weeding out many suspect publications. The repeated public notices, gazette notifications and circulars to institutions are sensitizing researchers to the dangers of plagiarism/self-plagiarism, publishing in predatory journals and unethical publishing practices. While all this is welcome, more needs to be done and the benchmark for research evaluation needs to be continuously raised.

UGC has to make academics and students familiar with the research methodology. Publications arise from research. If the research is poor, the outputs will naturally be poor. UGC needs to be strict about evaluation of the quality of research publications, and not just compute numbers. This also means being vigilant about the quality of research supervision. How research guidance is undertaken today must be rethought even more so in the fund-starved post-COVID dispensation in which we now find ourselves.

The golden mean would be a balance between quantitative and qualitative evaluation. The former could constitute a lower threshold and establish the minimum eligibility for an entry-level appointment or a preliminary/early career award. The latter should be the upper bound, directed at subsequent career advancement (promotions, higher posts), and seek to establish excellence and leadership. However, implementation of both these yardsticks needs a high measure of honesty and integrity.

Bhushan Patwardhan is in the University Grants Commission, New Delhi 110 002, India; Gautam R. Desiraju* is in the Indian Institute of Science, Bengaluru 560 012, India.*
**e-mail: bpatwardhan@gmail.com; gautam.desiraju@gmail.com*

Reconciling biodiversity conservation with agricultural intensification: challenges and opportunities for India

Vikram Aditya, P. S. Sumashini, N. A. Aravind, G. Ravikanth, Chandrashekara Krishnappa and R. Uma Shaanker

India will surpass China as the world's most populous country by 2050, with a projected population of 1.67 billion[1]. Although the rate of population growth has decreased, the total fertility rate of 2.2 will keep India's population growing for decades[2]. The challenges posed by such increase in population to India's food security, already under strain from land and resource scarcity, are enormous. Climate change and extreme weather events are already impacting agricultural production, disproportionately affecting vulnerable sections of society through higher food prices, lost livelihood opportunities, adverse health impacts and displacement. Alongside food security, alleviating malnutrition, particularly among women and children, remains a challenge. The Food Insecurity Report 2014 by the United Nations Food and Agriculture Organization, Rome reveals that one in nine persons in the world is chronically undernourished, with a large percentage being in India[3]. The challenge of ensuring food and nutritional security of its population, while grappling with the impacts of climate change and environmental stresses, is therefore a huge concern for the country.

Agricultural intensification – imperative to meet food demands

Globally, fertilizer and external input-intensive conventional farming practices have helped multiply agricultural output manifold over the decades. Food production increased 2.5 times between 1960 and 2000 through the use of hybrids and high-yielding varieties, application of fertilizers and pesticides, and increased irrigation[4,5]. Benefitting from this, India was able to meet its food production demands through intensification of agriculture. The Green Revolution in India in the 1960s, resulted in vast increases in per capita food supply. From 1951 to 1997, gross irrigated areas across the country expanded fourfold, from 23 to 90 m ha (ref. 6). India is also among the top producers of several crops, including rice, wheat and various pulses. To attain self-sufficiency in the production of oilseeds, wheat, maize and pulses, the Government of India (GoI) pushed for a second Green Revolution in 2011. Thus, despite all odds, India has been able to ensure food security of its population through agricultural intensification.

However, further intensification of agricultural production, though imperative, is faced with two major challenges. First, India has been rapidly losing arable land due to combined impacts of land degradation, salinity, desertification and urbanization, ranking third after the US and China in terms of decreasing arable land. It is estimated that about 44% of the country's land area is degraded due to various reasons, including overuse of agrochemicals, mismanagement of irrigation systems and natural hazards[7]. Thus, the extent of productive land available for food production is shrinking. Second, the 'yield ceiling' or maximum potential yield per unit area, is already close to saturation for many crops, making it difficult to attain any further increase in yield[8]. Added to these challenges, India is faced with a formidable target of doubling farmers' incomes by 2022 (ref. 9). In other words, meeting food security needs and sustaining it is perhaps one of the most challenging targets for the country in the coming years[5].

