically. However, the abundance of exotic species increased over the years, in part due to the tolerance of these species to anthropogenic changes [61]. Considering three types of land use, described as "artificial surfaces" (urban green and park areas), "agricultural areas" and "natural areas" (natural, semi-natural and wetlands areas), Deguines *et al.* 2012 demonstrated that the urbanization is the most prejudicial change in land-use to the frequency of flowers' visit by insects, including Coleoptera, Lepidoptera, Diptera and Hymenoptera. Agricultural and natural areas showed a high potential to shelter a greater diversity of floral visitors [62].

Huge changes occurred in tropical areas too, such as the broadening of crop cycles, loss of diversity of local cultivated varieties, the increase in the use of fertilizers and pesticides, the expansion of cultivated areas and the increased use of heavy machinery in the fields. These factors contributed to the conversion of diversified secondary habitats into more homogeneous ones, beyond the fragmentation of natural habitats [59]. All these changes may also result in limitation of the activity of pollinators, which are reflected in loss of fruits and seeds sets [63].

Researches conducted with several cultivated and native plant species in the world, relate the decrease in yield due to the loss of pollinators, which in turn would be associated with reduced coverage by native vegetation coupled with increasing distance between the remaining forest [15,29,30,63–68].

The subtropical forest fragmentation, for example, caused a decline in native bee visitation, which resulted in 73% decrease in the number of fruits and 79% in the number of seeds formed in the plant species studied [69]. The absence of pollinators may also be responsible for pollen limitation that is followed by the reduction in fruit set of some native plant species [70].

In Brazil, the causes and consequences of the decrease in pollinator diversity were discussed formally for the first time in 1998, during the "International Workshop on the Conservation and Sustainable use of Pollinators in Agriculture, with Emphasis on Bees", conducted in São Paulo. This event resulted in the drafting of a document: the Declaration on Pollinators [71]. The national and international initiatives created from this document in order to discuss the conservation status of pollinators and their importance in pollination enabled a significant increase in studies on this topic.

5. The Influence of Landscape Configuration on Pollinators

5.1. The Landscape Ecology as a Tool in Studies of Plant-Pollinator Interactions

Studies carried out in agricultural areas enable the evaluation of the effects of different farming practices on the abundance and species richness of pollinators. In addition, it helps to understand how pollinators respond to fragmentation, modification, and destruction of natural habitats, and at what scale these changes are felt by different species, besides proving the importance of the management of agricultural areas and landscape structure for the maintenance of pollination guilds. [72].

Since from 80's, the recognition that ecological processes are affected by anthropogenic disturbance on a landscape scale rather than on a habitat scale, gave the "Landscape Ecology" a key role on proposal of management and conservation of species [73,74]. This science studies the landscape's uses and its effects on different species, including animals and plants. To bee pollinators, the main landscape classes that can interfere in the distribution of organisms are the matrix, corridors and fragments of native forests [75].

The first one is described as an element that comprises the largest extension of a landscape [75] and, it is responsible for the greatest influence in the functioning of ecosystems [76]. Corridors are defined as narrow, natural or manmade lanes that can present different matrices on each of their sides [75]. Usually on large scales, landscapes are simultaneously separated and integrated by corridors [77], which may vary in length and function: linear corridors are usually a result of human activities, characterized by being narrow and serve for displacement between the edges. Ecologically they are the majors of forest remnants, which facilitate dispersion processes and increase the diversity of local species [78]. Fragments are nonlinear surfaces embedded in a matrix, different from the surrounding surface. They may present varied types (e.g., remnants of natural vegetation or exotic species), with one or several vegetal species, besides sizes and shapes that can vary from small to large patches, in many different formats, since geometric shapes till irregular forms, depending on the intensity deforestation [75].

5.2. The Effects of Landscape Fragmentation and Isolation on Pollinators and the Importance of the Remnant Forests to the Bees

When the fragmentation of natural landscapes is the result of human action, it can occur in a short period of time, which represents a risk to the ecosystem. The fragmentation of native forest areas certainly leads to changes in the shape and size of the fragments, increasing the isolation distance between them [79] and may compromise various processes and ecological functions of the affected ecosystem, as well as the loss of diversity of plant and animal species [80].

