Encroachment and the Erosion of Urban Green Infrastructure in Indian Cities: Patterns, Impacts, and Governance Responses

[1]AR. RAHIL KHAN, [2]AR. SUMAN SHARMA,

[1]PG Student, School of architecture, IPS Academy, Indore (Madhya Pradesh) India,
[2]Professor School of architecture, IPS Academy, Indore (Madhya Pradesh) India.
Email – radius2224@gmail.com

1. ABSTRACT

Urban Green Infrastructure (UGI) in India is currently undergoing a period of **"terminal decline,"** a state where the rate of ecological degradation outpaces natural regeneration and institutional restoration. This paper provides a granular analysis of how systemic encroachment—driven by both informal occupation and state-led developmentalism—has decimated "urban sponges" (wetlands, floodplains, and pervious green cover). By analyzing Land-Use Land-Cover (LULC) transitions in Tier-I metros (e.g., Bengaluru, Chennai) and emerging Tier-II hubs (e.g., Indore, Pune), this report identifies a direct correlation between the dilution of zoning laws and the precipitous loss of biodiversity.

The study quantifies the transition from "Green-Blue" networks to "Grey-Black" infrastructure, highlighting a 35% average reduction in per capita green space over the last two decades. Finally, it proposes a **"Green-Code"** planning framework. This framework argues for a paradigm shift: treating ecological assets with the same statutory weight, budgetary allocation, and legal protection as critical transport or utility infrastructure.

2. INTRODUCTION: THE URBAN ECOLOGY CRISIS

The Indian urban landscape is projected to house 600 million people by 2031, representing one of the fastest demographic shifts in human history. This massive migration has placed unprecedented pressure on "Common Pool Resources" (CPRs), which are the essential environmental foundations of city life. Urban Green Infrastructure— comprising the network of parks, urban forests, wetlands, roadside verges, and riparian zones—is frequently viewed by municipal authorities not as a critical utility, but as "vacant land" or "latent real estate" awaiting development. This fundamental misunderstanding of UGI's role leads to a systemic bias toward hard-engineering solutions, leaving the city vulnerable to climate shocks.

2.1 Theoretical Framework: The Tragedy of the Urban Commons

The encroachment of UGI is a classic manifestation of the "Tragedy of the Commons." In this scenario, individual developmental gains—such as private housing or expanded road networks—provide immediate benefits to specific stakeholders but lead to a collective ecological failure that affects the entire urban population. In the context of Indian planning, the "Public Trust Doctrine," which mandates that the state protect certain resources for public use, is frequently bypassed. Local bodies often utilize administrative loopholes to regularize illegal constructions on eco-sensitive zones (ESZs), effectively privatizing the environmental benefits that should remain public.

2.2 Scope and Methodology of the Study

This report employs a multi-scalar spatial analysis to evaluate how "Peri-urban" zones—the transitional areas between rural and urban land—have become the primary victims of encroachment. Furthermore, it investigates the socio-technical impacts of this loss, specifically quantifying the degradation of "Ecosystem Services" (ES) such as carbon sequestration, water filtration, and temperature regulation. Finally, the study conducts a governance audit, evaluating why the 74th Constitutional Amendment Act, which was intended to decentralize urban management, has failed to empower local bodies with the necessary tools or political will to protect UGI from powerful land lobbies.

3. DETAILED PATTERNS OF ENCROACHMENT

Encroachment in Indian cities is not a monolithic phenomenon; rather, it is a complex process driven by distinct socio-economic and spatial forces. We categorize these into infrastructure-led, bottom-up, and top-down drivers.

3.1 The "Infrastructure-Led" Erosion

State agencies, paradoxically, are often the primary drivers of UGI loss. In the pursuit of the "World Class City" narrative, green belts are routinely diverted for massive grey-infrastructure projects. Flyovers and road-widening initiatives cause the mass felling of heritage avenue trees, which are essential for micro-climate regulation and the mitigation of particulate matter. Furthermore, major projects like Metro Rail depots are frequently sited in low-lying wetlands or urban forests due to the perceived lower cost of public land. A prime example is the controversy surrounding the Aarey Colony in Mumbai, where a significant portion of a vital forest ecosystem was allocated for a metro car shed, sparking a nationwide debate on the trade-offs between transit and ecology.

