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IMPACT OF TEMPORAL CHANGES IN LAND USE AND LAND COVER ON SOIL ORGANIC CARBON AND BIODIVERSITY IN WILDLIFE CORRIDORS: A REVIEW FROM CENTRAL INDIA

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ABSTRACT:

This review critically examines the impact of temporal changes in land use and land cover (LULC) on soil organic carbon (SOC) stocks and biodiversity within wildlife corridors of Central India, with a focus on the Satpura-Maikal landscape. Rapid LULC changes—driven by agricultural expansion, coal mining, and urbanization—have resulted in significant forest loss, habitat fragmentation, and increased prevalence of degraded lands. These changes have led to a marked decline in SOC pools, particularly in surface soils, and a reduction in microbial activity, which together compromise soil fertility, carbon sequestration, and ecosystem resilience. Simultaneously, biodiversity has suffered due to habitat fragmentation, with negative effects on species richness, genetic connectivity, and ecosystem functionality. The review synthesizes findings from over 200 peer-reviewed studies and reports, highlighting the urgent need for integrated conservation strategies, restoration of degraded corridors, sustainable land management, and community engagement. Effective landscape-level planning and policy interventions are essential to mitigate the adverse impacts of LULC change on SOC and biodiversity, ensuring long-term ecological stability and climate resilience in Central India's wildlife corridors.

Keywords:- Land Use Land Cover Change, Soil Organic Carbon, Biodiversity, Wildlife Corridors, Central India.

INTRODUCTION:

The complexity of the land use and land cover processes, soil organic carbon stock and biodiversity of the wildlife corridors is an area of importance in the research especially in highly dynamic landscapes such as the tempera ones in central India. Wildlife corridors are important to sustain ecological functions because they connect fragmented sceneries, promote migration of species, and also support gene flow among isolated species. (Beier & Noss, 1998).

These corridors are located in central Indian landscape and are part of the bigger Satpura-Maikal landscape, which is one of the internationally recognized tiger conservation landscapes in India. These woody lands host a wide variety of taxa: apex predator species, including tigers and leopards; herbivores, such as deer and gaur; as well as a great number of species of flora and micro-organisms (Banerjee et al., 2020).

Nevertheless, the anthropogenic activities are threatening the ecological stability of these corridors, causing the degradation and loss of biodiversity (Mallegowda et al., 2015). These areas have experienced a lot of habitat loss and fragmentation due to agricultural growth, coal mining, urbanization and development of infrastructures. The works in the field of remote sensing have reported a catastrophic loss of dense forest cover and a simultaneous rise in the amount of degraded lands and scrub vegetation, which

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explains the acuity of conservation efforts (Banerjee et al., 2020).

The soil Organic Carbon (SOC) plays a pivotal role in the terrestrial ecosystem and determines the soil fertility, water retention, and carbon sequestration. Forest soils are also a good source of SOC, which has significant global carbon cycles and mitigation of climate change. The alteration of land use, particularly the transformation of forests into agricultural land and barren soil, causes a great loss of SOC, which in turn produces carbon dioxide into the atmosphere, which increases climate change (Padbhushan et al., 2022). Also, SOC loss has a direct effect on the biological activity of soil, changes microbial communities and nutrient cycling processes, which maintain plant productivity and ecosystem resilience.

At the same time, the biodiversity, including the aboveground and belowground, is inherently connected with the land cover types. Besides lowering species richness and abundance, forest fragmentation and habitat conversion cause changes in species composition as well as ecological interaction. The loss of keystone species and the simplifications of trophic structures may have extended consequences on the operation of the ecosystem, such as pollination and seed dispersal and pest control (Srivastava et al., 2020). Although research has reported negative effects of LULC changes on SOC and biodiversity in the world (Guo and Gifford, 2002; Lambin and Geist, 2006), there are few integrative studies on Indian wildlife corridors. The majority of the researches focus on the processes of soil carbon or biodiversity change separately without considering interdependent reactions to the landscape changes. The purpose of this review is thus to find a synthesis of scientific literature available to evaluate the impact of LULC alterations within the Central Indian wildlife corridors on the SOC dynamics and biodiversity patterns. The synthesis is going to offer important insights to landscape-scale conservation planning and mitigation of climate change strategies.

