Indian Journal of Modern Research and Reviews

This Journal is a member of the *'Committee on Publication Ethics'*

Online ISSN: 2584-184X

Research Article

Deforestation, Forest Fragmentation and Wildlife Habitat Decline: A Narrative Review with Special Reference to India and Jharkhand

Dr. Matiur Rahman [1*], Margaret Kujur [2]

Abstract:
Deforestation and forest degradation are among the most consequential anthropogenic pressures on terrestrial biodiversity. Their ecological effects extend beyond the direct removal of vegetation to include habitat fragmentation, edge effects, deterioration of microclimatic conditions, disruption of trophic interactions, reduction of breeding and feeding resources, population isolation, and loss of landscape connectivity. This narrative review synthesises peer-reviewed evidence, with emphasis on literature published between 2012 and 2022, on the relationships among forest loss, fragmentation, and wildlife habitat, with particular reference to India and Jharkhand. Global assessments show that forest cover alone is an incomplete indicator of ecological condition: forests can remain mapped as forest while experiencing structural degradation, edge effects, and declining connectivity. A global synthesis found that about 70% of remaining forest lies within 1 km of an edge and that fragmentation can reduce biodiversity by 13–75% while impairing key ecosystem functions, with effects greatest in the smallest and most isolated fragments and magnifying over time. Evidence from India demonstrates comparable landscape-scale risks. Historical analysis of Asian elephant ranges documented a 21.49% loss of forest cover between 1930 and 1975, a further 3.19% loss between 1975 and 2013, and a 39.6% reduction in core forest area across the full period. In Jharkhand, geospatial analysis of Dalma Wildlife Sanctuary quantified a measurable shift of forest away from core toward perforated, edge, transitional, and patch classes, with about 70% of the sanctuary showing an increasing trend in forest-fire severity as fragmentation intensified. Studies from the Saranda landscape further demonstrate forest stress in mining-associated environments. The evidence supports a shift from area-based forest accounting toward landscape-scale conservation that integrates habitat quality, ecological connectivity, species movement, mining and infrastructure pressures, and long-term wildlife monitoring. Protecting intact forests, restoring degraded native habitat, safeguarding functional corridors, and integrating remote sensing with field ecology are central priorities for biodiversity conservation in India and Jharkhand.

Keywords: Deforestation; forest fragmentation; wildlife habitat; biodiversity; landscape connectivity; Asian elephant; human–wildlife conflict; mining; Jharkhand; India.

Article History
- **ISSN**: 2584-184X
- **Received:** 25 Dec 2023
- **Accepted**: 25 Jan 2024
- **Published:** 30 Jan 2024
- **MRR:**2(1) Jan. 2024:41-50

- **Peer Review Process:** Yes
- **Plagiarism Checked**: Yes

Authors Details

Dr. Matiur Rahman
Assistant Professor, Department of Zoology, Doranda College, Ranchi, Jharkhand, India

Margaret Kujur
Department of Zoology, DSPMU, Ranchi, Jharkhand, India

Corresponding Author

Dr. Matiur Rahman
Assistant Professor, Department of Zoology, Doranda College, Ranchi, Jharkhand, India

1. INTRODUCTION

Forests are spatially complex ecosystems in which habitat amount, structure, continuity, and ecological processes jointly determine the persistence of wildlife populations. Conversion of forest to agriculture, settlements, roads, mines, industrial sites, and other land uses directly removes habitat, while selective logging, fire, linear infrastructure, and edge creation can degrade forests that remain visible in land-cover maps. Consequently, an increase or stability in mapped tree cover does not necessarily imply the maintenance of high-quality wildlife habitat. This distinction is increasingly important for conservation planning because animals respond to food availability, nesting and breeding resources, vegetation structure, movement permeability, disturbance, and connectivity rather than to forest area alone (Grantham et al., 2020; Haddad et al., 2015).

Habitat loss and fragmentation are related but analytically distinct processes. Habitat loss reduces the total amount of suitable environment; fragmentation alters the configuration of what remains by changing patch size, isolation, edge density, and connectivity. Their biological effects may therefore differ among species and landscapes. Global evidence encompassing thousands of animal species shows that sensitivity to fragmentation is especially pronounced in tropical regions and among species that depend on forest interiors (Betts et al., 2019). The surrounding matrix also matters: a forest patch embedded in a permeable, structurally complex matrix may retain greater functional connectivity than a similar-sized patch bordered by intensive agriculture, mining, urban development, or high-traffic infrastructure.

The issue is particularly important in India, where high human population density, rapid infrastructure development, mining, agriculture, and urban expansion coexist with globally significant biodiversity. Wide-ranging mammals such as Asian elephants and tigers require landscape connectivity extending beyond protected-area boundaries. Historical mapping of elephant ranges in India demonstrates substantial long-term contraction and fragmentation of core habitat, with the central Indian range among the most fragmented (Padalia et al., 2020). Central Indian tiger landscapes likewise show that potential structural connectivity does not guarantee actual habitat use when ecological constraints and human interactions limit movement (Puri et al., 2022).

Jharkhand offers a highly relevant regional context for examining these processes because large forest tracts, mineral-rich landscapes, transport networks, settlements, and elephant movement routes overlap spatially. Recent work in Dalma Wildlife Sanctuary provides quantitative evidence linking forest fragmentation with degradation and fire-severity trends in an elephant landscape (Chaudhary et al., 2022). The Saranda forest landscape provides a complementary example in which mining-associated forest stress and tree-species patterns can be evaluated using remote-sensing approaches (Kayet et al., 2020). A focused synthesis of these findings can therefore connect global fragmentation theory with practical conservation problems in eastern and central India.

