Role of pollinators for agricultural productivity

Pollination is an essential regulatory ecosystem service for crop production, directly linking wild ecosystems with agricultural production systems. Animal pollination accounts for roughly one third of the world's crop production, yet a decline in pollinator populations is a concern, prompting a response at the international policy level. Through the GEF/UNEP/FAO Global-sized Pollination Project, a protocol was developed for assessing and detecting if a crop production system is suffering a pollination deficit. Over a period of five years, the protocol was applied in 344 fields from 33 pollinator-dependent crop systems in small and large farms, for a study to quantify to what degree enhancing pollinator density and richness can improve yields. The study demonstrated that ecological intensification through enhancement of pollinators could contribute to synchronous biodiversity and yield outcomes

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An essential preliminary step for the sexual reproduction of flowering plants is pollination, or the transfer of pollen from the producing anthers to the receptive stigma. Pollination is a keystone process in both human-managed and natural terrestrial ecosystems, and it is critical for food production and human livelihoods, directly linking wild ecosystems with agricultural production systems. Indeed, pollination is a key ecosystem service, providing a regulatory service for the production of crops. Although pollination can be considered a "free" ecosystem service, in fact it requires resources such as refugia and forage. Pollination can therefore be managed and hence considered as a production factor for crops, as it can affect yield but also other factors such as fruit and seed set, fruit and seed quality as well as others such as uniformity of output. Extending this further, pollination management can also have an impact on the environment (such as through good pollination management practices) and on human livelihoods.

Importance of pollinators and pollination

Pollination can occur in different ways, including through cross-pollination, wind and animals – here, we look specifically at animal pollination, and in particular insect pollination. Animal pollination is important because it is essential for the production of globally important food crops such as orchard, oilseed crop, horticultural and forage production, as well as the production of seed for many root and fibre crops, plus many plant-derived medicines in the world's pharmacies. Animal pollination (including insects but also birds, bats and other vertebrates) affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide [1]. The contribution of insect pollination to economies is also highly significant – a study conducted in 2009 estimated that the value of insect pollination is € 153 billion annually [2]. More recently, given that pollinator-dependent crops rely on animal pollination to varying degrees, it was estimated that 5–8 percent of current global crop production, with an annual market value of $235 billion–$577 billion (in 2015, United States dollars) worldwide, is directly attributable to animal pollination [3].

Pollination also contributes to other aspects of human and environmental well-being. For example, pollination can have an impact on human nutrition. Here, the benefits of pollination include not just abundance of fruits, nuts and seeds, but also their variety and quality. Although more research needs to be conducted on this topic, recent studies have shown that the contribution of animal-pollinated foodstuffs to human nutritional diversity, vitamin sufficiency and food quality is substantial (recent studies have estimated that pollinators are responsible for up to 40 percent of the world's supply of nutrients) [4]. Indeed pollinator-dependent crops provide essential micronutrients (such as vitamin A, iron and folate) to those populations living in areas of the world where micronutrient deficiencies are common.

With regards to environmental health, using good pollination management practices contributes not only to improving pollinator-dependent crop production, but also to other ecosystem services. For example, keeping hedgerows promotes crop diversity; mulching contributes to enhancing soil fertility. Integrated pest management practices overall maintain beneficial insect populations – including pollinators - in agroecosystems. In unmanaged contexts, maintaining natural ecosystems in and around agroecosystems provides natural habitat and sources of forage for pollinator populations – this contributes to maintaining pollinator diversity and abundance and other biodiversity provided by the natural vegetation.

But why is insect pollination a topic of such concern to the global community? It has been observed that, globally, insect pollinator populations have been declining, affecting crop productivity. There are numerous reasons for this, including land use change, intensive agricultural management practices and unwise pesticide use, environmental pollution, invasive alien species, pathogens and climate change. These considerations raise a number of issues, at different levels – from the applied level (on-field agricultural practices), to the ecosystem level (for example forest conservation) to the policy level (for example national or regional policies on land management/use or pesticide regulation, to the international policy level). It also raises wider questions related to sustainable agriculture and farmer livelihoods. With over two billion people in developing nations – 83 percent of the global agricultural population – relying on smallholder agriculture (farms with less than two hectares), improving livelihoods through higher and more stable crop yields while also reducing negative environmental impacts is absolutely important for addressing issues related to achieving food security and reducing levels of poverty.