The ecological and environmental cost of intensification

Agricultural intensification has resulted in detrimental environmental impacts such as biodiversity loss, habitat loss, deterioration of soil fertility, shrinking groundwater, pollution of soil, air and water, and rising greenhouse gas (GHG) emissions. Land conversion for agriculture has been the major driver of ecosystem change globally and numerous studies have shown that agricultural expansion and homogenization of land cover is the major cause of biodiversity loss[10,11]. Besides being the leading cause of tropical deforestation, agricultural expansion has depleted over 45% of temperate forests, 50% of savannas and 70% of grasslands[12]. Agriculture is threatening the highest number of species with extinction compared to any other human activity[12,13]. The increasing use of pesticides and fertilizers is causing rapid accumulation of toxic chemicals in the soil and water, increased land degradation and topsoil erosion from deforestation besides severely impacting human health. Between 1990 and 2016, the agricultural sector in India released 16.13 gigatonnes of CO_2 equivalent GHG emissions (Figure 1). With food demand in India expected to double, these impacts on emissions and biodiversity will only multiply. Clearly, the current system of agricultural production has proven to be unsustainable. Thus, it is imperative to examine how India can meet the increasing food demands of its population, mitigate climate change and maintain biologically diverse landscapes.

Why reconcile biodiversity conservation with agricultural intensification?

Since agricultural intensification and biodiversity are so inextricably linked, it is important, both from a philosophical perspective and from practical considerations, to outline why it is necessary to reconcile biodiversity conservation with enhancing agricultural productivity. Farming essentially has to do with tending the wilderness. While farming might seem an efficient method of transformation of wild vegetation to production fields with orders of magnitude increase in output, it comes with a huge investment of 'energy', including fertilizers, pesticides, fossil fuels and human power. This would not be sustainable in the long term. Furthermore, with the depletion of both above and below-ground biodiversity, modern agriculture has dispensed with many natural services that will be difficult to restore. Modern intensive agriculture essentially replaces the ecological functions performed by biodiversity with chemical and mechanical inputs. From an economic perspective alone, the service provided by just one of these biodiversity elements, the pollinators, is huge. This loss of biological and landscape diversity will be the long-term burden of agriculture.

Numerous examples exist of civilizations overexploiting their biodiversity for agriculture or other production purposes, leading to an ecosystem collapse and eventually their own extinction. Jared Diamond[14] popularized the case of the fall of the Rapa Nui or Easter Island civilization located in the remote mid-Pacific, caused by an ecological catastrophe arising from resource overexploitation. The mighty Roman Empire was also reportedly a victim of overexploitation of resources and climate change. Closer home, overexploitation of natural resources reportedly led to the decline of the Vijayanagara empire[15].

Thus, in efforts to enhance the economic and food security status of the country, any model that is inclusive of biodiversity will be more robust and stable than those which are exclusive. With India experiencing rapid population and economic growth, the challenge then is to reconcile the twin goals of intensifying agriculture to meet the increasing food demands while conserving biodiversity. How can a country like India incorporate such perspective plans in its growth?

Models of reconciling biodiversity conservation with agricultural intensification

Biodiversity forms the basis of our food production systems by providing various ecosystem services to agriculture, including pollination, pest and disease control, maintenance of soil and nutrient cycling, all essential to enhance productivity. The potential of biodiversity to support a range of livelihoods through agricultural and allied production sectors, and to contribute to food and nutritional security of the communities involved is immense. Maintaining biodiversity within food production systems can deliver immense nutritional and livelihood benefits[16]. The key to reconciling biodiversity conservation and agricultural production is to explore ways and means by which food production systems can become inclusive of biodiversity. Several models of inclusive agriculture, such as agro-ecology, adaptive management of agro-ecosystems and increased crop diversification have been proposed and practised in the past. However, beyond this it is necessary to explore models in today's circumstances, where such inclusivity can be practiced. In other words, how do we achieve the sustainable intensification of agriculture?

