

GREEN INFRASTRUCTURE AND URBAN RESILIENCE IN INDIA: CHALLENGES AND POLICY PERSPECTIVES

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Abstract

Green infrastructure has become an increasingly important strategy for enhancing urban resilience in India as cities face growing risks from climate change, rapid urbanization, flooding, heat waves, air pollution, and ecological degradation. Indian cities are experiencing rising exposure to pluvial flooding, urban heat island effects, and the loss of natural drainage and green cover due to unplanned expansion and impervious development. Recent World Bank analysis of 24 Indian cities highlights that more than half of the urban infrastructure needed for 2050 is yet to be built, creating a critical window to embed resilient and nature-based approaches into urban growth, while also warning that flood losses could reach billions annually without timely adaptation. National and city-level initiatives such as river-sensitive planning guidance from the National Institute of Urban Affairs and heat adaptation efforts in cities like Ahmedabad illustrate the policy relevance of green and blue-green infrastructure in India. This study examines how green infrastructure—including urban forests, wetlands, parks, permeable surfaces, bioswales, and green roofs—can reduce climate risks, improve ecosystem services, and strengthen adaptive urban capacity. It also identifies key barriers such as land scarcity, weak integration into master planning, fragmented institutional responsibilities, limited municipal finance, and insufficient technical capacity. The study argues that mainstreaming green infrastructure into land-use regulation, stormwater management, urban finance, and participatory governance is essential for building inclusive, climate-resilient, and sustainable Indian cities.

Keywords-Green Infrastructure, Urban Resilience, India, Climate Change Adaptation, Nature-Based Solutions, Urban Flooding, Heat Island Mitigation, Sustainable Urban Planning, Blue-Green Infrastructure, Policy Perspectives

1. Introduction (India-Focused)

India is undergoing one of the fastest urban transitions in the world, and this rapid transformation has intensified the vulnerability of cities to climate-related and environmental risks. Urban centers across the country increasingly face recurrent flooding, heat waves, water scarcity, air pollution, land degradation, and the loss of natural ecosystems due to unplanned expansion, encroachment on wetlands, concretization, and inadequate drainage systems. According to a recent World Bank assessment of 24 Indian cities, India's urban population could reach **951 million by 2050**, and **more than 50 percent of the urban infrastructure required for 2050 is still to be built**, creating both a major challenge and a significant opportunity to embed resilience into future urban development. The same report warns that annual pluvial flood losses could reach **US\$5 billion by 2030** and **US\$30 billion by 2070** without timely adaptation, while stronger heat adaptation could save over **130,000 lives by 2050**.

In this context, **green infrastructure** has emerged as a critical strategy for building urban resilience in India. Green infrastructure refers to interconnected natural and semi-natural systems such as urban forests, parks, wetlands, lakes, river corridors, green roofs, permeable pavements,

bioswales, and community green spaces that provide ecological, hydrological, climatic, and social benefits. Unlike conventional gray infrastructure, which often focuses on engineered and capital-intensive solutions, green infrastructure works with natural processes to manage stormwater, reduce urban heat, improve air quality, restore biodiversity, and enhance urban liveability. In Indian cities, where climate risks are compounded by high population density, informal settlements, and infrastructure deficits, green infrastructure offers a cost-effective and multifunctional pathway toward sustainable urban adaptation.

Urban resilience refers to the capacity of cities to anticipate, absorb, adapt to, and recover from shocks and stresses while maintaining essential functions and services. In the Indian context, this concept is especially important because many cities are exposed to overlapping hazards such as monsoon flooding, heat stress, groundwater depletion, and pollution. Cities such as **Ahmedabad** have demonstrated how resilience planning can integrate nature-based and public health measures through the Heat Action Plan model, which combines early warning systems with long-term actions such as increasing green cover and promoting heat mitigation strategies. Similarly, national initiatives led by the **National Institute of Urban Affairs (NIUA)** and the **National Mission for Clean Ganga (NMCG)**—including *River-Sensitive Urban Planning* and the **River Cities Alliance**—have created policy frameworks that encourage cities to restore river ecosystems, wetlands, riparian buffers, and natural drainage networks as part of resilient urban planning. The River Cities Alliance expanded from **30 cities in 2021 to 146 member cities in 2024**, showing growing institutional interest in river-based green resilience approaches.

