POLLINATORS IN CHANGING LANDSCAPE OF AGRICULTURE: GLOBAL AND INDIAN SCENARIOS

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POLLINATION AND POLLINATORS

Pollination results in fruit set, upon which many animals are dependent, including human beings. Insects that provide pollination services provide an important ecosystem service upon which 60–90% of plant species are dependent (Kremen *et al*. 2007). The economic value of pollination worldwide as stated by Simon Potts, a leading scientist in pollination ecology, is thought to be between £30 billion and £70 billion each year (Kluser and Peduzzi 2007). About one third of crop production depends on animal pollinators (Kremen *et al*. 2007), and over 70% of tropical crops are dependent on pollination services (Roubik 1995, Klein *et al.* 2007) that are provided predominantly by insects. Even those crops that can set seeds and produce fruits with self-pollination have been shown to give higher yields when cross-pollinated. With respect to the value of insect pollination, vegetables and fruits are among the leading crops, followed by edible oil crops, stimulants, nuts and spices (Gallai *et al.* 2009).

LOSS OF POLLINATORS AND IMPORTANCE OF HONEYBEES

A major concern worldwide is the loss of pollinators for crops, which reduces the yield of pollinator-dependent crops and hence is linked directly to food security in the present scenario of an increasing world population. If the pollinator decline continues and measures are not taken, the world could face serious problems in terms of its food and nutrition supply (Kevan and Phillips 2001).

Pollinators important for crops include domesticated bees such as the honey bee *Apis mellifera* or wild bees. Domesticated bees were found to be sufficient for meeting pollination needs, but the latest findings indicate a decline both in domesticated bees and wild bees (Potts *et al*. 2010). The decline could be attributed to many anthropogenic factors such as agricultural intensification, habitat fragmentation, loss of habitat, use of agrochemicals and non-anthropogenic factors such as diseases and alien species (Potts *et al*. 2010). Also, the interaction between crop and pollinator could break down or weaken indirectly from changes in floral properties due to global environment changes (Tylianakis *et al*. 2008, Hoover *et al*. 2012).

Investigations have found and continue to find that honey bees are economically important for crops. However, in the face of collapses in managed bee colonies, as is now one of the major concerns in the Western nations, native wild bees could provide insurance against the loss of domesticated bees (Winfree *et al*. 2007). Garibaldi *et al*. (2011a) observed that fruit set was positively related to visitations by wild pollinators and not by honey bees, indicating the importance of wild pollinators for pollination of crops. Also, if native bees are as high in number as managed bees, they could complement the services provided by honey bees (Rader *et al*. 2009). Alongside a loss in total abundance of bees, a species meltdown would adversely affect the stability of pollination services (Ricketts 2004).

LANDSCAPE ELEMENTS AND POLLINATION

The wild population could be affected by landscape elements. For example, a study conducted by Carré *et al*. (2009) has shown that the abundance of wild bees in Europe is dependent upon landscape elements such as semi-natural habitats and

crop habitats. Crop habitats with more native vegetation have greater numbers of bee species compared with habitats with less natural vegetation (Cunningham *et al*. 2012).

Proximity to natural habitats could be beneficial for obtaining pollination services as it has been found that pollination services decline as the distance from a natural habitat increases (Ricketts *et al*. 2008, Carvalheiro *et al*. 2010, Garibaldi *et al*. 2011a).

Nesting resources could also be important for structuring bee communities through the availability of locations for nesting or nest-building materials (Potts *et al.* 2005, Chaplin-Kramer *et al*. 2011). Thus, conserving natural habitats could help maintain naturally occurring pollinator species, ensuring pollination services in agricultural fields (Ricketts *et al*. 2008, Rader *et al*. 2009).

INTERNATIONAL MEASURES AND CURRENT UNDERSTANDING

The pollination crisis and food insecurity have led to many global initiatives and collaborations aimed at quantifying the crisis, identification of species and the causes of loss of wild as well as domesticated bees (for example, the ALARM project, FAO Global Pollination Project). The pollination crisis, caused by incomplete pollen delivery by pollinators, has been attributed to the availability of fewer pollinator individuals because of the factors leading to a pollination decline (as mentioned above). The crisis leads to a mean decrease in the crop yield, to compensate for which more land is converted to agricultural fields (Garibaldi *et al.* 2011b). Also, in both developed and developing countries, a greater area is under pollinator-dependent crops (Aizen *et al.* 2008, Winfree 2008). It is therefore suggested that land use policies should restore and preserve natural habitats within the agricultural landscape, which should enhance pollination services (Garibaldi *et al.* 2011a). A basic understanding of the behaviour, ecology and foraging pattern of the pollinators is also important (Cunningham *et al*. 2012, Kevan and Menzel 2012) for this can help us take decisions on restoration measures.

POLLINATION CRISIS IN THE INDIAN CONTEXT

India has the second largest extent of arable land, and this is present in various bioclimatic zones. According to a 2009 World Bank report, the percentage area of agricultural land in India was 60.53 in 2009 (Trading Economics 2009). Many crops cultivated in India are pollinator dependent (Abrol 1993);and crops have been found to be associated with as well as dependent on many species of wild bee such as *Xylocopa* and *Apis* spp. as well non-apid bees such as members of the family Megachilidae (Thomas *et al*. 2009).

Though pollination limitation has been observed in wild varieties (Somanathan and Borges 2000, Sharma *et al*. 2011) whether such a problem exists in crop plants is not very well known. A study from the Himalayan region revealed that beekeeping has increased the yield of apples besides other crops, indicating the importance of pollinators and hinting at pollinator limitation. A recent analysis by Basu *et al*. (2011) of the vegetable yield from India over 45 years, using FAO data, indicates that there is pollination limitation in Indian agriculture. This is the first such report from India. Pesticides have been found to play a role in the decline of pollinators in the Himalayan region, which has affected the apple yield (Partap and Partap 2009). India is one of the most vulnerable countries due to the extensive pesticide-dependent agriculture that has been practised in the country over the last four decades and the fast-changing land use. A set of developing countries that use pesticides intensely and have lost forest cover are at greater risk of pollination limitation as observed by Basu *et al.* (unpublished).

LAND USE PATTERN AND POLLINATION IN INDIAN CONTEXT

According to a Monitoring Agri-trade Policy (MAP) report published in 2007, 60% of farmers in India have less than 1 hectare of land for cultivation. The average size of holdings has declined over time mainly because big farms have been divided on inheritance. Medium to large farms constitute just over 7% of all holdings. The land use and the crop acreages have also changed (Purushothaman and Kashyap 2010). Crops could be cultivated for sustenance or for their commercial value. Therefore, the pollinator requirements of a crop field depend on the size of the field and the types of crops cultivated. The effects of land use on pollinators in India are yet to be tested, and restoration of suitable habitats within the agricultural landscape may be required for the survival of pollinator species. However, as Ghazoul (2007) has warned, in a country like India, where the farmers are dependent on maximum returns from the land, the ecosystem approach, and hence saving pollinator-friendly sites, could be a problem.

Thus, there is an urgent need to assess the pollinator diversity as well as the pollinator requirements using standardised protocols. There is a serious gap in the quantitative data on pollination limitation in crop fields in various agro-ecological regions of the country, and this gap has to be bridged immediately. Finally, pollination limitation and land use patterns should be looked at together to correlate the land use pattern with such observations. These measures will help us understand the value of pollinators for crops in the changing agricultural landscape of India.

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