Chapter 12
Pollination services

12.1 THE IMPORTANCE OF POLLINATION SERVICES

About 75 percent of the most important crops worldwide depend on animals for pollination. Insects are especially diverse and important pollinators, supporting crops that are crucial for human nutrition, which are also vital to the economic development of different regions. The production and profitability of many crops depend entirely on insect pollination (for example, almonds, cocoa beans, blueberries and gourds), but the degree of dependence tends to differ across crops and varieties. Although some primary cash crops (for example, canola/rapeseed, soybeans, cotton and coconuts) appear to have a moderate or low dependency on pollinators, studies show that the disappearance of pollinators would still have a significant negative impact on their productivity.

When pollination deficits or other shortfalls lead to declining agricultural productivity, the typical response is to simply expand the area of cultivated land. This leads to environmental pressures that, when added to other inadequate short-term management strategies such as excessive pesticide use, result in greater losses of natural resources, generating a negative feedback loop. This natural habitat fragmentation impacts crops, typically reducing native pollinator populations in agricultural areas and decreasing overall crop pollination. Current trends show that the global quantity of pollinator-dependent crops continues to increase as the arable land area shrinks, threatening both food security and people's quality of life. Our current agricultural practices are clearly failing to support pollination services and native pollinators, and therefore there is a clear need to build a complementary framework to support both native and managed pollinators.

12.2 THE PROBLEMS OF CURRENT PRACTICES

Pollinator management affects not only the environment but also the producers' income, because pollination affects the quantity and quality of production levels. Perhaps due to a lack of knowledge or incorrect application of available information owing to a disconnect between the scientific literature and professional practice, current management strategies do not typically account for or take advantage of the potential synergies between managed and native pollination services.

When faced with insufficient pollination services, producers often compensate by simply increasing the amount of honeybee hives in their apiaries. However, obtaining a greater amount of hives (an approach known as "saturation") will not necessarily translate into greater pollination services. On the contrary, this action could even prove detrimental, because excessive visits and handling by non-native pollinators can inflict physical damage on flowers. Moreover, increasing the number of honeybees to exceedingly high levels can potentially harm wild bee populations, sometimes displacing them entirely, while also affecting the pollination of native plants that surround crop fields.

Numerous studies have shown that diverse communities of wild pollinators can be complementary and are in many cases more effective for agricultural productivity than the management of a single domesticated species. For example, one study found that strawberries pollinated by wild bees weighed on average 42 percent more than those visited only by honeybees. Complicating matters even further, crop expansion is typically preceded by the removal of natural and semi-natural spaces that offer many essential resources for both managed and wild pollinators, such as nesting sites and alternative floral resources. These resources are usually not available to crops grown on monocultural farms or they may only be available for a short period of time, limiting their availability to pollinators, and thereby limiting the pollinators available for crops.

It is also important to consider that large-scale colony losses have been observed in different regions over the last several decades, and even where the stock of honeybees is growing, this increase may be outpaced by the demand for pollination services. Staggeringly, losses can represent up to half of the total number of colonies per year in some countries. Some of these locations heavily depend on pollinators either for honey production or for the pollination of commercially important crops. As such, better management techniques are required to guarantee and optimize the pollination services provided by both honeybees and wild bees.

12.3 WHAT CAN BE CHANGED?

The spatial arrangement of beehives within a crop field plays an important role in pollination success rates, but there tends to be very little focus on planning this arrangement (for example, the distance between target crops and colonies). This oversight adds to the existing uncertainty around beehive management – for example, the health status or size of the individual colonies and similar unit-specific factors. External site-specific factors also exist, such as their

FIGURE 102
Crop pollination by different pollinator species
a) Synoeca cyanea in coffee; b) and c) Xylocopa frontalis and Oxaea sp. in urucú

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potential interactions with wild pollinators. However, contemporary practices often ignore these considerations and simply focus on the number of beehives per area, assuming that a higher number of domesticated pollinators leads to enhanced pollination services.

