

Human Encroachment and Habitat Fragmentation as Emerging Threats to Wildlife Conservation in Madhya Pradesh, India

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Abstract- Madhya Pradesh occupies a central place in wildlife conservation in India. It contains the country's largest forest area and supports important populations of tiger, leopard, sloth bear, gaur and hard-ground barasingha. The 2022 all-India tiger assessment estimated 785 tigers in the state. This recovery is a major conservation achievement, but a rise in animal numbers within protected areas does not by itself guarantee their long-term security. Forest conversion, settlement growth, mining and linear infrastructure are changing the wider landscapes through which wildlife moves between protected habitats.

This paper examines human encroachment and habitat fragmentation as interconnected threats in Madhya Pradesh. It is based on a critical review of government reports, statutory documents and peer-reviewed studies relating to the Central Indian Landscape. Evidence from the Pench–Satpura corridor, Panna Tiger Reserve, Bandhavgarh Tiger Reserve and Kuno National Park is used to understand how land-use change affects habitat continuity, animal movement, genetic exchange and interactions between people and wildlife. The review shows that roads, railways, canals and other infrastructure can create ecological barriers even when the total area under forest appears relatively stable. It also shows that conservation measures are most effective when ecological planning, site-specific mitigation, scientific

monitoring and fair participation of local communities are brought together. The paper therefore argues for a landscape-based approach that protects corridors and other connecting habitats in addition to the core areas of national parks and tiger reserves.

Keywords: habitat fragmentation, human encroachment, wildlife corridors, tiger conservation, linear infrastructure, human–wildlife interaction, Madhya Pradesh, Central Indian Landscape

1. Introduction- Madhya Pradesh has an exceptional responsibility in the conservation of India's forests and wildlife. According to the India State of Forest Report 2021, the state had 77,493 square kilometres of forest cover, the largest forest-cover area reported for any Indian state [1]. Its location in central India also gives it unusual ecological importance. Forests of the Satpura, Vindhya and Maikal ranges connect several protected areas and provide habitat for wide-ranging mammals. These connections enable animals to disperse, locate mates, recolonise suitable habitats and respond to local ecological change.

The recovery of the tiger offers a useful measure of both achievement and vulnerability. The national assessment for 2022 estimated 785 tigers in Madhya Pradesh, with a standard error of 58 [2]. This was the highest state-level estimate in that assessment. Yet tigers do not remain permanently within administrative

boundaries. Young animals disperse from established territories and may travel through reserve buffers, territorial forests, agricultural land and areas crossed by transport networks. Their survival therefore depends on the condition of the wider landscape, not only on protection inside reserve cores.

Habitat fragmentation occurs when a large and relatively continuous habitat is divided into smaller patches. A road, railway, canal, mine, settlement or intensively cultivated tract may reduce or interrupt the movement of wildlife between those patches. Fragmentation can take place even without the complete removal of forest. A strip of forest may continue to appear on a map while becoming less usable because of traffic, fencing, artificial light, noise or frequent human presence. For this reason, forest area and ecological connectivity should be assessed together.

Human encroachment and fragmentation often reinforce one another. Expansion at a forest edge increases access, resource extraction and disturbance. New roads can then encourage further settlement or land conversion, while the resulting gaps expose wildlife to traffic and conflict. The issue cannot be reduced to a simple opposition between people and wildlife. Many forest-edge communities depend on local landscapes for grazing, fuelwood and minor forest produce. Conservation policy must therefore distinguish organised or commercial land conversion from subsistence dependence and must provide lawful, fair and workable alternatives.

This paper studies these connected pressures in Madhya Pradesh and evaluates the value of landscape-level conservation. It focuses on evidence that can be traced to identifiable reports and peer-reviewed publications. Unsupported numerical claims and sources lacking complete publication details have been excluded.

