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9. The Impact of Land-Use Changes on Species Diversity and Ecosystem Functioning in Agricultural Landscapes

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Abstract:

Changes in ecosystem services and land use have an impact on one another and on people's well-being. The research literature on the effects of LUC on various ecosystem services and the resulting implications for human well-being is reviewed in this paper.

The variety of species and ecosystem functioning in agricultural settings are significantly impacted by changes in land use. Natural habitats have been transformed into croplands, pastures, and constructed environments as a result of the quick development of agriculture, industry, and urbanization. Among the main effects of land use change are soil erosion, water pollution, and the loss of habitat and biodiversity.

One of the primary causes of biodiversity loss and ecological degradation in the world is land-use change. In many regions of the world, land-use change has been attributed mostly to agricultural intensification, expansion, and abandonment. Species diversity and ecosystem functioning in agricultural environments may be significantly impacted by these changes. The effects of land-use change on species diversity and ecosystem functioning in agricultural landscapes will be discussed in this article, with an emphasis on the variables influencing these effects and the possible mechanisms underlying them.

Keywords:

Land-Use Changes, Species Diversity, Ecosystem, Agricultural Landscapes, Human Wellbeing, Urbanization, Environments, Soil Degradation, Climate Change, Habitat, Pollinators, Sustainable

9.1 Introduction:

The necessity to feed a growing population and satisfy the needs of economic development has led to a widespread trend in recent decades: the conversion of natural environments into agricultural landscapes. Significant effects on biodiversity and ecosystem functioning have resulted from this tendency, which has caused ecosystem fragmentation and the loss of natural habitats. ecological services, disturbance of ecological processes, and species extinction can result from habitat and biodiversity loss.

Among the main effects of land use change are soil degradation and water pollution, which have an impact on the quality of water resources and the productivity of agricultural systems. Through a number of methods, species diversity and ecosystem functioning are impacted by changes in land use. The composition and structure of ecological communities can be impacted by the loss and fragmentation of habitat, which can result in a decrease in species richness and abundance. The provision of ecosystem services may be impacted by changes in the functional characteristics of species brought about by the conversion of natural habitats into pastures and croplands. By using pesticides, fertilizers, and other inputs, agricultural intensification can also alter ecosystem composition and function, resulting in decreased soil fertility and deteriorating water quality. [1]

Globally, more resources and effort have been devoted to biodiversity conservation; nonetheless, the majority of biodiversity metrics indicate that, despite mounting human pressures, biodiversity is still declining. The use of the land for agriculture and habitation is one of the most significant human-caused stresses on biodiversity. In comparison to globally virgin ecosystems, it has been calculated that land use has resulted in an average loss of 13.6% of species in biological assemblages.

The organization of biological assemblages has already been significantly impacted by climate change, which is becoming a more significant driver of biodiversity change.

According to model predictions, the anticipated future climate change will cause many species to lose a significant percentage of their range or possibly become extinct worldwide. However, if species that benefit from climate change expand widely and settle in new areas, it has been suggested that climate change may lead to an increase in the diversity of ecological populations. [2]

9.2 Impact of Land-Use Change on Species Diversity:

Numerous factors, such as the type of land-use change, its magnitude, and the surrounding landscape's characteristics, influence how species diversity is affected by land-use change in agricultural environments. Particularly when natural ecosystems are transformed into agricultural land, agricultural growth can have detrimental effects on species diversity. Native species may lose their habitat as a result, and populations may become isolated and the remaining habitat may become fractured. When the conversion is large-scale and agriculture dominates the surrounding landscape, these effects are very noticeable. For instance, a study of bird groups in the Brazilian Cerrado revealed that species richness and abundance were significantly reduced when natural grassland was converted to soybean agriculture. [3]

Species diversity may also be negatively impacted by agricultural intensification, especially when pesticides and other chemicals are used. Pollinators and soil organisms are examples of non-target species that these chemicals may directly harm. They may also cause these species to lose their food supplies. Additionally, intensification can result in agricultural landscapes being simpler, which lowers the richness and diversity of habitats. On the other hand, there are instances in which agricultural intensification can benefit species variety, especially when it incorporates the use of sustainable techniques like organic farming and agroforestry. Native animals can find shelter and habitat diversity thanks to these practices. [4]

