



Original Research Paper

Telecoupled Conservation and Role of Distant Urban Consumption in Shaping Habitat Loss Within Protected Areas

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Key Words	Abstract
Telecoupling, Western ghats, Protected area management, Urban consumption, Habitat fragmentation, Land-use change, Biodiversity conservation.	Western Ghats, which is a global biodiversity hot spot, is being impacted by land-use change, which has its beginnings way outside the administrative borders of Protected Areas (PAs) in the Western Ghats. Although local human activities have frequently been cited as having caused habitat degradation, this paper uses a telecoupling model to examine how remote urban consumption and infrastructural pressures by hubs like Bengaluru, Mumbai, and Coimbatore contribute to habitat degradation within and in the surrounding areas of these PAs. The study examines the socioeconomic and environmental processes or flows linking the urban centers with the montane forests. Cities have triggered an evocation of luxury commodities, such as coffee, rubber, and timber, which have resulted in the transformation of the zones of significant buffers into commercial plantations. Moreover, the demand for nature-based tourism and second-home real estate has triggered the rapid infrastructure build-up, which consequently leads to linear encroachment, such as roads and resorts, that dissect the essential wildlife corridors. Through the combination of multi-temporal satellite images and city economic indicators, the paper measures the relationship between the capital of the city and loss of forest cover in major areas such as the Nilgiris biosphere reserve. Results indicate that the conventional methods of conservation, namely fence-and-fine, are inadequate in countering telecoupled market forces. The findings demonstrate that distal urban dietary changes and energy demand determine the level of habitat integrity in the Western Ghats, and this demand enforces large-scale hydroelectric projects in conserved landscapes. In an effort to alleviate these pressures, conservation policy would need to change towards telecoupled governance, rather than local-centric management. This involves the introduction of urban-financed Payment of Ecosystem Services (PES), tougher control of supply chains of Ghats-sourced foods, and obligatory green infrastructure of urban-urban transporting routes. Finally, the sustainability of Western Ghats biodiversity would be determined by the ability to balance the ecological boundaries of the Protected Areas with the growing footprint of the urban middle class in India.

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Introduction

Protected Areas (PAs) expansions are a pillar of biodiversity conservation in the entire world (González-García et al., 2022; Boillat et al., 2018). In spite of this quantitative growth of land area put under protection, in line with internationally set standards, including the Kunming-Montreal Global Biodiversity Framework, environmental health is still worsening (Pascual et al., 2022; Pröbstl et al., 2023). This protection paradox indicates that boundaries are set up, but they are still open to external socioeconomic forces. Formalization of PAs in the Western Ghats, a UNESCO World Heritage Site, has not completely stopped habitat fragmentation, implying that local management cannot shield against bigger systemic causes of environmental change.

The telecoupling framework offers a powerful lens to comprehend these external pressures. Telecoupling is the socioeconomic and environmental interaction between remote coupled systems of human-nature (Pierce et al., 2024; Obura et al., 2023). Telecoupling, in comparison to the traditional land-use models that consider local proximity, takes into consideration the movements of capital, people, and information over long distances (Busck-Lumholt et al., 2022; Chen et al., 2025; Piquer-Rodríguez et al., 2023). In this scenario, the Western Ghats (the sending system) and large metropolitan centers such as Bengaluru, Mumbai, and Coimbatore (the receiving systems) are connected by one another through the extraction of ecosystem services and inflow of urban investment (forming a complex network of

distal dependencies) (Ma et al., 2024; Liu et al., 2023 Sun, 2023).

Much of the literature on conservation is devoted to proximate causes of habitat loss, including local poaching, subsistence fuel-wood harvesting, or small-scale agriculture (Carmenta et al., 2023; Raymond et al., 2022). Nevertheless, these local actors usually serve as agents of the distal urban demands (Zhang et al., 2024). The situation is significantly deficient in studies on how the demand for high-value plantation crops (coffee, rubber) and luxury ecotourism, as well as urban energy security by their distal urban consumption, determines the destiny of habitat along the PA boundaries. Although the concept of the urban footprint has been extensively covered in broad strokes, its impact on the disruption of properties of the protected montane landscapes by telecoupled market signals has not been adequately examined (Persson et al., 2021; Anderson et al., 2023).

