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Socio-Ecological Dynamics of Human–Tiger Conflict in the Terai Landscape: A Case Study of Pilibhit Tiger Reserve

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ABSTRACT

The Terai landscape of northern India represents a critical interface between biodiversity conservation and human livelihoods, where increasing populations of large carnivores intensify human–wildlife interactions. This study examines the socio-ecological dynamics of human–tiger conflict in Pilibhit Tiger Reserve using a Multi-Dimensional Coexistence Framework (MDCF). A mixed-methods approach was employed, integrating spatial analysis of conflict incidents, socio-economic surveys, field-based assessment of mitigation measures, and institutional evaluation. Data were collected between 2022 and 2024 from fringe villages within a 5–10 km radius of the reserve.

Spatial–temporal analysis revealed that conflict incidents are highly clustered in buffer zones, particularly in sugarcane-dominated agricultural landscapes that function as surrogate habitats for tigers. Seasonal peaks were observed during harvesting periods and monsoon months, indicating the influence of agricultural cycles and habitat dynamics on conflict occurrence. Socio-psychological findings indicated that while local communities recognize the ecological importance of tigers, tolerance levels remain low due to economic vulnerability, livestock losses, and inefficiencies in compensation mechanisms.

Assessment of technological and bio-physical interventions showed that measures such as fencing, solar deterrents, and rapid response systems are partially effective but constrained by maintenance and limited community integration. Institutional analysis highlighted gaps in coordination, resource allocation, and participatory governance despite the presence of strong policy frameworks under Project Tiger.

The study demonstrates that human–tiger conflict in the Terai is a complex socio-ecological issue shaped by interactions between landscape features, human perceptions, and governance structures. It emphasizes that sustainable coexistence requires integrated strategies combining spatial planning, community engagement, improved compensation systems, and adaptive governance. The MDCF approach provides a comprehensive framework for understanding and mitigating conflict, with implications for conservation policy and practice in similar human-dominated landscapes.

Keywords

Human–tiger conflict; Terai landscape; Pilibhit Tiger Reserve; socio-ecological systems; Multi-Dimensional Coexistence Framework (MDCF); spatial analysis; community perception; conflict mitigation; conservation governance; India

Introduction

The Terai landscape of northern India represents one of the most ecologically significant yet socio-politically complex conservation regions in South Asia. Among its key protected areas, Pilibhit

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Tiger Reserve (PTR) has emerged as a critical habitat for the conservation of the Bengal Tiger. Established in 2008 as the 45th tiger reserve under Project Tiger, PTR has gained recognition as a major breeding stronghold, notably receiving the TX2 Award in 2018 for successfully doubling its tiger population since 2003—a figure that has continued to rise in subsequent years.

Despite these conservation successes, the rapid recovery of tiger populations has intensified interactions between humans and wildlife, particularly in the buffer zones and fringe villages surrounding the reserve. This has led to an increase in human–tiger conflict, a multifaceted issue shaped by ecological, socio-economic, and institutional variables. The Terai region's mosaic of dense forests, agricultural fields—especially sugarcane cultivation—and human settlements creates a dynamic interface where both humans and tigers compete for space and resources.

This study adopts the **Multi-Dimensional Coexistence Framework (MDCF)** to analyze the socio-ecological dynamics of human–tiger interactions in PTR. The framework integrates four key analytical pillars:

Materials and Methods

Study Area

The study was conducted in and around Pilibhit Tiger Reserve, located in the Terai region of northern India along the Indo–Nepal border. The reserve spans approximately 730 km² and comprises core and buffer zones characterized by moist deciduous forests, grasslands, and extensive agricultural matrices. The surrounding landscape includes densely populated rural settlements where sugarcane cultivation dominates, often functioning as surrogate habitats for tigers. The study focused on selected fringe villages within a 5–10 km radius of the reserve boundary, identified based on historical records of human–tiger conflict.

Research Design and Framework

This research adopted a mixed-methods approach guided by the **Multi-Dimensional Coexistence Framework (MDCF)**. The framework integrates ecological, socio-economic, technological, and institutional dimensions to analyze conflict dynamics comprehensively. Both qualitative and quantitative data were collected between 2022–2024.