METHODOLOGY

The given literature review has utilized a scientific literature to gather, assess and integrate scientific research on land use land cover (LULC) change, soil organic carbon (SOC) dynamics, and biodiversity patterns in wildlife corridors, specifically the Central Indian landscape. The review procedure was done according to the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) guidelines to the environmental sciences.

Peer-reviewed databases such as Web of science, Scopus, ScienceDirect, JSTOR and Google Scholar were thoroughly searched and supported by official reports by the Indian government about the forest cover in the country, including the Forest Survey of India, the Ministry of Environment, Forest and Climate Change and non-governmental environmental organizations. The search was done in literature dating back to 1990 to 2025. The search strategy involved the use of key words and Boolean operators that included: wildlife corridors, land use change, LULC dynamics, soil organic carbon, biodiversity loss, habitat fragmentation, Central India and carbon sequestration.

Inclusion criteria were based on studies that emphasized Central Indian region, though studies that had relevant insights about the world would have been addressed. Especially stressed were meta-analyses, remote sensing-based LULC measures, as well as a field-based biodiversity and SOC. They were extracted in terms of the extent and pattern of SOC changes among the land use categories, biodiversity reaction to habitat fragmentation and land cover change drivers.

Overall, more than 550 original publications were filtered on the relevance and methodological rigor. A curated dataset of 213 scientific articles was used to conduct this synthesis after eliminating the studies that did not meet the exclusion criteria (e.g., studies that did not include primary data or

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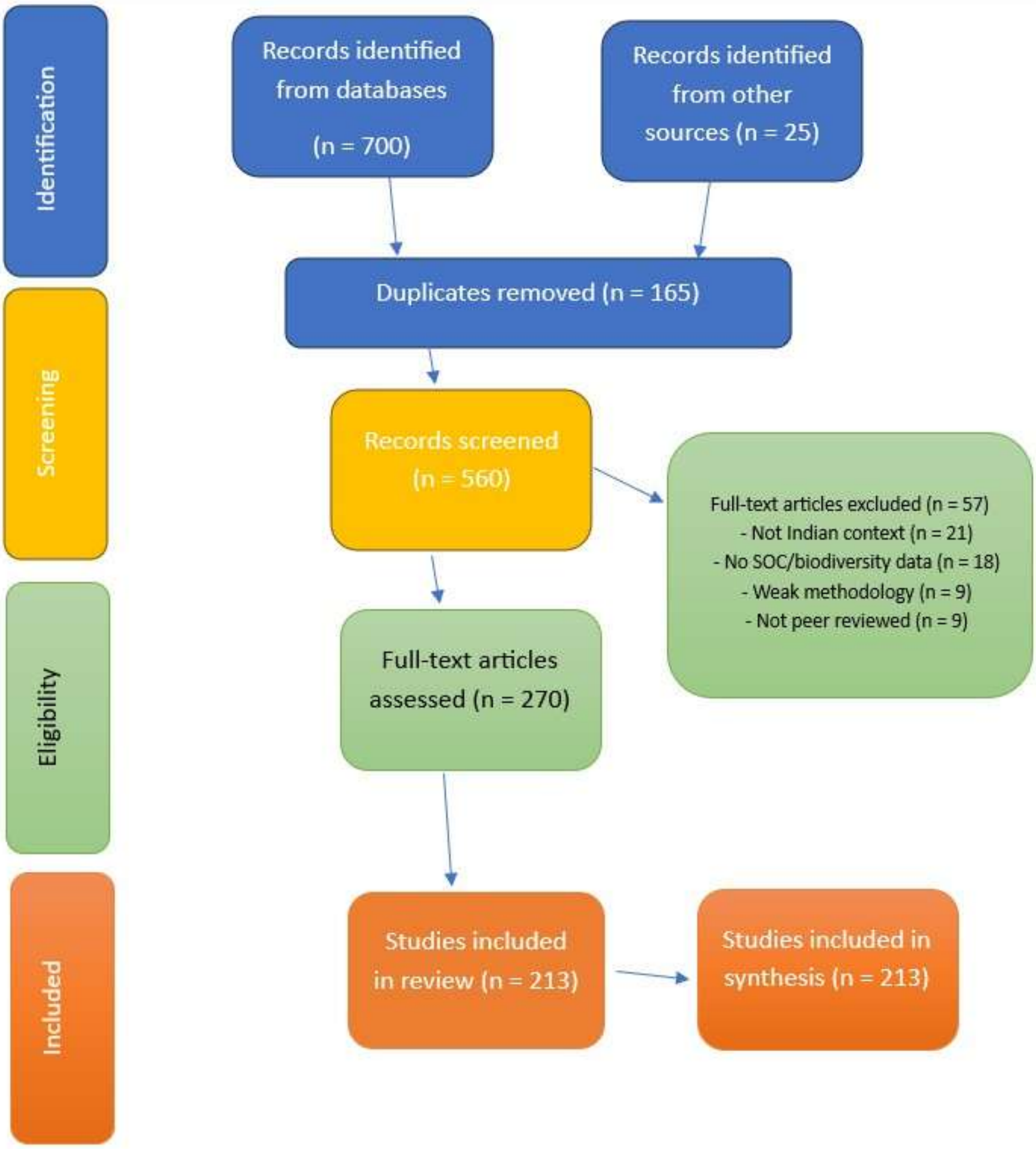
peer-review validation). Temporal changes of SOC pools and biodiversity patterns of different land use systems were compared through methods of comparative analysis using quantitative datasets where feasible.