The present article is framed as a narrative review rather than an original quantitative research study. It synthesises recent peer-reviewed evidence on deforestation, degradation, fragmentation, wildlife responses, connectivity, and conservation, and uses India and Jharkhand as focal contexts. This design avoids implying that a new primary dataset or meta-analysis has been produced, while still allowing quantitative findings from published studies to be critically compared.

2. OBJECTIVES OF THE REVIEW

1. To synthesise recent scientific evidence on global patterns and drivers of deforestation, forest degradation, and fragmentation.
2. To examine the ecological mechanisms through which forest loss and fragmentation affect wildlife habitats, ecological interactions, and population persistence.
3. To summarise quantitative evidence for effects on major wildlife groups and protected-area biodiversity.
4. To review the relationship between habitat configuration, landscape connectivity, and human–wildlife conflict in India.
5. To critically examine evidence from Jharkhand, with particular attention to Dalma Wildlife Sanctuary and the Saranda forest landscape.
6. To identify conservation priorities, policy implications, and research gaps for maintaining ecologically functional forest landscapes.

3. METHODOLOGY AND LITERATURE SEARCH STRATEGY

A structured narrative-review approach was used to organise evidence concerning deforestation, forest degradation, habitat fragmentation, and wildlife responses. The review was designed around peer-reviewed papers indexed in PubMed and papers discoverable through Google Scholar, with primary emphasis on publications from 1 January 2012 to 31 December 2022, defining a focused ten-year evidence window. Studies outside this window were not used, so that the synthesis reflects a consistent decade of peer-reviewed evidence.

Search concepts included combinations of the terms deforestation, forest degradation, wildlife habitat, habitat fragmentation, forest edge effects, biodiversity, food webs, wildlife corridor, landscape connectivity, Asian elephant, tiger connectivity, India, Jharkhand, Dalma Wildlife Sanctuary, Saranda forest, mining, and human-wildlife conflict. Priority was given to studies that reported quantitative ecological outcomes, used spatially explicit or field-based methods, or directly addressed mechanisms relevant to conservation.

Studies were considered relevant when they examined natural or semi-natural forest ecosystems; evaluated deforestation, degradation, fragmentation, connectivity, or associated land-use change; and reported outcomes related to biodiversity, wildlife populations, habitat suitability, movement, ecological interactions, vegetation structure, or ecosystem function. Opinion pieces, duplicate reports, and sources without a clear empirical or scholarly basis were not used as evidentiary references. Government reports from the original manuscript were not retained in the final reference list because the review was intentionally restricted to peer-reviewed literature published between 2012 and 2022 and indexed in PubMed or discoverable through Google Scholar.

Because the article is a narrative review rather than a systematic review or meta-analysis, no pooled effect size was calculated and no PRISMA flow diagram is presented. Quantitative values reported below are extracted from individual peer-reviewed studies and are explicitly attributed to their original sources. This distinction is important for reproducibility and prevents the manuscript from implying a statistical synthesis that was not performed.

4. Global Trends in Deforestation, Degradation and Fragmentation

Contemporary forest change must be understood through multiple dimensions. Deforestation denotes conversion of forest to another land use, whereas degradation may occur without complete conversion and can involve reduced canopy height, biomass, structural complexity, or ecological function. Fragmentation adds a spatial dimension by dividing continuous habitat into smaller or more isolated components. These processes often co-occur, but they should not be treated as interchangeable because their consequences for wildlife depend on the amount and arrangement of remaining habitat.

A global synthesis of fragmentation experiments spanning five continents and 35 years found that about 70% of remaining forest lies within 1 km of a forest edge, and therefore subject to the degrading effects of fragmentation (Haddad et al., 2015). The same synthesis reported that fragmentation reduced biodiversity by 13-75% and impaired key ecosystem functions by decreasing biomass and altering nutrient cycles, with effects greatest in the smallest and most isolated fragments and magnifying with the passage of time. Complementary work demonstrated rapid expansion of tropical forest edge area, with edge area increasing from 27% to 31% of total tropical forest area over a decade and the number of forest fragments increasing by approximately 20 million (Fischer et al., 2021). These changes matter because increased edge density exposes a larger proportion of forest to altered microclimate, human access, fire risk, invasive species, and mortality processes.

These findings show that the ecological footprint of degradation is larger than suggested by forest-cover maps alone. Long-term fragmentation experiments and Amazonian field studies indicate that edge effects strongly influence forest microclimate, tree mortality, carbon storage, and faunal communities, and that these effects can persist and even intensify over decades (Haddad et al., 2015; Laurance et al., 2018). Such findings support the central argument of this review: mapped forest cover is a necessary but insufficient indicator of wildlife habitat quality.

Protected areas are not immune to these pressures. Because the majority of remaining forest lies close to an edge, even legally designated reserves can experience internal fragmentation, edge encroachment, and loss of interior habitat where surrounding land uses intensify (Haddad et al., 2015). Effective conservation therefore depends not only on legal designation but also on landscape context, enforcement, connectivity, and management of external pressures.

