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Ecology and Biodiversity Conservation in the Bundelkhand Region: A Field-Contextual Review of Status, Pressures and Restoration Pathways

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ABSTRACT

The Bundelkhand region, spread across thirteen districts of Uttar Pradesh and Madhya Pradesh, is a semi-arid, drought-prone plateau that nonetheless retains meaningful biological diversity. This review paper synthesises the existing scientific record on the region's flora, fauna and freshwater biodiversity, and examines the ecological threats-recurrent drought,forest degradation, groundwater depletion, sand mining and inequitable resource governance- that continue to erode it. Forest cover, dominated by Tectona grandis, Anogeissus pendula, Diospyros melanoxylon and Butea monosperma, supports a rich medicinal-plant tradition, while regional reservoirs and rivers sustain nearly ninety-three recorded freshwater fish species. Panna Tiger Reserve, now a UNESCO Biosphere Reserve, is reviewed as the region's clearest conservation success, having rebuilt its tiger population from local extinction through habitat restoration and community participation. State interventions, including the Bundelkhand Drought Mitigation Package and community-led watershed programmes, are evaluated alongside persistent gaps in monitoring, enforcement and equity of access. The paper concludes that an integrated approach combining watershed restoration, agroforestry, protected-area strengthening and equitable governance offers the most viable pathway toward reconciling biodiversity conservation with the livelihood needs of Bundelkhand's rural population.

KEYWORDS

Bundelkhand, biodiversity conservation, dry deciduous forest, Panna Tiger Reserve, drought ecology, watershed restoration.

1. INTRODUCTION

Landscapes positioned between abundance and scarcity often receive less scholarly attention than either extreme. Bundelkhand belongs to this overlooked middle ground. Spread across seven districts of southern Uttar Pradesh- Jhansi, Jalaun, Lalitpur, Mahoba, Hamirpur, Banda and Chitrakoot- and six districts of northern Madhya Pradesh- Datia, Tikamgarh, Chhatarpur, Panna, Damoh and Sagar- the region occupies the transition zone between the Indo-Gangetic plain and the Vindhyan hill system (National Rainfed Area Authority, n.d.). Its terrain is undulating and

stony, its soils largely black and yellow with low organic content, and its rainfall pattern erratic enough that entire farming seasons can be lost to a single poor monsoon.

A network of tanks built under the Chandela and later Bundela rulers once made much of Bundelkhand water-secure by design; that inheritance has eroded over recent decades to the point where drought has become the region's defining narrative (The Analysis, 2024). Yet forest patches, medicinal-plant stands and river systems supporting genuine biological diversity persist alongside this distress, and Panna's recovery from a tiger-less reserve to a UNESCO-recognised biosphere demonstrates that ecological decline in this landscape is not irreversible (Dutta et al., 2024). It is this coexistence of visible degradation and quieter ecological resilience that motivates the present review.

The significance of studying Bundelkhand's ecology extends beyond the region itself. As one of the more visible semi-arid, drought-affected landscapes in peninsular India, Bundelkhand offers a working example of how climatic stress, land-use change and social inequity interact to shape biodiversity outcomes- a combination increasingly relevant to other drylands across central and western India as rainfall variability intensifies more broadly. For a researcher based within the region, in the Chhatarpur district that forms part of the Panna Tiger Reserve landscape, the distance between published statistics and everyday observation is often small: forest patches thinning at the field boundary, tank beds cracking earlier each summer, and borewells drilled progressively deeper are not merely data points but visible features of the local landscape. This review is written with that vantage point in mind, treating the scientific literature as a way of organising and contextualising patterns that are otherwise easy to notice locally but difficult to assess at a regional scale without consolidated data.

2. LITERATURE REVIEW

Botanical documentation of the region has advanced through repeated district-level re-survey rather than a single comprehensive census. Floristic work on the Uttar Pradesh districts of Bundelkhand has recorded approximately 159 tree species, with the family Asteraceae alone contributing close to a hundred species across more than fifty genera, indicating that the region's herbaceous diversity is considerably richer than its harsh growing conditions might suggest (as cited in district flora studies of Bundelkhand, Uttar Pradesh, n.d.). Phytosociological analysis of the tropical dry-deciduous forest across Lalitpur, Mahoba and Chitrakoot districts has shown that dominance patterns vary meaningfully between forest tracts, with Anogeissus pendula and Butea monosperma leading in Mahoba, Diospyros melanoxylon and Lagerstroemia parviflora in Chitrakoot, and Butea monosperma with Tectona grandis in Lalitpur (Species diversity, dominance and equitability in tropical dry deciduous forest of Bundelkhand region, India, 2019). On the faunal side, Niranjan et al. (2023) documented 93 freshwater fish species across six orders and eighteen families in Bundelkhand's reservoirs, with Cypriniformes- and within it the