Agricultural abandonment can affect species diversity in both beneficial and bad ways, depending on the features of the surrounding landscape and the abandoned area. When abandoned agricultural land is situated within a matrix of natural ecosystems, it can occasionally serve as vital habitat for native animals. Opportunities for ecological restoration and the regeneration of ecosystem functioning can also be found on abandoned property. But especially if it is surrounded by agricultural area, abandoned land can also decline and be overrun by non-native species. [5].

9.2.1 Techniques for Controlling Land Use Change to Improve Ecosystem Function and Species Diversity:

Addressing the economic, social, and environmental facets of sustainable development calls for a variety of approaches to managing land use change in order to improve species diversity and ecosystem functioning.

Promoting sustainable land use methods that increase soil fertility, lessen soil erosion, and enhance water quality is one strategy. This can involve actions like encouraging crop rotation, agroforestry, and integrated pest management. Preserving ecological corridors and natural habitats, which are crucial for preserving species diversity and ecological connectedness, is another tactic. Creating protected places, repairing damaged habitats, and encouraging green infrastructure are a few examples of such actions. In order to keep ecosystems operating in the face of growing environmental variability, a third tactic is to make ecosystems more resilient to climate change. This may entail actions like promoting the use of climate-smart farming methods and strengthening ecosystem-based adaptation. [6]

9.3 Review of Literature:

Since land use change (LUC) is a major driver of changes in both the natural environment and human activities, it needs to be precisely measured in order to assess the effects of these changes. LUC includes various changes to the earth's surface. Since the term encompasses changes that do not require later human usage of the land, LUC includes changes in land cover. According to Abd El-Kawy et al. (2011), LUC has a significant impact on (and is impacted by) global climate change and the ecosystem responses that follow in terms of sustainable development. Rapid LUC is occurring in the majority of emerging nations worldwide as a result of changing lifestyles brought on by increasing earnings and population increase. [7]

The way land-use governance is structured in each nation gives national, regional, and municipal authorities varying levels of authority and responsibility (Getzner and Kadi, 2020). For instance, land policy in Austria is structured within a federal policy system with nine federal states, leading to nine rules with varying or even conflicting objectives and strategies for housing policy, flood risk management, environment conservation, and spatial planning, among other areas. The spatial planning system in Austria also gives local governments a lot of authority over local development and zoning plans, whereas regional planning is "weak" or nonexistent in some situations. [8]

It is still unclear how future land-use and climate change will interact globally to influence the diversity of biological assemblages. Species distribution models, or models of the consequences of climate change, are based on point-occurrence data for species that are widely distributed around the world. These data are frequently resolved too coarsely to allow for a precise match with land-use data. Therefore, expert-drawn maps indicating the range of occurrence and distribution of those species have been a common component of global research of the effects of climate change on species. These forecasts have rarely taken land use into account and have instead relied on expert ratings of each species' preferred habitat, which are only accessible for a small percentage of species worldwide and categorize habitat as either suitable or unsuitable at best. The sensitivity of biodiversity to various land-use types was not taken into account in other research that modeled the effects of climate change; instead, they merely overlaid predictions of land-use change. (Hof C, 2011) [9] Because of the decreased impact of raindrops and the stable biogenic structures formed by edaphic fauna, agroecosystems that preserve surface leftovers and healthy soil macrofauna communities (such as agroforestry) contribute to improved soil aggregation in contrast to more intensive farming techniques. These biological soil aggregates are more resistant to deterioration and facilitate a variety of ES, including nutrient retention, infiltration, and soil carbon storage. The impacts of land use conversion on plants and soil macrofauna, as well as the implications for various soil processes, are still poorly understood, despite the fact that forests are known to be important for maintaining soil structure and conserving soil biodiversity (Brussaard, 2012). This is particularly true for aboveground–belowground biological interactions that affect hydrological regulation and related ecological functions. [10]

9.4 Objectives:

- Land-use changes generally led to a decline in ecosystem services (ES).
- Identify the mechanisms that drive changes in biodiversity and ecosystem services in response to land use change.
- Analyze the policy implications of land use change for sustainable development.