2. Review of Literature- Research on central India increasingly treats protected areas as parts of a larger ecological network. Schoen and colleagues synthesised multiple connectivity analyses for the Central Indian Landscape and showed that important connecting areas overlap substantially with human land use and proposed development [3]. Their work is significant because it moves the discussion beyond individual corridors. It shows that differences in modelling methods do not remove the wider conclusion that habitat connections need explicit consideration in land-use decisions. At a more local scale,

and land-cover change in the Pench-Satpura corridor [4]. Their study documented a decline of 2,054.60 hectares in the combined category of dense and open forest between the selected study years and an expansion of agricultural land. The finding is often described loosely as forest diversion for agriculture, but the study is more accurately understood as a remote-sensing analysis of change in land-cover categories. This distinction matters because satellite classification records landscape change; it does not by itself establish the legal status or immediate cause of every changed parcel.

Research on habitat selection also demonstrates that different carnivores respond differently to human pressure. Rather, Kumar and Khan used multi-scale modelling to assess tiger and leopard distribution in the central Indian region [5]. Their results indicate that road density, settlements and patterns of land cover influence habitat suitability. Tigers generally show stronger dependence on larger, better-connected habitat, whereas leopards can use more human-modified landscapes. Greater adaptability, however, may increase the frequency with which leopards encounter livestock and people.

Landscape connectivity also has a genetic dimension. Yumnam and colleagues found that habitat corridors have helped maintain gene flow among tiger populations in central India [6]. Their study underlines a central conservation principle: small populations may persist for a time in isolated reserves, but long-term viability is strengthened when individuals can move between populations and reproduce. Physical connectivity and functional connectivity are therefore both important. A corridor may remain visible as vegetation but cease to function if animals consistently avoid it.

Linear infrastructure has become one of the most closely studied sources of fragmentation. The Wildlife Institute of India's guidance on roads, railway lines, canals and power lines explains that route selection is the first and most important stage of mitigation [7]. Where avoidance is not possible, scientifically located crossing structures, fencing or guiding features, speed management and long-term monitoring may reduce impacts. These measures cannot be applied through a uniform design because species, terrain, drainage and movement patterns vary across sites.

strong evidence that intensive monitoring and sustained management can rebuild a locally lost population [8]. At the same time, their conclusions emphasise the need to secure habitat beyond the reserve so that the recovered population can function within a wider metapopulation. Panna therefore represents both the possibility of recovery and the continuing importance of landscape connectivity. Together, these studies support three propositions. Protected areas remain indispensable, connectivity must be treated as a measurable conservation objective, and conservation outcomes depend on social as well as ecological conditions.

3. Objectives

1. To identify the major processes contributing to habitat loss and fragmentation in wildlife-rich landscapes of Madhya Pradesh.
2. To examine the effects of roads, railways, canals, mining and changing land use on wildlife movement and corridor function.
3. To analyse the ecological consequences of fragmentation for tiger, leopard, sloth bear and other large mammals.
4. To study the relationship between fragmented habitats and interactions between people and wildlife.
5. To assess the relevance of existing legal, policy and management measures.
6. To suggest practical measures for landscape-level conservation in Madhya Pradesh.

4. Research Questions

1. How does land-use change affect the continuity and permeability of wildlife habitats in Madhya Pradesh?
2. What forms of linear infrastructure create the greatest barriers to animal movement?
3. How can fragmentation affect dispersal, genetic exchange and the long-term viability of wildlife populations?
4. Why do interactions between people and large mammals become more frequent in some forest-edge landscapes?
5. What lessons can be drawn from the Pench–Satpura, Panna, Bandhavgarh and Kuno landscapes?
6. Which combination of legal protection, engineering mitigation, scientific monitoring and community participation is most appropriate?

5. Methodology- The paper uses a descriptive and analytical review design. Its evidence base consists of the India State of Forest Report, the 2022 national tiger assessment, reports and guidance issued by the National Tiger Conservation Authority, the Ministry of Environment, Forest and Climate Change and the Wildlife Institute of India, together with peer-reviewed research articles. Sources were selected on four grounds: direct relevance to Madhya Pradesh or the Central Indian Landscape, clear authorship and publication details, availability

through an official or scholarly platform, and a demonstrable relationship to the claim for which the source was used. The material was organised under five themes: land-use change, linear infrastructure, ecological connectivity, interactions between people and wildlife, and conservation response.