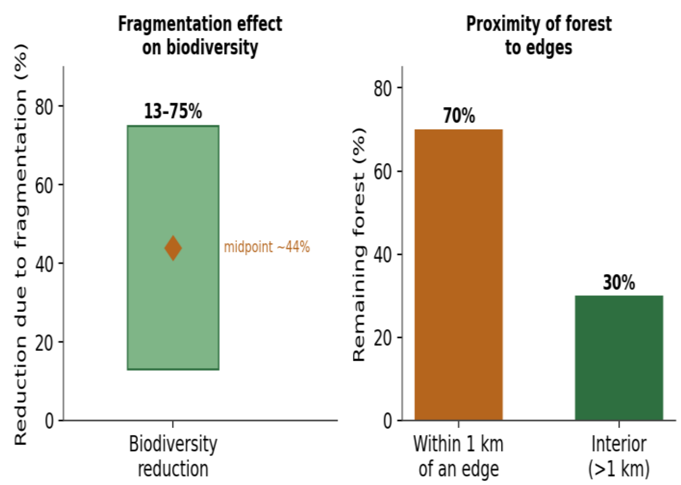

Figure 1. Reduction in biodiversity attributable to habitat fragmentation across fragmentation experiments (reported range and mid-point), alongside the proportion of remaining forest lying within 1 km of an edge. Data redrawn from Haddad et al. (2015).

5. Major Drivers of Forest Loss and Degradation

5.1 Agricultural expansion

Agriculture is the dominant direct driver of tropical deforestation. Pendrill et al. (2022) synthesised pantropical evidence and estimated that 90-99% of tropical deforestation from 2011 to 2015 was driven by agricultural expansion, although only 45-65% of deforested land became productive agricultural land within a few years. This distinction is important because it shows that forest clearance can be linked to speculative land conversion, shifting cultivation, pasture expansion, commodity production, and broader governance processes rather than to a simple one-to-one conversion of forest into stable cropland. For wildlife, agricultural expansion can simultaneously reduce habitat amount, increase edge exposure, simplify vegetation structure, alter food resources, and intensify contact with people.

5.2 Infrastructure and linear development

Roads, railways, power lines, canals, pipelines, and expanding settlements can cause a relatively small direct loss of forest while producing disproportionately large connectivity effects. Linear infrastructure subdivides habitat, increases mortality risk, facilitates human access, and may alter animal movement even when substantial forest remains on either side. Long-term Amazonian studies show that roads and the edges they create generate persistent structural degradation, altered microclimate, and elevated tree mortality that extend well into the adjacent forest (Laurance et al., 2018). For wide-ranging species, the ecological consequence of a road therefore depends on traffic, fencing, crossing opportunities, adjacent land use, and whether the alignment intersects a habitual movement route or corridor.

5.3 Mining

Mining is especially relevant to mineral-rich regions of eastern and central India. Surface mining can remove vegetation directly and can also create roads, waste dumps, settlements, dust, noise, altered drainage, and long-term barriers to wildlife movement. Mishra et al. (2022), using remote sensing and spatial analysis in Odisha, documented mining-related forest-cover change over 2001-2019 and demonstrated the value of integrating mining footprints with land-cover trajectories. In Jharkhand, the Saranda forest has been investigated using hyperspectral and Landsat data, with mining-associated areas showing vegetation stress relevant to tree-species diversity and sustainable forest management (Kayet et al., 2020). These studies support the need to evaluate cumulative landscape effects rather than only the area directly leased for extraction.

5.4 Selective logging and degradation

Selective logging can leave a landscape classified as forest while altering species composition, demographic rates, canopy structure, and microhabitat availability. Long-term remeasurement in the Western Ghats showed that logged and unlogged plots remained compositionally distinct decades after logging, indicating that disturbance legacies can persist even where broad measures such as species richness appear relatively stable (Wilson et al., 2022). For wildlife, such structural changes can affect nesting cavities, fruiting trees, understorey density, prey communities, and microclimatic refuges.

5.5 Fire and interacting disturbances

Fire, drought, logging, roads, and edge effects can reinforce one another. Degraded forests may become more flammable; roads increase ignition and access; and repeated burning can further reduce canopy cover and biomass. In Dalma Wildlife Sanctuary, Chaudhary et al. (2022) found that increasing forest fragmentation was associated with greater forest-fire severity, with fires most likely along transitional forest margins. Thus, conservation strategies should treat degradation as a potential precursor to complete conversion rather than as a benign intermediate condition.

Table 1. Major drivers and principal ecological pathways

Driver	Direct forest effect	Wildlife pathway	Representative evidence
Agricultural expansion	Forest conversion; edge creation	Habitat loss, food-resource change, conflict	Pendrill et al., 2022
Roads / infrastructure	Linear clearing; access; edge degradation	Barrier effects, mortality, disturbance	Laurance et al., 2018
Mining	Vegetation removal; waste; roads; dust	Habitat loss, stress, corridor disruption	Mishra et al., 2022; Kayet et al., 2020
Selective logging	Reduced structure; altered composition	Loss of nesting / feeding microhabitats	Wilson et al., 2022
Fire / degradation	Canopy and biomass loss	Microclimate change; reduced habitat quality	Chaudhary et al., 2022; Haddad et al., 2015

6. Mechanisms Linking Deforestation to Wildlife Decline

6.1 Direct habitat loss

The most immediate effect of deforestation is a reduction in the amount of habitat available to organisms. This can lower carrying capacity, compress home ranges, eliminate refuges and breeding sites, and increase competition for remaining resources. Habitat amount is often the dominant landscape variable for biodiversity, but the effect is conditioned by species traits and the quality of retained patches. Large mammals, interior specialists, low-dispersal taxa, and species with narrow ecological requirements are generally less able to persist when suitable habitat becomes scarce.