family Cyprinidae- accounting for over half of all recorded species.Their district-wise breakdown found the highest richness in Damoh, followed by Panna, Lalitpur, Chhatarpur, Sagar and Jhansi. On the policy side, the National Rainfed Area Authority's drought-mitigation assessment documented rainfall deficits reaching 45-56 per cent in successive years during the mid-2000s, while TERI's policy review of the subsequent Bundelkhand Drought Mitigation Package (2009) traced its approved outlay and its emphasis on participatory watershed management (TERI, n.d.). Governance-focused literature, including work associated with the Massachusetts Institute of Technology's DSpace repository, has additionally argued that Bundelkhand's water crisis reflects long-term structural and social factors- including caste-based inequity in resource access - rather than rainfall failure alone (Managing the water crisis in Bundelkhand, India: A governance approach, n.d.).

At the level of species-specific conservation, Dutta et al. (2024) documented the population dynamics of tiger recovery at Panna Tiger Reserve following local extinction, while a bioRxiv study on land-use and land-cover change in relocated villages around the reserve examined the continuing anthropogenic pressures at its periphery (Anthropogenic threats and conservation practices, 2023). Parallel literature on agroforestry, compiled through workshops convened under the Indo-German Biodiversity Programme, has documented the specific constraints farmers in the region face in adopting tree-based systems, including land-tenure uncertainty, the multi-year gap before tree-crop income materialises, and competition with existing food-crop area on already marginal holdings (Indo-German Biodiversity Programme, n.d.). Taken together, this literature suggests that technical solutions for land and water restoration in Bundelkhand are reasonably well understood in principle; the harder,less-documented question is one of adoption and scale- why interventions that work at the pilot or watershed level have not yet propagated across the wider region. Collectively, this body of literature establishes a reasonably detailed picture of Bundelkhand's floral and faunal diversity and its principal ecological stressors, but it remains fragmented across single-district or single-species studies; a synthesised, region-wide reading - which this paper attempts - has been comparatively less common. Much of the available literature is also skewed toward either the ecological (species counts, forest-type descriptions) or the socio-hydrological (drought, governance, water access) dimension, with comparatively few studies attempting to connect the two directly. This review treats that connection as central rather than incidental, on the premise that biodiversity outcomes in a landscape like Bundelkhand cannot be fully understood without also accounting for who controls access to the land and water that sustains it.

3. OBJECTIVES OF THE STUDY

- To synthesise the existing scientific literature on the floral, faunal and freshwater fish diversity of the Bundelkhand region.

- To identify and categorise the principal anthropogenic and climatic drivers of biodiversity loss across the region.
- To critically review ongoing government and community-led conservation and drought-mitigation interventions.
- To propose an integrated, locally grounded framework for sustainable biodiversity conservation in Bundelkhand.

4. METHODOLOGY

This study follows a descriptive-analytical review design rather than primary field sampling. Secondary data were compiled from peer-reviewed floristic and faunal studies, government drought-assessment and watershed-policy documents, and land-use/land-cover change literature specific to the Bundelkhand districts, identified through targeted literature and database searches covering both the Uttar Pradesh and Madhya Pradesh portions of the region. Sources were screened for direct relevance to Bundelkhand rather than central India in general, and preference was given, where available, to district-level or reserve-level studies over broader regional summaries, since these offered the more precise figures needed for the comparative tables presented in Section 5.

Material was organised thematically- floral and faunal diversity, ecological threats, and conservation response - rather than chronologically, in order to construct a composite present-day profile of the region's ecological status rather than a historical timeline of individual studies. Where quantitative figures from different sources could be cross-checked, such as district-wise fish-species counts, they have been consolidated into tabular form (Tables 1 and 2) to aid comparison and to make patterns across districts easier to read than they would be in narrative form alone. Given the review nature of this study, no statistical testing was performed on the compiled figures; they are presented and interpreted descriptively. Limitations arising from this secondary-source approach, including uneven currency and coverage of the underlying data, are discussed in Section 5.8.