Global and Regional LULC Change Trends

3.1 Global Trends

One of the most powerful forces of ecosystem degradation and biodiversity loss are land use and land cover (LULC) changes which take place globally. The conversion of natural ecosystems especially in the tropical and subtropical forests in a wide-scale conversion into agricultural lands, plantations and new cities and towns has changed the ecological processes significantly (Lambin and Geist, 2006). There was a loss of about 178 million

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hectares of global forest cover between 1990 and 2020, with most of the losses being sustained in the tropical areas of South America, Africa and southeast Asia (FAO, 2020). The cutting of oil palms and soy in Southeast Asia and Amazon, logging, and building infrastructure has broken up landscapes, separated animal species, and emitted large amounts of soil organic carbon (Ahrends et al., 2015).

The economic growth and the growing population has led to urbanization, which in turn, has turned forests and agricultural lands into impervious surfaces that lower soil permeability, change the hydrological cycles. Large-scale habitat degradation and soil contamination has been caused by industrial scale mining especially in Africa and South America. Also, land cover changes caused by climate, including desertification and frequency of wildfires, have worsened LULC transformations (IPCC, 2021).

Encroachment and habitat fragmentation is also being experienced in the conservation corridors and the protected areas all over the world. The examples of the Miombo woodlands in Africa, the Mesoamerican Biological Corridor, and in the eastern ranges of Australia have all shown that even the areas, which are supposed to be a part of the conservation system, are under pressure because of the illegal agricultural practices, cattle grazing, and the construction of infrastructures (Beier and Noss, 1998).

3.2 Central Indian Landscape

The Central Indian landscape that covers the states of Madhya Pradesh, Maharashtra and Chhattisgarh states is one of the most important biodiversity repositories and tiger habitats of India. This area is the main part of the Satpura-Maikal landscape, which joins the most important tiger reserves like Pench, Satpuda, Kanha and Melghat. The tiger dispersal and genetic interaction between fragmented forests take place through wildlife corridors in this region. Nevertheless, the ecological connectivity of the area is under threat due to the rapid transformations in LULC (Banerjee et al., 2020).