6.2 Fragmentation and spatial configuration

Fragmentation changes the configuration of remaining habitat by reducing patch size, increasing patch number and isolation, and altering the distance among resources. Betts et al. (2019) analysed 73 datasets encompassing 4,489 animal species and found that the proportion of fragmentation-sensitive species was almost three times higher in regions with low historical disturbance than in more disturbance-prone regions, with sensitivity increasing strongly toward lower latitudes. However, fragmentation per se should not be assumed to have a universally negative effect independent of habitat amount. Rybicki et al. (2020) showed theoretically that fragmentation effects on species diversity can change direction depending on the total amount of habitat. Consequently, strong inference requires separate measures of habitat amount and configuration rather than treating fragmentation as a single surrogate for habitat loss.

6.3 Edge effects and microclimatic change

Edges alter radiation, temperature, humidity, wind, vegetation structure, human access, and species interactions. Global vertebrate analyses have shown widespread edge-related abundance changes, particularly among forest-core species. In the Western Ghats, Krishnadas et al. (2019) found lower seedling alpha- and gamma-diversity near forest edges, with recruitment patterns suggesting that some interior species were unable to regenerate near edges. At broader scales, long-term Amazonian research has documented structural edge effects on microclimate, tree mortality, and biomass extending well beyond the immediate forest margin (Laurance et al., 2018), and global analysis indicates that the large majority of remaining forest is close enough to an edge to be affected (Haddad et al., 2015). The ecological depth of an edge therefore depends on the response variable considered: microclimate, tree recruitment, canopy structure, and vertebrate abundance can operate at different spatial scales.

6.4 Food-web and interaction disruption

Forest conversion can reorganise energy flow and trophic structure even where some species remain. Wang et al. (2020) experimentally showed that fragmentation can alter the relative influence of top-down predation and bottom-up environmental control on forest regeneration. Long-term Amazonian synthesis further indicates that fragmentation shifts tree-community composition, increases liana abundance, and disrupts the animal-mediated pollination and seed-dispersal interactions on which many plant species depend, so that the most vulnerable taxa are often those tied to these mutualisms rather than those simply reduced in number (Laurance et al., 2018). Evaluating ecological processes and interactions is therefore as important as counting species.

6.5 Reproductive effects

Reproductive success can decline when forest loss removes nesting trees, den sites, breeding pools, display sites, or seasonally available resources. Fragmentation can also reduce mate-encounter rates and increase the energetic cost of moving among breeding sites. These effects can remain difficult to detect in short-term surveys because adult individuals may persist after recruitment has declined, creating an extinction debt. Recruitment-focused studies, such as those from the Western Ghats, are therefore valuable because they detect demographic bottlenecks before complete population disappearance.

6.6 Population isolation and genetic connectivity

Population isolation occurs when suitable habitat patches become too distant, or intervening land uses too hostile, for routine dispersal. Reduced movement can decrease gene flow and increase vulnerability to demographic stochasticity. For wide-ranging carnivores and megaherbivores, maintaining permeability among protected areas is especially important because viable populations frequently extend beyond reserve boundaries. Connectivity should therefore be measured functionally, using occupancy, movement, genetic, or telemetry evidence where possible, rather than inferred solely from the presence of a narrow strip of vegetation.

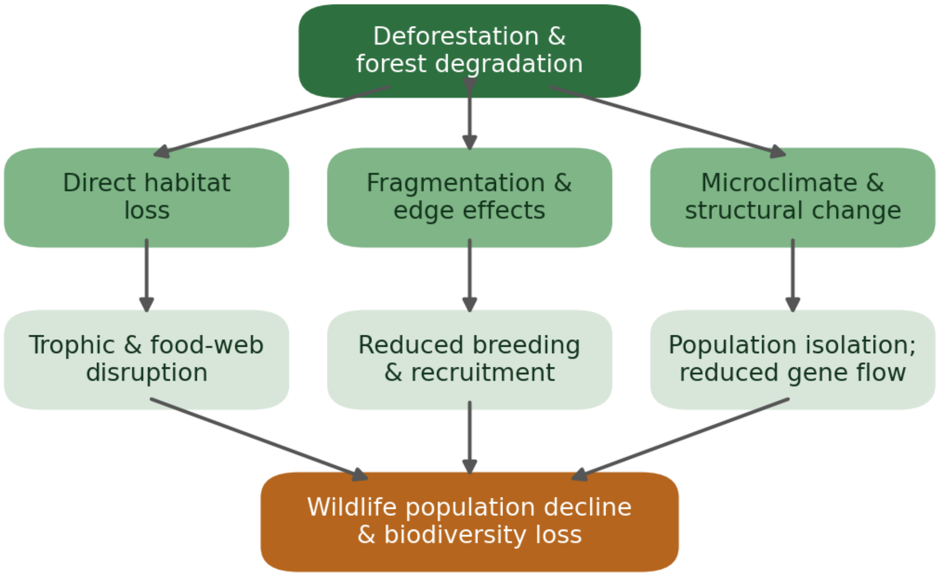

Figure 2. Conceptual pathways linking forest loss and degradation to wildlife decline. Diagram prepared for this review from mechanisms synthesised in the cited literature.

7. Evidence Across Wildlife and Ecological Groups

Quantitative evidence demonstrates that wildlife responses to forest loss are neither uniform nor limited to a single taxonomic level. Responses range from population abundance and movement to plant recruitment, trophic interactions, and ecosystem energy flow. Table 2 summarises representative findings selected because they quantify either the scale of habitat alteration or a biologically meaningful response.

