# Are managed pollinators ultimately linked to the pollination ecosystem service paradigm?

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Crop pollination performed by wild pollinators is arguably the best understood animal-based ecosystem service. Pollination by wild pollinators originating from natural habitats is recognised as an important ecosystem service; in contrast, managed pollinators – overwhelmingly represented by *Apis mellifera* (the European honey bee) – are regarded by most as an agricultural input.[1-3] Globally, both wild and managed insect pollinators are important for crops requiring pollination.[2,4-6] The principal difference between these two pollination services is that wild pollinators are residents while managed pollinators are imported for crop pollination (Figure 1). However, there are cases in which managed honey bee hives are kept at permanent locations. These managed honey bees, akin to resident wild pollinators, follow the available forage resources found within flying distance.

Globally, the demand for insect pollinated crops is increasing at a phenomenal rate and as the human population continues to increase and improve its standard of living, demand can only increase.[1] Global food demand has in the past been met by monoculture environments transformed during the green revolution[7], resulting in a predominance of this agroecosystem at the expense of more diverse crop-natural margins, at least in developed countries.[4] Consequently, before the focus on wild pollinators, research on managed honey bees dominated the crop pollination literature.[4,6]

However, in the last two decades, there has been a complete turnaround. Most published studies on insect crop pollination services are introduced by stating three 'near universal' facts: (1) animal pollinators provide an important ecosystem service but these pollinators are now threatened, (2) managed honey bees are commonly used to mediate their loss but are themselves declining and (3) more effort must be placed in making crop ecosystems more pollinator friendly for wild pollinators to restore the free service they provide. There are now numerous studies and global meta-analyses that document a concurrent increase in pollinator diversity and crop yields as a result of better pollination (and thus improved food security) with practices that are ecologically friendly and promote on-farm wild pollinator conservation.[2,4,8] These reports have led to calls to reverse native pollinator declines by improving the on-farm environment for pollinators.[4,5,8]

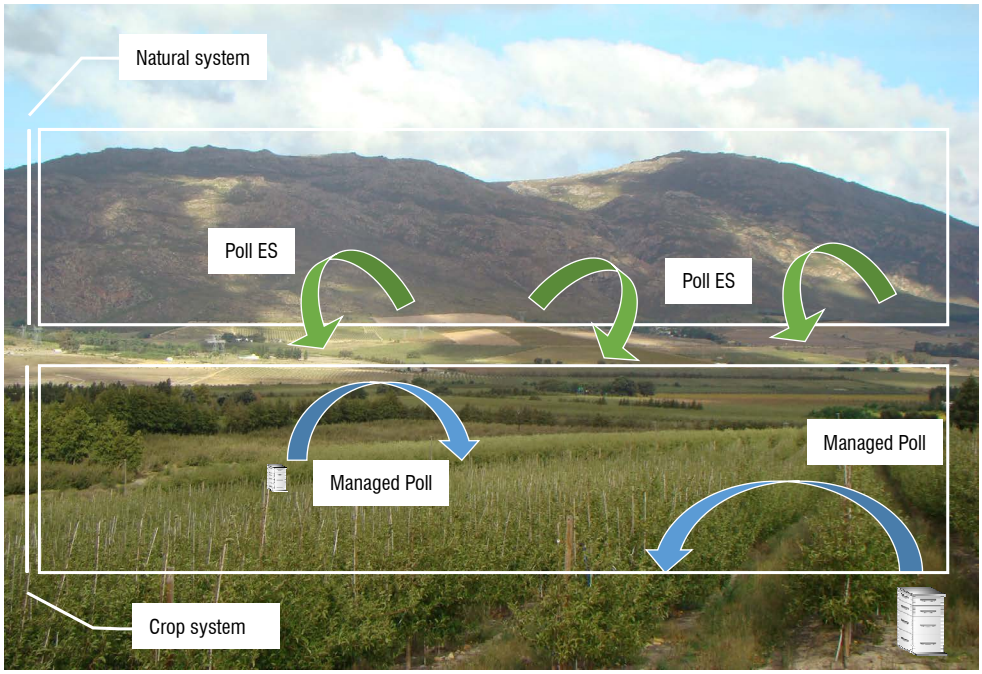


**Figure 1:** A comparison of pollination services – wild and managed pollination services offered to a deciduous crop farmer. A grower's options for using pollination ecosystem services is strongly determined by landscape context and field size. In contrast, rented honey bees do not have this constraint but are a paid-for service.

While the current research effort into pollinator conservation, ecologically intensifying agriculture and resulting initiatives are commendable, it does not change the fact that there is a forced dependence on managed pollinators.[3,9,10] For many global crop hectares, there is no access to viable wild pollination services[6,11] and restoration efforts will not be able to replace the contribution of managed pollinators[12,13]. I argue that the implications of the necessary contribution of managed pollinators is not fully comprehended by many.