The present paper seeks to fill this gap, which will determine the direct relationship between urban market oscillation and the middle-class consumption systems in the Tier-1 cities of India, and habitat degradation and species pressure in Western Ghats PAs. The study aims to establish that the geographical location of the poor is not the major cause of the encroachment, but the economic prosperity that is far away, accompanied by the telecoupled demand of goods and services that are land-intensive.

The rest of this paper will be divided into the following sections: Section 2 will provide the conceptual framework of the Urban-Ghats nexus. Section 3 explains the methodology that

incorporates remote sensing data with the urban economic indices. Section 4 shows the findings of the spatiotemporal analysis of habitat loss. In Section 5, it is explained how these findings are relevant to the context of telecoupled governance. Section 6 gives certain policy advice on demand-side conservation. Section 7 ends with the conclusion of the shift needed in the management of Protected Areas toward a more holistic and telecoupled management.

Conceptual Framework: The Urban-Ghats Nexus

The telecoupling model is an organized method of comprehending the multidimensional connections between the Western Ghats and India, which has witnessed the expansion of the metropolitan cities. Having classified these interactions as sending, receiving, and spillover systems, one gets to see that the drivers of habitat loss in Protected Areas (PAs) are external, market-driven processes, and not just local ones.

The Sending System: Ecosystem Services and Resource Extraction

The Western Ghats serve as the main sending system, which provides the biophysical conditions for the expansion and consumption of the cities. The export of freshwater and hydroelectric power services to the national grid to serve industrial hubs is among the critical ecosystem services that are exported by protected areas and surrounding forest fragments. In addition to energy, the sending system offers commodities that are land-intensive and highly valued, e.g., shade-grown coffee, timber, and spices. These products are cleared out of the

montane scenery and cited to the faraway markets, which commonly stimulates the intensification of plantations in the PA buffer zones. This makes the forest a production Region that will be used to fulfill the resource demands of the urban population miles away.

The Receiving System: Urban Hubs as Drivers of Demand

Large urban areas, namely Bengaluru, Mumbai, and Coimbatore, are the system of receiving the capital and demand. These Tier-1 cities have a lot of disposable income, and therefore provide a pull in the market that keeps creating a market that is constantly drawing agricultural products that are luxurious, as well as products that provide the experience of the wilderness. This urban affluence is being displayed in the Ghats by direct investment in real estate of a second home and the growth of high-end resorts. Moreover, the policy-making that is developed in these city administrative centers is based on infrastructure, i.e., interstate highways and high-tension power lines, which open up the flow of goods and people but physically undermine the integrity of the forest cover of the sending system.

Spillover Systems: Fragmentation and Socio-Ecological Impacts

This issue of telecoupling cities and the Ghats has large spillover effects that surpass the desired flow of trade or utility. Fragmentation of migratory routes of megafauna, mostly the Asian elephant and Bengal tiger, is the most dangerous spill-over. PAs are also cut by urban-to-urban transit corridors, causing an urban-rural conflict

between human and wildlife populations. Also, there is the experience of the local indigenous communities being displaced or having limited access to the traditional resources, as the buffer lands would be turned into commercial areas. These spillover effects demonstrate the

ecological and social costs that are not very visible to keep the urban-Ghats nexus going, where the benefits of the consumption are held in the city, whereas the burdens of the environment are in the mountains.