Table 2. Representative quantitative evidence across systems and groups

System / group	Quantitative finding	Interpretation	Source
Global forests	~70% of remaining forest within 1 km of an edge; fragmentation cuts biodiversity 13-75%	Edge exposure is pervasive and degrades ecosystem function	Haddad et al., 2015
Global animal assemblages	4,489 species across 73 datasets; fragmentation sensitivity highest in low-disturbance / tropical regions	Species traits and evolutionary history mediate response	Betts et al., 2019
Asian elephants, India	21.49% forest loss (1930-1975); 3.19% (1975-s2013); core forest reduced 39.6%	Long-term contraction and fragmentation of elephant habitat	Padalia et al., 2020
Dalma landscape, Jharkhand	Core forest shifted toward perforated (+2.72%), edge (+10%), transitional (+4.75%) and patch (+5.3%) classes; ~70% shows rising fire severity	Fragmentation degrades an elephant landscape and raises fire risk	Chaudhary et al., 2022
Western Ghats tree recruitment	Lower seedling alpha / gamma diversity near edges	Edge effects can create recruitment bottlenecks	Krishnadas et al., 2019
Amazonian forest fragments	Shifts in tree composition, liana increase, disrupted pollination / seed dispersal	Functional restructuring may exceed what species counts reveal	Laurance et al., 2018

8. Deforestation and Human–Wildlife Conflict

Human-wildlife conflict is frequently treated as a behavioural problem, yet habitat change often determines where and when encounters occur. Reduction or degradation of natural food resources can draw herbivores toward crops; fragmentation can force animals to cross settlements, roads, rail lines, and farms; and expansion of agriculture around protected areas can increase the length of the human-forest interface. Conflict risk should therefore be interpreted as an emergent property of landscape structure, resource distribution, and human activity.

The Dalma landscape provides a particularly clear example. Chaudhary et al. (2022) documented progressive forest fragmentation within the sanctuary, with core forest giving way to edge, transitional, and patch classes and a rising trend in forest-fire severity as fragmentation intensified. Because elephants are wide-ranging and depend on continuous, good-quality habitat, such fragmentation forces movement through increasingly edge-dominated, human-influenced terrain, which is where encounters with people and crops concentrate. This implies that restoring and maintaining continuous, functional habitat may reduce, although not eliminate, conflict.

Conflict mitigation should therefore combine short-term measures such as early warning, compensation, crop protection, and rapid response with long-term habitat measures. Without addressing habitat quality and connectivity, local deterrence may simply shift animals and conflict to neighbouring areas. Spatially explicit conflict mapping, combined with land-use and movement data, can help identify repeated bottlenecks where targeted restoration or crossing structures may have disproportionate conservation benefits.

9. Indian Scenario: From Forest Cover to Habitat Function

India's wildlife conservation challenge is not adequately captured by national forest-cover totals. A landscape may retain tree cover while losing old-growth structure, interior habitat, riparian continuity, or permeability between protected areas. Conversely, small restored patches can sometimes increase stepping-stone connectivity even when total forest area changes little. Conservation assessment should therefore integrate forest amount, patch configuration, disturbance, species-specific habitat suitability, and actual wildlife response.

Asian elephants provide one of the clearest national-scale examples. Padalia et al. (2020) reconstructed forest cover in major elephant-ranging provinces using maps for 1930, 1975, and 2013. They found a loss of 21.49% of the original forest cover from 1930 to 1975 and a further 3.19% from 1975 to 2013, while core forest declined by 39.6% across the full period. The central range was identified as the most fragmented among the assessed elephant ranges. These findings are particularly relevant to Jharkhand because the state lies within the central/eastern landscape where elephant movement intersects mines, roads, settlements, and agriculture.

Connectivity is equally important for carnivores. In the Kanha-Pench landscape, Puri et al. (2022) showed that potential structural connectivity, habitat use, and negative interactions with people are related but not identical. A corridor that appears suitable in a GIS layer may function poorly if prey availability, disturbance, human presence, or landscape barriers constrain use. Conservation planning should therefore combine structural and functional connectivity evidence.

Indian forest restoration also requires attention to disturbance legacies. The Western Ghats studies cited in this review show persistent compositional differences after logging and altered recruitment near edges. These findings caution against assuming that all tree-covered land has equivalent conservation value. Native species composition, vertical structure, interior conditions, and continuity with surrounding habitat are central attributes of ecological restoration.

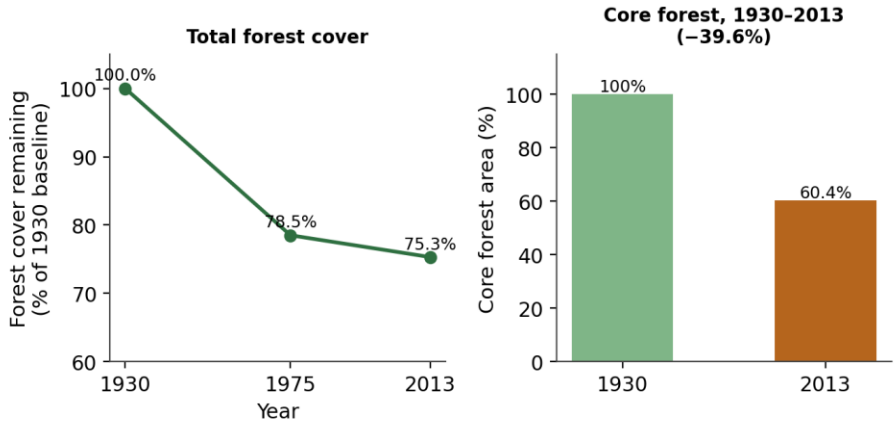

Figure 3. Historical changes in forest habitat within Asian elephant ranges of India. Data redrawn from Padalia et al. (2020).