Melathopoulos et al.[3] and others consider managed pollinators to more closely resemble an agricultural input, because in most parts of the world these managed pollinators are often non-native[4], have only a temporary dependence on the habitat surrounding the fields they pollinate[3], and instead are highly dependent on manufactured food substances (such as sucrose and processed plant proteins) and chemical inputs such as miticides and

antibiotics[14,15]. It is precisely this strong human dependence that allows these species to function in highly intensified agro-ecological landscapes that would otherwise not support comparable levels of pollination ecosystem services.[6,16] For managed pollinators that are in the front lines of intensive agriculture, are human interventions such as disease control[17] and optimising dietary demand[18] enough to ensure a sustainable pollination service?

There is widespread consensus that managed honey bees also benefit from a varied landscape with not only flower strips, but also the proximity of natural vegetation. Several studies have shown that the availability of pollinator habitat can be used as a gauge for pollination ecosystem services[8,11] and some of these studies explicitly show that bee habitat is not only a year-round habitat for wild bees, but also a food resource for managed honey bees[9,13]. However, the issue discussed here is not the provision of forage for managed honey bees at a single site, but rather, what other sites are needed to support these managed pollinators throughout a year?

A recent review on pollination ecosystem services in South Africa[19] concluded that more research is needed to document wild pollination services, citing the under-reporting of wild versus managed honey bees pollinating specific crops as the biggest stumbling block. Nonetheless, it is well documented that managed honey bees play a pivotal role in the pollination of South Africa's crops.[19,20] Given the case studies already presented which show a predominance of honey bee flower visitation (cited in Melin et al.[19]), and because most commercial agricultural crops are intensively grown without diversified flower strips or proximity to natural vegetation to support wild honey bee colonies[11,21,22], we can assume that there is no wild pollinator replacement for the managed pollination services currently offered in South Africa[22-25]. Thus, irrespective of international trends, South Africa's biggest threat to meeting the ever-increasing crop pollination demand seems to be an insufficient number of managed honey bees for hive rental services.

It is my opinion that current international literature overemphasises the importance of pollination ecosystem services because managed pollinators are simply considered an agricultural input, and their dependence on off-farm sites containing natural and semi-natural flower resources (required as forage when they are not pollinating crops) is not being considered. Such forage can be seen as a provisioning ecosystem service[26], similar to providing forage for free-range domestic livestock or game farming. In the absence of forage sources, beekeepers rely on sub-optimal and expensive artificial feed.[24,27] While it is true that managed pollinators are owned and transported to crops by a beekeeper (pollinator manager) – which cannot be considered a pollination ecosystem service – the forage required to sustain these colonies during a year *does* require a forage provisioning service. Usually a range of foraging areas (typically not owned by the beekeeper) are used, thereby allowing beekeepers to track floral pulses and allow high-density beekeeping.

Some countries, such as China and Argentina, are rich in forage and typically dominate other countries' honey sales. South Africa is a forage poor country because most of the country experiences low rainfall and the majority of honey is now imported from these forage rich countries.[22] There are even further imbalances in areas such as the Western Cape where there is a very high crop pollination demand, such that forage is usually not used for honey production but for supporting managed pollination services (hives are rented for pollination). For this reason, the dependence of managed pollinators on the natural and human modified environment to provide forage in the form of pollen and nectar, should be thought of as a provisioning ecosystem service[26], or, more specifically, as the ecosystem service of off-farm (i.e. when not rented for on-farm pollination) forage provision for managed pollinators (Figure 2).

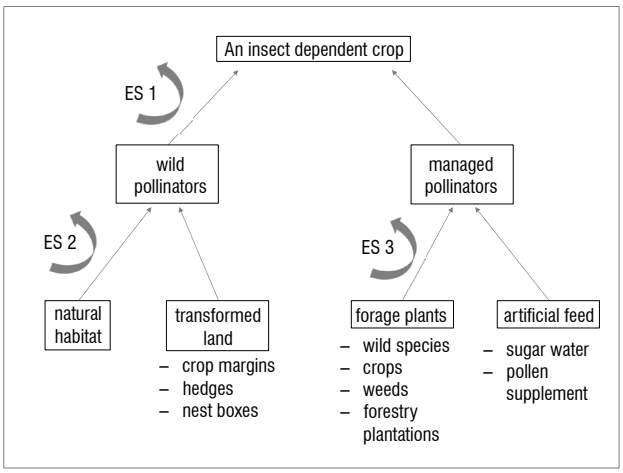


**Figure 2:** Framework to illustrate pollination of insect-dependent crops. Pollination by wild pollinators is an ecosystem service (ES 1), while managed pollinators placed near the crop via human intervention is not. Wild pollinators are supported by natural habitat which provides forage and nesting sites, i.e. the ecosystem service of biodiversity maintenance (ES 2), or can be accommodated in transformed land which has been ecologically enhanced by keeping natural, exotic or crop species nearby. In comparison, the food requirements of managed pollinators can be met by keeping them at sites with plant species (natural, exotic or crops) that provide nectar and/or pollen, i.e. a forage provisioning ecosystem service (ES 3), or they can be fed artificial feed as a forage replacement.

