Biodiversity in and around Farmlands

Food and Nutritional Security and Rural Livelihoods

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Farmlands and farm practices are increasingly getting homogenised due to the all-pervasive intensification of agriculture. Often blurred in this production maximising system is the biodiversity in and around farms—both wilderness and agricultural—that dots farm neighbourhoods. Unfortunately, unlike biodiversity associated with more recognisable landscapes, such as protected areas and nature reserves, loss of biodiversity in and around farms due to agricultural intensification has not gained as much attention as it deserves. This paper highlights the potential roles that it can play to address challenges of food and nutritional security and securing rural livelihoods by drawing upon specific case studies across India and elsewhere.

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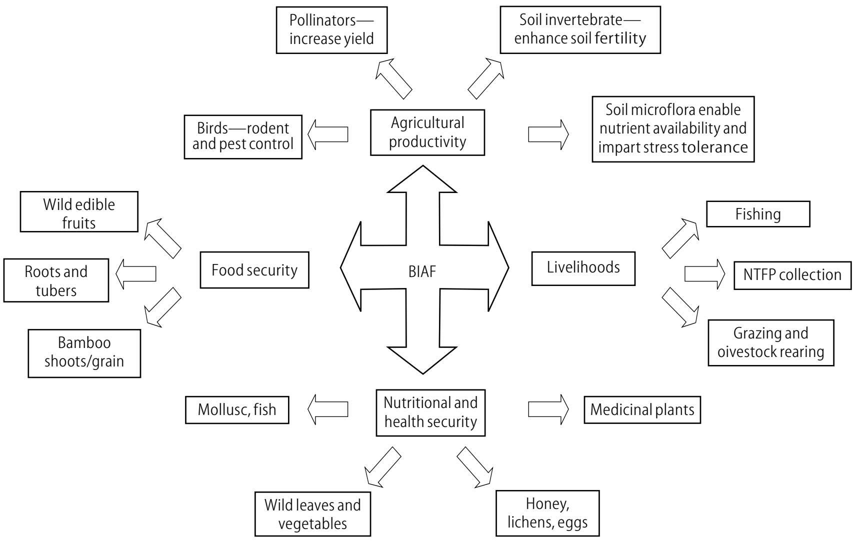
India is primarily an agrarian economy. An overwhelming majority of the country's population is engaged in food production and allied activities. Employing over 50% of India's workforce, "agriculture, forestry and fishing" contributes to a fifth of the country's economic output in gross domestic product (GDP) terms (India Economic Survey 2018). Agriculture remains the dominant land-use form in India increasing from 92 million hectares to 140 million hectares between 1880 and 2010 (Tian et al 2014). This expansion of agriculture and other land-use forms has placed immense pressure on biodiversity, particularly in forests and grasslands/scrublands. In fact, agricultural expansion and the ensuing land-cover homogenisation remains the major cause of biodiversity loss, water depletion and large-scale environmental pollution, particularly in many tropical countries, including India (Aditya et al 2020; Norris 2008; Rockström et al 2009; Balmford et al 2012). Over 45% of temperate forests, 50% of savannahs, and 70% of grasslands in the tropics have been depleted due to agriculture (Balmford et al 2012). Globally, between 1992 and 2015, area under agriculture increased by 3% (~35 million ha) from the conversion of tropical forests (IPBES 2020). Compared to all other human activities, agricultural expansion alone resulted in the highest number of species extinctions (Butler et al 2007). The gross irrigated area in India expanded fourfold from 22.6 million hectares in 1951 to 95.8 million hectares in 2013–14 making it the largest in the world (Douglas et al 2009; Modak 2018). While such agricultural intensification seems inevitable for meeting the country's food security, land-cover homogenisation caused by intensive agriculture has rapidly eroded agrobiodiversity and remains a perpetual threat to the remaining biodiversity. The loss is not confined to biodiversity but extends to the traditional use cultures, and knowledge associated with this diversity (Dweba and Mearns 2011; Aswani et al 2018).

Ironically though, biodiversity—the anti-thesis of intensive agriculturalisation—forms the basis of all sustainable food production systems. From providing pollinator, pest and diseases mitigating services to maintaining soil health and fertility, biodiversity is intricately linked to enhancing productivity and sustaining it. Besides, in countries such as India, with a large proportion of the small landholders, often less than 0.8 hectares, biodiversity has been an important source of nutrition as well as off-farm, off-crop livelihoods. In this context, incorporating biodiversity-based models of agriculture might not only ensure a sustainable intensification of agriculture (increased yield without causing substantial environmental

Figure 1: Schematic Representing the Interlinkages of BIAF with Agricultural Productivity, Food Security, Nutritional and Health Security and Livelihoods



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impact and without conversion of non-agricultural land) but could also help augment nutritional security and rural livelihood opportunities. Here, we describe the concept of biodiversity in and around farms (BIAF) and highlight its importance in enhancing agricultural productivity and demonstrate how biodiversity can simultaneously be conserved and utilised in meeting food and nutritional security and in supplementing the livelihood requirements. We also discuss the need to conserve BIAF through policy interventions that in the long run would converge with the larger sustainable development goals.