9.5 Research Methodology:

In this study, we examine a number of future agricultural growth scenarios in India and evaluate possible trade-offs between biodiversity (SDG 15), climate mitigation (SDG 13), and food production to alleviate famine (SDG 2). We modify and use an integrated modeling framework for our investigation, which blends various spatially explicit models with an economic model. We have selected 2030 as the time framework for the scenarios since it is the year that the UN Agenda identifies as a target year to achieve significant progress toward the SDGs. The applicable models and the scenario assumptions are explained in the section that follows. A section outlining the outcomes of our simulation and a discussion of our key conclusions follow this.

9.6 Result and Discussion:

9.6.1 Modeling Framework:

The modeling framework (Figure 9.1) consists of two empirical models for the analysis of the effects of land use change on biodiversity and carbon stock changes in soils and vegetation, the spatially explicit land use model Land SHIFT, and the International Model for Policy Analysis of Agricultural Commodities and Trade. Southeast Asia and East Africa have previously seen the effective implementation and application of this kind of IMPACT-Land SHIFT model coupling for different scenario studies. Data from exogenous climate and socioeconomic scenarios powers both models. [11]

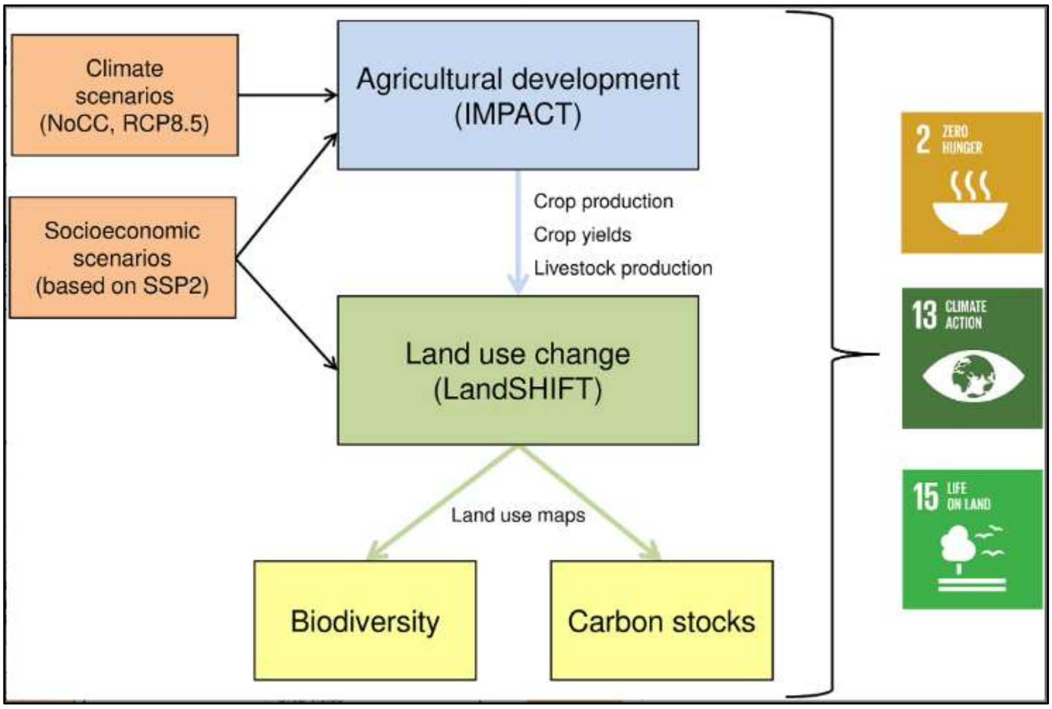

Figure 9.1: Modeling framework used for the scenario analysis.
(Source: https://agupubs.onlinelibrary.wiley.com/)

The IMPACT model is used to forecast how India's shifting socioeconomic and climatic conditions would affect crop yields and agricultural productivity. An economic equilibrium model called IMPACT makes predictions for international agricultural markets and trade. It takes into consideration shifts in net trade as well as the supply and demand of agricultural products in India and other countries.

