International Journal of
Human Computations & Intelligence
Vol. 04, Issue. 05, 2025
RESEARCH ARTICLE OPEN ACCESS

Spatial-Computational Assessment of Land-Use Strategies Impacting Wildlife and Infrastructure in Dooars Region

Dipayan Samanta[1] . Rabin Kumar Mullick[2] . Rakesh Kumar Mandal[2] . Priyankar Sanphui[3]

[1]Sukanta Mahavidyalaya, Dhupguri, West Bengal, India
[2]University of North Bengal, Darjeeling, West Bengal, India
[3]Sree Chaitanya College, Habra, West Bengal State University, India

DOI: **10.5281/zenodo.17044345**
Received: 2 August 2025 / Revised: 29 August 2025 / Accepted: 2 September 2025
©Milestone Research Publications, Part of CLOCKSS archiving

Abstract — The Indian Dooars region, an ecologically rich zone at the Himalayan foothills, is a mosaic of forests, grasslands, riverine systems, and human-modified landscapes. This area is a vital corridor for megafauna such as the Indian rhinoceros (Rhinoceros unicornis), Asian elephant (Elephas maximus), and Bengal tiger (Panthera tigris tigris), yet faces unprecedented pressures from agricultural expansion, infrastructural development, and tourism. This paper presents a computational framework for assessing the effectiveness of land-use policies designed to mitigate the economic and infrastructural impacts on wildlife in the Dooars. Integrating Geographic Information Systems (GIS), multi-criteria decision-making (MCDM) approaches, graph-theoretic connectivity models, and predictive conflict mapping, the proposed framework enables policymakers to evaluate policy alternatives before implementation. The methodology is designed to quantify ecological, socio-economic, and infrastructural outcomes in a spatially explicit manner, ensuring that conservation and development objectives can be pursued in tandem. This study focuses on policies such as Joint Forest Management (JFM), Eco-Sensitive Zone (ESZ) delineation, and eco-tourism regulations, exploring their potential to enhance habitat connectivity, reduce human-wildlife conflict, and promote sustainable livelihoods. The analysis emphasizes participatory governance, adaptive policy-making, and the integration of computational insights into real-world decision-making processes.

Index Terms — Computation, intelligence systems, graph-theoretic, computer-vision, wildlife

I. INTRODUCTION

The Dooars, stretching across the northern part of West Bengal and adjoining Assam, occupies a unique ecological niche as a transition zone between the Himalayas and the Gangetic plains. This region forms part

MILESTONE
RESEARCH.IN
OPEN ACCESS

ISSN (Online): 2583-5696
Int. Jr. of Hum Comp. & Int.

of the Terai-Duar savanna and grassland ecoregion, characterized by fertile alluvial soils, a humid subtropical climate, and high biodiversity (WWF India). The name “Dooars” derives from the word “doors,” referencing the numerous passes into Bhutan, highlighting its historical and geographical significance. Ecologically, the Dooars serves as a critical link in the network of protected areas that span northeastern India, Bhutan, and Nepal. It supports flagship species such as the Indian rhinoceros, Asian elephant, and Bengal tiger, along with diverse avifauna and herpetofauna. The river systems of the Teesta, Jaldhaka, and Torsha nourish its grasslands and forests, making it a hotspot for both wildlife and human settlement.

However, the region is under increasing pressure from anthropogenic activities. The expansion of tea plantations, infrastructural projects like highways and railways, and unregulated tourism have intensified habitat fragmentation. Elephants face heightened mortality risks from train collisions, while agricultural encroachment leads to frequent crop-raiding incidents. These pressures create a dual challenge: maintaining ecological integrity while supporting the livelihoods of local communities. Land-use policies have emerged as a primary tool to address this challenge. Initiatives such as Joint Forest Management (JFM), Eco-Sensitive Zones (ESZs), and eco-tourism regulations aim to balance conservation objectives with economic development. Yet, evaluating the real-world effectiveness of these policies requires robust, data-driven methodologies that can account for ecological complexity, socio-economic trade-offs, and spatial heterogeneity.