In the further discussion, we refer BIAF as a subset of biodiversity that includes agrobiodiversity and species harvested for food, fodder, fibre, fuel, medicine and organisms that support agriculture (such as soil invertebrates, soil microbiota, pollinators, etc) as well as those that support agroecosystems comprising largely of pastoral and aquatic systems. BIAF plays a major role in improving soil productivity, enhancing nutrient status, supplementing food and nutritional security and in ensuring climate resilient agriculture (Figure 1). Many trees around farms are important nitrogen fixers and therefore contribute indirectly to agricultural output and myriad other ecosystem services. Large trees act as windbreaks and stabilise crop bunds, thereby directly aiding soil conservation. Numerous examples demonstrate the direct role of BIAF in augmenting agricultural output, and indirectly supporting agriculture through diverse ecosystem services (Tezzo et al 2020; Burkle et al 2013; Garibaldi et al 2013). Furthermore, in much of the tropics, BIAF has also been recognised to contribute in enhancing rural livelihoods (Lehmann et al 2020; Ticktin 2015).

Value of BIAF

Both scientific evidence and traditional knowledge recognise the value of BIAF and diverse food production systems for maintaining ecosystem services such as pollinators, predators of crop pests, reduced vulnerability to climatic and market shocks, soil fertility and efficiency in use of resources (Wagner et al 2019; Garcia et al 2020). A majority of food crops worldwide depend upon insect pollination, such as by bees, for seed and fruit set (Burkle et al 2013; Garibaldi et al 2013; Potts et al 2016; Rader et al 2016; Kremen et al 2018). In India, more than 687 plant species, including crop plants and those in the wild, are estimated to depend upon the Indian rock bee *Apis dorsata* for pollination (Basavarajappa and Raghunandan 2013). Mixed-species flocks of birds residing in tea plantations in the North East India, effectively control caterpillar pests (Sinu 2011, see Box 1). In southern India's Malai Mahadeshwara Hills Wildlife Sanctuary, 92 species of wild edible plants among the BIAF were found to be important sources of food, medicine and beverage for the local communities (Harisha and Padmavathy 2013). Across forest dwelling communities in central India, flowers of Mahua or *Madhuca latifolia*, a common hedge tree frequently raised along crop margins, are collected in summer and used as a traditional food, and are also preserved and sold (Hegde et al 2019). Soil microbial diversity, a component of BIAF, confers protection against soil-borne disease, boosts nutrient availability and water-use efficiency, thereby conferring economic benefits to farmers (Brussaard et al 2007). Yet another important role of BIAF is in facilitating habitat connectivity amongst fragmented agricultural landscapes. Trees and shrubs facilitate the movement of birds, mammals and other species and thereby gene flow, which is often impeded by homogeneous agricultural fields (Crome et al 1994; Burel 1996). Large trees

Box 1: Owls in BIAF and Rodent Control

In India and elsewhere in the world, rodents cause enormous damage to various crops and stored commodities by feeding or by causing indirect damage during on-farm and post-harvest stages. Almost all field crops are vulnerable to rodents. It is estimated that rodents cause about 10%–15% damage to cereal crops and up to 60% damage to oil seed crops, such as sunflower, soyabean and groundnut during preharvest and post-harvest stages (Govind Raj 2018; Alice and Chakraborty 2020). Besides causing millions of dollars loss to agricultural and horticultural crops, rodents are also major carriers of more than 60 diseases that are transmissible to humans and livestock.

Owls which reside in and around farmlands have significantly contributed to managing the rodent population. More than 30 species of owls have been documented in India and they form one of the key biodiversity components of the BIAF. It is estimated that one single barn owl family could remove 3,466 rodents in a full year (Johnson and George 2020). Owls are environmentally friendly pest management alternatives and have indirectly contributed to enhancing crop productivity as well as in reducing the disease risk from rodents. The trees in BIAF form an ideal roosting place for these birds and has ensured their contribution to agricultural productivity.

in farm bunds act as roosting sites for birds and pollinators (see Box 1).