Powell and Powell published, in 1987, the first scientific research that explicitly examined the effects of changes in the spatial distribution of habitats on the activities of pollinators, and it was developed in Brazil [81]. In this study, the authors examined the density variation of Euglossine males in a region in Central Amazonia, in continuous forests and in fragments of different sizes, which ranged from one hectare, 10 ha and 100 ha. The results showed that the density was significantly greater in the areas of continuous forest. The authors further found that deforested areas with 100 m of width, acted as physical barriers, isolating some fragments. Fragments of smaller sizes have also been considered unfeasible for maintaining a population of Euglossine [82].

Considering all group of insects, a study from 1996 was a pioneer in demonstrating the effect of habitat fragmentation on ecological processes mediated by pollinators, seed predators, parasitoids and decomposers. The authors found that the richness and abundance of all species decreased with the fragmentation of natural environments, in which the specialized ones were most affected, suggesting that most specialist species tend to be more susceptible to forest fragmentation than more generalist ones. [32]. So, plant species pollinated by specialist bees must be connected to a variety of habitats in a restricted range. Isolated plants, distributed in homogeneous and fragmented landscapes, depend on generalist pollinators with ample ray of flight to transport pollen [28–30].

A review of the literature [83] related the effects of agricultural landscape on pollinator diversity, with focus on bees. Most studies in this paper showed a strong relationship between the productivity of different crops such as understory palm [84], cherries [66], coffee [85], watermelon [86] among others, and the presence of fragments of native vegetation in its vicinity. These remnants of native vegetation can offer lots of nesting sites for different groups of social and solitary bees and thus, ensure the permanence of different pollinator species, which forage in the near surroundings in search of additional sources of food [87]. Therefore, the closer the distance of cultivation to remmant forest, the greater will be the reproductive success of plants. This relationship was confirmed for the cultivation of coffee in Indonesia [85], where in all cultivated studied areas, there were, in surrounding, remnants of native vegetation, but at varying distances: in crops closer on average to 250 m of fragments, the percentage of fruit set was 90%, whereas in crops distant around 900 m of forest remnants, the percentage of fruit set was 70% [85].

In almond orchards located in California, the species richness of solitary bees, the frequency of visitation in flowers and fruit production was directly proportional to the presence of semi-natural habitats adjacent to crops [88]. For coffee cultivation, in Costa Rica, mango crops, in South Africa and cultures of passion fruit, in Brazil, the distance of crops to the remaining forests was a determining factor in the rate of visitation of flowers, where crops closer to fragments received more visits [64,89,90]. So, it can be argued that the diversity and abundance of bees and consequently the efficiency of this group in pollination is affected by the isolation of crops.

In addition to the distance between fragments of remnant forests and isolation of cultivated areas, the percentage of groundcover with native vegetation surrounding the crops also influences the richness, abundance and consequently pollination process. On a scale of up to 2 km, as observed for apple crops, in different regions of the Wisconsin State [91] and crops of olives, in the Mediterranean [27], this landscape class can affect positively the richness and abundance of bees and consequently the crops productivity. A study, conduced in São Paulo, Brazil [68] and another one conduced in Vera Cruz, Mexico, evaluated the reproductive success of *Solanum viarum* Dun. and *Coffea arabica* L. [92] respectively, upon the hypothesis that more diversified habitats (heterogeneous landscapes) would support higher pollinator diversity and therefore warrant greater reproductive success. This hypothesis was rejected, however among the studied landscape classes, only the percentage of forests' coverage showed a positive relationship with pollinator diversity and reproductive success of *S. viarum* Dun. and coffee [68,92]. Despite the results obtained in these studies, several authors have reported the diversity of habitats and landscapes and the presence of enabling habitats to the establishment of pollinators as important to ensure the pollination process [9,17,28,67,93,94].

5.3. The Importance of the Habitat Configuration for Pollinators

The landscape configuration is an important element that influences the presence of pollinators in cultivated areas. Buildings, roads and grassy areas may adversely affect the richness and abundance of species of wild bees [91]. A large matrix with few flowers or that shelters few species of flowering plants, for example, can act as a barrier to pollinators, while a matrix occupied by a group of plants flowering can promote connectivity and provide nectar and pollen resources during periods of floral shortages in remaining habitats [94].

In intensive agricultural landscapes, many species of bees are confined to small non-cultivated areas, such as in marginal fields. It is suggested that these small elements of habitat may not support viable populations of pollinators [95], because they usually have fewer species blossoming in. This scenario favors social bees, with more generalist habits, such as *Apis* sp. [28] and may impact both the population of solitary bees [28,65], due to a possible competition with social bees, as well as the population of specialist plants that rely on specific groups of bees.