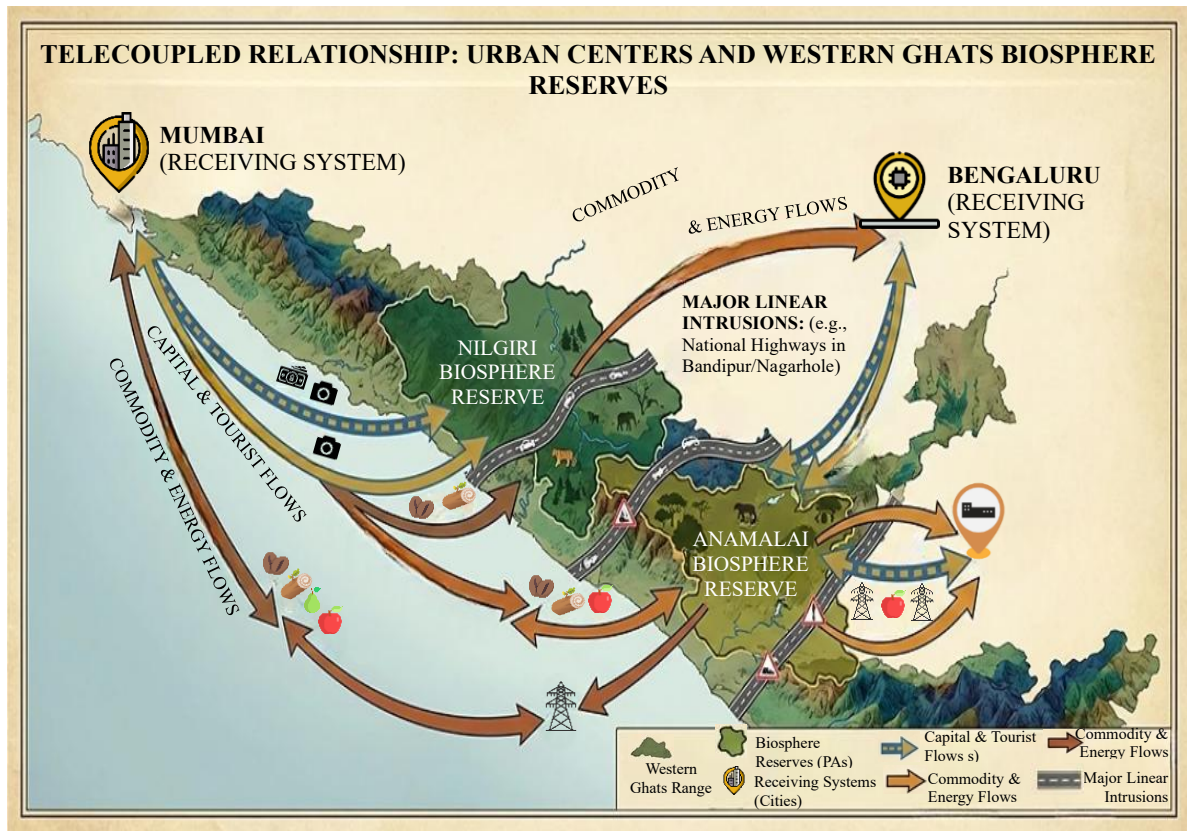


Figure 1: Telecoupled Relationship: Urban Centers and Western Ghats Biosphere Reserves

The telecoupled interaction between three major Indian metropolitan areas (Mumbai, Bengaluru, and Coimbatore) and the main Protected Areas of the Western Ghats, namely, the Nilgiri and Anamalai Biosphere reserves, is shown in Figure 1. Graphically, its classification of these urban centers as a group of "receiving systems," which have a strong market pull due to the capital investments and high exchange of tourists to the montane landscape, is made. In its turn, the export of key commodities and energy, such as coffee, timber, and hydroelectric power,

taken out by the Biosphere Reserves to meet the demands of distant urban locations, fulfills this need. More importantly, the map marks key linear intrusions, including national highways and power grids, as those physical pathways through which these flows occur and at the same time divide important wildlife habitats and pathways.

Methodology

The multi-scalar research methodology is used to measure the telecoupling of the relationship between the urban centers and the

Western Ghats. The study separates the effects of distal urban demand on the integrity of Protected Area (PA) by the use of both geospatial data and socioeconomic indicators.

