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Giving the cold shoulder: why and how do we conserve farmland herpetofauna in India?

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Summary

Numerous studies highlight the adverse impacts of agriculture on farmland biodiversity. Balancing increased agricultural production along with biodiversity conservation is a critical global challenge, especially in India. Amphibians and reptiles face the greatest threats from agriculture. This perspective article highlights the need to conserve amphibian and reptile diversity in farmlands, presenting evidence of their decline and emphasizing their ecological importance. It calls for forward-looking research and policies to combat unprecedented biodiversity loss. Furthermore, I propose strategies aimed at redesigning agricultural landscapes to transition towards ecological intensification, thereby maintaining productivity and profitability while safeguarding biodiversity and regenerating rather than undermining the ecological processes that sustain food production. As agricultural intensification increases, it should be aligned with nature, leveraging biodiversity to sustain ecological functions rather than replacing them.

Introduction

Agricultural intensification in the twentieth century has severely affected biodiversity globally (Majumder 2023). However, slowing intensification is inconceivable in the current circumstances. Several studies have highlighted the detrimental effects of agriculture on farmland biodiversity, and that increases in agriculture will have costs for biodiversity. Food production has been the predominant cause of land-use change worldwide, with 80% of forest cover globally being converted to farmlands in recent decades (FAO 2016). Over the past two decades, the world has consistently lost 3–4 million hectares (7.4–9.9 million acres) of tropical forest every year (World Resources Institute 2023). At the current rate, agricultural land use is expected to increase by between 165 and 600 million hectares by 2050 (Global Landscapes Forum 2022), with a projected human population of 9.7 billion in the next two decades and an increase of 70–100% in global food demand (Population Matters 2024).

Loss of biodiversity owing to agriculture is severe, especially in the tropics and subtropics, where 73% of forest cover has been transformed into agricultural land (FAO 2016). Asia has the highest proportion globally of area under agriculture (52%) and the lowest proportion globally of forest cover (19%; FAO 2016). Within Asia, particularly India, 60% of the total geographical area is currently under cultivation, and only 5% of forest is included in the protected area network (Srivathsa et al. 2023). Furthermore, agricultural intensification is imperative in India considering the rapid human growth of its population, which is estimated to reach 1.67 billion by 2030 (Vision 2050 2015, Population Reference Bureau 2019). India stands second worldwide in agricultural production. More than two-thirds of its population directly or indirectly depend on agriculture. India's food demand is expected to rise to ~400 million tonnes by the year 2050, which requires an agricultural growth rate of 4% per annum (Vision 2050 2015).

Of the c. 25 000 species identified as threatened with extinction, 13 382 are threatened by agricultural land clearing and degradation alone (Tilman & Williams 2021). Amphibians and reptiles (herpetofauna) are at the apex of vulnerability due to their unique anatomical, ecological and physiological demands (Vitt & Cadwell 2014, Greene 2000, Ghosh 2021). Their specificity to microclimate, dependence on aquatic habitat and low dispersal ability make them vulnerable to agricultural land use (Cayuela et al. 2015). At present, 2249 amphibian species and 1143 species of reptiles are listed as Critically Endangered, Endangered or Vulnerable globally due to habitat degradation in the form of agriculture and its management practices (IUCN 2024). India hosts 453 species of amphibians and 681 species of reptiles, of which 73% and 47%, respectively, are endemic (Gohain 2023).

This perspective article aims to discuss the impacts of agricultural intensification on herpetofauna and why these biota are important to farmlands and human well-being. Additionally, I propose strategies for how herpetofauna might be conserved without affecting the increasing agricultural production in India.