According to the studies on remote sensing by Banerjee et al. (2020), in the operational wildlife corridor Pench-Satpuda, the alterations in the 17 years (200219) are drastic. The natural forests with dense forest cover, which was composed of high-canopy forests, reduced by 54.9 percent, which indicated high levels of degradation and deforestation. The increase in open forests was only 15.8 per cent, which was mainly caused by the conversion of the dense forests into the secondary growth. The scrublands which included invasive species and degraded lands increased by an astonishing 150.9 percent, which showed extensive forest cover and secondary succession.

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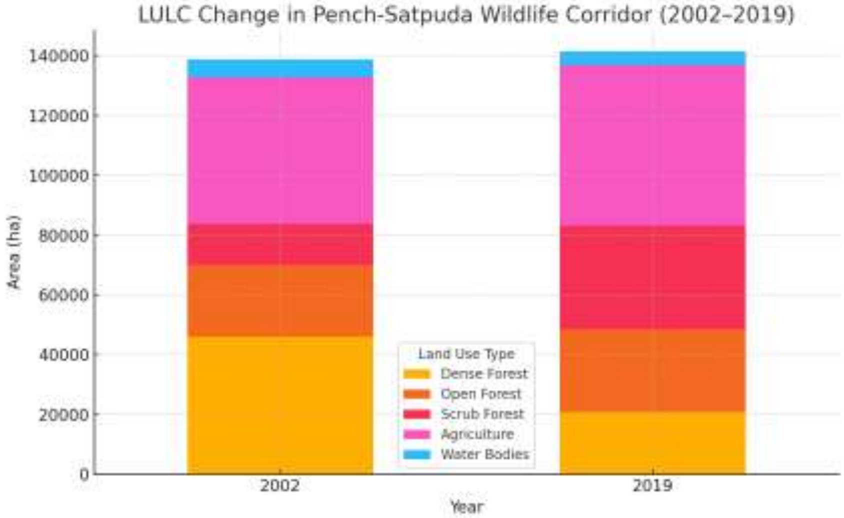

Figure 2: LULC Change in Pench-Satpuda Wildlife Corridor (Banerjee et al. (2020)

There was an expansion on agricultural encroachment by a rate of 10.1 which showed the growing food production and subsistence farming by the local people. The paper also noted the fact that there was a 25.4% decline in water bodies, which shows disrupting hydrological regimes that are associated with loss of forest cover and land degradation. These trends are worsened by the proliferation of coal mining especially the open-cast mines in Chhindwara and Betul districts. The corridor is overlaid with large size deposits of coal, and this is a direct threat of forest diversion to extract minerals.

These findings of remote sensing are supported by field studies. The data given by camera traps show that the tigers have been reduced to very little movement across patched areas, and leopards are more flexible, still traversing such areas (Joshi et al., 2013). There has been an increase in human-wildlife conflict due to crop raiding and livestock depredation in places where the forest cover has been cleared by agriculture as well as scrubland.

Besides, the growth of settlements, development of roads and railroads, and unrestricted tourist activities disrupt habitats and heighten anthropogenic demands. Forest resources are extremely important to villages in and near the corridor in terms of fuelwood, grazing, and non-timber forest products (NTFPs), resulting in unsustainable extraction and habitat destruction (Srivastava and Tyagi, 2016).

Although such corridors are important in preserving the tigers and protecting climate change, they are not officially recognized by the Indian land management policies. Demarcation and protective status are lacking and this exposes them to competing land use priorities.

Relative to other global wildlife corridors, Central Indian wildlife corridors reflect the global trend in which anthropogenic forces have broken and destroyed important landscapes, and Central Indian wildlife corridors also point to region-specific forces like coal mines and high populations. The ecological functionality of these corridors is doomed to irreversible downfall unless there is a sense of urgency to conserve it and develop it in terms of landscape level planning.

4. Response SOC Dynamics to LULC Change.

Soil Organic Carbon (SOC) is an essential part of the terrestrial carbon pool and a crucial factor in soil productivity, water retention and fertility of the soil. Changes in land use and land cover (LULC) are paramount to SOC dynamics because the vegetation type, litter inputs, root biomass, and

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land management practices have a direct effect on the carbon storage and turnover in soils (Ngatia et al., 2021).