Study Site Selection and Spatial Scope

The Nilgiri and Anamalai Biosphere Reserves are the target of research, and particular areas of conflict, like Bandipur-Nagarhole and the Anamalai Tiger Reserve, are targeted. These locations are chosen as the main "sending systems" since they are only the key sources of the commodity and energy flows that are used in the remote urban centres. The area being covered is the Western Ghats mountain system and its physical and economic linkages directly with the receiving systems of Mumbai, Bengaluru, and Coimbatore.

Land Use and Land Cover (LULC) Analysis

Multitemporal satellite imagery in the form of Landsat and Sentinel missions is used to observe forest transformation and loss across a certain period of time. The analysis focuses more on establishing how the native forest cover has changed into commercial plantations to produce coffee, timber, and fruit commodity flows. Also, the methodology involves mapping the hospitality presence through determining the resistive clusters of resorts and the presence of the second-home real estate development in the eco-sensitive buffer zones, which are the physical manifestations of urban tourist and capital flows.

Economic Proxies and Urban Correlation Analysis

The research uses a correlation analysis in order to correlate urban prosperity in the receiving systems and ecological degradation in the sending system. The increase in the rate of urban GDP and disposable income in Bengaluru and Coimbatore can be used as proxies for the growing demand for luxury goods and energy. The information about the second-home registration and the urban origin tourist arrivals is tied to the expansion of built-up regions in the Ghats, which is the circulation of urban capital. This makes it possible to quantify that the market changes in the city itself cause land-use changes through the remote Protected Areas.

Infrastructure and Linear Intrusion Mapping

The map of infrastructure is provided as the physical expression of telecoupling, which is the channel through which the exchange between systems occurs. The digitization of major country highways that serve urban-to-urban transit purposes in places like Bandipur and Nagarhole is done to determine their impact on the wildlife corridors. Moreover, the nomenclature of linear intrusion of the high-tension power lines and footprints of hydroelectric dams are mapped to illustrate how the urban energy security needs precondition the loss of the habitat in the PA boundaries. These characteristics are grouped as significant linear invasions which contribute to the external circulation of energy, besides also breaking up the interior environment of the Biosphere Reserves.

Results

The findings of the spatiotemporal and socioeconomic analyses are divided into three tables in order to show the particular effects of the commodity demand, infrastructure expansion, and capital-based tourism on the Western Ghats.

Commodity-Driven Encroachment

Table 1 shows the quantification of the influence of the outflow of high-value goods on the urban receiving systems as the driving force

of land-use change at the edges of Protected Areas.

Table 1 shows that the urban market indicators are very sensitive to the encroachment creep. With the growing demand for coffee and luxury spices in hubs like Mumbai and Bengaluru, the outward movement of commodities aggravates, leading to the conversion of the primary forest in the Nilgiri and the Anamalai buffer areas to agricultural production areas.

Table 1: Impact of Distant Urban Commodity Demand on PA Forest Cover

Exported Commodity	Primary Urban Destination	Market Price Volatility Correlation	Observed Encroachment Rate (Annual)
Shade-Grown Coffee	Bengaluru, Mumbai	High (Positive)	+4.2%
Timber & Pulp	Coimbatore, Bengaluru	Moderate	+2.8%
Luxury Fruits/Spices	Mumbai	High (Positive)	+5.1%

Infrastructure and Linear Intrusions

Table 2 explains how the physical couplings needed to achieve connectivity of urban energy and transit impingement on the habitat integrity.

Table 2 identifies infrastructure as the physical form of telecoupling. The energy

movements to Coimbatore and Bengaluru require power grids and dams that dissect the interior of the Biosphere Reserves, and highways used in transit between urban areas are death traps to migratory megafauna such as tigers and elephants.

Table 2: Linear Intrusion Density and Habitat Fragmentation

Infrastructure Type	Primary Urban Purpose	Intrusion Density (km/km²)	Wildlife Corridor Impact
National Highways	Inter-city Transit	0.85	Severe Bisection (Elephant)
High-Tension Power Lines	Urban Energy Security	1.20	Canopy Fragmentation
Hydroelectric Dams	Industrial Power Supply	0.45 (Area %)	Submergence of Riparian Habitat

Capital and Tourism Flows

Table 3 is a quantification of the change in the PA landscape by the influx of urban wealth and recreational demand.