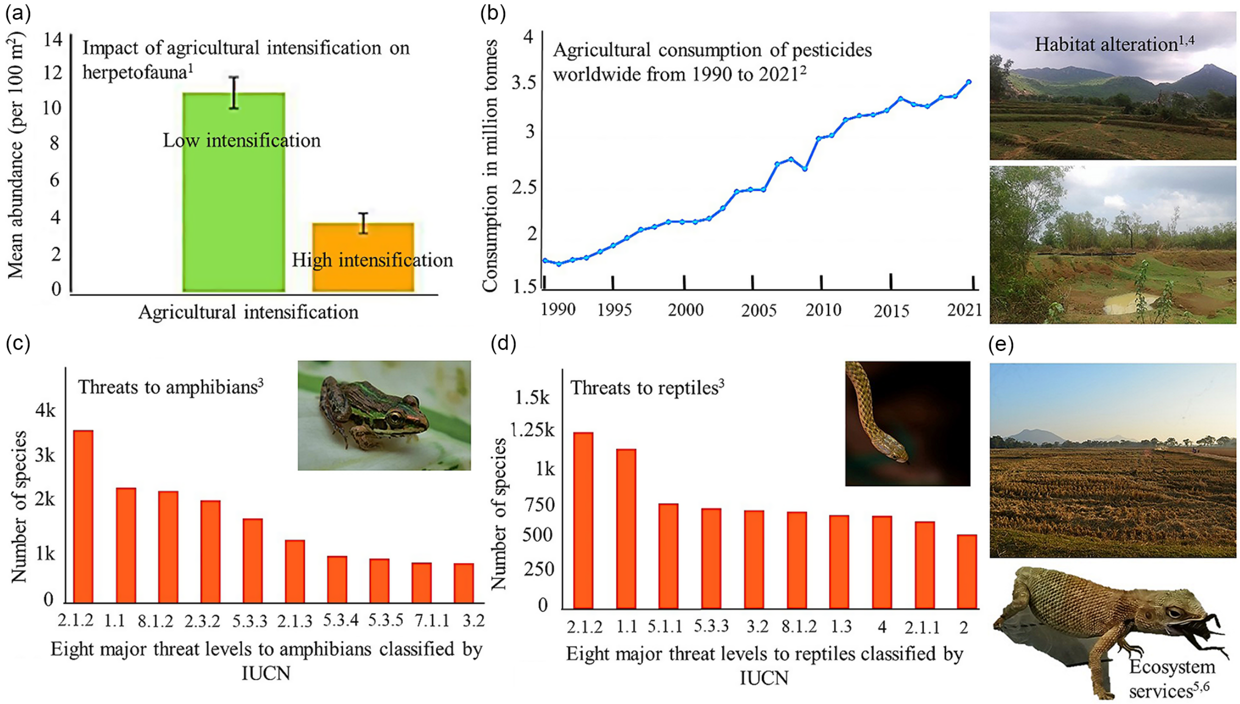

Figure 1. Illustration of the diverse impacts of agricultural intensification on herpetofauna diversity and their ecosystem services facing similar threats following the International Union for Conservation of Nature (IUCN) categorization system (IUCN 2024): (a) the difference in diversity between low and high agricultural intensification; (b) the trends in pesticide application; (c) the threats listed by IUCN for loss of amphibians; (d) the threats listed by IUCN for loss of reptiles; and (e) photographs showing the change in landscape from low to high agricultural intensification and ecosystem services such as bioregulation of crop pests provided by farmland herpetofauna. All photographs by DG. The threats mentioned here follow the IUCN categorisation system: 1.1 Housing & urban areas; 1.3 Tourism & recreation areas; 2 Agriculture & aquaculture, 2.1.1 Shifting agriculture, 2.1.2 Small-holder farming; 2.1.3 Agro-industry farming; 2.3.2 Small-holder grazing, ranching or farming; 3.2 Mining & quarrying; 4 Transportation & service corridors, 5.1.1 Intentional use (species being assessed is the target), 5.3.3 Unintentional effects: subsistence/small scale (species being assessed is not the target) [harvest], 5.3.4 Unintentional effects: large scale (species being assessed is not the target) [harvest], 5.3.5 Motivation unknown/unrecorded, 7.1.1 Increase in fire frequency/intensity, 8.1 Invasive non-native/alien species/diseases. References in the figure are: [1]Ghosh (2021); [2]Statista (2024); [3]IUCN (2024); [4]Srivathsa et al. (2023); [5]Monagan et al. (2017); [6]Ghosh and Basu (2023).