Rural Livelihoods

Rural livelihoods are largely sourced from BIAF. Income from sustainable harvest of aquatic resources (fishes/molluscs from ponds/paddy fields) or from harvesting bamboo shoots, wild fruits and greens around farms help improve rural livelihoods (Ticktin 2015; Setty et al 2008). In the north-eastern ghats, tribal communities depend upon 29 species of woody trees for various livelihood and food requirements (Aditya 2019).[1] The Soppinabettas or foliage forests are minor forests that surround agricultural landscape and are used by areca nut (betel nut) cultivators in a system of agroforestry for their leaf manure and other organic material in the Western Ghat region of Karnataka, where plantations are integrated within forests and farmlands. These forests are retained by farmers around their fields to support agriculture (Nayak et al 2000; Shastri et al 2002). Likewise, paddy is traditionally intercropped with Babul, *Acacia nilotica* on field bunds in agroforestry systems maintained by farmers in parts of Chhattisgarh (Viswanath et al 2000). The biomass obtained from the babul trees are used as fuel, charcoal and timber for agricultural implements by farmers. Certain native woody trees such as *pongamia,* jatropha and simarouba also yield biofuel, and integrating these with farms can provide livelihood opportunities. Toddy tappers depend on palms growing in and around agricultural fields to support their livelihoods in South Indian states (Franco et al 2020). In summary, as evident from a number of examples, BIAF not only enhances resilience against pests and diseases but also contributes to securing food and nutritional security and livelihoods.

Biodiversity-based Models of Agriculture

In the context of the disconnect between agricultural intensification and loss of biodiversity related services, Pimentel (2006) and Perfecto and Vandermeer (2010) proposed a biodiversity-based paradigm of agriculture as a potential solution for the environmental and socio-economic problems associated with the adoption of resource-intensive production systems. Adopting production strategies that allow for biodiversity-based models will yield benefits and has distinct possibilities in improving food and nutritional security. It is not unexpected that such models are already in place in many of the less intensive and subsistence agricultural systems in the world. Lessons from such examples can greatly benefit modern agriculture in making it biodiversity-inclusive.

It is well known that agroecological approaches harness natural ecological processes in agriculture for various functions ranging from pest control to building soil fertility and enhancing production, and can therefore have substantial biodiversity benefits, with significantly higher yields than conventional farming systems (Badgley et al 2007; Pretty et al 2011; Altieri et al 2012). Such methods integrate forests and BIAF with agricultural production systems building on local ecological knowledge, and can therefore have multiple benefits from improving soil fertility and ecosystem services (Kuyah et al 2016; Dollinger and Jose 2018; Lehmann et al 2020). Agroecological principles combined with multiple cropping practices have also been adopted across India, particularly in water-stressed regions (Saratchand 2018). Multicropping offers opportunities for intensification by allowing multiple and simultaneous uses of a single field while also enhancing crop diversity and providing more suitable habitat for fauna, particularly when woodland pasture and agroforestry practices are adopted (Borchers et al 2014). Higher crop diversity at various scales offers stronger biological pest control, thus lowering chemical insecticide dependence, while also enhancing food security and resilience against climate change (Redlich et al 2018).

Village ponds have traditionally supported fish agri-food systems for rural communities across South Asia. Adopting improved fish polyculture and community-based management of fisheries in village ponds provides livelihood opportunities to fishing communities, while also having environmental benefits (Rossignoli and Philips 2020). Aquaculture practices have been integrated into multifunctional paddy-dominated landscapes and provide alternative income sources across India (Tezzo et al 2020; Karim et al 2011). Village ponds could also function as a store for occasional fisheries and thus conserve local aquatic diversity (Karim et al 2011). Such interventions can improve the prospects for sustainable agricultural land use (with very little inputs) in biodiversity rich areas, while enhancing rural incomes (Bawa et al 2007). BIAF can also be harnessed to boost fisheries and freshwater production systems, for instance in the mulberry grove–fish pond multifunctional system in the Pearl River Delta of China, where the fallen parts of the mulberry tree raised along pond edges and excrement of silkworms are applied as feed to fish ponds and organic residue from ponds are in turn applied as fertilisers to the trees (Pimbert 1999).

Policy Interventions

Considering the overwhelming role of BIAF it is important that suitable policy interventions are made to further strengthen and conserve BIAF. This is imperative because in the current scenario, at least in India, there is no distinct recognition of BIAF as it neither is entirely in the forests nor in the farms. Thus, being in an amorphous existence, BIAF is often the first casualty in agricultural expansion and intensification.

Incentivising farm-level conservation activities and biodiversity-friendly food production systems that ensure nutritional security through payment schemes would encourage sustainable use of farmlands that would benefit both biodiversity and communities (Kumar et al 2019). For instance, Payments for Agrobiodiversity Conservation Services (PACS) on the lines of Payments for Ecosystem Services (PES) programmes that prioritise natural resource conservation, have been implemented in Latin America involving the conservation of 130 threatened varieties across several major food crops such as quinoa, potato and maize (Narloch et al 2011a, 2011b; Padulosi et al 2015). PACS have also been attempted for millets in India and Nepal (Krishna et al 2013). These incentives involve identification of sites with high ecosystem service densities and high threat levels, therefore ensures conservation of BIAF (Drucker and Ramirez 2020).