9.6.2 Biodiversity, Land Use Change, And Climate Change:

All human activity takes place on land, which is also the source of the resources required for this activity.

The "land use" that results from human use of land resources varies depending on the biophysical properties of the land itself as well as the uses it serves, such as food production, shelter supply, recreation, material extraction and processing, and so on. As a result, human demands and environmental characteristics and processes are the two main drivers influencing land usage. Change is the core of life, therefore neither of these forces is stationary; rather, they are always changing.

A given area's natural vegetative cover types are referred to as its "land cover." Although human activity can also change them, these typically reflect the local climate and topography. Examples of broad land cover categories are desert, steppe, savannah, forest, and tundra. These can be further subdivided into more specific groups that represent particular plant communities, such as mangroves, oak-pine scrublands, seasonally flooded grassland, etc.

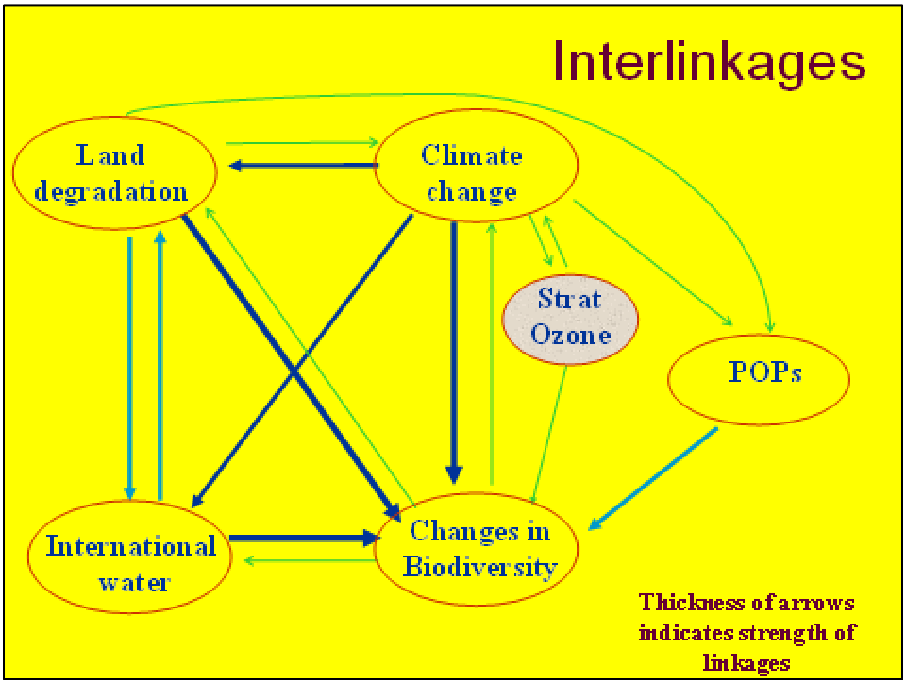

Figure 9.2: Interlinking of land use changes with soil, biodiversity and climate
(Source: https://grimstad.uia.no/)

More and more people are realizing that humans are the primary cause of environmental change on a worldwide scale. Among all the environmental effects caused by humans, changes in land use are probably the oldest. Land-cover change, particularly the conversion of forest lands into other uses, has been found to be a major contributor to the loss of biological diversity and to be responsible for 33% of the rise in atmospheric CO2 since 1850. [12]

9.6.3 Drivers of Land Use Change:

There are two main categories of land use change drivers: direct and indirect drivers.

Demographic, economic, social, scientific, technical, cultural, and religious variables are the primary indirect human drivers (underlying causes).