Several approaches have been proposed and practised in the past towards a biodiversity-friendly agriculture. For example, substitution of conventional agricultural practices with a range of biodiversity-friendly cultivation practices, including multi-cropping and rotational cultivation, often referred to as 'conservation agriculture' have been in practice in many parts of the world. The concept of maintaining a balance between land-sharing, where agriculture is integrated with biodiversity through ecologically friendly food production methods ('land sharing'), and land sparing, by keeping a portion of land 'spare' solely for conservation ('land sparing')[17], is yet another. This practice is also termed as 'wildlife-friendly farming'[18], and studies in India have shown that sparing land can significantly enhance biodiversity[19]. The wise use of community-managed resource

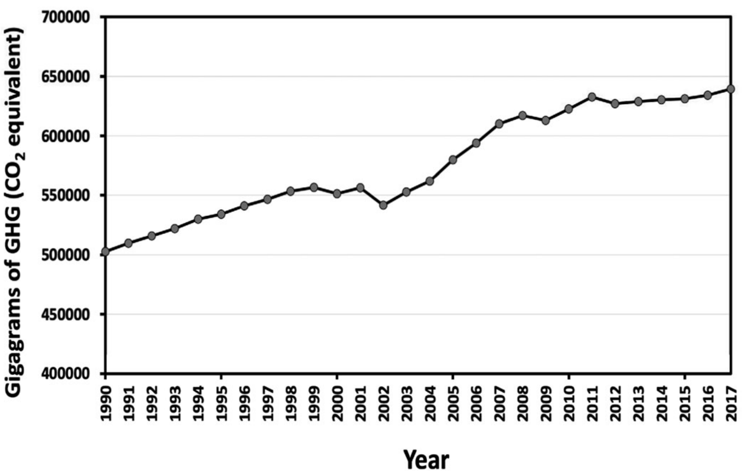

Figure 1. Greenhouse gas emissions (CO_2 equivalent) from agriculture in India between 1990 and 2017 (source: FAO, 2017).

commons, such as village grazing lands, ponds and forests can significantly contribute to conservation, especially of agro-biodiversity[20]. The use of such approaches as well as many others has been shown to significantly increase the biological and landscape diversity, while also lowering nutrient leaching and soil erosion[21] (Figure 2). There are numerous examples around the world of farmers restoring wildlife habitats without compromising their agricultural production, or otherwise undermining the profitability of their enterprise by following nature friendly practices[22], showing that these biodiversity-friendly models of agriculture can work.

Nowhere is this better exemplified than in the high-intensity conventional cultivation systems such as the Indo-Gangetic Plains. Despite being one of the most intensively cultivated landscapes globally with the fifth highest human density, the Gangetic floodplains remain multifunctional, producing 22% of the rice grown in the Indian subcontinent and retaining high avian diversity[23]. Threatened birds such as sarus cranes and black-necked storks have persisted over the long term in these paddy fields in Uttar Pradesh, thanks to the retention of their nesting habitats as community lands by villages. Community ownership and participation in conservation can help retain significant biodiversity in intensive agricultural landscapes. On the other hand, multi-cropping and polyculture approaches can provide habitats for several species even in an intensively cultivated farming region. Similarly, studies in southern India have shown that intensive agriculture having certain features such as intercropping with multiple woody, understorey species and integration with the nearby forestland can support significant biodiversity, even decades after conversion to irrigated farmland[24]. Mixed agricultural fields, particularly close to natural habitat patches, are also known to retain high arthropod diversity[25]. Thus, incorporating habitat requirements for species alongside traditional farming practices by providing a gradient of habitat diversity and complexity can retain the long-term multifunctionality of agricultural landscapes for food production, while also remaining vital for biodiversity conservation[26–28]. Such biodiversity-friendly approaches can also optimize yields, releasing more land for conservation (Figure 2). Therefore, even while pursuing agricultural intensification, adopting polyculture or mixed farming and other sustainable farming techniques can not only support higher biodiversity, but also function as a safety net for farmers by assuring stable incomes from at least one crop in the case of crop failure[5,26,29]. This strategy of diversifying crops minimizes risk to farmers, stabilizes yields and helps boost nutritional security by promoting dietary diversity[30].

Conclusion

In summary, the sustainable intensification of agriculture will not only lead to improved agricultural productivity, enhanced food and nutritional security, and livelihood opportunities but also conserve biodiversity at large. Policy design towards biodiversity-based enterprises and strategic land-use planning for farming, protection and restoration of farm landscapes will help restore biodiversity. Overall, these efforts can help meet the United Nations Sustainable Development Goals 2030, specifically poverty eradication, eliminating hunger and protection of biodiversity (Figure 3). In an effort to address some of these goals, GoI has recently initiated a mission-mode programme on biodiversity and human well-being.