4.1 Stock Decline with LULC Change in SOC.

The regions with the largest SOC stocks are forests which have dense vegetation cover with limited soil disturbance. Nevertheless, in cases of clearing forests to grow agricultural products, plantations, or towns, SOC stocks reduce significantly. Indian meta-analyses by Padbhushan et al. (2022) found that forest-to-cultivation conversions cause 31.1 percent decrease in the stocks of SOC and forest-to-grassland conversions cause a decline of 36.1 percent. Convincing to barren lands recorded maximum loss of SOC as a result of total clearing of vegetation cover and laying bare the soils to erosion and oxidation.

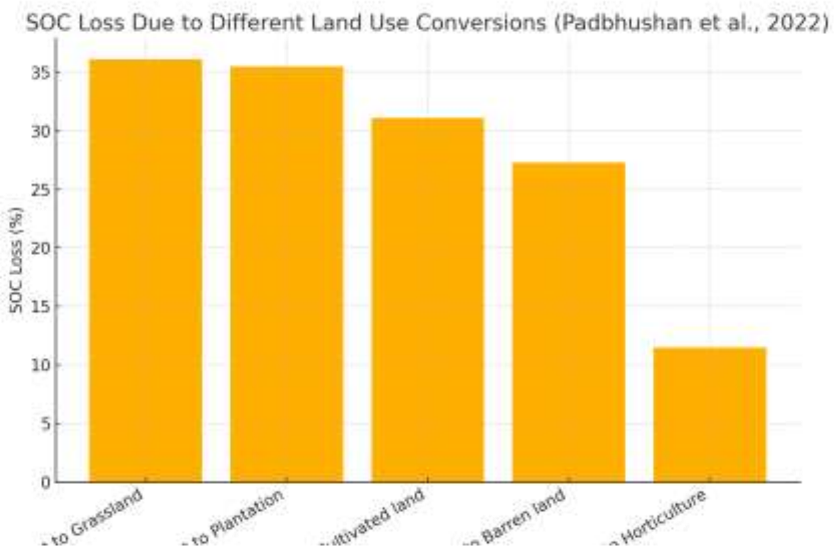

Figure 3: Loss of SOC as a result of various land use conversions (Padmbhushan et al., 2022)

The most severe depletion occurs in the surface layer of soil (015 cm) where most of the organic carbon is located after LULC change. SOC loss is enhanced by mechanical tilling of agricultural soils and extraction of crop residues and the decrease in litter inputs. Conversely, agroforestry systems and plantations, in a sustainable management system, have partial SOC stocks restoration, and they can store carbon at a landscape scale (Ngatia et al., 2021).

The effect on the microbial biomass of the soil and nutrient cycling.

Microbial biomass is intricately associated with SOC that causes decomposition and nutrient cycling. Padbhushan et al. (2022) found that the forest soils had higher carbon (MBC) and microbial quotient (MQ) in their microbial biomass than the cultivated, barren and scrubland soils. Reduced microbial activity reduces nutrient supply, soil aggregation and suppression of disease resulting in additional soil erosion.

The potential of carbon sequestration and restoration under fermentation conditions is 4.3.

In spite of these losses, there are LULC transitions like reforestation, adoption of agroforestry and conservation tillage which have shown potential of restoring SOC. A recovery rate of up to 48% in sustainable managed plantations in terms of SOC was reported by Padbhushan et al. (2022). The rebuilding of soil carbon pools is also achieved through grassland restoration, organic amendments and little tillage.