Role of herpetofauna in human well-being and farmlands

The herpetofauna are pivotal in maintaining environmental stability and resilience as they provide indicators of ecosystem health and contribute to nutrient cycling and therefore support human well-being (Valencia-Aguilar et al. 2013). The herpetofauna are even important in the medical field (Brozio et al. 2021). Newts, salamanders and tadpoles of frogs regulate vectors of several disease-carrying microbes (Perrin et al. 2023). Of all the services herpetofauna deliver regarding human well-being, they have long been identified as 'farmers' friends' because they improve soil quality and aeration, reduce biogas emissions, help in dispersal of seeds, improve crop health and enhance pollination (Olesen & Valido 2003, Fang et al. 2019). Amphibians and reptiles are effective bioregulators of crop pests (Monagan et al. 2017, Ghosh & Basu 2023). Amphibians are major regulators of ground-dwelling pests, while reptiles feed on both ground-dwelling insects and arthropods in flight or at the crop surface (Ghosh & Borzée 2024). Furthermore, snakes also reduce the populations of rodents and other small mammals, thereby benefitting agriculture (Majumder 2022). Additionally, herpetofauna display diverse foraging modes (i.e., active and ambush foraging modes), which have differential impacts on crop pest regulation (Ghosh & Borzée 2024). However, in India, there is very limited information regarding ecosystem service provisioning by farmland herpetofauna (Deuti et al. 2022). Thus, considering their important roles in ecosystems (Cogălniceanu et al. 2021), the loss of herpetofauna could have a cascading effect on whole agro-ecological systems.

Racing towards extinction

India is among the top 15% of regions in the world that could experience a phylogenetic diversity loss of reptiles owing mainly to habitat destruction from agricultural expansion (Cox et al. 2022). In India, of 426 amphibian species that have been assessed to date, 310 are endemic (Re:wild et al. 2023). In the Western Ghats of India there is a concentration of 139 threatened amphibian species, with 16 species being Critically Endangered, 72 being Endangered and 51 being Vulnerable (Gohain 2023).

Amphibians and reptiles share common threats, including agriculture, urbanization, tourism, small-holder grazing ranching, mining and quarrying, transportation, fire, invasive species and diseases, of which agriculture is the most severe (Fig. 1a,b; IUCN 2024). Being cold-blooded, herpetofauna have unique physiological demands and therefore narrow tolerances and specific needs for microclimates, rendering them the most vulnerable of the vertebrates (Ghosh & Basu 2020). Air humidity, temperature, light intensity and nature of habitat impact the diversity and

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Figure 2. Impacts of pesticide application (e.g., carbofuran and cypermethrin), showing dead (a) a checkered keelback snake and (b) Dicroglossidae and Microhylidae amphibians from rice paddies in India. All photographs by DG.

abundance of herpetofauna, as well as their breeding, spatial activity, foraging, movement, choice of retreat and thermoregulation (Wisler et al. 2009). Moreover, herpetofauna species have small home ranges and low dispersal rates, to the extent that many amphibians are philopatric and only travel a distance of 400 m to a few kilometres in their lifetime (Fonte et al. 2019, Guiller et al. 2022), making them even more sensitive to land-use changes associated with agriculture.

Agricultural intensification is manifested through several factors such as excessive use of pesticides and fertilizers, agricultural land conversion, types of cropping systems, cropping intensity, intensity of grazing and the proportion of natural habitat remaining around farmlands at a landscape level, and therefore the pathways through which it affects species are difficult to discern (Concepción et al. 2015, Ghosh & Basu 2020). These agricultural factors operate at several spatial and temporal scales, affecting both amphibians and reptiles across their various life-history stages, including their dispersal and range distribution (Arntzen et al. 2017, Guiller et al. 2022), and causing a loss of genetic diversity due to reduced gene flow (Gauffre et al. 2022). Of all these factors, pesticides have been recognized as representing one of the major threats to herpetofauna, causing deformities in amphibians, altering movement patterns in snakes and reducing offspring numbers (Fig. 2a,b; Hopkins et al. 2005, Guerra & Aráoz 2016, Simbula et al. 2021). Despite their detrimental impacts, the use of pesticides is still increasing, with their use projected to increase from 4.30 to 4.41 million tonnes between 2023 and 2027 (Statista 2024). In India, intensive agriculture hosts only half the herpetofaunal diversity of traditional rain-fed agriculture with less pesticide input and more forest cover (Ghosh & Basu 2021).