Computational approaches offer significant promise in this context. Geographic Information Systems (GIS) can integrate ecological, infrastructural, and socio-economic datasets; Multi-Criteria Decision-Making (MCDM) techniques can prioritize land-use allocations; graph theory can model habitat connectivity; and predictive analytics can forecast human-wildlife conflict zones. When combined, these tools enable a comprehensive assessment of policy impacts before implementation.

The objectives of this study are threefold:

1. To analyze how current and proposed land-use policies affect habitat connectivity and wildlife movement in the Dooars.
2. To evaluate the socio-economic and infrastructural trade-offs inherent in these policies.

To develop a computational assessment framework that can guide adaptive, evidence-based policy-making in ecologically sensitive regions. The conceptual land use and wildlife corridor map for the Dooars region has been shown in Fig. 1.

II. BACKGROUND & CONTEXT

A. Land-Use Policies in the Dooars

Joint Forest Management (JFM). Introduced in India in the late 1980s, JFM is a participatory forest management approach where local communities are given usufruct rights in exchange for their involvement in forest protection [1]. In the Dooars, recent revisions have expanded benefits to include a 15% share of timber revenue and 25% from forest thinning operations. While this has incentivized community participation, it also raises concerns over long-term forest resource sustainability. Protected Areas and Tiger Reserves. The Buxa Tiger Reserve, declared in 1982–83, exemplifies the state’s efforts to safeguard critical habitats. However, enforcement often conflicts with traditional rights of forest-dependent communities, leading to tensions [2]. Striking a balance between biodiversity protection and community rights remains an ongoing policy challenge.

Eco-Sensitive Zones (ESZs). ESZs function as regulatory buffers around protected areas, restricting certain types of development to minimize ecological damage (MoEFCC). In the Dooars, their delineation is complicated by fragmented forest patches interspersed with settlements and tea gardens. Adaptive ESZ zoning, tailored to local land-use patterns, has been suggested as a more effective approach [3]. Eco-Tourism and Smart Infrastructure. The growth of eco-tourism in the Dooars, particularly near Gorumara and Jaldapara National Parks, has generated both economic opportunities and environmental concerns. The adoption of smart infrastructure—solar-powered facilities, e-rickshaws, and ICT-based visitor management—offers pathways to reduce ecological footprints, though poorly planned projects risk fragmenting habitats [4].

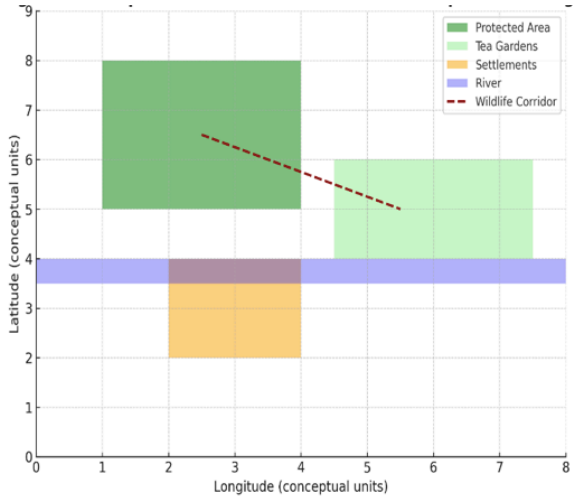

Fig. 1. Conceptual Land Use and Wildlife Corridor Map for the Dooars Region.

B. *Challenges to Wildlife and Communities*

The primary ecological challenge is habitat fragmentation, which disrupts the movement of wide-ranging species like elephants. Infrastructure such as railways not only fragments habitat but also poses direct mortality risks. For example, train-elephant collisions have been a recurring problem along key migration routes [5]. From a socio-economic standpoint, communities face losses from crop depredation and property damage caused by wildlife. Inadequate compensation schemes and delayed payments exacerbate tensions. Moreover, conservation regulations sometimes restrict access to forest resources, which can disproportionately affect marginalized groups dependent on forest-based livelihoods [6]. These intertwined ecological and social challenges necessitate policies that are spatially nuanced, economically viable, and ecologically sound—an intersection where computational assessments can be most impactful.