Four landscapes were considered as focused examples: Pench–Satpura for corridor change and infrastructure pressure, Panna for tiger reintroduction and external development pressure, Bandhavgarh for the forest–settlement interface, and Kuno for habitat restoration and species reintroduction. These are comparative illustrations rather than statistically identical case studies.

The study has two limitations. First, it is based on secondary sources and does not claim to provide new field estimates. Second, comparable district-level data on encroachment, wildlife mortality and compensation are not consistently available for the same years. Consequently, the discussion avoids presenting unsupported statewide totals and does not infer causation from isolated incidents.

6. Major Drivers of Habitat Fragmentation

6.1 Agricultural expansion and settlement growth

Agriculture is an essential livelihood in rural Madhya Pradesh, but expansion into narrow forest links can have a disproportionate ecological effect. A relatively small loss at the narrowest point of a corridor may interrupt movement more severely than a larger loss elsewhere. The Pench–Satpura land-cover study recorded both forest decline and agricultural expansion within its study landscape [4]. Such change increases edge habitat and may reduce the cover available to animals moving between larger forest blocks.

Settlements near reserve boundaries also influence habitat use through roads, grazing, fuelwood collection, artificial lighting and repeated human movement. These effects are not uniform. A village with regulated resource use and secure waste and livestock management may create less pressure than an unplanned commercial development covering a smaller area. Effective planning should therefore assess the intensity and location of land use rather than treating every human presence as ecologically identical.

6.2 Mining and associated development

Mining affects wildlife through more than the area occupied by a pit. Approach roads, worker colonies, transport, noise, illumination, dust and increased access can extend the zone of disturbance. In central India, the ecological concern is especially serious

where mineral-bearing areas overlap with forests that connect protected habitats. The impact of a project must therefore be evaluated at the landscape scale and should include cumulative effects from associated infrastructure.

The Panna landscape illustrates the need for such assessment. The reserve's tiger recovery has increased the importance of securing adjoining habitat [8]. Any major project in or near this landscape should consequently be examined not only for direct forest loss but also for its effects on movement routes, water regimes and the integrity of the larger tiger habitat.

6.3 Roads, railways, canals and power lines

Linear projects divide habitats lengthwise and may affect a much larger area than their physical width suggests. Roads can cause direct mortality, avoidance, noise and faster access to previously remote areas. Railways may create similar risks, while steep-sided canals can obstruct movement. Power lines and related service corridors may add further disturbance. National Highway 44 in the Pench landscape has become a prominent example of mitigation through wildlife crossing structures. The important lesson is not that underpasses automatically solve fragmentation, but that appropriate structures can reduce barrier effects when they are located on evidence-based movement routes and accompanied by habitat management and monitoring. Wildlife Institute of India guidance accordingly gives priority to avoidance and careful alignment before structural mitigation [7].

6.4 Incremental and cumulative change

Many landscape changes occur gradually. One access track, field extension or small construction may appear insignificant when considered alone. Their cumulative effect can narrow a corridor, increase the density of edges and make an area less permeable. Project-by-project appraisal may miss this pattern. Strategic assessment is therefore needed at the corridor and landscape scales.

7. Ecological Consequences

7.1 Restricted dispersal and genetic exchange

Dispersal enables wildlife populations to remain connected. When a corridor is severed, individuals may be unable to establish new territories or breed with animals from another population. Landscape-genetic evidence from central India shows that corridors have contributed to tiger gene flow [6]. Protecting connectivity is thus a preventive measure against long-term isolation rather than simply a means of increasing animal movement.

7.2 Reduced habitat quality- Fragmentation cre-

ates more forest edge relative to interior habitat. Edge areas may experience altered vegetation, light, temperature and disturbance. They can also be more accessible to livestock, people and invasive plants. The biological effect depends on species. Tigers generally require sufficient cover, prey and low disturbance, while leopards can use a wider range of modified habitats [5]. The latter pattern should not be mistaken for absence of risk; frequent use of human-dominated areas can intensify conflict.