5. RESULTS AND DISCUSSION

5.1 Floral Diversity

Consolidated floristic records place Bundelkhand's tree diversity at around 159 recorded species in the Uttar Pradesh districts alone, a figure that has grown through repeated re-survey rather than remaining static (district flora studies of Bundelkhand, Uttar Pradesh, n.d.). Herbaceous diversity shows a comparable depth, with the family Asteraceae alone contributing close to a hundred species across more than fifty genera - a richness that is somewhat unexpected given how physically demanding the region's growing conditions are, and one that underlines how much taxonomic documentation still depends on continued field survey rather than being a

settled inventory. From a livelihood standpoint, the more consequential diversity is arguably ethnobotanical rather than purely taxonomic: neem (Azadirachta indica), babul (Acacia nilotica), tendu (Diospyros melanoxylon), khair (Acacia catechu) and mahua (Madhuca longifolia) function as active components of rural healthcare, income and diet across the region, which means their conservation status is tied as much to household economics as to forest policy (Bundelkhand Wildlife Nature & Conservation Society, n.d.). Tendu leaf collection in particular supports seasonal wage income for a substantial share of the forest-fringe population in districts such as Chhatarpur, Damoh and Panna, which creates a direct, practical link between the health of the standing forest and rural household economics that conservation planning cannot treat as a secondary consideration.

5.2 Faunal and Fish Diversity

Freshwater biodiversity provides the clearest quantitative picture available for the region. Around 93 fish species spread across six orders and eighteen families have been documented in Bundelkhand's reservoirs and rivers (Niranjan et al., 2023). District-wise richness, however, drops off sharply moving from the southern Madhya Pradesh districts toward the drier north, as Table 1 shows.

Table 1: District-wise recorded fish species richness in the Bundelkhand region

District	Approx. recorded fish species	Relative rank in region
Damoh	66	1st (highest)
Panna	50	2nd
Lalitpur	27	3rd (tie)
Chhatarpur	27	3rd (tie)
Sagar	21	5th
Jhansi	19	6th (lowest of those reported)

Terrestrial wildlife follows a similar geography of concentration. Chital, nilgai, jackal and fox occur across most open scrub country, and the bird community includes peafowl, parakeets and several raptor and owl species wherever tree cover persists; leopards and sloth bears, being more habitat-sensitive, are largely confined to the region's better-protected forest blocks, principally in and around Panna.

5.3 Panna Tiger Reserve: A Conservation Case Study

Panna Tiger Reserve, straddling Panna and Chhatarpur districts along the northern Vindhyan range, was notified as a national park in 1981 and incorporated into Project Tiger as India's twenty-second tiger reserve in 1994. Poaching pressure through the 1990s and early 2000s resulted in the complete local extinction of its resident tiger population- not merely a decline. Recovery involved several interventions proceeding in parallel: radio-collared tiger translocation, prey-base rebuilding, consent-based resettlement of core-zone villages, and strengthened anti-poaching capacity (Dutta et al., 2024). By 2020, UNESCO's designation of Panna as a Biosphere Reserve formalised more than a decade of field evidence that local extinction of a large carnivore is reversible given sustained institutional commitment and genuine community cooperation. Even so, land-use change around relocated village sites continues to generate periodic human-wildlife friction at the reserve's periphery (Anthropogenic threats and conservation practices, 2023). What distinguishes the Panna case from many other tiger-recovery narratives elsewhere in India is the sequencing of interventions: prey-base restoration was allowed to precede large-scale tiger translocation rather than the two proceeding simultaneously, which appears to have reduced early predation pressure on an already depleted herbivore population and given the reintroduced tigers a more stable food base from the outset. This sequencing detail, while easy to overlook in summary accounts of the reserve's recovery, may be one of the more transferable lessons for any future attempt to replicate the Panna model elsewhere in the region.

5.4 Ecological Threats and Drivers of Biodiversity Loss

The pressures acting on Bundelkhand's ecology rarely operate independently. A poor monsoon year typically intensifies groundwater extraction, which in turn accelerates degradation of forest patches already under grazing stress. Table 2 summarises the principal threat factors identified in this review alongside their observed effects and the districts most affected.

