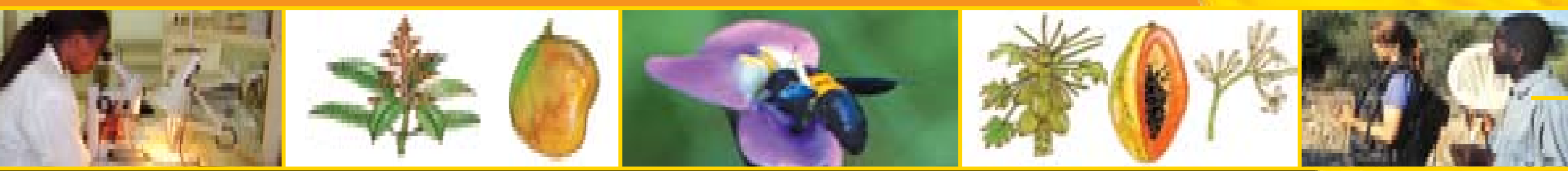
POLLINATION SERVICES FOR SUSTAINABLE AGRICULTURE

Pollinators are essential for orchard, horticultural and forage production, as well as the production of seed for many root and fibre crops. Pollinators such as bees, birds and bats affect 35 percent of the world's crop production, increasing outputs of 87 of the leading food crops worldwide. Food security, food diversity, human nutrition and food prices all rely strongly on animal pollinators. The consequences of pollinator declines are likely to impact the production and costs of vitamin-rich crops like fruits and vegetables, leading to increasingly unbalanced diets and health problems. Maintaining and increasing yields in horticultural crops under agricultural development is critically important to health, nutrition, food security and better farm incomes for poor farmers.

In the past, pollination has been provided by nature at no explicit cost to human communities. As farm fields have become larger, and the use of agricultural chemicals has increased, mounting evidence points to a potentially serious decline in populations of pollinators under agricultural development.



The process of securing effective pollinators to "service" agricultural fields is proving difficult to engineer, and there is a renewed interest in helping nature provide pollination services through practices that support wild pollinators.

On a global level, the Convention on Biological Diversity has identified the importance of pollinators with the establishment of the International Initiative for the Conservation and Sustainable Use of Pollinators (also known as the International Pollinators Initiative-IPI) in 2000, facilitated and coordinated by FAO. Other intergovernmental fora have also noted the importance of ecosystem services – such as pollination – to agriculture, including the Commission on Genetic Resources for Food and Agriculture and the Committee on Agriculture of FAO.

To meet requests for technical assistance with respect to pollination, the Plant Production and Protection Division of FAO (AGP) has established a Global Action on Pollination Services for Sustainable Agriculture. The Global Action provides guidance to member countries and relevant tools to use and conserve pollination services that sustain agroecosystem functions, and to formulate policies that will ensure sustainability of these ecosystem services. The flyers within this folder highlight different aspects of the Global Action.

KNOWLEDGE MANAGEMENT OF POLLINATION SERVICES

The process of securing effective pollinators to "service" agricultural fields as farms intensify production is proving difficult to engineer, and there is a renewed interest in helping nature provide pollination services. This requires new forms of knowledge management.

INTRODUCTION

Crop pollination – key to food production and security – has been little understood, in part because it has been provided by biodiversity at essentially no cost. As farm fields have become larger, production systems have intensified, and the use of agricultural chemicals that impact beneficial insects such as pollinators has increased.

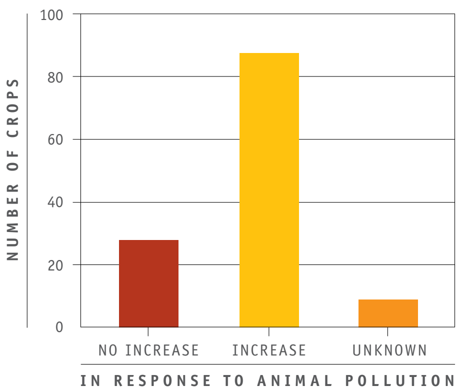
Many horticultural crops depend on pollinators to produce optimal yields and good quality seed or fruit

A result of this is that pollination services are showing declining trends in a number of instances. A major barrier to enhanced pollinator conservation and management is that the existing knowledge base is scattered and often inaccessible to people who need such information to introduce appropriate pollinator-friendly practices into agricultural management.