5. Biodiversity as a Response to LULC Change.

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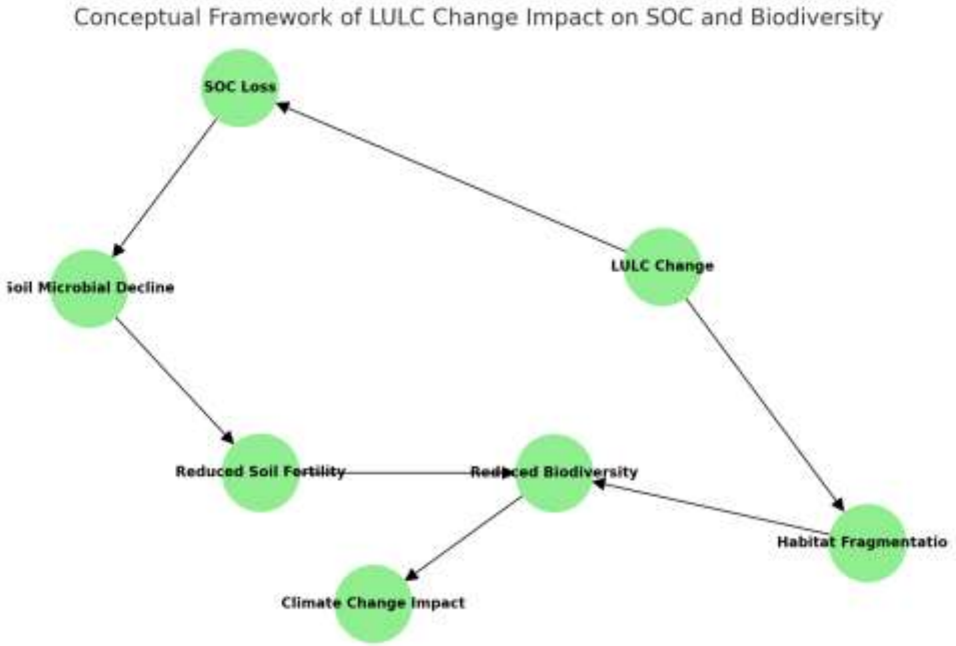
Land use and land cover (LULC) transformations are hence critical in the dynamic of biosphere especially in fragmented wildlife corridors where species require the continuity of their habitats to survive and reproduce. The ecological effects of fragmentation and habitat transformation have cascades of negative ecological effects, including disturbance of species assemblages, genetic diversity loss, and impaired ecosystem services (Beier and Noss, 1998; Srivastava et al., 2020).



5.1 Habitat Fragmentation and Species Movement Restrictions

Deforestation, agricultural activities, and mining negatively affect the movement of wide-ranging species including tigers, leopards, and elephants through habitat fragmentation. The tracking and connection of landscapes and camera trapping in the Pench-Satpuda corridor by Banerjee et al. (2020) exposed that the movement of tigers has been strongly limited, with incidental data of crossover in fragmented areas. By contrast, the habitat generalists such as leopards still use degraded landscapes but are at risk due to the rise in human-wildlife conflict (Joshi et al., 2013).

The existence of fragmented habitats secludes the wildlife populations, which is a risk to the genetic bottlenecks and local extinctions. The metapopulation dynamics theory is that the isolated patches are at greater risk of extinction because of decreased gene flow and demographic stochasticity (Hanski, 1998). Corridors are dispersal channels, and this increases the viability of populations of scales.

5.2 Effects of the Plant Diversity and Composition.

LULC change modifies plant community structure by giving an advantage to the opportunistic and invasive species over the native plants. According to Srivastava et al. (2020), degraded forest patches of the Vindhyan dry tropical area experienced a significant reduction in native species richness and functional diversity. Agricultural conversion and scrublands makes the vegetation communities simpler and decreases the heterogeneity of the habitat and food supply to herbivores and pollinators.

Secondary succession, in future agricultural lands and poor scrublands, might encourage partial recovery of the vegetation, however, they are usually overwhelmed by invasive species like Lantana camara and Parthenium hysterophorus

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that prevent the regeneration of native species (Dogra et al., 2010).

The impacts on Soil Biodiversity and Microbial Communities 5.3.

LULC changes are sensitive to soil biodiversity, especially the microbial biomass, earthworms, and arthropods due to a change in SOC stocks and in the microhabitat conditions. Padbhushan et al. (2022) reported that cultivated and barren lands had significant decreases in microbial quotient (MQ) and carbon in the microbial biomass than soils in forests. This reduction in the microbes worsens nutrient cycling, decomposition, and maintenance of soil structure, with ripple effects on the interaction between plants, soil, and fauna (Ngatia et al., 2021).