There are over 20 000 species of bees (Figure 102) and many of them can contribute to agricultural productivity through pollination, thereby complementing honeybee-delivered services. Since few species have been successfully domesticated, most of the pollinators present in a healthy agroecosystem will be wild. Although bees may be the most relevant group, other animals such as beetles, moths, butterflies, wasps, ants, birds and bats also have important roles in crop pollination. Maintaining balanced assemblages (for example, moderate honeybee density alongside bumblebees, other primitively eusocial species, solitary bees, stingless bees, and other pollinators) leads to better crop performance for several reasons. Diverse species of pollinators will be active during different periods and in different places, can thrive with different resource pools (including nesting sites, will react differently to climatic conditions, and will choose flowers of different morphology. This diversity of responses can contribute to greater stability of agricultural yields across crops and landscapes. Additionally, high species richness increases the potential for finding the most effective pollinator (the pollinators that guarantee the highest levels of seed or fruit production) for a given crop. In some cases, especially with cavity-nesting bees, wild bees can be managed to provide complementary or even superior pollination services to honeybees for certain crops. This scenario becomes more feasible when pollinator activity monitoring and pollinator-friendly habitat management are adopted as essential agricultural practices.

Flower-visitor monitoring

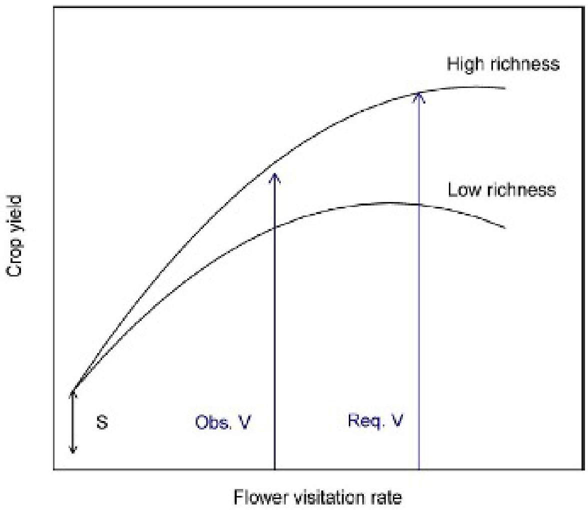
The number of visits necessary for pollination is a fundamental metric for crop performance at scale, and a key component for measuring this metric is the development of effective pollinator monitoring practices (Figure 103). The two most used techniques are transect counts and visitation rates.

Transects are paths along which a surveyor slowly walks examining plants and/or capturing insects with a net. While transect counts cover more ground, visitation rate counts – when sufficiently spread across a site – can provide a more precise measurement, as they only count legitimate flower visits (i.e. effective contact of a pollinator with the reproductive parts of the flower). Alongside complementary studies of the number of visits needed to fertilize each flower, visitation rate metrics are an exceptionally powerful measure for assessing pollination services. Beyond the species-level biological requirements of the plant to be pollinated, the number of visits required depends on various factors, including the climate, the type of pollinator and the crop type. Once standardized on a per-crop basis, and accounting for these additional complexities, visitation rates can be used as a universal reference when carrying out management interventions.

A quick and easy protocol to effectively assess pollination rates and define the pollination "level" of a crop should include the following considerations:

- What should be measured?
  Visits of different types of pollinators that make contact with the reproductive parts of the flower.
- How?
  Counting the number of contacts made with individual flowers during a fixed observation period (usually ten minutes), and at different parts of the day (in relation to pollen availability and receptivity).
- Where?
  In the centre of the field – as pollinators find this area more difficult to reach – to gauge the maximum pollen limitation in the system.
- When?
  Ideally when crops have 25, 50, and 75 percent of flowers open.

FIGURE 103
An example of a simple predictive model using knowledge on the crop characteristics that can be tailored to crop variety, required visitation rates and observed visitation rates



Source: Garibaldi *et al.* (2013); Garibaldi *et al.* (2016), Garibaldi *et al.* (2020).

The results of visitation rates can then be compared with the target values published in Garibaldi *et al.* (2020). This enables determination of whether sufficient crop pollination services are guaranteed or if it is necessary to modify management practices to enhance them.

Notes:

- S = crop variety (production without pollinators).
- Req. V = required visitation rates.
- Obs. V = observed visitation rates (measured by the farmer).

Generally, crop yield increases with flower visitation at different rates according to pollinator richness. Greater diversity of pollinator species (high richness) further increases the positive effect of visitation rates on crop yield compared with low species diversity (low richness).