The Food and Agriculture Organization of the United Nations (FAO) has coordinated a response to these needs by developing a pollination information management system.

FIGURE 1

Response of leading crops and commodities to animal pollination (from Klein *et al.* 2007)



DESIGN OF A POLLINATION INFORMATION MANAGEMENT SYSTEM (PIMS)

The central modules of the system should help pollination practitioners find answers to the following key questions:

- What are the pollination needs of a particular crop?
- What is the current understanding of managing pollination for this crop?
- What studies have been carried out on the pollination of this crop?
- What is known about the pollinators of this crop?
- What practices can promote the conservation and management of the pollinators of this crop?

What are the pollination needs of a particulare crop?

The pollination requirements for crops important in global markets has recently been reviewed (Figure 1).

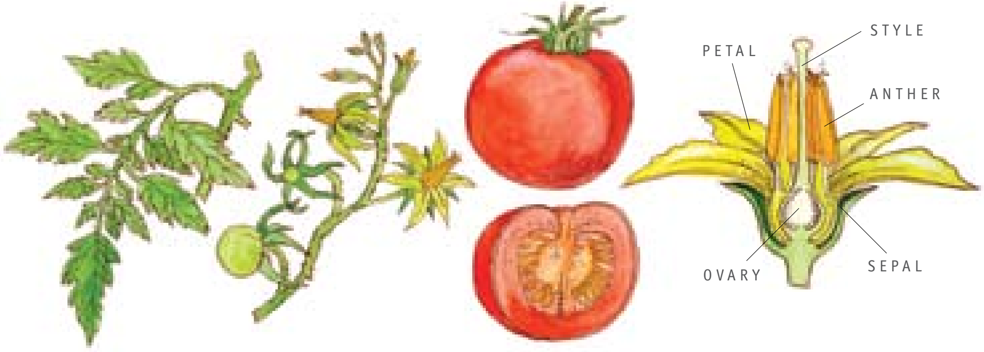
What is the current understanding of managing pollination for this crop?

The major reference book on crop pollination, long out of print and largely inaccessible to practitioners in developing countries – Insect Pollination of Crops by John Free – has been converted to digital format, with new diagrams of crop plant parts that are important for pollination (Figure 2). Its extensive bibliography, and additional literature on crop pollination, can be searched through the PIMS.

A knowledge base and bibliography is only as useful as it can be efficiently searched for relevant information, based on careful selection of search terms and key words. With contemporary full-text search engines and widely available search tools, it may seem that the need for careful searches on the basis of keywords becomes less important. But the biodiversity and agriculture communities suffer not from too little information, but from too much. The Pollination Information Management System includes a pollination glossary and thesaurus, as a means of making searches of bibliographies and other information systems more effective, and more accessible to non-specialists.

FIGURE 2

Tomato leafy branch, flowering branch, fruit and flower parts that are important for pollination (FAO 2008)



© Douglas Williamson

With sufficient and timely pollination of chili peppers, farmers can produce peppers early in the season when prices are higher, and have a longer harvesting period

What is known about the pollinators of this crop?

Little understanding of the ecological needs and life histories of effective pollinators often challenge informed management of pollinator services.

Pages that describe each known crop pollinator species or groups provide information on their descriptions, distributions, natural history, nesting needs, and alternate resources that they are known to make use of, in addition to crop flowers.

What practices can promote the conservation and management of the pollinators of this crop?

The selection of environmentally-friendly pesticides is an important agricultural management practice, with critical implications for pollinators.

The current status of information on pesticide toxicities for pollinators is available through the Pollination Information Management System, along with profiles of best practices in managing wild pollinators for crop production.

CONCLUSION

Consolidating the current knowledge base on the management of pollination services, and making this accessible to field practitioners is the first and most fundamental step in building human capacity to secure the benefits of biodiversity for improved management of pollination services.

© Dino Martins

Long-distance flying moths pollinate crops such as papaya, and need other plants for additional food and egg-laying sites

OVERCOMING THE TAXONOMIC IMPEDIMENT TO POLLINATOR CONSERVATION AND USE

In order for society to be able to capitalize upon the value of bees in pollination and environmental monitoring, a variety of solutions to the taxonomic impediment will be required.