III. COMPUTATIONAL TECHNIQUES FOR ASSESSMENT

A. *GIS-Based Multi-Criteria Decision-Making (MCDM)*

GIS enables the integration of multiple datasets—land cover, species distribution, infrastructure, socio-economic indicators—into a spatial framework. When combined with MCDM techniques such as the Analytic Hierarchy Process (AHP) and Technique for Order of Preference by Similarity to Ideal Solution (TOPSIS), it becomes possible to prioritize zones for conservation, eco-tourism, or infrastructure placement [7]. Weighting schemes like CRITIC and entropy weighting can enhance objectivity in the decision-making process.

B. Graph Theory and Corridor Modeling

In graph-theoretic models, habitat patches are represented as nodes and potential movement pathways as edges, with weights assigned based on resistance to movement. Algorithms such as Kruskal's Minimum Spanning Tree help identify optimal corridors, while centrality measures highlight critical habitat nodes for protection [8].

C. Conflict Prediction Models

Predictive analytics can be applied to historical human-wildlife conflict data to forecast future hotspots. Features like land-use type, proximity to water bodies, and crop patterns serve as predictors. Even with sparse datasets, feature selection methods can improve model performance, enabling targeted interventions [9].

D. Geospatial Conservation Prioritization

Conservation prioritization frameworks divide the landscape into grid cells, each evaluated for biodiversity value and disturbance levels. This approach has been successfully adapted from mountainous to lowland regions, and could identify high-priority restoration areas in the Dooars [10]. The computational assessment workflow for land-use policy evaluation has been shown in Fig. 2.

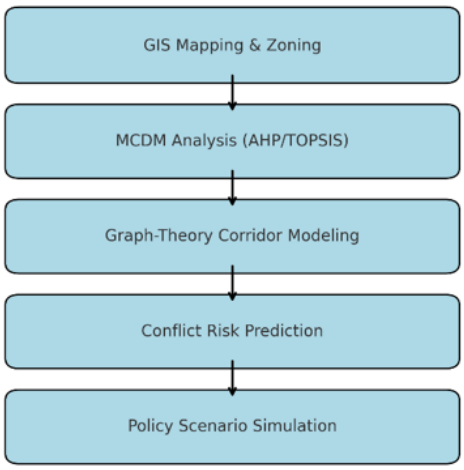

Fig. 2. Computational Assessment Workflow for Land-Use Policy Evaluation.

IV. PROPOSED METHODOLOGICAL FRAMEWORK

The framework consists of seven interlinked components:

- **Study Area Definition** — Selecting representative zones within the Dooars based on habitat diversity and conflict prevalence.
- **Data Acquisition** — Integrating remote sensing imagery, species movement data, socio-economic surveys, and infrastructure maps.
- **Mapping and Zoning** — GIS-based delineation of ecological, economic, and infrastructural features.

- **MCDM Analysis** — Ranking zones for various land-use priorities using weighted criteria. The Multi-Criteria Decision-Making process for eco-tourism suitability analysis has been shown in Fig. 3.
- **Graph-Theoretic Modeling** — Identifying and optimizing wildlife corridors.
- **Conflict Risk Modeling** — Predicting potential human-wildlife conflict zones.
- **Policy Scenario Simulation** — Testing alternative land-use policies for ecological, economic, and infrastructural outcomes.

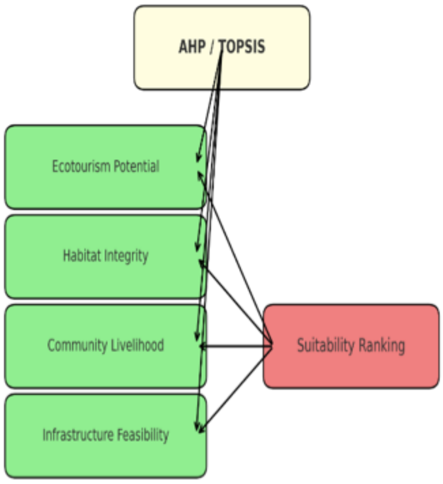

Fig. 3. Multi-Criteria Decision-Making Process for Eco-Tourism Suitability Analysis.