Integrated habitat management

Pollinator-friendly habitat management can be achieved at different scales and does not necessarily require a significant investment of time or money, while also providing clear advantages such as retaining or recovering native biodiversity that often benefits overall crop productivity. Two of the simplest and most effective methods of pollinator-friendly management are increasing the quantity and quality of flower resources by diversifying crops or varying them over time, and protecting or restoring natural and semi-natural habitats to provide sufficient space for alternative floral resources and bee nesting sites. Notably, these methods benefit both honeybees and native bees, as well as other pollinators, making them an important component of any effort to synthesize pollination services across managed and wild pollinators. Using controlled burning and a moderate level of intensive practices such as heavy tillage and grazing can also help to promote the growth of diverse plant communities, as unmanaged habitats may become dominated by a few, fast-growing species that may not be suitable for pollinators. However, a sustainable balance must be struck between these activities, as excessive grazing and most tilling activities can be detrimental to pollinators (but the effects of these activities will vary depending on the environmental characteristics of each area. Even sublethal doses of synthetic inputs such as pesticides and herbicides often damage pollinator health and affect wild plants that may offer valuable alternative resources, so appropriate planning must be carried out to reduce their application. While chemical use should always be minimized, it is especially important to never use pesticides or other chemicals during the bloom period, when pollinators will be most active and susceptible to these treatments.

On a spatially smaller scale, various species of legumes and other pollinator-friendly plants can be planted along field margins, and safe microenvironments or structures where pollinators can nest may be placed nearby to provide a longer-term habitat in the future. Ground that is left bare, without tilling, can serve as a habitat set aside for miner bees, some of which will nest in huge aggregations of tens or even hundreds of thousands of bees that can provide substantial pollination services for crops (for example, *Nomia melanderi*, the alkali bee). However, if natural areas are too sparse or if monocultural lands are too expansive, pollination may not occur equally across the landscape. A deeper understanding of the foraging distances covered by different pollinator species is necessary to ensure the effectiveness of these practices. Although prior studies relate flight distance to body size, this is a topic that has been little explored so far. Nonetheless, it is now well-known that pollination services decrease as the distance between the pollinators and the natural spaces and natural resources that they require increases. Some bee species show strong fidelity to small habitats, often linked to either floral or nesting resource distribution, making these smaller-scale practices especially important.

12.4 CONCLUSION

It is important to reiterate that the success of these practices depends on numerous factors and therefore there is no one-size-fits-all solution. We cannot simply add more managed bees to provide more pollination services, because the demand is increasingly exceeding the supply. The unsustainable transportation and use of managed honeybees for agriculture are thought to be key causes of recent honeybee declines (in part due to pathogen spread, though much work remains to be done to fully understand these dynamics

(Becher *et al.*, 2013). For these reasons (and where possible), project planners should note that the ideal management practice factors both direct pollinator monitoring and agricultural-landscape scale considerations into decision-making in order to synergistically maximize yield and biodiversity, maintaining balanced assemblages and managing, preserving, and improving pollinator-friendly habitats.

Expanding our knowledge of pollinators' activities and efficacy is the first step towards understanding how changes to conventional practices translate into investments in the long-term sustainability of agroecosystems. Consequently, all reared pollinator management practices could be modified and adapted to improve pollination success rates and crop yields.

All these actions will be more effective if policymakers align their policies, regulate pesticide use, control the transportation of managed pollinators, create incentives for producers who adopt biodiversity-friendly practices, recognize pollination services as a critical agricultural input, and promote green infrastructure as a whole, to name but a few desirable actions.

Integrated crop pollination is an interesting unifying theme proposed by Isaacs *et al.* (2017). It aims to combine various strategies supporting crop pollination that can be developed, coordinated and delivered to growers and their advisers.

Proper management maintains the resilience and sustainability of agricultural land, strengthening the stability of both crop production and producers' income. These are incredibly important aspects of pollination services, but their benefits certainly exceed the functioning of agricultural systems alone. Pollinators' activities ultimately sustain all terrestrial ecosystems, as they are essential for the reproduction of countless plants that form the basis of ecosystems worldwide. Therefore, the conservation of pollinators contributes either directly or indirectly to most of the SDGs and thereby a more balanced, sustainable and socially just world.