Government programmes also increasingly recognize the relevance of green and blue-green infrastructure. Under **AMRUT 2.0**, project planning templates explicitly include **rejuvenation of water bodies and development of parks and green spaces**, while the broader reform agenda emphasizes water security, conservation, groundwater management, and reuse. These policy shifts indicate that green infrastructure is gradually moving from a peripheral environmental concern to a core component of urban resilience and service delivery. However, implementation remains uneven due to land scarcity, fragmented institutional mandates, weak integration into master plans, limited municipal finance, insufficient technical expertise, and poor maintenance systems.

Therefore, assessing the role of green infrastructure in India is essential not only from an environmental perspective but also from governance, economic, and social standpoints. This study examines how green infrastructure contributes to urban resilience in Indian cities by reducing climate risks, improving ecosystem services, and strengthening adaptive capacity. It also evaluates the major barriers to implementation and highlights policy pathways for integrating green infrastructure into urban planning, disaster risk reduction, climate adaptation, and municipal governance. The study argues that India's current phase of urban expansion presents a historic opportunity to mainstream green infrastructure as a strategic foundation for resilient, inclusive, and sustainable cities.

Result Tables (India-Specific)

Table 1: Major Urban Resilience Challenges in Indian Cities and the Relevance of Green Infrastructure

Urban Challenge in India	Nature of the Problem	Relevant Green Infrastructure Response	Resilience Benefit
Urban Flooding	Encroachment on lakes, wetlands, and natural drains; poor stormwater systems	Wetland restoration, bioswales, rain gardens, permeable pavements, urban lakes rejuvenation	Reduces runoff, improves infiltration, lowers flood risk
Urban Heat Island Effect	Dense built-up areas, reduced tree cover, heat-trapping surfaces	Urban forests, street trees, green roofs, shaded parks	Lowers ambient temperature and heat stress
Air Pollution	Vehicular emissions, industrial pollution, dust, low green cover	Green belts, urban forests, roadside plantation	Improves air filtration and public health
Water Scarcity	Groundwater depletion, poor recharge, loss of water bodies	Lake rejuvenation, rainwater harvesting landscapes, permeable surfaces	Enhances recharge and water security
Biodiversity Loss	Habitat fragmentation, wetland destruction, riverfront encroachment	Ecological corridors, wetlands, river buffers, urban biodiversity parks	Restores habitats and ecosystem stability
Public Health Stress	Heat exposure, poor air quality, lack of recreational space	Community parks, neighborhood green spaces, shaded public areas	Supports physical and mental well-being

Interpretation

This table shows that many of the most serious urban risks in India—especially flooding, heat, and water stress—are directly linked to the degradation of natural systems. Green infrastructure addresses these vulnerabilities by restoring ecological functions that conventional urban development has weakened.

Table 2: Key Forms of Green Infrastructure and Their Relevance in Indian Cities

Green Infrastructure Type	Examples in Indian Context	Primary Function	Urban Resilience Outcome
Urban Lakes and Wetlands	Lake rejuvenation projects in Bengaluru, Hyderabad, Chennai	Stormwater retention and groundwater recharge	Flood moderation and improved water security
Urban Forests and Tree Canopies	City plantation drives, urban biodiversity parks, avenue plantations	Heat reduction and air purification	Lower heat island effect and better air quality
River Corridors and Riparian Buffers	River-sensitive planning under NIUA–NMCG frameworks	Floodplain protection and ecological restoration	Reduced riverine risk and stronger blue-green networks
Parks and Open Spaces	Public parks under AMRUT and Smart City projects	Recreation, cooling, emergency gathering spaces	Social resilience and public health support
Green Roofs and Vertical Greening	Emerging in metros and institutional campuses	Surface cooling and rainwater retention	Reduced building heat load and runoff
Permeable Streetscapes and Bioswales	Sustainable drainage in selected urban renewal projects	Stormwater infiltration and filtration	Reduced waterlogging and improved drainage

Interpretation

Indian cities can benefit from a mix of blue-green infrastructure rather than relying on a single intervention. Lakes, wetlands, and river corridors are especially significant because many Indian cities historically evolved around water systems that now require ecological restoration.