7.3 Mortality and behavioural change

Transport corridors may result in collisions, but mortality is only one visible outcome. Animals may alter routes, avoid suitable habitat or become concentrated at limited crossing points. Infrastructure can also change predator-prey encounters. Monitoring should therefore record the use of crossing structures, failed crossings, mortality and changes in movement over multiple seasons.

7.4 Greater interaction between people and wildlife-

When natural habitat is narrowed or prey is unevenly distributed, carnivores may move through farms and settlements. Livestock kept close to forest boundaries can become vulnerable, while wild herbivores may damage crops. The resulting loss has a direct effect on household security and local attitudes towards conservation. Conflict mitigation must therefore combine prompt verification and compensation with preventive measures such as safer livestock enclosures, local warning systems and habitat management.

8. Implications for Major Wildlife Species

8.1 Tiger- The tiger is particularly dependent on connected landscapes because individuals occupy large territories and juveniles disperse. The estimate of 785 tigers demonstrates the conservation value of Madhya Pradesh, but it also increases the importance of dispersal habitat outside reserve cores [2]. Management success should be judged through population viability, connectivity and coexistence, not numbers alone.

8.2 Leopard- Leopards often persist in fragmented forests and agricultural mosaics. This behavioural flexibility enables survival outside strictly protected habitats, yet it can increase encounters with livestock and people. Planning for leopard conservation must therefore include peri-urban and agricultural landscapes where conventional protected-area management has limited reach.

8.3 Sloth bear- Sloth bears use forests, scrub and rocky habitats and may encounter people collecting

forest produce or travelling through forest edges. Chaudhuri and colleagues showed the value of spatial and temporal analysis for identifying areas of sloth bear-human interaction in central India [9]. Site-specific mapping can guide awareness, seasonal access management and rapid response.

8.4 Hard-ground barasingha

The hard-ground barasingha has a highly restricted distribution and depends on carefully managed grassland and woodland mosaics. Its conservation demonstrates that connectivity is not the only concern. Habitat quality within protected areas, including grassland management and control of unsuitable vegetation change, remains equally important.

9. Landscape Illustrations

9.1 Pench-Satpura

The Pench-Satpura landscape connects major tiger habitats across a mosaic of forest, cultivation and settlements. Remote-sensing evidence of forest decline and agricultural expansion indicates pressure on this corridor [4]. Connectivity synthesis for central India further shows that infrastructure and development decisions need to be assessed against multiple recognised movement models [3]. The landscape is therefore an important testing ground for cumulative-impact assessment and the monitoring of mitigation structures.

9.2 Panna

Panna lost its resident tiger population and subsequently rebuilt it through translocation, protection and intensive monitoring. The recovered population provides strong evidence that coordinated conservation can reverse local loss [8]. It also shows why the surrounding landscape matters: a restored population requires space for dispersal and exchange with other suitable habitats. Future development decisions should take this metapopulation requirement into account.

9.3 Bandhavgarh

Bandhavgarh contains a productive tiger habitat surrounded by villages, agriculture and transport routes. High animal density and frequent use of adjoining areas can increase pressure at the forest edge. Here, conservation requires reliable incident records, protection of dispersal routes, preventive livestock management and compensation procedures that are accessible to affected households. Describing every interaction as encroachment would obscure the social complexity of the landscape; management must distinguish unlawful land conversion from customary or livelihood dependence.

9.4 Kuno- Kuno illustrates the ecological opportunities created by habitat restoration and reduced pressure within a protected landscape. It is also the site of India's cheetah introduction programme, governed by an official action plan [10]. Its experience should be evaluated through long-term evidence on habitat, prey, animal survival, movement and relations with neighbouring communities. Restoration is a continuing process rather than a one-time administrative intervention.

10. Legal and Policy Framework-The Wild Life Protection Act 1972 provides the principal statutory framework for protected areas and wildlife protection in India. It was substantially amended in 2022, with the amended provisions brought into force in 2023 [11]. The legal discussion in current research should therefore refer to the Act as amended rather than treating the original 1972 text as unchanged.