© Laurence Packer/Cory Sheffield

INTRODUCTION

Bees are essential components of almost all of the world's terrestrial ecosystems. They provide both pollination services, and are excellent indicators of the state of terrestrial environments including responses to global warming. A major challenge to knowing how to manage wild bees for pollination services or to using their occurrence as an indicator of ecosystem health is the taxonomic impediment to identifying the exact name of a pollinator.

Knowing the taxonomy of a bee assists in knowing many aspects of its ecology and natural history – where it nests, for instance, and how it may be affected by climate. Bee experts are too few to provide identification services all around the world. Furthermore, a beginner trying to identify bees faces immense obstacles. Yet this taxonomic impediment is not insurmountable.

© Keystone Foundation, 2008

SOLUTIONS

Web-based, illustrated identification guides

There are numerous computer-assisted methods that can help with the construction of user-friendly identification guides.

It is possible, with newly developed tools to create locally relevant, well-illustrated interactive keeys for each region for which bee identifications are required. Keys must be easy for non-specialists to use. Such keys are available or under construction already in Africa, Europe, North America, and Vietnam, amongst other localities.

© Wanja Kinuthia

© Hannah Nadel

Field practitioners need to be able to link scientific names to pollinators, to understand their resource needs

DNA barcoding

DNA barcoding uses a fragment of a gene that has been shown to have minimal variation within species, but considerable divergence between closely related species. If this fragment has been characterized for a species, a new specimen can be analysed to see if it matches existing known characterizations.

DNA barcoding works for bees, both for regional faunas and for entire difficult species complexes. The long term objective of the barcoding enterprise is to have almost all organisms on the planet identifiable with a hand-held device that can generate a DNA sequence and communicate with a global database through wireless technology.

© Remy Pasquet

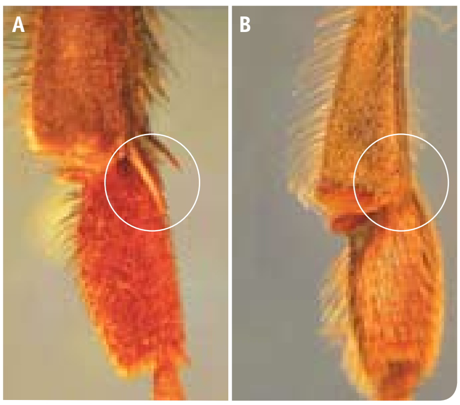
Although this seemed far-fetched only a few years ago, recent advances in miniaturization suggest that a similar system may be available within a decade or two. A global bee-barcoding campaign is currently underway.

© Jeremy Herren

Tools exist to assist in rapid identification of specimens

FIGURE 2

Example of dichotamous web-based key couplet, from a key to the genera of Canada.
A) Hind leg with tibial spurs present,
B) Hind leg with tibial spurs absent *(Apis mellifera)*



The Need for Experts

All of the aforementioned solutions ultimately rely upon the availability of experts to verify the quality of the data. The lack of expert taxonomists remains the most important impediment. The most important products of taxonomic research are revisionary studies that deal with all species in a group.

For anything other than the smallest number of species, these studies take inordinate amounts of time. This shortage is exacerbated by the increasing pressures upon practicing taxonomists to engage in the extremely time consuming activities of identifying specimens for pollination and biodiversity studies rather than to work on species revisions.

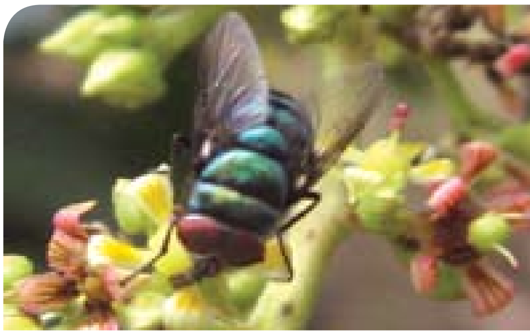
DNA barcoding and user-friendly keys may reduce this time sink. Another approach, adopted in the Brazilian Pollinator Initiative, is to use a network structure: taxonomic experts are training "identifiers" who will be capable of performing the more routine identifications leaving the experts more time to complete revisions.