Table 3 shows the contribution of urban capital and flows of tourists to a rearrangement of land ownership and use. The huge expansion of the hospitality industry, serving tourists who

live in the city in particular, can be associated with the 35 % increase in the area under the built-

up, which directly increases the rate of human-wildlife interactions.

Table 3: Urban Capital Investment and Hospitality Sector Growth

Investment Source	Receiving System	Growth in Built-up Area (2015-2025)	Conflict Intensity (Human-Wildlife)
Real Estate (2nd Homes)	Mumbai, Bengaluru	+22%	Moderate
Luxury Ecotourism	Coimbatore, Mumbai	+35%	High
Corporate Plantations	Bengaluru	+12%	High

Discussion

The outcomes show that the ecological path of the Western Ghats is closely connected with the socioeconomic development of the urban receiving systems in India. The implication of these telecoupled flows on long-term conservation is discussed herein.

The Middle-Class Footprint: The Tourism Paradox

The problem that is critically discovered is the paradoxical influence of the increasing urge of the urban middle-class to have the luxury of nature (Sietz et al., 2025; Frans & Liu, 2024). Mumbai, Bengaluru, and Coimbatore, the capital and tourist flows, have triggered a 35 % expansion in the hospitality industry in the eco-sensitive areas. Although these urban tourists are pursuing the aesthetic and recreational values of the Nilgiri and Anamalai Biosphere Reserves, the subsequent mushrooming of resorts and second homes is destroying the same landscapes, which they hope to appreciate. This city footprint is expressed as a luxury degradation whereby the top-end tourism infrastructure results in permanent man-built upfronts in important buffer areas, resulting in more waste production and

more conflict between man and wildlife (Bond et al., 2022).

Urban Energy Hunger: Distal "Theft" of Habitat

Energy flows analysis shows that there is a kind of theft of the habitats distal, in that the urban industrial needs determine the areas of the land of Protected Areas to be submerged. The Hydroelectric dams and high-tension grids are located in the sending system of the Ghats to meet the electricity needs of the receiving systems, such as Coimbatore and Bengaluru. These linear intrusions are energy-powered attacks that symbolize the prioritization of urban energy security in place of PA integrity. Direct ecological costs incurred by the Ghats because of power lines fragmenting its canopy and loss of its riparian habitat through reservoir submergence are the benefits of powering urban sprawl.

Governance Gaps: Friction in Management Mandates

One of the threats that has been identified is tension between local conservation requirements and state development objectives. Although local forest departments have the mandate of upholding the boundaries of the Nilgiri and Anamalai reserves, they, in most cases, have no

power to control the distal drivers of change. Inter-city transportation creates the necessity of widening national highways, which are significant linear intrusions that cut through the wildlife habitats and are state-authorised. This was a gap in governance, as the urban-based development policy, which puts an emphasis on the commodity and energy circulation, often prevails over the local ecological interests of the PAs. Conservation in the telecoupled world needs a paradigm change in moving towards the forest-gate management to an integrated model that considers the urban-driven infrastructure and investment.

Conservation Implications and Policy Recommendations

The telecoupled Western Ghats means the need to change the localized fortress conservation to demand-side management. The policy interventions will have to deal with the urban receiving systems that steer the outward flow of the commodities and energy of the Biosphere Reserves.

Urban-Funded Payment for Ecosystem Services (PES)

To solve the lack of balance in the urban-Ghats nexus, the Payments for Ecosystem Services (PES) model is suggested. Within this model, the metropolitan centers such as Bengaluru, Mumbai, and Coimbatore, which are the main receiving centers, would make their contribution to a Conservation Fund as a local tax on the high-consuming utilities, such as water and hydroelectric power, that are supplied by the Ghats. They ought to be reallocated to the Nilgiri

and Anamalai Biosphere Reserves to cover the drain of the habitat in the distal sense and to offer financial incentives to the local communities to resist the infiltration by the commercial streams of commodities.