V. CASE STUDY APPLICATION (METHODOLOGICAL PILOT)

A. Pilot Scenario Selection

To demonstrate the application of the proposed computational assessment framework, a pilot study area within the Eastern Dooars is conceptually defined. This area encompasses portions of the Gorumara–Chapramari landscape and adjacent tea garden belts. The selection criteria include: (a) high biodiversity value, (b) known elephant and rhino movement corridors, (c) proximity to human settlements and agricultural land, and (d) existing or proposed infrastructure projects such as railway lines and tourism facilities. This zone is representative of the broader challenges in the Dooars, combining protected areas, buffer zones, community forests, and production landscapes. It is also a hotspot for human–elephant conflict, making it a prime candidate for policy simulation exercises.

B. Data Layers and Sources

For the pilot, multiple spatial and non-spatial datasets would be required:

- **Remote Sensing Data**: High-resolution satellite imagery for land-cover classification (e.g., Sentinel-2, Landsat 8).
- **Wildlife Occurrence and Movement Data**: GPS telemetry data (if available), camera trap records, and field survey data from the Forest Department and NGOs.

- **Socio-Economic Data**: Census data, household surveys on livelihoods, income sources, and perceptions of wildlife.
- **Infrastructure Data**: Locations of railway tracks, roads, settlements, tourism facilities, and agricultural areas.
- **Conflict Records**: Historical data on human–wildlife conflict incidents, including crop depredation, property damage, and human injuries/fatalities.

C. Step-by-Step Methodological Application

Step 1: Mapping and Zoning. GIS analysis would be conducted to map existing land-use types, habitat patches, settlement clusters, and infrastructure corridors.

Step 2: MCDM Analysis. Using AHP or TOPSIS, different zones would be ranked for their suitability for eco-tourism, conservation, or agricultural expansion. Criteria might include habitat quality, economic potential, connectivity, and risk of human–wildlife conflict.

Step 3: Graph-Theoretic Corridor Modeling. Habitat patches identified in Step 1 would serve as nodes. Resistance values for edges would be derived from land-use type and infrastructure barriers. Corridor optimization would identify routes with the least resistance for wildlife movement.

Step 4: Conflict Risk Prediction. Historical conflict data would be used to train a machine learning model (e.g., Random Forest) to predict high-risk areas under current conditions and alternative policy scenarios.

Step 5: Policy Scenario Simulation. The framework would model scenarios such as:

- Expanding ESZ boundaries around Gorumara NP by 10%.
- Implementing community-based eco-tourism in low-conflict zones.
- Realigning or elevating railway tracks in key corridors.
- Introducing crop-switch programs to reduce attractiveness to elephants.

Step 6: Performance Evaluation. Each scenario would be evaluated against ecological metrics (connectivity index, patch integrity), socio-economic metrics (income diversification, employment generation), and infrastructural metrics (conflict reduction, project cost-effectiveness).

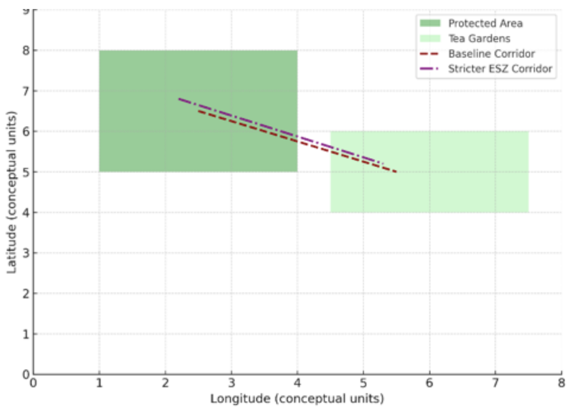

Fig. 4. Policy Scenario Overlay Concept for Corridor Integrity Assessment.

VI. DISCUSSION & POLICY IMPLICATIONS

A. Integration of Computational Insights into Policy

Computational assessments allow policymakers to move beyond reactive decision-making. For example, if modeling shows that a modest shift in ESZ boundaries significantly improves corridor connectivity while affecting only marginal agricultural land, such a policy could be prioritized. Likewise, predictive conflict maps could guide the timing and location of crop protection measures or the deployment of rapid response teams. The policy scenario overlay concept for corridor integrity assessment has been shown in Fig. 4.