Can redesigning agricultural landscapes reverse biodiversity loss?

Habitats within farmland such as ponds, drainage ditches, flooded fields and woodlots are regularly used by amphibians and reptiles at various life-history stages and are considered critical for the persistence of local herpetofaunal populations (Boissinot et al. 2019). Conventional agricultural intensification relies on synthetic fertilizers and pesticides (Kremen 2020), which have negative effects on biodiversity and the ecosystem. Ecological intensification, on the other hand, provides greater environmental stability by minimizing these detrimental consequences, supporting natural processes that promote, replenish and regenerate the ecosystem services on which farmers can rely and bringing societal benefits including good water quality and biodiversity conservation (Kremen 2020, Mondal & Palit 2021). Pollinators and natural crop pest predators positively respond to ecological intensification (Garibaldi et al. 2011). In California, ecological intensification increased the species richness and functional diversity of specialized and rare species of native bees and birds (M'Gonigle et al. 2015), including several threatened ones (Kross et al. 2020). In India, ecological intensification has also been shown to improve rice quality and yields (Kumar et al. 2023).

Ecological intensification can be achieved by either improving heterogeneity in agricultural landscapes through diversifying crop types (higher compositional heterogeneity) or through improving the spatial heterogeneity of the cropped areas by increasing the diversity and spatial pattern complexity of arable land-cover types (configurational heterogeneity; Fahrig et al. 2011). Higher crop diversity provides greater resources for different species, thus increasing biodiversity (Novotný et al. 2015), as has been seen for birds, plants and different arthropod groups (Fahrig et al. 2015).

Another strategy for increasing landscape heterogeneity is through promoting and maintaining hedgerow landscapes. Hedgerow networks are amalgamations of natural and anthropized habitats that connect diverse habitats to a greater extent than purely agricultural landscapes and are thus favourable to natural biodiversity (Boissinot et al. 2019). Hedgerows improve ecosystem services through pest control and pollination (Kremen 2020). Microhabitat quality is also dependent on the hedgerow structure and presence of herbaceous borders, which positively affect biodiversity (Graham et al. 2018). The hedgerow landscape is important for the biodiversity of several groups (Fig. 3a; insects, Chamberlain et al. 2000; rodents, de la Peña et al. 2003; birds, Cornulier et al. 2011; amphibians, Arntzen et al. 2017). Reptiles also occupy hedgerows, forest edges and other anthropic habitats such as stone walls (Martinez-Freiria et al. 2019). Such linear habitats offer multiple benefits, including microhabitats for thermoregulation and hydroregulation and the provision of shelter and food (Guillon et al. 2014). These linear habitats also facilitate dispersion and thus connectivity between populations and offer breeding sites (Arntzen et al. 2017).

Different vegetation types enhance diversity at a regional level (Michael et al. 2012). Plants impact amphibians by affecting abiotic factors such as resource quality and the nature and strength of interspecific interactions between amphibians and other species such as predators and their abundance (Burrow & Maerz 2022). Reptile diversity increases with greater native plant species in farmlands. Thus, hedgerow landscapes consisting of complex mosaics of pastures, ponds and hedges connected to forest patches could effectively reverse the loss of farmland herpetofauna in India (Fig. 3b).