The earthworms which are one of the most important soil health indicators are found to be less in abundance and diversity in monoculture agricultural systems than in forest and agroforestry systems (Lavelle et al., 2006).

5.4 Biodiversity Decrease and Human-Wildlife Conflict.

The change in LULC enhances edge effects and interfaces between human settlements and wildlife habitats and enhances human-wildlife conflict. The Pench-Satpuda corridor has also been experiencing increased cases of crop-raiding, livestock destruction, and human injuries as a result of wildlife, which is evidence of the strain caused on the fragmented populations(Banerjee et al., 2020**)**.

6. Ecosystem Interactions and Climates.

Land use and land cover (LULC) change in the wildlife corridors has far-reaching impacts on the ecological processes and climate control. In their application in the carbon storage, water regulation, and habitat connectivity, wildlife corridors, when preserved, are known to stabilize the ecosystems. Nonetheless, with their fragmentation associated with deforestation, agriculture, and mining, these corridors lose their ecological processes significantly (Ngatia et al., 2021). Ecosystem stability and resilience is undermined by the loss of biodiversity. The presence of functional groups like pollinators, seed dispersers, and decomposers reduces with simplification of the habitat, which affects the ecosystem functions (Hooper et al., 2005). Less predator prey interactions disturb the trophic interactions, which further disrupt ecological integrity.

The depletion of soil organic carbon (SOC) means that soil will not retain moisture, support vegetation, and capture carbon dioxide in the atmosphere. This reduces the fertility and resilience of the soil to erosion and loss of nutrients. The loss of biodiversity also contributes to this condition because functional groups, including decomposers, pollinators, and seed dispersers, decrease, and the nutrient cycle and vegetation regeneration is disturbed (Srivastava et al., 2020).

This interaction between the SOC loss and biodiversity decrease caused by LULC is synergistic and does not contribute to resilience in these ecosystems to changes in climate variability. Poor forest cover and SOC stocks reduce the capacity of the landscape carbon sequestration and lead to a higher concentration of carbon in the atmosphere and global warming (Padbhushan et al., 2022).

7. Future Research Needs

Although significant progress has been made in remote sensing and ecological monitoring, there are still a number of gaps in essential knowledge in understanding long-term effects of LULC changes on soil organic carbon (SOC) and biodiversity in wildlife corridors. The future study must focus on long-term, landscape scale observation of SOC processes in different land use landforms and soils depth, more so in discontinuous corridors. Seasonal and interannual variations should be included in such studies in order to model the potential of carbon sequestration under the various restoration situations.

In the same manner, biodiversity measurements in wildlife corridors cannot be limited on the

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charismatic megafauna but to understudied organisms like soil microbes, arthropods and understorey vegetation. It is also important to understand how these groups of people play functional roles in maintaining the ecosystem processes, to have a holistic conservation planning. Further research needs to use the more sophisticated spatial modeling and scenario analysis to anticipate the results of other land management practices and policy interventions to SOC stocks and habitat connectivity. By including socioeconomic factors that cause land use change, such as, community reliance on forest resources and mining economics, the conservation recommendations would become more relevant.

Finally, adaptive management systems and experiments on restoration ecology will be important in degraded corridors to formulate evidence-based approaches to recover ecological functionality and prevent the effects of climate change.

8. Management Implications

Unsustainable land use and land cover (LULC) change are also major challenges to the conservation of biodiversity and sustainability of the ecosystems in the form of degradation of wildlife corridors. To manage these landscapes well, integrated approaches to restoring them, legal frameworks and active involvement of the communities are essential to reduce the ecological degradation and rehabilitate nature to provide the ecosystem services.

8.1 Restoration Strategies

The process of restoring deteriorated wildlife corridors should focus on the natural regeneration process, which is supplemented by assisted natural regeneration (ANR) and silvicultural interventions. ANR is the conservation of the available vegetation and propagation of native species through limiting human interference. Reforestation and gap planting with native plants can be used in severely degraded areas to restore canopy cover, increase soil organic carbon (SOC) stocks and increase the quality of habitats.

