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Effects of Land Use Change on Wildlife Communities and Ecological Interactions Across Human-Dominated Landscapes

Dr. Ankita Nihlani[1*], Dr. Nishtha Sharma[2], Dr. Komal Khatter[3]

[1]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.*
Email: ku.ankitanihlani@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0002-7447-8544
[2]Assistant Professor, Kalinga University, Naya Raipur, Chhattisgarh, India.
Email: ku.nishthasharma@kalingauniversity.ac.in, ORCID: https://orcid.org/0009-0006-4689-2712
[3]Associate Professor, New Delhi Institute of Management, New Delhi, India.
Email: komal.khatter@ndimdelhi.org, ORCID: https://orcid.org/0000-0001-6933-8745

Key Words

Land use change, Wildlife communities, Ecological interactions, Biodiversity loss, Human-Dominated landscapes, Species diversity, Food web dynamics, Habitat transformation, Community ecology, Ecosystem functioning.

Abstract

Land use change is the main cause of current biodiversity loss as natural habitat is transformed into agricultural, urban and other human land uses at unprecedented scales globally. Beyond its direct effect on reducing the number of species and their abundance, land use change transforms the interactions between species, the structure of food webs and trophic relationships which govern ecosystem functioning. This review compiles global evidence on how land use change influences the composition of communities and interactions between species in wild animal communities using large-scale biodiversity compilations, food web manipulations, and syntheses for specific taxa. In the most disturbed environments globally, there is substantial reduction in species richness and abundance locally compared to the undisturbed baseline levels. This effect of land use change is selective in nature, favouring disturbance-adapted generalists over many specialists. Apart from the reduction of biodiversity, land use change modifies the network of interactions among species in such a way that it alters food web structure despite minimal variation in species richness and pollinator activity, and vertebrates' community structure leading to higher numbers of species that can act as hosts to zoonotic pathogens. The removal of large bodied predators in human-altered landscapes leads to the alteration of trophic cascade effects throughout several food web levels. All these factors show that human-induced changes in land use modify not only the identity of the species but also their interactions in the human-affected landscapes.

* Corresponding Author's email: ku.ankitanihlani@kalingauniversity.ac.in
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Introduction

Over 75% of Earth's ice-free land surface has been modified through anthropogenic land use practices to turn forests, grasslands, wetlands, and other natural landscapes into agricultural and plantation land, pastures, and urban spaces. Where impacts on the diversity and abundance of organisms due to land use modification are already well understood, land use change can also impact the ecological interactions between the surviving organisms in terms of mutual interactions such as pollination and antagonistic interactions such as predation and parasitism, among other trophic interactions within ecological communities. Often ignored in surveys that look at species presence alone, the impact of changes in interaction levels can have a huge impact on the functioning of ecosystems, which is just as crucial as the diversity of species itself.

Community-Level Effects: Richness, Abundance, and Composition

Global Patterns of Biodiversity Loss

The first truly global evaluation of the impacts of land use on local biodiversity using data from a terrestrial assemblages database with unprecedented geographical and taxonomic coverage reported that in the most impacted habitats, human land use and its impacts cause reductions in sample species richness of 76.5%, in total abundance of 39.5%, and in rarefaction-based richness of 40.3% compared to natural baseline conditions (Newbold et al., 2015). On a global scale taking into account all levels of land use intensity, such pressures have resulted in reductions in average sample richness of 13.6% and in total abundance of 10.7%, with more substantial future losses expected under the projected business-as-usual scenario of land use changes (Newbold et al., 2015).

Biotic Homogenization

All species respond differently to changes in land use. The synthesis of research findings shows that human activities are non-random in their influence on biota in that most species become extinct due to human land use, while a relatively small number of tolerant species thrive in such modified ecosystems (McKinney & Lockwood, 1999). Since the winning species tend to be similar irrespective of the different biogeographic regions where these species occur, such a trend leads to the biotic homogenization phenomenon, which is characterized by greater similarity among the different organisms irrespective of their geographic locations. Biotic homogenization may lead to decreased diversity in regions even where the actual local species richness may not be greatly affected.

Shifts Favouring Zoonotic Reservoir Species

The transformation of land use also systematically modifies which vertebrate species are able to survive within human dominated landscapes in a way that carries important implications for human health. Global analysis of 6,801 assemblages of ecological species and 376 host species showed that those species of wildlife that were known to carry pathogens common to humans made up a significantly larger fraction of

species richness (18-72% higher) and abundance (21-144% higher) in human-use landscapes – like secondary, agricultural and urban areas – compared to undisturbed lands, most pronounced among rodents, bats, and passerine birds (Gibb et al., 2020). Such a pattern shows that those traits which allow certain species to co-exist with human dominated landscapes also coincide with being a zoonotic reservoir, and thus both homogenizing wildlife communities and increasing the local presence of potentially harmful species to humans.