CONCLUSION

In order for society to be able to capitalize upon the value of bees in pollination and environmental monitoring, a variety of solutions to the taxonomic impediment will be required: locally relevant, open access, web-based, easy-to-use identification guides; DNA-based taxonomy; and networks of "identifiers" trained by, and continuously associated with, expert taxonomists that are able to complete large scale taxonomic revisions.

Crops that benefit from fly pollinators include chili peppers, mango and avocado; moths and butterflies pollinate papayas. Other pollinating groups in addition to bees also need attention to taxonomic impediments

© Ian Gordon



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CLIMATE CHANGE AND POLLINATION SERVICES

The healthy functioning of ecosystem services ensures the sustainability of agriculture as it intensifies to meet growing demands for food production. Climate change, however, may have major impacts on key ecosystem services and functions, such as pollination services.

IMPACTS

Changing climates may cause changes in the time of growth, flowering and maturation of crops, with consequent impacts on crop-associated biodiversity, particularly pollinators.

Key biological events such as insect emergence and date of onset of flowering need to occur in synchrony for successful pollination interactions. Effective crop pollination is heavily dependent on biological timing, of both the crop and its pollinators.

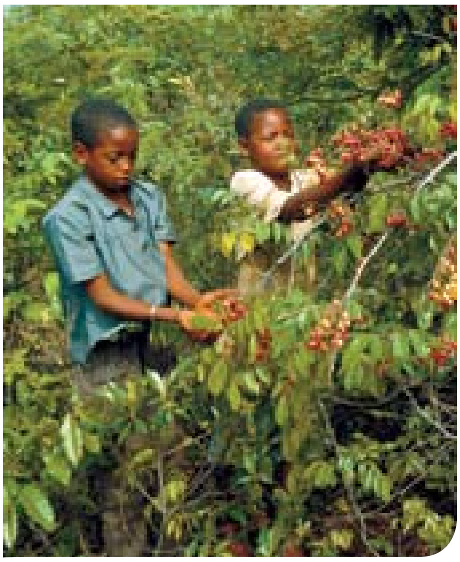
Crops such as mangoes in tropical regions, or almonds or cherries in temperate regions, have periods of mass blooming over relatively short periods, requiring a tremendous peak in pollinators.

To be maintained in the ecosystem, and available for these peak periods of pollination demands, alternate resources for pollinators are needed to bracket crop flowering. Climate change may have profound impacts on the timing of these events.

Present species extinction rates are 100 to 1000 times higher than normal due to human impacts. Insects are considered likely to make up the bulk of future extinctions. The greater risk is not that pollinators fail to adapt, but that too many of them fail to survive.

The extreme weather events that will accompany global warming may have severe impacts on pollinators already stressed from climatic change. Less mobile pollinators (small bees and beetles, for example) may be most severely impacted.

Global warming and extreme weather events will have impacts on crop growth, flowering, and pollination



Mangos bloom in mass numbers, requiring peaks of pollinators

ADAPTATION

Ecosystem services build important measures of resilience and risk mitigation into agriculture – elements that are increasingly important under changing climates.

The greater number and kinds of facilitative interactions in an ecosystem – any ecosystem, but even more so in a simplified farming system – means that as conditions change, there are different groups of organisms that are favored to continue providing ecosystem services.

Farming communities may best adapt to climate change impacts on pollinators by:

- Giving consideration to the season-long resources needed by pollinators, both before and after crop flowering (often provided by wild or semi-wild areas of habitat in agricultural landscapes)
- Ensuring connectivity of natural habitats in farming areas, so that pollinators can more easily disperse and make needed range shifts in response to changing climates.

© FAO photo library / 16211

Climate change may impact seasonal availability of pollinators, and consequently have impacts on fruit markets

© James Cane

The growing zones for crops, including indigenous fruits, may shift with changing climatic patterns

MITIGATION

Measures to promote beneficial insects that help to reduce crop pests, similarly to measures to promote pollinators, include providing more non-crop flowering resources in fields, such as cover crops, strip crops or hedgerows.