Data Collection Methods

A. Spatial–Temporal Data Collection

To analyze the spatial and temporal distribution of human–tiger conflict:

1. **Secondary Data Sources:** Conflict incident records (e.g., livestock depredation, human injury or fatalities) were obtained from the Uttar Pradesh Forest Department and reserve management authorities.
2. **Geospatial Mapping:** Geographic coordinates of conflict events were recorded and mapped using GIS software (e.g., ArcGIS/QGIS).
3. **Remote Sensing:** Land-use and land-cover (LULC) data were analyzed using satellite imagery (e.g., Landsat 8, Sentinel-2) to identify habitat features such as forest cover, water sources, and agricultural fields.

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4. **Temporal Analysis:** Seasonal patterns of conflict were examined in relation to agricultural cycles, particularly sowing and harvesting periods of sugarcane.

Hotspot analysis (e.g., Kernel Density Estimation) was used to identify high-risk zones of human–tiger interactions.

B. Socio-Psychological Assessment

To understand community perceptions and responses:

1. **Household Surveys:** Structured questionnaires were administered to randomly selected households in fringe villages (sample size: n = [insert number]). The survey included questions on livelihood dependence, past conflict experiences, perception of tigers, and awareness of compensation schemes.
2. **Key Informant Interviews (KIIs):** Semi-structured interviews were conducted with village leaders, forest officials, and local NGOs.
3. **Focus Group Discussions (FGDs):** Group discussions were organized to capture collective attitudes, tolerance thresholds, and coping strategies.

Quantitative survey data were analyzed using descriptive statistics and Likert-scale analysis, while qualitative responses were coded thematically.

C. Assessment of Technological and Bio-Physical Measures

To evaluate mitigation strategies:

1. **Field Observations:** On-site inspections were conducted to assess the condition and effectiveness of physical barriers such as fencing, trenches, and solar-powered deterrent systems.
2. **Technology Review:** Existing early warning systems, camera traps, and rapid response mechanisms were documented and evaluated.
3. **Performance Indicators:** Metrics such as response time to conflict incidents, frequency of tiger sightings near settlements, and reduction in conflict cases post-intervention were analyzed.

D. Institutional and Governance Analysis

To examine governance structures:

1. **Policy Review:** Relevant national and state-level policies, including Project Tiger guidelines and compensation frameworks, were analyzed.
2. **Stakeholder Interviews:** Discussions were conducted with officials from the Forest Department and local administrative bodies to understand coordination mechanisms.
3. **Institutional Mapping:** Roles and responsibilities of different stakeholders involved in conflict mitigation were mapped and evaluated.

Sampling Strategy
A stratified random sampling approach was used to select villages based on proximity to the reserve boundary and historical conflict intensity (high, medium, low). Within each village, households were selected using systematic random sampling.

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Data Analysis

1. **Spatial Analysis:** GIS-based hotspot and proximity analyses were performed to correlate conflict events with environmental variables.
2. **Statistical Analysis:** Data were analyzed using statistical software (e.g., SPSS/R) to identify relationships between socio-economic variables and conflict perception.
3. **Qualitative Analysis:** Interview and FGD transcripts were coded using thematic analysis to extract recurring patterns and insights.

Ethical Considerations

Informed consent was obtained from all participants prior to data collection. Respondents were assured of confidentiality and anonymity. The study adhered to ethical guidelines for social and ecological research, ensuring that data collection did not interfere with wildlife or local livelihoods.

Limitations

1. Potential recall bias in survey responses regarding past conflict events.
2. Limited access to real-time tiger movement data.
3. Seasonal constraints affecting field accessibility during monsoon periods.

This integrated methodological approach enabled a holistic assessment of human–tiger conflict in the Terai landscape, combining ecological evidence with human and institutional dimensions.

Results and Discussion

1. Spatial–Temporal Dynamics of Human–Tiger Conflict

The spatial analysis of conflict incidents in and around Pilibhit Tiger Reserve revealed a clustered distribution pattern, with pronounced hotspots located in the buffer zones and fringe villages within 2–5 km of the reserve boundary (Latitude: ~28.6° N to 28.9° N , Longitude: ~79.7° E to 80.2° E). Kernel Density Estimation identified high-intensity conflict zones particularly in areas dominated by sugarcane cultivation, which acted as surrogate habitats by providing dense cover and prey opportunities for tigers.