In this case, even human-dominated ecosystems that contain foraging plants can support managed pollination (Figure 3), with both the beekeeper, agricultural producers, and society at large benefiting from the maintenance and availability of such forage resources. The ecosystem service of forage provision can thus be seen to subsidise the rental cost of the managed honey bee pollination service.[27] Consequently, similar to classical ecosystem service use, if the private landowner is not incentivised to maintain forage resources, the beekeeper and everyone else who benefits, will lose a resource, resulting in knock-on effects along the supply chain to the consumer of pollinator-dependent products. For South Africa which is a major fruit exporter, this loss of resources would also mean a loss of export revenue. If it is only a matter of user-pays, beekeepers would have to pay for forage used, thus limiting the number of colonies kept and/or increasing the rental price for pollination. Growers in turn would experience higher costs or production deficits and would at best sell the same quantity of produce at a higher price, resulting in a loss of consumer welfare.[28] De Lange et al.[27] show the cost of replacing forage by either restoring natural vegetation or providing artificial feed is orders of magnitude greater than the cost of renting these managed pollination services. Therefore, the cost of managed pollination rental is a gross underestimate of the value of managed crop pollination services to food production.[20,27,29] It can thus be seen that off-farm forage for managed pollinators is also a critical resource to support sustainable crop pollination and food security.

This view, however, will not be readily accepted internationally by scientists working on pollination ecosystem services because in most places *Apis mellifera* is not native and/or is heavily dependent on beekeepers for forage supplements.[3] Furthermore, the presence of managed pollinators (including *Bombus terrestris*) can have negative implications for the viability of wild congeners.[30,31] Nonetheless, there is a strong case to be made where the honey bee is native and receives minimum forage supplements – as is the case in South Africa. In fact, one could argue that because European countries (where *Apis mellifera* is also native) have not in the past explicitly considered the service of forage provision for managed honey bees when their agricultural systems were becoming very intensive (and uninhabitable for wild pollinators), there was no planning for forage areas and as a consequence they now have a very

dependent managed pollinator species. In contrast, South Africa makes use of 'robust' beekeeping with minimum input from beekeepers and there is an arbitrary separation between wild and managed honey bee colonies.[22]

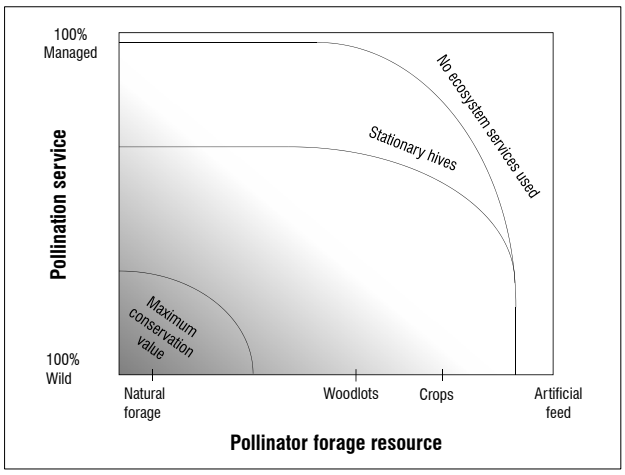


**Figure 3:** Hypothetical relationship between pollination services, floral resource use and the degree of harnessing ecosystem services for crop pollination (degree of grey fill indicates level of ecosystem service use). There is not a binary ecosystem service dependence but rather a gradient of pollination services and forage resources used, that at times may even have conservation importance (i.e. native managed pollinator and native plant species, respectively). Managed honey bee hives kept at a permanent forage site that happens to be near a pollinator dependent crop is an interesting case in which a hybrid crop pollination service is provided.

Mitigation measures to secure wild pollinators are now globally well established – both scientifically and through policy.[5,32,33] South Africa, however, cannot simply follow international trends by over-promoting wild pollination services at the expense of resources for managed honey bees. Thus, the resources used when honey bees are not being rented for crop pollination also need to be accounted for[25,26,34,35] and it is here where there is a lack of comprehensive information for South Africa; globally, there is no consideration of how many managed honey bee hives are required annually for the pollination of all pollinator-dependent crops, not to mention how these hives are supported.

On-farm forage resources for wild pollinators is certainly important, but it is equally certain that off-farm forage resources for migratory-managed pollinators are at least as important. Regarding managed pollinators simply as an ecologically inert agricultural input discounts the ecosystem resources on which they rely, which then weakens policy initiatives aimed at improving crop pollination and food security. Consider for a moment how the recent drought in the Western Cape has shown the importance of maintaining catchments free of alien invasive plants to maximise water recharge (a classic ecosystem service).[36] However, in the same region where there is very limited managed honey bee forage provisioning, while eucalyptus stands are being cleared to liberate water resources, the forage provisioning service these plants provide is at the same time being destroyed.[5] Careful consideration must be given to the trade-off between the ecosystem services of water provision and that of forage provision.[27] I propose that explicitly considering forage provision for managed pollinators as an ecosystem service (e.g. Mensah et al.[26] and Melin et al.[35]), will help correct the perception that sustainable managed pollination is only an agricultural issue.

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