Many possible mitigation measures, taken together, contribute to the long-term stability of agroecosystems by helping to provide greater and more continuous biomass cover on-farm. These same practices, retaining large quantities of biomass and soil organic matter, may serve to enhance the ability of agricultural systems to sequester carbon.

CONCLUSION

Farmers and farming communities have the potential to undertake measures that can conserve and strengthen linkages between different aspects of agrobiodiversity, and contribute to long-term stability in the face of climate change.

POLLINATOR DIVERSITY AND ABUNDANCE ON FARMS

© John Ascher, 2006-2007

Farming environments can support large and diverse populations of pollinators - including rare and specialised species.

INTRODUCTION

Natural habitats, forests and protected areas are usually thought to support greater biodiversity than do neighbouring agroecosystems. But this may not be the case with pollinators; their density and diversity can be even greater on farms than in adjacent wild areas, under some management practices.

BEES AROUND KAKAMEGA FOREST, KENYA

Kakamega Forest in western Kenya is one of the most species-rich tropical rain forests in Kenya but is heavily impacted by past and current human disturbances, including high population pressures at the perimeters of the park, illegal deforestation and bushmeat hunting.

Yet the highest species richness and bee diversity were found in farming areas, followed by secondary forests. Bee species richness decreased as forests grew more mature. The surrounding farming areas – with higher availability of floral resources, and bare ground and pithy plants for nesting – supported bee communities year-round, including when most of the flowering plants in the forest were not in bloom. Contrary to expectations, greater generalization was found amongst the bee communities in more mature forests, and more specialized and rare bee species were found in the open and agricultural habitats.

The bee fauna in the farms neighbouring Kakamega forest may be less threatened by human factors than in other agroecosystems. After crops are harvested the land is left fallow until the next season. This enhances the growth of herbs and shrubs, which provide rich food sources for bees. In addition, farmers around the forest do not to overuse chemicals such as fungicides, insecticides and herbicides.

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The research of M. Gikungu found higher bee diversity on farms than in the adjacent Kakamega forest of western Kenya

The research of R. Winfree in New Jersey, USA also found higher bee diversity on watermelon farms than in nearby wild habitat

BEE COMMUNITIES IN NEW JERSEY, USA

Similarly, in southern New Jersey, USA bees were more abundant and diverse in agricultural fields and suburban and urban developments than in extensive forests.

Specialist bees did not show strong positive associations with forest habitat, and the extensive forest contained fewer unique species than agricultural fields or fragmented forest sites. Low-intensity land use may be compatible with the conservation of many, but not all, bee species.

CONCLUSION

Low-intensity or diverse farming systems may provide suitable resources for many bee species, that in turn can provide pollination services for agricultural production.

FIGURE 1

Cumulative number of bee species collected at seven study sites over 24 months, Kakamega Forest, Kenya (from Gikungu 2006)