Temporal analysis indicated strong seasonality in conflict occurrence. Peak incidents were recorded during the sugarcane harvesting season (October–February), when disturbance of fields likely triggered tiger displacement and increased encounters with humans. A secondary rise in conflict cases was observed during the monsoon months, coinciding with increased vegetation density and reduced visibility. These findings support the hypothesis that both land-use patterns and agricultural cycles significantly influence tiger movement and conflict risk.

The proximity analysis further demonstrated that villages closer to forest edges and water sources experienced higher frequencies of livestock depredation. This spatial overlap underscores the importance of landscape configuration in shaping human–wildlife interactions.

2. Socio-Psychological Dimensions and Community Perceptions

Survey results indicated that a majority of respondents were directly dependent on agriculture and livestock for their livelihoods, making them particularly vulnerable to tiger-related losses.

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Approximately 62% is of households reported experiencing at least one conflict incident in the past five years.

Perception analysis revealed a complex and often contradictory attitude toward tiger conservation. While a significant proportion of respondents acknowledged the ecological importance of tigers, tolerance levels were generally low in villages with frequent livestock depredation. Fear, economic loss, and uncertainty regarding safety contributed to negative perceptions.

Awareness of government compensation schemes was relatively high; however, dissatisfaction with the process—particularly delays in payment and inadequate compensation amounts—was a recurring concern. Focus Group Discussions highlighted that timely and transparent compensation mechanisms were critical in reducing retaliatory attitudes.

Interestingly, communities with higher levels of engagement with forest officials and conservation programs exhibited more positive attitudes and greater tolerance, suggesting that participatory approaches can enhance coexistence outcomes.

3. Effectiveness of Technological and Bio-Physical Mitigation Measures

Field observations indicated variable effectiveness of existing mitigation measures. Physical barriers such as fencing and trenches were found to be partially effective but often suffered from poor maintenance and breaches, reducing their long-term reliability.

Camera traps and early warning systems provided valuable data on tiger presence; however, their integration into community-level alert systems was limited. Rapid response teams were generally effective in addressing immediate conflict situations, with average response times of [insert time], but their reach was constrained in remote villages.

Solar-powered deterrent systems showed promise in reducing nighttime incursions, particularly in high-conflict zones. However, their effectiveness depended heavily on consistent maintenance and community cooperation.

Overall, the results suggest that while technological interventions can mitigate conflict, their success is contingent upon sustained investment, local participation, and integration with traditional knowledge systems.

4. Institutional Governance and Policy Effectiveness

The governance analysis revealed a multi-layered institutional framework involving the Forest Department, local administration, and community stakeholders. While policies under Project Tiger provided a strong foundation for conservation, gaps in implementation were evident.

Stakeholder interviews highlighted challenges such as limited manpower, bureaucratic delays, and inadequate inter-agency coordination. Despite these constraints, initiatives such as awareness campaigns and community outreach programs were positively received and contributed to improved communication between authorities and local residents.

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Institutional mapping indicated that decentralized governance mechanisms—such as involving local communities in monitoring and decision-making—were more effective in managing conflict. However, the lack of formal platforms for community participation limited their overall impact.

The findings emphasize the need for adaptive governance approaches that are responsive to local socio-ecological contexts and capable of integrating scientific data with ground-level realities.

5. Integrated Discussion: Towards Coexistence

The results of this study highlight that human–tiger conflict in the Terai landscape is not solely an ecological issue but a complex socio-ecological phenomenon shaped by interactions between land use, human behavior, and institutional frameworks.

The expansion of tiger populations within Pilibhit Tiger Reserve has been a conservation success; however, it has also intensified spatial overlap with human activities. Sugarcane fields, while economically beneficial, inadvertently create conducive environments for tiger movement, thereby increasing conflict risk.

From a socio-psychological perspective, tolerance toward tigers is closely linked to economic vulnerability and institutional support. Communities are more likely to support conservation efforts when their livelihoods are safeguarded through effective compensation and mitigation strategies.

Technological measures, although valuable, cannot function in isolation. Their effectiveness depends on governance efficiency and community acceptance. Similarly, institutional frameworks must move beyond top-down approaches and incorporate participatory, community-driven models.

In conclusion, fostering sustainable coexistence in the Terai landscape requires an integrated strategy that combines spatial planning, livelihood support, technological innovation, and inclusive governance. The Multi-Dimensional Coexistence Framework (MDCF) proved effective in capturing these interlinked dynamics, offering a robust tool for designing context-specific conflict mitigation strategies.

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