Agroforestry systems that combine trees with crops or animals are an example of sustainable land-use options with livelihood benefits but lack biodiversity conservation value and even have a positive impact on soil health (Ngatia et al., 2021). Controlled grazing and the management of invasive species in grasslands can enhance the soil cover and population growth of the herbivores that help to limit the wildlife intrusion into the farmlands.

8.2 Policy Recommendations

The boundary demarcation and zoning rules should be developed as part of the legal status of wildlife corridors to limit inappropriate land use like mining and intensive agriculture (Srivastava and Tyagi, 2016). District level spatial plans should also include conservation compatible land use planning in order to guarantee the landscape connectivity and ecological operations.

Open-cast mining especially mining of coal should be curtailed in areas that are of critical wildlife. Sustainable land management can be used to provide incentives to the local livelihoods to support conservation objectives, such as payments through ecosystem services (PES) and community-based forest management initiatives.

8.3 Community Engagement

The ecotourism, NTFP value chains, and organic farming are sustainable livelihood interventions that can decrease the local reliance on forest resources. Corridor stewardship participates in planning land use and joint management of forests (JFM).

Conservation-minded attitudes and mitigating human-wildlife conflicts can be developed through education and sensitization of people, especially the youth and women self-help groups (SHGs). Wildlife monitoring and early warning mechanism can be facilitated by setting up local monitoring groups.

The management of eco-tourism in these important wildlife corridors needs to be integrated, and

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managed on a landscape scale to balance conservation and development demands.

9. Conclusion

The current review is a synthesis of the major and intertwined effects of land use and land cover (LULC) alterations on the soil organic carbon (SOC) processes and biodiversity in the wildlife corridors, especially regarding the Central Indian landscape. The Pench-Satpuda and Pench-Nagzira wildlife corridors are the best examples of how the anthropogenic forces of agricultural growth, coal mining, and uncontrolled developmental activities fragment the habitats, degrade the soil resources and interfere with the natural ecological processes. The results highlight that the LULC change is a major cause of habitat fragmentation and SOC depletion, which are two processes that have a severe detrimental effect on ecosystem stability and resilience.

The loss of SOC stocks especially the surface soils which are most biologically active is highly attributed to the conversion of dense forests to agricultural lands, plantations and barren lands. This SOC loss does not only contribute to carbon emissions in the atmosphere; it also affects the soil fertility and the microbial activity. The reduction in microbial biomass and soil fauna continues to decrease nutrient cycling efficiency and soil health in a feedback loop which continues to cause ecological degradation. This type of soil erosion reduces the quality of habitats that are required to sustain a variety of wildlife species and provides a landscape of fragments and degradation that is incapable of supporting the ecological needs of species such as the tiger, leopard and other herbivores and pollinators.

The reactions to LULC change in bio-diversity are multi-scalar. Fragments inhibit species migration, separate populations and risk extinction. The direct impacts of habitat conversion include simplification of plant communities, destruction of heterogeneity in habitats and an aggravation in the human-wild conflict. The corridors previously important in the movement of wildlife now have less functional connectivity, as shown by the decreasing population of tigers in degraded areas of the Pench-Satpuda corridor (Patil et al 2022).

In spite of such difficulties, the review points out ways of restoration and sustainable management. Nature-based based solutions including assisted natural regeneration, agroforestry and soil conservation practices have potential solutions to replenish SOC stocks and recover habitat connectivity. Nonetheless, such initiatives have to be backed with strong policy frameworks that formally acknowledge and safeguard wildlife corridors, curtail the incompatible land activities like mining, and incorporate conservation in other land use planning activities.

The conservation activities in the future should take a holistic and landscape approach that integrates ecological integrity with sustainable development objectives. The participation of the communities including financial incentives and participatory governance will be necessary in harmonizing the local livelihoods to the conservation of the corridor. The long-term sustainability of these important wildlife landscapes could be guaranteed through the integration of scientific research, policy reforms, and community-based interventions to help maintain biodiversity, reduce climate change, and provide ecological resilience in the region

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