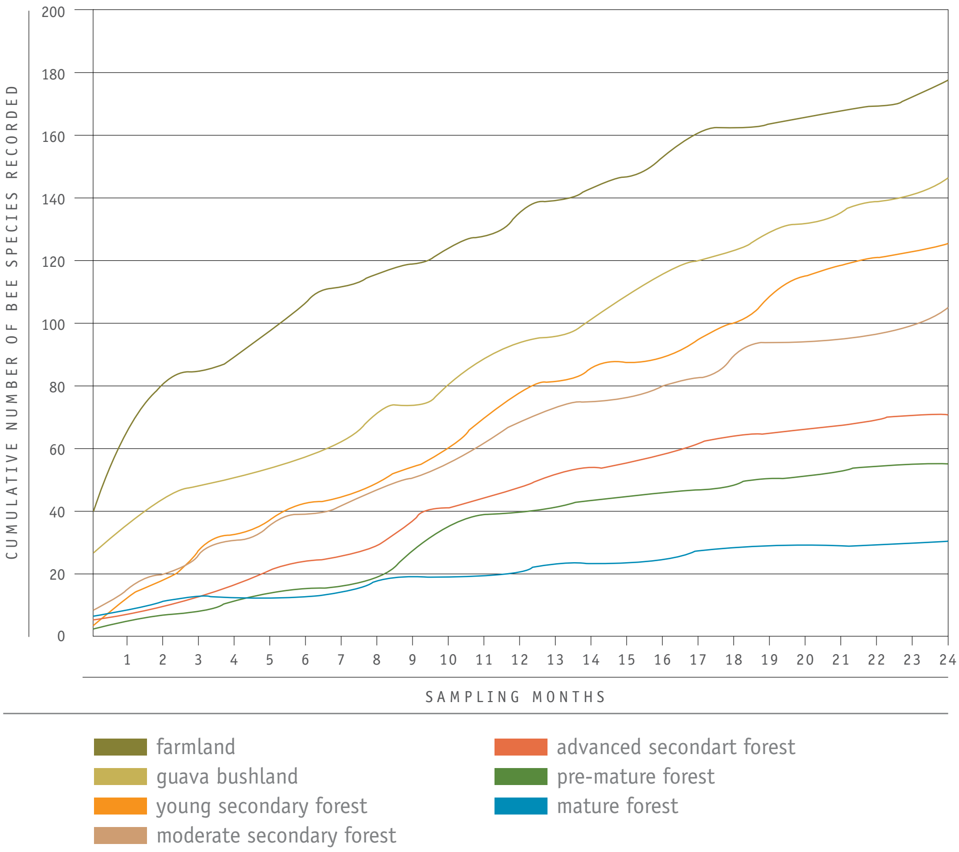
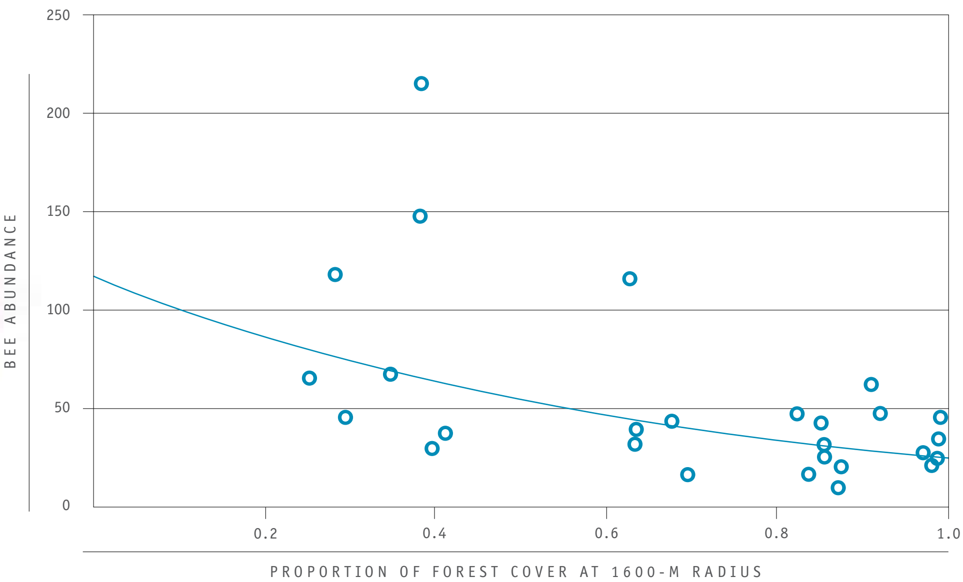


FIGURE 2

Bee abundance as a function of the proportion of forest cover in the surrounding landscape at a 1600 m radius (from Winfree et al. 2007)



BEST PRACTICE PROFILES FOR MANAGEMENT OF POLLINATION SERVICES FROM AROUND THE WORLD

Wild pollinators visiting crops can increase the effectiveness of pollination, and thus the yields and quality of crop production. Profiles of practices that can affect the diversity and abundance of wild pollinators visiting crops give options for farmers and land managers to promote wild pollinators at different scales of management.

© Stuart Roberts, 2008

INTRODUCTION

Biodiversity in agricultural landscapes can provide important pollination services, and serve as a critical form of insurance against the risks of pests and diseases amongst managed pollinators.

Specific practices that farmers can undertake to promote pollinators on their farms, however, are less well understood or appreciated.

FAO, working with experts, has carried out an initial survey of existing good practices to conserve and manage wild pollination services, upon which new practices can be based.

RANGE OF PRACTICES

Farmers can introduce measures to promote pollinators at a variety of different scales. Most commonly, farmers can make modifications to how they apply farming practices in their fields that will benefit pollinators.