10. Jharkhand and the Central Indian Landscape: A Focused Case Study

10.1 Dalma Wildlife Sanctuary

Dalma Wildlife Sanctuary is a strategically important elephant landscape in eastern India and provides one of the strongest recent peer-reviewed datasets for characterising forest fragmentation and its consequences in Jharkhand. Chaudhary et al. (2022) applied a morphological fragmentation analysis based on two pixel-integration indicators-connectedness and density-together with Normalized Burn Ratio-derived forest-fire severity on the Google Earth Engine platform, covering the period 1995-2019.

The study quantified a measurable transformation of the sanctuary's forest structure: relative to the core-forest baseline, the landscape shifted toward perforated (+2.72%), edge (+10%), transitional (+4.75%), and patch (+5.3%) classes, indicating progressive break-up of continuous interior habitat. Around 70% of the area showed an increasing trend in forest-fire severity, and fragmentation and fire severity were statistically linked, with fires most likely in transitional forest along fragment margins. This is directly relevant to elephant conservation because the loss of core forest and the expansion of edge and patch habitat erode precisely the continuous, low-disturbance conditions on which the sanctuary's elephants depend.

For management, these results support protection of remaining core forest, maintenance of forest connectedness, regulation of new linear infrastructure, and integrated fire management, together with spatial targeting of conflict mitigation. They also demonstrate how geospatial fragmentation and disturbance metrics can identify where restoration is likely to provide the greatest benefit.

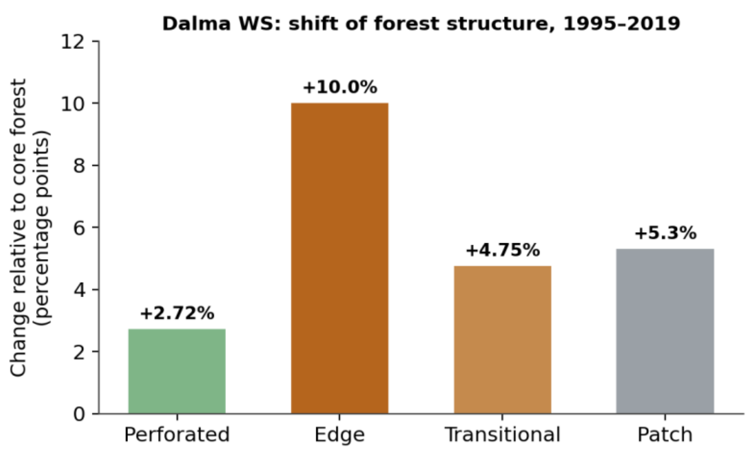

Figure 4. Fragmentation-driven shift of forest structure in Dalma Wildlife Sanctuary, shown as the percentage-point change in each morphological class relative to the core-forest baseline (1995–2019). Data redrawn from Chaudhary et al. (2022).

10.2 Saranda forest and mining-associated stress

The Saranda Forest represents a complementary conservation problem in which high forest value overlaps with mining pressure. Remote-sensing analysis using Hyperion hyperspectral and Landsat data has been used to classify tree species and estimate diversity in mining-associated hilltop forest environments. The study reported high-stress vegetation conditions around mining fields, illustrating the potential of spectral data to detect ecological change not visible from simple forest/non-forest classification (Kayet et al., 2020).

Saranda is therefore suitable for a landscape-level monitoring framework that combines mine expansion, canopy condition, vegetation stress, fragmentation metrics, road density, and wildlife occurrence. Such an approach would make it possible to distinguish direct clearing from broader degradation and to test whether areas of high vegetation stress correspond to reduced wildlife use or increased movement through neighbouring corridors.

11. Wildlife Corridors and Landscape Connectivity

Wildlife corridors are intended to maintain movement, dispersal, gene flow, seasonal access to resources, and demographic rescue among habitat patches. Their effectiveness depends on width, habitat quality, human activity, topography, road crossings, and the behavioural ecology of the focal species. A corridor should therefore be understood as a functional landscape rather than as a narrow line connecting two protected areas on a map.

Central Indian tiger studies demonstrate the value of combining graph-theoretic connectivity with field-based habitat-use data. Puri et al. (2022) showed that potential connectivity and realised use can diverge when ecological constraints and human interactions intervene. This has direct relevance to elephant corridors in Jharkhand, where inactive routes identified in Dalma may require habitat restoration, disturbance reduction, or mitigation of road and settlement barriers before they function effectively.

At the policy level, connectivity conservation should identify core habitat, stepping-stone patches, pinch points, and high-risk crossings. Maintaining multiple pathways is generally preferable to dependence on a single narrow corridor because alternative routes increase resilience to future land-use change. Where infrastructure is unavoidable, species-specific crossing structures, speed reduction, fencing design, and monitoring should be incorporated during project planning rather than added only after conflict or mortality increases.

12. Climate Change Interactions

Climate change interacts with forest loss rather than acting independently of it. Fragmentation increases edge exposure and can reduce access to microclimatic refuges, while drought and warming can increase tree mortality, fire risk, and shifts in vegetation composition. Species in isolated patches may be unable to track suitable climate because movement pathways have already been disrupted.