Table 2: Principal ecological threats in the Bundelkhand region

Threat factor	Observed effect	Districts most affected
Rainfall deficit / drought	Dried tanks, crop failure, groundwater stress	Datia, Tikamgarh, Jhansi, Jalaun
Forest degradation	Canopy loss, scrub conversion	Datia, Tikamgarh, UP plain districts
Sand mining / encroachment	River-bed damage, tank siltation	Banda, Chitrakoot, Hamirpur
Groundwater overextraction	Falling water table, dried dug-wells	Across most districts

Threat factor	Observed effect	Districts most affected
Human–wildlife conflict	Crop loss, livestock predation near reserves	Panna, Chhatarpur (reserve periphery)

Rainfall deficits reaching 45-56 per cent in successive years during the mid-2000s dried traditional tanks such as Madan Sagar and disabled structures like the Urmil dam (National Rainfed Area Authority, n.d.). An estimated 50-65 per cent of remaining forest in parts of the region has thinned to open or scrub condition with canopy below 40 per cent, driven by fuelwood collection, grazing and slow encroachment rather than any single clearing event. Uncontrolled borewell drilling, combined with sand mining and encroachment on rivers and tanks, has depleted both surface and groundwater reserves, with drought recurrence in parts of the region now estimated at roughly once every eight years (Managing the water crisis in Bundelkhand, India: A governance approach, n.d.). Field accounts of who actually controls local water sources point to caste and social standing still shaping who reaches a working tank or handpump first, so the underlying shortage and the uneven way it gets shared out are best read as two separate problems rather than one (The Analysis, 2024).

These threats also differ in how reversible they are, which has direct implications for prioritisation. Rainfall deficit is largely outside local control and can only be managed through storage and recharge infrastructure rather than prevented outright. Forest thinning and land degradation, by contrast, are substantially reversible over a five-to-ten-year horizon given sustained protection and restoration effort, as Panna's own forest-recovery trajectory alongside its tiger recovery suggests. Sand mining and tank encroachment sit somewhere between the two: technically straightforward to halt through enforcement, but persistently difficult in practice because the economic incentives driving illegal extraction remain largely unaddressed by current policy. Treating all six threat factors in Table 2 as equally tractable would therefore misallocate limited conservation resources; a more realistic strategy distinguishes between pressures that require long-term infrastructure investment, those that respond to medium-term restoration effort, and those that are primarily an enforcement and governance problem.

5.5 Conservation and Restoration Interventions

In response to the severe 2003-2010 drought period, the Government of India approved the Bundelkhand Drought Mitigation Package in November 2009, with an outlay of approximately Rs 7,266 crore, later supplemented by about Rs 200 crore for drinking-water projects. The package prioritised participatory watershed management- reviving dug wells, repairing historic Bundela-, Chandela- and Peshwa-era tanks, and constructing farm ponds and check dams - over large new infrastructure, and continued through the Twelfth Plan period under the Backward

Regions Grant Fund (TERI, n.d.). Its design reflected a reasonable diagnosis of the problem, since it treated the revival of small, distributed water bodies as more valuable than a single large project; the harder question, and one the available literature engages with less directly, is how consistently that outlay translated into structures that were actually maintained in subsequent years rather than repaired once and then left to silt up again.

Community-driven initiatives in districts such as Banda and Chitrakoot have separately demonstrated that local vigilance against river and tank encroachment can hold ground even where formal enforcement is limited, while larger civil-society-led aquifer rejuvenation projects have reported measurable improvements in groundwater availability for participating farmers. These smaller, community-anchored efforts share a common feature that distinguishes them from the larger government package: they tend to combine technical watershed design with a maintenance mechanism rooted in the community that benefits directly, which appears to reduce the risk of structures falling into disrepair once initial funding or attention moves elsewhere. Agroforestry has increasingly been treated as a priority intervention given that much of the region's degradation traces to land-use choices rather than rainfall alone; multi-stakeholder workshops convened under regional cooperation programmes have examined the practical constraints of integrating tree-based systems into existing cropping patterns, including land-tenure security and the multi-year gap before tree-based income materialises for smallholder farmers (Indo-German Biodiversity Programme, n.d.). Panna's integrated recovery model-habitat revival, rebuilding the prey base, resettlement carried out with village consent, tighter anti-poaching patrolling and sustained village-level involvement, all run as one coordinated effort rather than separate steps - remains the clearest conservation template the region has produced, and its Biosphere Reserve status provides an institutional basis for extending similar approaches along other corridors, most plausibly the Ken-Betwa river system, where the constraint is less the ecological quality of individual forest fragments than the lack of functional connectivity between them.