Changes in local land use and land cover (the global increase in lands used for agriculture and grazing has historically been the major change in land use); species introductions or removals; external inputs (such as fertilizers and pesticides); harvesting; air and water pollution; and climate change are the main direct human drivers (proximate causes or pressures).

Environmental circumstances, local culture, and economy are some of the factors that affect human activity. Soil quality, biodiversity, climate, and LUC are all directly correlated (Figure 9.3). Climate change, biodiversity decline, and a loss of ecosystem functioning are all consequences of land-use changes.

The global carbon cycle depends heavily on soil organic carbon (SOC), and SOC varies significantly with LUC. With the conversion of natural forests into plantations or other LUC, SOC sharply declines. Native biodiversity may be directly or indirectly impacted by changes in land use. Diversity of species is a key factor in ecosystem sustainability since it indicates soil fertility and ecological stability. More species were lost when land use changed to a monoculture cropping system as opposed to a mixed cropping system (Reidsma et al. 2006). Native biodiversity would suffer if broad-acre agriculture replaced grazing as the primary practice. Grazing reduces most soil nutrients through grazing and subsequent erosion because of reduced ground cover, but it enhances the bulk density and moisture content by compaction and sun exposure. Native vegetation is removed as a result of land disturbance, especially from grazing, mining, and urbanization, and disturbed soil typically encourages invasive alien species.

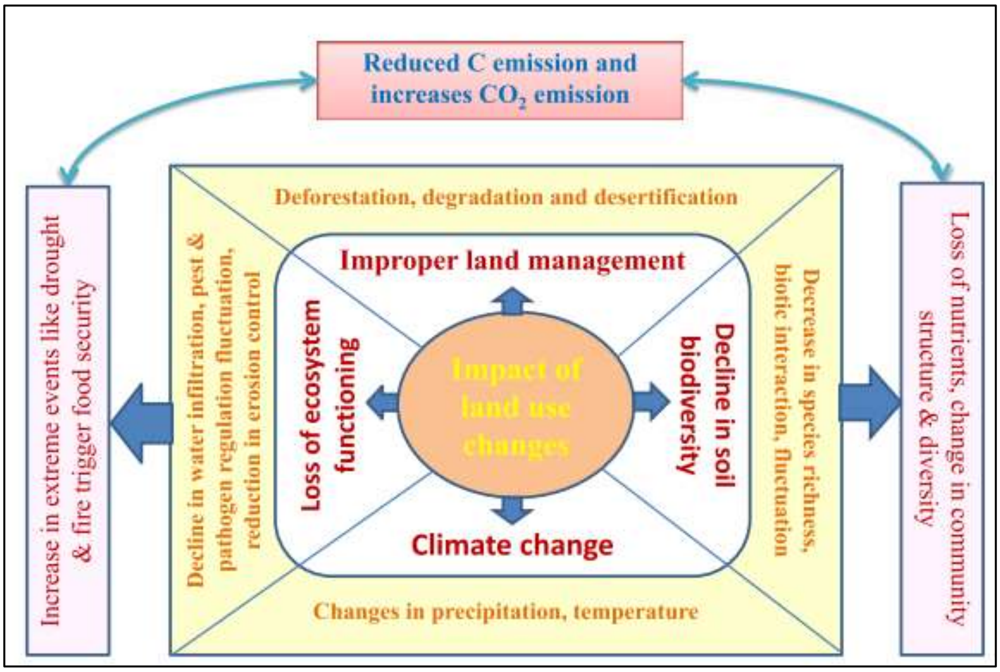

Figure 9.3: Impact of Land Use Changes. [13]