The programme lays emphasis on five thrust areas critical to addressing the larger implications of biodiversity conservation while meeting India's food and nutritional security, besides enhancing

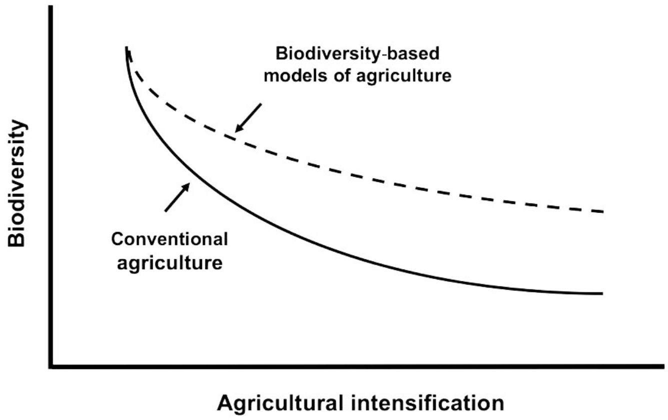

Figure 2. A hypothetical graph showing how incorporating biodiversity-based models of agriculture can reduce biodiversity loss for any given level of agricultural intensification.

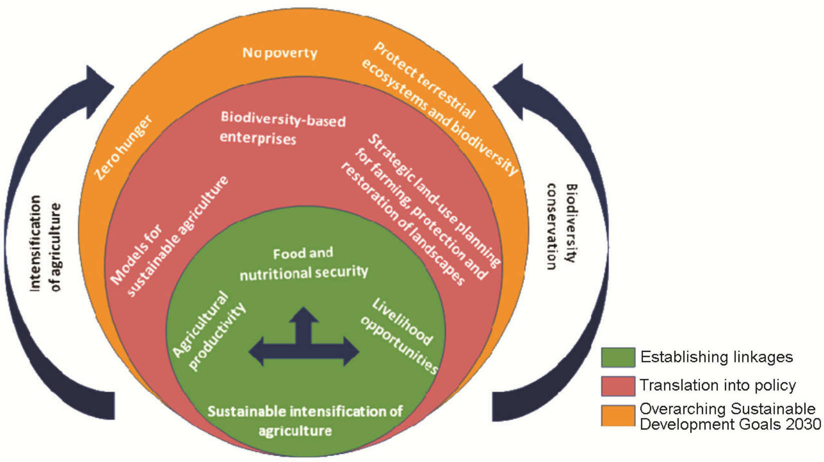

Figure 3. A strategic framework for reconciling biodiversity conservation with agricultural intensification for meeting food and nutritional security and livelihood opportunities, that can help India meet the United Nations Sustainable Development Goals 2030.

livelihoods of rural households. This is being achieved through development of models to quantify the contribution of biodiversity to primary and secondary agriculture, conservation and diversification of agro-biodiversity, diversification of livelihood opportunities and enhancing incomes of rural households through biodiversity-based skill development. This would not only enhance agricultural productivity, but also provide nutritional security to many marginal and poor communities across the country. This programme is further expected to lead to the development of policies towards sustainable management of India's biodiversity that relate to securing India's food security and livelihood opportunities. The mission will be implemented through a network of agricultural research institutions of the Indian Council of Agricultural Research and the State Agricultural Universities.

In 2008, realizing the urgent need for reconciliation between meeting food demands on the one hand and the looming threat to India's biodiversity on the other, M. S. Swaminathan said, 'If conservation of natural resources goes wrong, nothing else will go right'. A decade later this statement is even more pertinent as it will be for decades to come, especially for countries such as India, faced with the Himalayan challenge of meeting her food demands. If India can do it, any others can. In fact, India can emerge as a global leader in developing and showcasing such models of reconciling biodiversity conservation and agricultural intensification.

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Vikram Aditya, P. S. Sumashini, N. A. Aravind and G. Ravikanth are in the Ashoka Trust for Research in Ecology and the Environment, Royal Enclave, Sriramapura, Jakkur Post, Bengaluru 560 064, India; N. A. Aravind is also in the Yenepoya Research Centre, Yenepoya (Deemed-to-be) University, University Road, Derlakatte, Mangaluru 575 018, India; Chandrashekara Krishnappa and R. Uma Shaanker are in the School of Ecology and Conservation, University of Agricultural Sciences, GKVK, Bengaluru 560 065, India.*
**e-mail: umashaankar@gmail.com*