Evidence from India suggests that climate variables have contributed to historical forest loss, although anthropogenic land-use drivers remain dominant in many regions. A national analysis found substantial regional and seasonal variation in associations between climate trends and forest loss, and emphasised the importance of climate velocity for future protection planning (Haughan et al., 2022). In the Western Ghats, climate and forest loss were shown to interact in shaping the trait composition of tree communities, suggesting that fragmented forests may assemble differently under climatic stress (Krishnadas, 2022).

For wildlife management, climate adaptation should therefore include connectivity across elevational, hydrological, and climatic gradients. Restoration of riparian strips, maintenance of shaded movement routes, and protection of larger interior patches may simultaneously reduce fragmentation effects and increase resilience to warming and drought.

13. Conservation and Ecological Restoration

Effective conservation should prioritise avoidance of further loss of intact natural forest before relying on compensatory planting. Plantations can provide tree cover, carbon storage, and some habitat functions, but they cannot be assumed to reproduce the structural complexity or species interactions of mature native forest. Restoration objectives should therefore be defined ecologically: recovery of native composition, canopy structure, understorey heterogeneity, food plants, breeding substrates, riparian function, and landscape connectivity.

Restoration is especially valuable at corridor bottlenecks, degraded edges, riparian zones, and small stepping-stone patches that connect larger habitat blocks. In heavily modified landscapes, even relatively small patches may contribute disproportionately to movement if they occupy strategic positions. However, restoration outcomes should be monitored with wildlife indicators rather than vegetation survival alone. Camera traps, acoustic monitoring, dung/sign surveys, telemetry, genetic sampling, and repeated occupancy analysis can reveal whether restored habitat is actually being used.

Protected-area management should also address external land-use pressures. Because most remaining forest lies close to an edge and fragmentation effects intensify over time, legal protection reduces but does not eliminate habitat loss and internal degradation (Haddad et al., 2015). Buffer zones, corridor conservation, land-use zoning, and cumulative-impact assessment are therefore essential complements to reserve-based conservation.

14. Policy Implications

1. Protect remaining intact and high-integrity natural forests as the first conservation priority.

2. Report forest quality, degradation, and connectivity alongside forest-cover area in planning and monitoring.
3. Identify, legally safeguard, and ecologically restore functional wildlife corridors and movement bottlenecks.
4. Require cumulative landscape-level assessment of mining, roads, railways, and other infrastructure in biodiversity-rich regions.
5. Integrate remote sensing, GIS, camera-trap, occupancy, telemetry, and conflict data in wildlife management decisions.
6. Prioritise elephant corridors and recurrent human-elephant conflict zones in Jharkhand for habitat-focused interventions.
7. Design road and railway mitigation using documented animal movement rather than generic engineering assumptions.
8. Use native species and ecological-function targets in restoration rather than tree-planting counts alone.
9. Include local communities in monitoring, conflict mitigation, and sustainable forest management.
10. Maintain long-term, spatially explicit wildlife and habitat datasets so that conservation outcomes can be evaluated quantitatively.

15. Research Gaps and Priorities

The literature reviewed here reveals several gaps that are especially relevant to Jharkhand. Long-term forest-change datasets are increasingly available, but relatively few studies directly link fragmentation metrics with repeated wildlife observations, demographic outcomes, or genetic connectivity. Elephant movement is often inferred from sightings, signs, or conflict reports rather than from multi-year GPS telemetry. Similarly, mining studies frequently quantify land-cover change or vegetation stress without simultaneously measuring large-mammal occupancy, bird communities, or movement permeability.

Future work should therefore integrate land-use/land-cover change, forest fragmentation metrics, canopy condition, road and mining density, water availability, elephant or carnivore occurrence, and georeferenced conflict records. A particularly strong Jharkhand study could combine annual satellite-derived forest change with elephant movement or conflict data to test whether specific fragmentation thresholds predict corridor failure or increased conflict. Genetic sampling could further determine whether apparently connected populations maintain effective gene flow.

Additional research is needed on taxa that receive less conservation attention than large mammals. Birds, reptiles, amphibians, insects, and soil fauna may respond rapidly to degradation and can provide early-warning indicators of ecological decline. Multi-taxon monitoring would also help determine whether restoration that benefits elephants or tigers simultaneously restores broader biodiversity and ecosystem function.

Table 3. Priority research questions for Jharkhand

Research gap	Recommended data/method	Potential output
Fragmentation-elephant relationship	LULC time series + landscape metrics + GPS/sign data	Thresholds of corridor use and habitat suitability
Mining impacts on wildlife	Mine footprint + canopy stress + camera traps/occupancy	Cumulative-impact maps and mitigation priorities
Human-elephant conflict	Geocoded conflict records + crop/settlement/road layers	Predictive conflict-risk model
Functional connectivity	Telemetry or genetics + circuit/graph models	Validated corridor network
Restoration effectiveness	Before-after habitat and wildlife monitoring	Evidence-based restoration standards
Under-studied taxa	Bird/amphibian/insect surveys across disturbance gradients	Multi-taxon biodiversity indicators

16. CONCLUSION

Deforestation is not simply the removal of trees; it is a transformation of habitat amount, structure, spatial configuration, and ecological process. Recent research demonstrates that degradation and fragmentation can persist within landscapes that remain classified as forest, and that these changes can influence wildlife through edge effects, altered microclimate, trophic restructuring, reproductive constraints, reduced movement, and population isolation. Conservation assessment must therefore move beyond forest-area statistics to evaluate habitat quality and functional connectivity.