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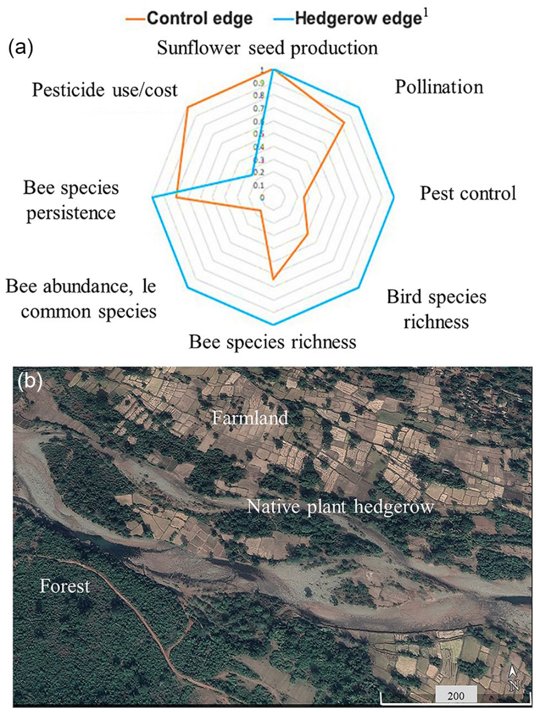

Figure 3. Examples of (a) hedgerows positively influencing crop yields while improving ecosystem services and biodiversity in farmlands (adapted from Kremen 2020) and (b) a landscape in India that shows connectivity with diverse landscapes such as forests and water bodies and the presence of linear strips of native plants in rice paddies as an indication of how farmlands can be redesigned (image created using Google Earth Pro, version 7.3.6.9796). [1]Kremen (2020).

The importance of hedgerows in India was tested between 1994 and 2001. North-east India is an excellent case that demonstrates the importance of hedgerows (Sundriyal 2003). Developing hedgerows incurred initial costs due to the procuring of the seeds of hedgerow species and the establishment and maintenance of hedgerows but provided consistent profits in the following years and increased major crop yields by 1.5–3.0% (Sundriyal 2003). The impact on crops has been seen to be more significant for vegetable and root crops. Hedgerows of Jum cultivation have also been reported to contribute significantly to reductions in nutrient runoff and soil erosion (Sundriyal 2003). Therefore, establishing hedgerows would require selecting species that are fast-growing, that require minimal inputs while producing high biomass and that contribute to ecosystem services including nitrogen fixation and preventing soil erosion. Low costs would be incurred to create and maintain hedgerow landscapes while also increasing profits.

The uptake of ecological intensification from science to practice is still rather limited. It is estimated that 29% of all farms worldwide have integrated some form of ecological intensification (Pretty 2018). Of the total land area in India, only 46% is available as cultivable land, with more than 250 cropping systems and cereal cultivation accounting for c. 75% of the cultivatable land (Hobbs & Gupta 2003). As per the Government of India (2015) report, the small and marginal landholding farmers, dominated by Scheduled Castes and Scheduled Tribes and accounting for c. 85% of the total agricultural landholders, cultivate over 72 million hectares of land and contribute 50–60% of India's total food requirement (Nath et al. 2018). Therefore, alongside improving food security and preventing natural resource depletion, in India ecological intensification needs to consider farmers' socio-economic status as well. Adoption of this approach would require awareness to be generated within the farming community and convincing of local non-governmental organizations to implement these technologies, which could prove to be an effective strategy (Sundriyal 2003).

Conclusion

Although there is a general consensus on the negative influences of agriculture on amphibians and reptiles (Trochet et al. 2016), farming practices are not necessarily in conflict with their conservation. Different species of herpetofauna show differential responses to the various components of agricultural landscapes. Though amphibians and squamate reptiles are known to utilize hedgerows, there is a significant lack of understanding of the role of hedgerow landscapes in maintaining the diversity of these taxa (Hansen et al. 2019), especially in India. Based on the ecological requirements of the herpetofauna species, relevant landscape conservation policies (e.g., promoting pond quality and density, patches of woodland and hedge networks) could be developed at the local and landscape scales. Based on the available evidence, hedgerows do offer a potential option for promoting the conservation of species and the ecosystem services they provide while also improving crop yields. This transition towards ecological intensification in India can be expected to result in increased food security through the use of natural resources (e.g., increased natural pest predators, pollinators, etc.), while also maintaining socio-economic balance (in the form of yields, market value and livelihoods; Kumari et al. 2019). Maintaining the status quo will mean the continued loss of these beneficial animals. In the face of the dual challenges of food security and environmental sustainability, ecological intensification stands out as a compelling solution for harmonizing human needs with ecosystem health.

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