Mandating Green Infrastructure for Linear Intrusions

The policy on infrastructure needs to develop towards the reduction of the discontinuity brought about by the huge intrusions. All the national highways and rail lines that are available as an urban-to-urban transit route are suggested to be retrofitted with compulsory overpasses and underpasses for wildlife. These measures are essential in the restoration of the permeability of wildlife pathways that are cut through by transit requirements. Moreover, any future energy infrastructure, including power grids and dams to serve Coimbatore and Bengaluru, should go through vigorous telecoupled impact assessments to ensure that the energy flows will not be at the expense of interior forest integrity.

Sustainable Consumption and Urban Certification

To reduce the encroachment caused by commodities, there is a need to change the purchasing capacity of the urban middle class. Urban certification schemes on goods produced in the Western Ghats, like "PA-Safe" coffee, spices, and timber, should be enforced at the receiving hubs. Such programs would see to it that products are not sourced in areas that are illegally encroached or buffer zones of the Biosphere Reserves. This would help in halting

the encroachment creep caused by high market demand in places such as Mumbai.

The policy framework in Table 4 uses the conservation interventions according to the desired telecoupled flows that are to be regulated. The Municipal Conservation Tax focuses on the urban system of receiving the energy and water flow to the urban dwellers, thus taxing the flow of the water and energy to create a sustainable revenue source for the management of the Protected Area in the Ghats. Mandatory Wildlife Crossings consider the aspect of physical infrastructure flows or the highways and transit

corridors that couple the remote systems to restore habitat connectivity to migratory species. Moreover, the Ghats-Origin Certification intervention targets urban customers to control the commodity movement by not allowing the demand for such products as coffee or spices to justify the illegal intrusion into the Nilgiri Biosphere Reserves or the Anamalai Biosphere Reserves. Lastly, Impact Assessment Reform is aimed at the sending system to avoid habitat loss at the hands of the expansion of energy infrastructure to meet the distant urban energy hunger.

Table 4: Policy Framework for Telecoupled Conservation

Policy Intervention	Target System	Targeted Flow	Primary Goal
Municipal Conservation Tax	Receiving (Urban)	Energy & Water Flows	Fund PA management and PES for local guardians
Mandatory Wildlife Crossings	Coupled (Infrastructure)	Capital & Transit Flows	Restore corridor connectivity for megafauna
"Ghats-Origin" Certification	Receiving (Urban Consumers)	Commodity Flows	Reduce encroachment for coffee and spices
Impact Assessment Reform	Sending (Ghats PAs)	Energy & Infrastructure	Prevent habitat loss from new hydroelectric projects

Conclusion

The ecological integrity of the Western Ghats with the help of localized conservation of the region (the so-called fortress conservation) is no longer possible. As this paper will show, local anthropogenic stresses are not the main causes of habitat loss in the Nilgiri and Anamalai Biosphere Reserves, but the proximate market indications and insatiable demands of the rapidly growing megacities in India. Telecoupling of Mumbai, Bengaluru and Coimbatore with these montane landscapes has formed a network of commodities, energy and capital flows

continuously transcending the boundaries of traditional Protected Areas. Conserving of the western Ghats simply demands a basic appreciation of the fact that each cup of coffee that is consumed, each unit of the hydroelectric power that is used and each luxury resort trip by a city dweller, leaves a physical footprint on the forest floor. Conservation policy needs to change its paradigm shift in order to be effective in the world that is increasingly globalized and telecoupled. The management measures should cease focusing on the forest gate with a concentration on local enforcement and

perimeter fencing to the city gate, where the real causes of environmental change are rooted to. Future research should incorporate urban consumption taxes, supply chain transparency, and sustainable infrastructure planning into the fundamentals of biodiversity strategy. The Western Ghats could turn into a row of islands of habitats without dealing with the linear intrusions and commodity-based encroachment that is promoted by an urban-to-urban transit and capital investment. The key to the survival of this global biodiversity hot spot lies in the need to reconcile the lifestyle needs of the urban middle class and the biophysical constraints of the natural systems that support them.

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