Analysis of the spatial configuration of habitat fragments on a landscape scale, for example, can help identifying fragments closer to the crops, which can support a greater variety of bees, depending on the resources they offer [63,96]. These analyzes can also identify more distant fragments, which may contain alternative sources of food and nesting. In these cases, creating ecological corridors that direct the movement of bees to crop areas can make these distant fragments more accessible to bees [97]. This was demonstrated in a study in the UK, where remnants of natural vegetation and cultivated areas of *Salvia pratensis* L. (Fam. Lamiaceae) was connected or not with linear elements of the landscape. The ecological corridors with plants flowering, either natural or artificial, had influenced the flight direction of *Bombus* sp. Crops of *Salvia* sp. in highly connected areas received more visits of pollinators, higher quantity of pollen and had a superior reproductive success than plants in isolated areas [97].

So, ecological corridors, when composed by species blooming throughout the year, may offer an additional foraging habitat. For this purpose, these areas should be managed in such a way that the pruning frequency remains low [98]. In addition to this management, preserving elements such as hedgerows or tree trunks can provide nesting sites for bees, maintaining the necessary habitat diversity for the permanence of populations of pollinators in the landscape [99].

5.4. Farming Management: Organic vs. Conventional

The management of the area is another factor that can influence the presence of pollinators in crops. The use of pesticides or even the synergistic effect of chemical products used in the crops may affect the community of pollinators in a cultivated area [15,100], managed according to the standards of conventional cultivation. The use of pesticides during the flowering of a mangoes' crop, in the Valley Region of São Francisco, Brazil decreased by 50% the frequency of visits of bees in the flowers [101].

Another factor that may harm the presence of pollinators is the control of weeds around in the conventional crops. The eradication of these species reduces food sources for bees. In the areas of organic farming, which does not use pesticides, the risks for bees are smaller, moreover, in these areas the producer usually tolerate the growth of weeds surrounding the cultivation, which increases the foraging niches for bees attracting them to the crop, besides ensuring food sources during periods of harvest [43,102].

However, there are evidences that the area management does not only influence the richness and abundance of pollinators, and consequently the pollination of crops. Those indexes appear to respond not only to the crop management on a local scale, but to a combination of this and the surrounding of crop on a larger scale. In a study of eggplants, the abundance and species richness of bees was slightly higher in areas with organic farming, however the yield of crops did not differ between the study areas, including organic and conventional management [103]. In this study, the environmental diversity, formed by different landscape classes (e.g., forest cover, dirty pasture, cultivated plants, *etc.*), in a range of 500 m, was more important to the productivity than just the sort of management [103]. Similar data were observed for watermelons cultivated in California [86] and grapes, located in northeast Italy [104].

Given that only the management of the area or landscape configuration in which a crop is inserted are not responsible for maintaining bees in cultivated areas, the persistence of these pollinators, so will depend on maintaining the diversity of habitats in the vicinity of farms associated with practices management sites that may offset the impacts of intensive monoculture agriculture [105]. Knowing that bees require different nesting and feeding sites, it is possible to manage the area and around the crops to ensure the presence of bees in the area. To do so it is necessary regions where the producers performs the minimal influences and avoid pruning ruderal plants, for example. In properties where these areas are available, it is possible to manage leaving parts of it without interference (e.g., plots with different flowering plants) [72]. Delaplane (2010) describes the nesting habits of several species of bees, suggests practices that favor the persistence of pollinators in the fields and also provides a list of species of plants used by bees to be introduced on the property [106].

6. Challenges for Bee Conservation

The number of studies aiming to evaluate the importance of pollinators and the necessity of bee conservation has increased in recent years. In a review of the literature about conservation of pollinators [107] it was emphasized the importance of development of researches on the biology of pollination of some crops in particular. In addition, the authors also emphasize the importance of studies from which results support proposals of agricultural practices compatible with the conservation of pollinators and, consequently, the maintenance of pollination. One of the earliest challenges is to determine the quality of habitats for pollinators [108–110].