But there are other scales of management that are also important, from practices on non-farmed land and field edges, to management of agricultural landscapes.

FIELD SCALE

At the field scale, pollinator-friendly practices include minimizing the use of farm chemicals, through organic production, integrated pest management, or finding alternatives to agrochemicals.

A reduction in the use of herbicides, as well as pesticides, is recognised as having benefits for keeping pollinators in the crop fields. One innovative mango farmer in Ghana switched to clearing the weeds manually instead of chemically, despite a seven-fold increase in costs. Herbicides killed the weeds to their roots, whereas they were quick to regenerate with the rains when cut by machete; by allowing the weeds to selectively flourish when the mangos were in bloom, he could attract more pollinators into his fields and boost fruit yields.

Cardamom farmers in the Western Ghats in India are learning to subtly manipulate shade-tree cultivation in their fields to ensure continuity of pollinators.

Because cardamom requires pollinators for fruit production it is crucial to ensure that large numbers of pollinators are available during the blooming season.

Most pollinators of cardamom are wild and thus move freely through the landscape. Because cardamom does not bloom year round, pollinators may leave cardamom plantations once blooming finishes and they do not necessarily return the following season. Many cardamom farmers also cultivate coffee, with an even shorter mass blooming season.

Farmers are beginning to plant a diversity of flowering tree species (called "sequential blooms") that provide reliable pollen and nectar resources for valuable native bees at times of the years when neither cardamom nor coffee is blooming. For example, farmers may use two species of *Schefflera* whose flowers are attractive to bees. Both flower almost immediately after coffee finishes blooming in the region and just before cardamom begins – thus greatly reducing the number of bees that leave plantations during the off-season.

FARM SCALE

The way farmers organise different land uses across their farms can influence pollination services. In Colombia, farmers recognised that they encouraged pollinator populations by conserving diverse cropping patterns in their farms, for example by combining mixed cropping, kitchen gardens and agroforestry systems, and providing habitat on their farms for bees.

Similarly, farmers in Tanzania understood and encouraged the nesting of carpenter bees in their houses, despite some minor structural damage.

LANDSCAPE SCALE

Farmers from many regions recognised that they benefited from areas of natural vegetation in close proximity to farmland. Such habitat patches provided flowering resources and nesting sites that sustain pollinators.

Pollinator resources – such as Acacia trees – often had multiple benefits for farmers, providing not just food for pollinators but tradable commodities or livestock feed at critical points, or sources of traditional medicines. In Colombia, farmers recognised the importance of maintaining biological corridors across the landscape for native flora and fauna.

CONCLUSION

Practical applications of good practices in on-the-ground settings are informative for people learning to better manage pollination services.

© V. Belavadi

Mixed coffee and cardamom plantation, Karnataka, India (coffee on the left, cardamom on the right, diverse shade trees interspersed)

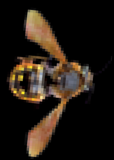
Evaluation of good practices for their impacts on pollinators, and their relative costs and benefits to farmers and land managers is also useful, since the value of these practices must withstand the test of providing sufficient benefits, considering the time, effort and costs of implementing them.

TABLE 1

Range of good pollination practices profiled

CONTINENT	CROP	LOCATION/ FARMING SYSTEMS	PRACTICES
Africa	Papaya	Kerio Valley, Kenya	Bomas, hedgerows, native plants and conserving male trees
Africa	Pigeon Pea	Mwanza district, Tanzania	Natural vegetation and traditional building materials provide resources for bees on-farm
Africa	Mango	Dodowa, Ghana	Selective weeding practices
Africa	Vanilla	Western Uganda	Benefits of natural habitat near farms
Africa	Coffee	Jimma, Ethiopia	Agroforestry cultivation
Asia	Cardamom	Western Ghats, India	Managing bloom sequences to keep pollinators in fields
North America	Blueberries	Maine, USA	Small-scale cultivation practices
North America	Fruit, vegetables, nuts and oil crops	California, USA	Habitat corridors and hedgerows
South America	Lulo	Columbian Andes	Management and conservation of wild bees

GLOBAL ACTION ON **POLLINATION SERVICES**
FOR **SUSTAINABLE AGRICULTURE**



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