B. Economic and Infrastructural Trade-offs

Land-use policy decisions in the Dooars are often influenced by the perceived trade-off between economic development and ecological preservation. However, computational simulations can reveal "win–win" scenarios where economic gains from eco-tourism or sustainable forestry coincide with conservation goals. Conversely, they can also highlight "lose–lose" outcomes where poorly sited infrastructure causes both ecological damage and economic inefficiency [11].

C. Community Engagement and Governance

No computational model can replace the legitimacy derived from community participation. Involving local stakeholders in the modeling process—through participatory GIS or community workshops—can ensure that policy scenarios reflect lived realities. Equitable benefit-sharing mechanisms, such as fair distribution of eco-tourism revenue or transparent allocation of JFM funds, are essential for building long-term community support.

D. Limitations and Future Work

The accuracy of computational assessments depends heavily on the quality and resolution of input data. In many cases, wildlife movement data in the Dooars is incomplete or outdated. Furthermore, socio-economic data may be underreported due to informal economies. Future work should focus on integrating real-time monitoring systems, such as GPS collars and automated camera traps, with dynamic policy simulation tools. Additionally, cross-border cooperation with Bhutan is essential, given the transboundary nature of wildlife corridors.

VII. CONCLUSION

The Dooars region is at a crossroads where rapid economic growth and infrastructural expansion threaten to undermine its globally significant biodiversity. Traditional policy-making, while well-intentioned, often lacks the spatial precision and predictive capacity needed to balance competing demands on the landscape. This paper proposes a computational framework that integrates GIS-based multi-criteria decision-making, graph-theoretic connectivity modeling, and predictive conflict analysis to evaluate the effectiveness of land-use policies in the Dooars. By simulating alternative policy scenarios and quantifying their ecological, economic, and infrastructural impacts, decision-makers can adopt strategies that are both conservation-friendly and development-oriented. The methodology emphasizes adaptability, stakeholder participation, and evidence-based decision-making. While data gaps and implementation challenges remain, the integration of computational insights into policy design offers a promising path toward sustainable coexistence between people and wildlife in the Dooars. Ultimately, the future of this landscape will depend on the willingness of policymakers, conservationists, and communities to collaborate in designing land-use policies that are informed not only by ecological science but also by computational foresight.

REFERENCES

1. Sarker, D. (2015). Joint forest management in West Bengal: A critical analysis. Indian Journal of Forestry, 38(3), 210–220.
2. Kumar, S. (2011). Community rights and conservation conflicts: Lessons from Buxa Tiger Reserve. Economic and Political Weekly, 46(23), 485–493.
3. Chakraborty, A., & Dutta, R. (2018). Eco-sensitive zone management in Eastern India: Policy challenges and opportunities. Environmental Policy and Governance, 28(1), 65–78.
4. Bhattacharya, D. (2019). Sustainable tourism practices in the Eastern Himalayas: A case study of Dooars. Journal of Sustainable Tourism Development, 12(3), 150–165.
5. Das, P. (2017). Railway infrastructure and elephant mortality in North Bengal. Indian Forester, 143(2), 199–205.
6. Roy, R. (2021). Human–wildlife conflict and livelihood vulnerability in the Dooars region. Asian Journal of Environment and Development, 25(2), 300–312.
7. Malczewski, J. (2006). GIS-based multicriteria decision analysis: A survey of the literature. International Journal of Geographical Information Science, 20(7), 703–726.
8. Urban, D., & Keitt, T. (2001). Landscape connectivity: A graph-theoretic perspective. Ecology, 82(5), 1205–1218.
9. Barua, M., et al. (2012). The influence of development on human–elephant conflict in Assam, India. Biological Conservation, 153, 56–62.
10. Margules, C. R., & Pressey, R. L. (2000). Systematic conservation planning. Nature, 405(6783), 243–253.
11. Balmford, A., et al. (2002). Economic reasons for conserving wild nature. Science, 297(5583), 950–953.