Agroforestry and farm forestry practices provide up to 80% of the wood and wood products demand in the country (Ahmad et al 2020). Agroforestry plantations have played a role in stabilising the tree cover of the country. Studies show that 69% of India's geographic area retains high suitability for enhancing agroforestry (Ahmad et al 2020; Jat et al 2020). Therefore, promoting agroforestry approaches in accordance with the National Forest Policy, 1998 and the National Agroforestry Policy, 2014 can provide livelihoods, fuelwood and minor forest produce needs of rural populations while helping conserve BIAF. Adopting agroecological approaches can enhance ecosystem functioning and sustainably transform food production systems in order to achieve the United Nations Sustainable Development Goals (SDG), particularly ending hunger, achieving food security, nutrition and sustainable agriculture (SDG 2), ensuring sustainable consumption and production patterns, protect, restore and sustainably use of terrestrial and marine ecosystems (SDG 14 and 15) (FAO 2018).

Sustainable agriculture emphasises sustainable use of resources and enhancing ecosystem services in agriculture for optimising production for achieving maximum sustainable yield while conserving BIAF. Promoting efficient use of resources will increase production while easing pressure on natural habitats. Enhancing water productivity through improved water application, and soil moisture management and conservation practices will result in improved yields. For instance, the system of rice intensification (SRI) has been demonstrated to be capable of reducing water requirements and has been adopted in many rice-growing regions in India and abroad (Glover 2011). Although enhancing efficiency of resource use in agriculture is not possible everywhere, encouraging sustainable use of soil and water could yield significant conservation benefits.

Conclusions

BIAF is a distinct unit of biodiversity, interfacing farmlands with wilderness. By the very nature of its spatial and functional attributes, it forms a unique yet an amorphous body of invaluable repository of flora and fauna that provides numerous services to farmlands that subtend them. Yet, BIAF has largely been ignored in mainstream models of agriculture. BIAF provides food and nutritional security besides livelihood in times of distress, and is vitally important for conserving biodiversity at large given the vast areas under agriculture. BIAF is of particular importance in rain-fed areas with low productivity, and in regions with a high malnourishment index (especially to small and marginal farmers). In particular, BIAF can play a crucial role in alleviating rural poverty and farm distress while conserving biodiversity in the aspirational districts.

In the light of the pre-eminent role that BIAF can play in harmonising the nutritional and economic well-being of people at farm, it is important that policies that specifically address the conservation and sustainable use of BIAF be drawn that further promote and strengthen BIAF. First, from the point of view of land use it would be important to consider how present-day agriculture in the country can or should accommodate BIAF. What should be the relationship of BIAF with the size of landholding? How do different farming systems support BIAF? Considering that a one-size-fits-all approach may not apply given the heterogeneity of farm and farming systems and the varying property ownership and rights over BIAF, it would be important to drive policy that in principle agrees to a land sparing or land sharing, as the case may be. Second, incentivising to have BIAF can drive a massive conservation programme outside of the mainstream conventional biodiversity-rich areas such as the reserved forests and protected areas. The incentives could be tied to market linkages such as is done for shade coffee. Thus, incentives can be driven not necessarily through national or state funds but supported by market forces. Third, policy related to governance of BIAF could help in mapping and managing this important national resource and could be tied to the several ministries including the Ministry of Environment, Forest and Climate Change, Ministry of Rural Development, Ministry of Micro, Small and Medium Enterprises, etc. A lesser but nevertheless important policy could arise from the role BIAF could play in climate resilience and climate disaster management. BIAF could offer succour in times of distress and hence an appropriate policy connecting climate change with BIAF could foster a greater role of BIAF in overcoming challenges posed by climate adversities (IPCC 2018). Finally, many sectoral policies in agriculture and forestry can be suitably amended to include BIAF to offer a more rounded solution to the problem of conservation of biodiversity on the one hand and maximising agricultural productivity on the other.

In closing, as a part of the "National Mission on Biodiversity and Human Well-being" launched by the Government of India, a programme on Biodiversity, Agriculture, Food and Nutritional Security and Rural Livelihoods, expressively attempts to develop a road map for mainstreaming biodiversity-based models of agriculture that would augment food and nutritional security and enhance rural livelihoods. This programme also hopes to develop policies and practices for sustainable management of India's biodiversity that relate to securing India's food and nutritional security and livelihood opportunities.

NOTE

1 These include timber of trees like *Pterocarpus marsupium*, *Adina cordifolia*, *Dalbergia latifolia*, fruits and flowers of *Artocarpus heterophyllus*, *Diospyros melanoxylon*, *Mangifera indica*, *Sterculia urens*, leaves of *Bauhinia vahlii*, toddy from *Aeschynomene aspera* and soapnut from *Acacia sinuata* (Aditya 2019).

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