Interaction-Level Effects: Food Webs and Mutualisms

Restructuring of Food-Web Architecture

Changes in land use have been shown to potentially restructure species interaction networks even when the number of species remains stable. A recent study involving the analysis of 48 host-parasitoid food webs of cavity-nesting bees, wasps, and their parasitoids in a tropical habitat manipulation gradient in Ecuador demonstrated dramatic changes in network structure along the gradient from rain forest to intensive agriculture despite no differences in species richness between the habitats studied (Tylianakis et al., 2007). In particular, network evenness has been reduced with habitat manipulation as the energy flows along one or a few dominant pathways only within intensively manipulated agricultural habitats and there is a significant increase in the ratio of parasitoids to hosts and the overall parasitism rate in the manipulated habitats (Tylianakis et al., 2007). The inability of conventional richness-based descriptions of community structure to reveal these changes indicates that changes in the structure of interactions is a functionally important but subtle effect of land use change that could be completely missed by another research.

Decline of Pollinator Communities and Pollination Function

Pollinator impacts associated with land use due to the fact that animals contribute towards pollinating almost 87% of the world's flowering plant species means that their impact on the pollinator community has repercussions that transcend far beyond the pollinators themselves. In the case of the impacts of land use change on the major groups of pollinators, namely, bees, butterflies, flies, birds, and bats, there was a predominance of negative impacts due to land use changes, although extremely variable in nature, depending on the taxa and study design, with landscape-level studies being more likely to find negative pollinator responses compared to comparative studies of specific land use categories (Winfree et al., 2011). The above-mentioned scientific findings clearly show that there is no uniformity in the pollinator decline in human-altered landscapes and that its detection and severity depend largely on the scale and context of the landscape studied.

Trophic Cascades and the Loss of Large Predators

The impact of changes in land use and the related human pressures has caused marked reductions in the population size and distribution of the world's largest terrestrial carnivores. The

Global Status and Strategy for the Conservation of the 31 Largest Carnivores, an assessment of the 31 largest mammalian carnivores, indicates that the vast majority of these animals have suffered major population declines as well as range losses over the last two hundred years, and more recent studies have found that large carnivores have marked top-down impacts on the ecosystem in which they occur, and many cascading trophic interactions emerge because of such impacts mediated either via the prey populations or via macropredators sympatric to the large carnivores, both in situations where the large carnivores have been extirpated from and when they have been reestablished in an ecosystem.

Discussion

Considering all the evidence together, land use change appears to be an influence factor which acts both at the level of community composition and at the level of ecosystem interactions, and neither of these can substitute for another measure of its impact. Global biodiversity richness and abundance reductions are indeed large and quite well documented, but the phenomenon of biotic homogenization which takes place at the same time indicates that richness alone is often insufficient to reflect the real ecological impact because it does not consider how specialized, disturbance sensitive and, in the case of vertebrates, more zoonotic the remaining species are McKinney & Lockwood (1999) and Gibb et al., (2020). Another evidence provided by food webs and pollination networks proves that land use change influences the ecosystem functioning even if species richness is not considerably reduced (Tylianakis et al., 2007; Winfree et al., 2011). Evidence relating to the role of apex predators provides yet another aspect of proof, inasmuch as a relatively small number of large animals may result in effects that propagate over several trophic levels, thereby proving once more that a mere tally of species does not give an adequate understanding of the ecological relevance of land-use-induced decline. Taken together, all the above-mentioned evidence points to the need to change our approach to monitoring the effects of land use in the direction of considering both interaction structure, functional trait composition, and trophic role in addition to biodiversity metrics, because these aspects seem to have at least equal weight.

Conclusion

Changes in land use affect wildlife communities in human-dominated landscapes via the drastic reduction in species diversity and abundance as well as the more indirect impact of changing the ecological interactions, food chains, mutualism of the pollinators, and top-down control exerted by apex predators. Each of biotic homogenization, modification in interaction networks, impairment in pollination services, and loss of top-down control is an independent mechanism of the effect of changes in land use on the ecology of the ecosystems. Any attempts to develop an effective conservation strategy or approach land use planning in human-dominated landscapes should take into account these mechanisms and their impact beyond mere species presence or absence.

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