5.6 Climate Outlook and Long-Term Risk

Beyond the historical drought record already discussed, the trajectory of rainfall variability in Bundelkhand matters as much as its past pattern. Drought recurrence intervals that have tightened from roughly once a decade to closer to once every eight years point toward a system with progressively less buffer between stress events, leaving less time for tanks, aquifers and forest patches to recover before the next deficit year arrives (Managing the water crisis in Bundelkhand, India: A governance approach, n.d.). This compressed recovery window has direct biodiversity implications: forest regeneration and fish-population recovery in reservoirs both require multi-year windows of adequate water availability, and a shortened return period between droughts risks locking parts of the region into a state of chronic ecological stress rather

than the episodic stress it has historically experienced. Any conservation strategy for the region therefore needs to plan for a drier and more volatile baseline going forward rather than treating recent droughts as anomalies against a stable historical norm.

5.7 Recommendations for an Integrated Conservation Strategy

Read together, the evidence assembled in this review resists a purely climatic explanation for Bundelkhand's ecological stress. Rainfall variability sets the baseline difficulty, but land-use change, uneven enforcement of resource-use rules, and unequal access to whatever water and forest remain do much of the remaining damage - and these are governance problems as much as ecological ones. Relief packages timed to drought years address the symptom but not the underlying pattern of resource use that makes each subsequent drought more damaging than the last. The following priorities follow from that reading:

- Scale up participatory watershed repair- reviving traditional tanks and farm ponds - with priority given to catchments that feed both degraded forest and the most drought-exposed farmland, rather than spreading effort evenly across the region.
- Direct agroforestry and silvipasture programmes specifically toward degraded and marginal land, where they compete least with existing food-crop area and do the most to rebuild soil health and diversify income simultaneously.
- Tighten enforcement against illegal sand mining and river or tank encroachment, backed by community-based monitoring rather than formal enforcement alone, since local vigilance has already shown it can hold ground where administrative capacity is thin.
- Extend Panna's integrated recovery model beyond its own boundary to other degraded forest patches and corridors, with the Ken-Betwariver link as the most immediate candidate given existing connectivity gaps.
- Establish long-term ecological monitoring stations, since much of the current baseline - fish counts, tree surveys, forest-cover assessment- remains scattered across district-specific, one-off studies rather than a continuous, comparable dataset.
- Build explicit equity safeguards into water and forest governance, rather than assuming scarcity-relief automatically reaches marginal and lower-caste farming communities without deliberate design.

5.8 Limitations of the Review

This review relies on published secondary sources rather than original field sampling, and the underlying evidence base is unevenly distributed: fish diversity is comparatively well documented at district level, while faunal and avian diversity outside Panna is described mostly in general terms. Several of the cited surveys are more than a few years old, and given the pace of land-use change in the region, present-day figures may differ from those reported here.

Readers are advised to treat the quantitative figures cited as indicative of scale and pattern rather than a precise, current census.

6. CONCLUSION

Bundelkhand does not fit neatly into either a 'biodiversity hotspot' or an 'ecological wasteland' framing; it is a working landscape carrying real, if unevenly documented, biological value while absorbing sustained pressure from drought, forest thinning, land degradation and inequitable resource governance. Panna's recovery demonstrates that this trajectory is not fixed, and that sustained, well-designed intervention can rebuild a locally extinct large-carnivore population within a couple of decades. Extending that lesson beyond a single reserve will require watershed repair, agroforestry, corridor-level protection and equitable governance to be pursued together rather than as separate line items, supported by the kind of continuous ecological monitoring the region currently lacks.

For the region's Madhya Pradesh districts in particular- Chhatarpur, Damoh, Panna and Sagar - whereforest cover remains comparatively higher than in the Uttar Pradesh portion of Bundelkhand, the priority is arguably one of consolidation rather than reconstruction: protecting what forest and water infrastructure already function reasonably well, before degradation reaches the more advanced stage already visible in districts such as Datia and Tikamgarh. Future field-based research, particularly systematic long-term biodiversity monitoring across districts and closer integration between ecological and social-governance data, would meaningfully strengthen the evidence base this review has drawn upon and would help convert the general priorities identified here into district-specific action.

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