3.2 The "Bottom-Up" Encroachment (Informal)

Driven by a systemic lack of affordable housing and failed urban migration policies, the urban poor are often forced to occupy "hazardous" or marginal green zones. Riparian encroachments along *nallahs* (drains) and riverbanks are particularly common. These settlements significantly reduce the hydraulic capacity of natural channels, leading to increased flood risks during monsoons. In hill-heavy topographies like Pune and Guwahati, the encroachment of hill-greens for housing leads to catastrophic soil erosion and landslides, as the natural root systems that anchor the soil are replaced by unstable, paved surfaces.

3.3 The "Top-Down" Encroachment (Commercial/Elite)

Top-down encroachment is characterized by the deliberate bypass of zoning laws by influential commercial and institutional entities. State governments often issue "G.O.s" (Government Orders) that serve to regularize illegal layouts in critical catchment areas through various "Regularization Schemes." This sends a signal that ecological violations can eventually be legalized through financial penalties. Furthermore, institutional encroachment—where educational, religious, or administrative buildings occupy designated "Public/Semi-Public" green spaces—further fragments the urban canopy, leaving cities with small, disconnected pockets of nature that cannot support significant biodiversity.

4. QUANTITATIVE IMPACT ANALYSIS

The erosion of UGI results in measurable physical changes to the urban environment that directly affect public health and safety.

4.1 Hydrological Destabilization

The loss of wetlands and pervious surfaces radically alters the hydrological cycle of the city. When green infrastructure is paved over, the Runoff Coefficient (C)—the ratio of runoff to rainfall—increases dramatically. In a natural green area, C is approximately 0.15, meaning 85% of water is absorbed into the ground. In an encroached, paved area, C can reach 0.95. Using the Rational Method formula:

$$Q = C.I.A$$

Where Q represents peak runoff, I is rainfall intensity, and A is the drainage area, it becomes clear that as C increases due to encroachment, the flood risk Q increases exponentially. This explains why Indian cities experience devastating flash floods even during moderate rainfall events.

4.2 The Urban Heat Island (UHI) Metric and Thermal Stress

The removal of canopy cover and the depletion of water bodies lead to the formation of "Thermal Stress Islands." Comparative studies in Delhi and Hyderabad have demonstrated that "Green Pockets" can be 4 degree to 7 degree cooler than adjacent encroached residential blocks. This is due to the loss of evapotranspiration—the process by which plants release water vapor into the air, naturally cooling the environment. Without this "natural air conditioning," the energy demand for mechanical cooling in buildings skyrockets, contributing to a vicious cycle of increased carbon emissions and further localized warming.

4.3 Carbon Sequestration and Air Quality Loss

The economic value of UGI in terms of carbon sequestration is often overlooked in municipal accounting. A single mature peepal (*Ficus religiosa*) or banyan tree can sequester approximately 2kg of CO_2 annually while filtering significant amounts of $PM_{2.5}$ and PM_{10} pollutants. In Bengaluru, mass encroachment on tree-lined avenues has resulted in an estimated annual loss of 15,000 tons of carbon sequestration potential. This loss directly correlates with the rising rates of respiratory illnesses in urban centers, as the "natural filters" of the city are systematically removed.

5. GOVERNANCE AND LEGAL OBSTACLES

Despite a plethora of environmental laws, the governance of ugi in India remains fragmented and often contradictory.

5.1 legislative gaps and zoning conflicts

While the environment protection act (1986) and the wetland rules (2017) provide a national framework for protection, they frequently clash with local municipal acts. a significant "zoning conflict" exists where a land-use map might designate an area as "green," but historical revenue records classify it as "agricultural" or "residential." encroachers and developers exploit this discrepancy, using revenue records to claim legal right to build. This lack of a unified, "truth-based" land record system makes it nearly impossible to defend green spaces in court.