Agricultural landscapes have been intensified and expanded for food production and biofuels, changing many ecosystems on Earth. The conversion of rainforest to monoculture cash crops, like oil palm and rubber, is a serious threat to biodiversity in tropical countries, which are home to extraordinarily high levels of biodiversity. For a long time, research in temperate and tropical regions has concentrated on the direct effects of land-use change on one or two trophic groups (for instance, plants, butterflies, or birds). However, this strategy has limitations because it frequently produces results that are very variable or contradictory depending on the model taxon. In addition, these studies usually don't take into account potential biotic interactions that could cause cascade effects through top-down or bottom-up forces. The quantification of land-use impacts on multi-trophic systems10 has gained more attention in recent years, though, as it has become clear that biotic interactions are essential to the provisioning of ecosystem functioning and that ignoring these interactions could result in biased conclusions about the magnitude of land-use consequences. Nevertheless, study has mostly remained limited to a small number of trophic levels, ignoring cascade effects across numerous higher-level taxa over multiple trophic levels. The way that land-use impacts affect taxa across many trophic levels, both directly (Figure 9.4a) and indirectly (Figure 9.4b) through trophic cascades, is therefore still unclear.

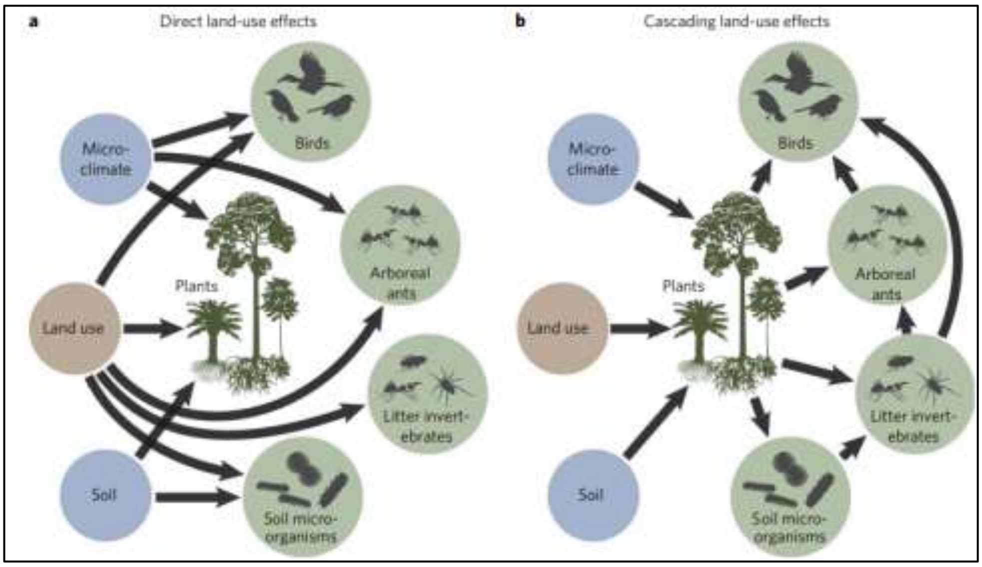

Figure 9.4: How land-use change may directly and indirectly alter whole ecosystems.

a. According to the direct land-use effects theory, changes in land use have an immediate influence on all trophic levels and taxonomic groups.
b. According to the cascading land-use effects theory, all effects of changes in land-use at higher trophic levels spread through a series of bottom-up cascades.

9.7 Conclusion:

In agricultural landscapes, land-use change is a key factor contributing to ecosystem degradation and biodiversity loss. Depending on the kind of land-use change, its magnitude, and the features of the surrounding environment, agricultural expansion, intensification, and abandonment can all have a substantial effect on species diversity and ecosystem functioning. A variety of underlying factors, including as habitat loss and fragmentation, chemical contamination, and the simplification of agricultural landscapes, influence how land-use change affects species diversity and ecosystem functioning. One of the main causes of species extinction and ecosystem deterioration in agricultural environments is land use change. Ecosystem functioning and species distribution and abundance are significantly impacted when natural habitats are turned into agricultural land. The expansion of exotic species, increased water pollution, and decreased soil fertility are just a few of the detrimental effects that may result from this. Although biodiversity and ecosystem functioning are seriously threatened by land use change, there is also room for improvements. Agroforestry, conservation agriculture, and integrated pest management are examples of sustainable land use techniques that can support rural livelihoods and food security while enhancing ecosystem functioning and promoting biodiversity conservation.

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