The difficulty in determining the minimum viable area, necessary for the maintenance of each population represents an extra challenge, since the ideal for the conservation of pollinator species would be to increase the area of natural reserves [96,111]. Nevertheless, a greater challenge is to maintain the monitoring of landscapes, which requires a detailed spatiotemporal perspective, in order to monitor the role of different habitats during all seasons of crops; in flowering and in harvest, when there are no flower in the cultivation. So, that it can keep the conditions required for the permanence of pollinators in the area [34,112]. Campos *et al.* (2006) suggests the maintenance of assort elements surrounding the crops, because these elements could contain different nesting sites, which may include the need for different groups of bees, as described previously, varied sources of pollen, nectar and oil, in addition to water sources [72].

The sustainable management of agricultural landscapes must therefore consider a variety of strategies for the establishment and the permanence of pollinators in cultivated areas [91,94,102,113,114] during flowering and out of flowers periods, ensuring production optimization [66]. This form of management must also consider the landscape configuration, such as the presence or absence of fragments and patches of habitat, and the connectivity and the size of their areas. Despite all the knowledge about the needs of the pollinators, further studies are necessary in the ecosystems of entire world, especially in Brazil, where such approaches are still recent [68]. In South Africa and Madagascar, the challenges for bees' conservation are even greater. The diversity of the apiarian fauna in these regions is certainly underestimated, partly due to the great extension and difficult access in the fields and the lack of resources and taxonomists. Furthermore, conservation plans for this group are restricted to ecological parks, which does not make them very functional, being necessary conservation strategies at smaller scales [115].

Byrne and Fitzpatrick (2009) present a list of global policies and legislation for the conservation of invertebrates and the impact on the use and conservation of bees' strategy. The most recent of these is the International Pollinators Initiative of the Convention on Biological Diversity (CBD), which priority is to "promote coordinated action worldwide and proposed" and it is the global policy platform for pollinators, including bees. In addition to the global initiatives, there are regional ones, which together with the legislation gain strength in policy development for the conservation of bees. The inclusion of species in Red List, along with lists of conservation priorities provide an extra mechanism to put in practice management plans and conservation of pollinators [116].

However, to conservations plans imposed by government become effective, it is necessary to prove to the community, through researches, that the presence of pollinators is beneficial and necessary, especially for the maintenance of agriculture [115].

7. Conclusions

All studies on plant-bee interactions demonstrate the extreme importance of this group for ecosystems, maintained the native plants and for the global economy, especially on food production. Nevertheless, the true number of species present in almost all biomes is very outdated. The huge changes in the landscape from the 40s caused by agricultural intensification resulted in large losses of habitats, which prior sheltered a greater diversity of bees. This resulted in a threatening decline of pollinators, which are responsible for the reproduction of most native and cultivated plants. The decline of bees even brought losses to agriculture, about 30% in the U.S., for example [14], starting the Pollination Crisis. Since the 90s, the importance of pollinators has become widespread among researchers from the whole world. In 2000, the Union Convention on Biological Diversity and the FAO (Food and Agriculture Organization) created the International Pollinators Initiative, aiming to coordinate scientific research on conservation of pollinators [23].

The first step is try to close the gaps existent on bees' survey and evaluate their historical presence in the fields, particularly in developing countries, where financial and structural resources are limited [115]. It should also prioritize research into the biology and ecology of species of bees entered the Red List, develop and implement emergency action plans for the management and conservation of these pollinators.

The studies on bee conservation shall directly assess the relationship between the pollination promoted by wild bees and the maintenance of mosaics where cropped areas and native vegetation coexist [63]. Moreover, it should be emphasize the need for studies with a more integrated approach, including all ground cover, to evaluate the effects of landscape context on the diversity and abundance of bees [27] and the productivity of crops. So, it is necessary to determine the damage that pollinator decline may have on ecosystem services, agricultural production and human health [117].

Researches of this nature can provide specific data that strengthen the need for the conservation of different species of plants and animals, and offer subsidies to propose management plans as well as necessary information for the execution of public and private policies, aimed at the conservation of the biodiversity.

Another challenge and maybe the most important, is the need to produce and disclose materials for dissemination about the importance of bees as pollinators of native and cultivated plants. These materials must be printed in national and regional levels, and should target audience since from large producers to smallholders. Therefore, it is important to maintain a network of information, especially by Internet, where researchers from around the world can exchange information and maintain updated the data on the conservation of bees.

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- Gleiciani Bürger Patrício-Roberto: conceived and designed the study.
- Gleiciani Bürger Patrício-Roberto and Maria José de Oliveira Campos: searching, reading and analyzing of articles used in this review, writing and finalization of the text.

Conflicts of Interest

The authors declare no conflict of interest.

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