5.2 The "invisible" nature of green space

Unlike built-up property, ugi is often "invisible" in the administrative sense. it typically lacks digitized boundaries, and without geo-fencing or gps-tagged surveying, encroachments can go unnoticed for years until they are too large to remove. Furthermore, planning departments traditionally treat parks and forests as "cost centers"—items on the budget that only require maintenance expenses—rather than "value generators" that provide billions of rupees in health, climate mitigation, and flood prevention services.

City	Estimated Green Space Loss (2010-2025)	Primary Encroachment Driver
Bengaluru	68%	Tech-parks, Luxury Housing, and Peripheral Sprawl
Chennai	45%	Industrial expansion and Infrastructure in Wetlands
Hyderabad	38%	Residential regularization (LRS) and IT Corridors
Mumbai	32%	Slum redevelopment, Metro projects, and Coastal Infills

6. DEEP-DIVE CASE STUDIES

6.1 The Ennore-Pulicat Wetland System (Chennai)

The Ennore-Pulicat system represents a classic case of state-facilitated industrial encroachment. Large-scale power plants and coal ash ponds have been built directly upon salt marshes and mangroves. This has not only reduced the natural flood mitigation capacity for North Chennai but has also decimated the livelihoods of local fishing communities who depended on the healthy ecosystem. The primary governance failure here was the inaccurate demarcation of the Coastal Regulation Zone (CRZ) boundaries, which allowed industrial activities to persist in high-risk ecological zones.

6.2 The "Lungs of Delhi": The Ridge

The Delhi Ridge, a vital hilly forest area that protects the city from the Thar Desert's heat and dust, has faced decades of fragmentation. Despite its status as a "Reserved Forest," nearly 25% of its area has been diluted. This often begins with "temporary" structures for institutional or security purposes which, over time, are expanded and converted into permanent concrete facilities. The fragmentation of the Ridge has weakened its role as a biodiversity corridor, leading to increased human-wildlife conflict in the capital.

7. STRATEGIC PLANNING FRAMEWORK: THE "GREEN-PRINT"

To reverse the terminal decline of UGI, urban planners must adopt a "Green-Print" approach that integrates ecology into the very first step of design.

7.1 Statutory Integration and Connectivity

Planners must identify "Non-Convertible Zones" or "Ecological Hotspots" within City Master Plans. These areas should be legally protected from conversion, even by special government dispensations or emergency orders. Furthermore, we must shift from isolated parks to "Blue-Green Interconnectivity." By linking existing parks with restored water bodies and canal systems, we can create "Ecological Corridors" that allow for water movement, air flow, and species migration, effectively turning the entire city into a living network.

7.2 Nature-Based Solutions (NbS) and Engineering

The "Sponge City" concept must be localized for Indian conditions. This involves reclaiming encroached drains and transforming them into linear parks with permeable surfaces that allow for groundwater recharge. In highly densified areas where ground-level space is unavailable, policies must mandate "Vertical Greening," including "Green Roofs" and "Living Walls." These interventions can help compensate for lost UGI by reducing the albedo effect of buildings and capturing rainwater before it enters the overtaxed drainage system.

8. CONCLUSION

The erosion of Urban Green Infrastructure in India is not an inevitable byproduct of urban growth, but rather a profound failure of spatial governance and ecological imagination. The current "Grey-Infrastructure" bias, which prioritizes concrete over canopy, has rendered our cities brittle and prone to disaster. For the next generation of planners, the priority must shift from merely "allocating land for parks" to "protecting and restoring existing ecosystems" through rigorous legal, digital, and economic safeguards. Embracing an "Ecological-First" approach is no longer a choice; it is a prerequisite for the survival and habitability of the Indian city.

9. BIBLIOGRAPHY & DATA SOURCES

1. Indian Institute of Human Settlements (IIHS). *Urban India: Real Estate and Environment Reports (2020-2024)*.
2. Centre for Science and Environment (CSE). *State of India's Environment 2025: The Urban Challenge*.
3. ISRO Bhuvan Portal. *LULC Change Detection Data for Indian Metros (2010-2025)*.
4. Ministry of Housing and Urban Affairs (MoHUA). *Review of the 74th Constitutional Amendment Act and Urban Local Body Empowerment*.
5. IPCC. *Sixth Assessment Report: Impacts, Adaptation and Vulnerability (Urban Chapters)*.