At the global level, in more recent years, insect pollination has increasingly garnered attention, including at the international policy level. More specifically, the Convention on Biological Diversity (CBD) recognized the threat of pollinator population declines to agricultural production. The International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the "International Pollinators Initiative") was established, under the CBD's Programme of Work on Agricultural Biodiversity, at the CBD Fifth Meeting of the Conference of Parties in 2000, in consideration of the urgent need to address the issue of worldwide decline of pollinator diversity. In 2002, the Sixth Meeting of the Conference of Parties of the CBD adopted the plan of action for the International Pollinators Initiative. More recently, the Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) undertook their first thematic assessment on pollinators, pollination and food production. The thematic assessment focused on the role of native and managed pollinators, the status and trends of pollinators and pollinator-plant networks and pollination, drivers of change, impacts on human well-being, food production in response to pollination declines and deficits and the effectiveness of responses. The summary for policy makers of this assessment was approved at the Fourth IPBES Plenary in February 2016, and contains a comprehensive set of key messages [3].

Pollinator deficits and crop yield outcomes

In a larger context, "business as usual" agricultural production is increasingly considered as a non-viable option for sustainable agriculture that respects the natural environment while simultaneously improving crop yield – and ensuring not only ecosystem health but also human health. Highly diverse and stable ecosystems are necessary for sustainable agriculture, as they provide the necessary ecosystem services that ensure agricultural production – examples include nutrient cycling, natural pest control and animal pollination. Despite this, there has been limited "real-world" research conducted on the importance and contribution of ecosystem services to farming, and in particular, for small-scale farming.

We also see that increasingly, agriculture has become more dependent on pollinators as a result of a significant increase of the area cultivated with pollinator-dependent crops. The 2016 IPBES Thematic Assessment on Pollinators, Pollination and Food Production says that in the past 50 years the volume of agricultural production dependent on animal pollination has increased by 300%. Furthermore, crops with greater pollinator dependence have shown lower growth in yield and greater yield variability relative to less pollinator-dependent crops [5]. At the global scale, a decline of pollinators and pollination services has been documented in a growing number of areas in the world, and pollination deficits have been associated with important crop yield losses [6]. Thus there is a growing need to identify and assess pollination deficits in a large array of crops in order to better mitigate and protect against crop losses in the event of pollination deficits. As a contribution towards the implementation of the International Pollinator Initiative and through the GEF/UNEP/FAO project on the "Conservation and management of pollinators for sustainable agriculture, through an ecosystem approach", FAO and its partners – together with INRA (Institut National de la Recherche Agronomique, a public research body of the French government), developed and used a protocol for assessing and detecting if a crop production system is suffering a pollination deficit [7][1]. The protocol, published in 2011, was developed to be applied and address pollination in a way that is realistic for farmers, so that yield is the primary focus. It aimed to address pollination as a production factor at the farm scale level, and as such, stressed that as a production factor in its own right, pollination management needs to be fully integrated into the overall farm management system to optimize production in a holistic and sustainable way. Therefore, it addressed focal crops at the farm scale level to (i) detect and assess pollination deficits in field situations in a standard and statistically testable way; and (ii) draw management conclusions from the proposed experiment for possible action to eliminate or at least reduce these deficits. More specifically, the protocol aimed at applying methods following a standard experimental design to assess the degree to which pollination is a limiting factor in the production of a focal crop at the field scale. Comparing crop responses under pollination levels resulting from current practices with those from enhanced pollinator abundance or diversity would indicate the presence, and degree, of a pollination deficit.

This protocol was used to detect and assess pollination deficits for major crops in the seven countries (Brazil, Ghana, India, Kenya, Nepal, Pakistan and South Africa) that were project partners in the GEF/

UNEP/FAO project on the "Conservation and Management of Pollinators for Sustainable Agriculture through an Ecosystem Approach". In 2013, the Norwegian Environment Agency (NEA) provided support to FAO to extend training and research implementation to an additional six countries in applying the protocol.
Ultimately, during the period from 2010-2014, the protocol was used across regions and crops on 344 fields from 33 pollinator-dependent crop systems in large and small farms from Africa, Asia and Latina America. The results from applying this pollination deficit protocol in all these countries were analysed, through a meta-analysis, to quantify to what degree enhancing pollinator density and richness can improve crop yields. The results were published in *Science*, in January 2016 [2]. Here, yield gaps (which are not uncommon for smallholdings in many developing countries) were defined as the difference in crop yield between high- and low-yielding farms of a given crop system. For fields less than 2 hectares, they found that yield gaps (the difference between potential and actual productivity) could be closed by a median of 24 percent through higher flower-visitor density. For larger fields, such benefits only occurred at high flower-visitor richness. The study thus demonstrated that ecological intensification through enhancement of pollinators could contribute to food security and nutrition, and create mutually beneficial scenarios between biodiversity and crop yields worldwide.

[1] During the process of development of the protocol, it was agreed that crop pollination deficit refers to inadequate pollen receipt that limits agricultural output

[2] Garibaldi, L.A. *et al.* 2016. "Mutually beneficial pollinator diversity and crop yield outcomes in small and large farms". *Science*, Vol 351, Issue 6271. 22 January 2016. http://science.sciencemag.org/content/351/6271/388

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