India illustrates this challenge clearly. Historical contraction and fragmentation of Asian elephant habitat, the dependence of tiger movement on permeable multi-use landscapes, and the long-lasting ecological effects of forest edges and logging all show that wildlife requires more than nominal tree cover. Jharkhand is particularly important because mineral extraction, roads, settlements, agriculture, forests, elephant movement, and human-wildlife conflict converge within the same landscapes. Evidence from Dalma demonstrates measurable break-up of core forest into edge and patch habitat with a rising trend in fire severity; Saranda demonstrates the value of remote sensing for detecting mining-associated forest stress.

The conservation priority is therefore landscape functionality: protect intact natural forests, restore degraded native habitat, maintain multiple movement routes, regulate cumulative infrastructure and mining impacts, and link remote sensing with field-based wildlife monitoring. A shift from counting trees to measuring ecological integrity, connectivity, and wildlife response would provide a more scientifically defensible basis for forest and biodiversity policy in Jharkhand and India.

17. Declarations

Funding
No external funding was received for this narrative review.

Conflict of interest
The author declares no conflict of interest.

Ethics approval
Not applicable. This article is a narrative review of previously published literature and does not involve new research on human participants or animals.

Data availability
No new dataset was generated. All quantitative values reported in the review are derived from the peer-reviewed studies cited in the text.

Author contributions
The author conceptualised the review, synthesised the literature, interpreted the evidence, and prepared the manuscript.

REFERENCES

1. Betts MG, Wolf C, Ripple WJ, et al. Extinction filters mediate the global effects of habitat fragmentation on animals. Science. 2019;366(6470):1236-9. doi:10.1126/science.aax9387.
2. Chaudhary SK, Pandey AC, Parida BR, Gupta SK. Using geoinformatics to link forest fire severity and fragmentation in India's Dalma Wildlife Sanctuary. Trop Ecol. 2022;63(3):453-62. doi:10.1007/s42965-021-00202-0.
3. Fischer R, Taubert F, Müller MS, et al. Accelerated forest fragmentation leads to critical increase in tropical forest edge area. Sci Adv. 2021;7(37):eabg7012. doi:10.1126/sciadv.abg7012.
4. Grantham HS, Duncan A, Evans TD, et al. Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. Nat Commun. 2020;11:5978. doi:10.1038/s41467-020-19493-3.
5. Haddad NM, Brudvig LA, Clobert J, et al. Habitat fragmentation and its lasting impact on Earth's ecosystems. Sci Adv. 2015;1(2):e1500052. doi:10.1126/sciadv.1500052.
6. Haughan AE, Pettorelli N, Potts SG, Senapathi D. Determining the role of climate change in India's past forest loss. Glob Change Biol. 2022;28(12):3883-901. doi:10.1111/gcb.16161.
7. Kayet N, Pathak K, Chakrabarty A, Kumar S, Singh CP, Chowdary VM. Assessment of mining activities on tree species and diversity in hilltop mining areas using Hyperion and Landsat data. Environ Sci Pollut Res Int. 2020;27(34):42750-66. doi:10.1007/s11356-020-09795-w.
8. Krishnadas M. Climate and forest loss interactively restructure trait composition across a human-modified landscape. Ecol Evol. 2022;12(11):e9361. doi:10.1002/ece3.9361.
9. Krishnadas M, Kumar AN, Comita LS. Edge effects reduce α-diversity but not β-diversity during community assembly in a human-modified tropical forest. Ecol Appl. 2019;29(8):e01996. doi:10.1002/eap.1996.
10. Laurance WF, Camargo JLC, Fearnside PM, et al. An Amazonian rainforest and its fragments as a laboratory of global change. Biol Rev. 2018;93(1):223-47. doi:10.1111/brv.12343.
11. Mishra M, Santos CAG, Nascimento TVM, Dash MK, da Silva RM, Kar D, et al. Mining impacts on forest cover change in a tropical forest using remote sensing and spatial information from 2001-2019: a case study of Odisha (India). J Environ Manage. 2022;302(Pt B):114067. doi:10.1016/j.jenvman.2021.114067.
12. Padalia H, Ghosh S, Reddy CS, Nandy S, Singh S, Kumar AS. Assessment of historical forest cover loss and fragmentation in Asian elephant ranges in India. Environ Monit Assess. 2020;191(Suppl 3):802. doi:10.1007/s10661-019-7696-5.
13. Pendrill F, Gardner TA, Meyfroidt P, et al. Disentangling the numbers behind agriculture-driven tropical deforestation. Science. 2022;377(6611):eabm9267. doi:10.1126/science.abm9267.
14. Puri M, Srivathsa A, Karanth KK, Patel I, Kumar NS. Links in a sink: interplay between habitat structure, ecological constraints and interactions with humans can influence connectivity conservation for tigers in forest corridors. Sci Total Environ. 2022;809:151106. doi:10.1016/j.scitotenv.2021.151106.
15. Rybicki J, Abrego N, Ovaskainen O. Habitat fragmentation and species diversity in competitive communities. Ecol Lett. 2020;23(3):506-17. doi:10.1111/ele.13450.
16. Wang R, Zhang X, Shi YS, et al. Habitat fragmentation changes top-down and bottom-up controls of food webs. Ecology. 2020;101(8):e03062. doi:10.1002/ecy.3062.
17. Wilson VK, Ayyappan N, Parthasarathy N. Decadal forest dynamics in logged and unlogged sites at Uppangala, Western Ghats, India. Environ Monit Assess. 2023;195(1):66. doi:10.1007/s10661-022-10706-4.