The law commonly known as the Forest Conservation Act 1980 was amended in 2023 and is now titled the Van Sanrakshan Evam Samvardhan Adhiniyam 1980. Prior approval of the Central Government remains central to the regulation of specified non-forest use of forest land [12]. Correctly naming the current law is important for the accuracy of policy analysis.

The National Wildlife Action Plan 2017–2031 recognises landscape-level conservation, ecological connectivity and the need to integrate wildlife considerations into development planning [13]. The Wildlife Institute of India guidance gives this objective an applied form by setting out principles for avoiding and mitigating the effects of linear infrastructure [7]. Together, these frameworks provide a basis for corridor-sensitive planning, although outcomes depend on project appraisal, compliance and monitoring.

11. Findings and Discussion-First, wildlife abundance within protected areas and the security of the wider landscape are not the same measure. Madhya Pradesh can support a high tiger population while still experiencing deterioration of particular dispersal routes. Second, fragmentation is both physical and functional. A forest strip may remain present but become difficult to use because of traffic, disturbance or settlement intensity. Monitoring limited to changes in forest area will not fully capture this effect. Third, linear infrastructure mitigation is valuable but secondary to avoidance. Crossing structures are most effective when their placement and dimensions are based on species and site data, when access is controlled, and when effectiveness is

monitored after construction [7]. Fourth, interactions between people and wildlife are shaped by exposure, livelihood conditions, husbandry practices and institutional response. Conservation cannot succeed through enforcement alone. Fair compensation, preventive support and credible participation influence whether local communities see wildlife as a shared asset or an uncompensated burden.

Fifth, recovery programmes such as Panna demonstrate that ecological decline is not always irreversible [8]. Their long-term success, however, depends on protecting sufficient habitat beyond the immediate release or core area.

12. Recommendations- Wildlife corridors should be incorporated into district and state land-use plans through publicly available, periodically updated spatial maps. Proposed roads, railways, canals and transmission corridors should first be tested for alternative alignments that avoid critical habitats. Mitigation structures should be used where avoidance is demonstrably not possible. Environmental appraisal should examine cumulative landscape impacts instead of considering each nearby project in isolation. Crossing structures should be monitored with camera traps and other appropriate field methods. Monitoring results should inform maintenance and future design.

Forest-cover reporting should be supplemented by indicators of corridor width, disturbance, traffic intensity and functional animal movement. Conflict records and compensation outcomes should be maintained in a transparent, standardised and time-bound system. Preventive assistance should accompany compensation. Forest-edge communities should participate in identifying movement routes, seasonal risks and locally workable prevention measures. Participation must be informed and should not transfer statutory responsibility from the state to villagers. Restoration should prioritise native vegetation, prey habitat and connections between existing forest patches. Translocation should remain a scientifically assessed tool, not a substitute for habitat protection. Universities and research institutions in Madhya Pradesh should be encouraged to conduct long-term, independently reviewable studies of corridor function and human–wildlife interactions.

13. Conclusion- The wildlife conservation achievements of Madhya Pradesh are substantial, but their future depends on what happens outside the best-protected core habitats. Agricultural expansion, settlement growth, mining and linear infrastructure can narrow or interrupt the routes that connect wildlife

populations. These pressures also increase the likelihood that animals will move through areas used intensively by people.

The available evidence supports a transition from an exclusively protected-area-centred model to a broader landscape approach. This does not reduce the importance of national parks and tiger reserves. Rather, it recognises that protected areas function within ecological and social surroundings. Avoiding critical habitats, designing infrastructure with reliable field evidence, monitoring functional connectivity, restoring degraded links and treating local communities fairly are mutually supporting elements of conservation. Madhya Pradesh's standing as a leading tiger state will be durable only if population recovery is accompanied by secure habitats, viable connections and workable coexistence. The central policy question is therefore not whether development and conservation can be placed in separate spaces, but how development decisions can remain within ecological limits while protecting the rights and security of affected communities.

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