Table 3: Institutional and Policy Initiatives Supporting Green Infrastructure in India

Policy Programme Initiative	Institution / Agency	Green Infrastructure Relevance	Resilience Significance
AMRUT 2.0	Ministry of Housing and Urban Affairs (MoHUA)	Includes rejuvenation of water bodies and development of parks & green spaces in project planning	Supports water security and climate-resilient urban services

Policy Programme Initiative	Institution / Agency	Green Infrastructure Relevance	Resilience Significance
River-Sensitive Urban Planning (RSUP)	NIUA & NMCG	Provides framework for integrating rivers, wetlands, buffers, and stormwater-sensitive planning	Promotes flood resilience and ecological restoration
River Cities Alliance (RCA)	NIUA, NMCG, partner institutions	City platform for healthy urban rivers; grew from 30 cities (2021) to 146 (2024)	Encourages collaborative river-based resilience planning
Heat Action Plans (e.g., Ahmedabad)	City governments with technical partners	Combines early warning with long-term measures such as increased green cover	Reduces heat vulnerability and health risks
Smart Cities Mission	MoHUA / Urban Local Bodies	Supports area-based development, public spaces, and some green mobility/open space interventions	Enhances localized urban sustainability and liveability
State/City Climate Action Plans	State governments and municipal bodies	Increasing inclusion of nature-based and ecosystem restoration measures	Mainstreams climate adaptation into urban governance

Interpretation

India’s policy landscape increasingly acknowledges the value of green infrastructure. However, many programmes still treat green assets as complementary rather than core infrastructure, which limits their scale, budgeting, and maintenance.

Table 4: Major Challenges and Policy Perspectives for Green Infrastructure in Indian Cities

Challenges	India-Specific Description	Policy Perspective / Recommended Action
Land Scarcity and Encroachment	Wetlands, lakes, floodplains, and open spaces are often occupied or converted	Protect ecological land through zoning, no-build buffers, and stronger land-use regulation

Challenges	India-Specific Description	Policy Perspective / Recommended Action
Fragmented Governance	Multiple agencies manage water, parks, drainage, planning, and environment separately	Create integrated urban resilience cells and inter-departmental coordination frameworks
Weak Integration in Master Plans	Green infrastructure often remains ornamental rather than functional	Mandate blue-green networks in master plans, development plans, and building bylaws
Limited Municipal Finance	ULBs often lack funds for restoration, maintenance, and monitoring	Use green bonds, climate finance, PPPs, CSR partnerships, and performance-linked grants
Inadequate Technical Capacity	Limited expertise in ecological design, hydrology, and maintenance	Build capacity through NIUA, state urban institutes, and technical training for ULB staff
Poor Maintenance and Monitoring	Parks, lakes, drains, and plantations degrade without long-term upkeep	Create lifecycle-based maintenance budgets and citizen/community stewardship models
Low Community Participation	Projects may fail without local ownership and behavioral support	Encourage ward-level participation, RWAs, NGOs, and local monitoring groups
Data and Mapping Gaps	Incomplete data on floodplains, drainage paths, urban heat, and ecosystem services	Use GIS-based urban ecological mapping and climate risk assessments before planning

Interpretation

The major barrier in India is not the absence of policy intent but the gap between policy and implementation. Effective urban resilience through green infrastructure requires stronger legal protection, integrated governance, financing innovation, and institutional capacity at the city level.

Suggestions

Indian cities should institutionalize green infrastructure as a mandatory component of urban master plans, climate action plans, and disaster management frameworks. Priority should be given to protecting and restoring lakes, wetlands, urban forests, river corridors, and open spaces through ecological zoning and no-build regulations. Urban Local Bodies should adopt blue-green

infrastructure standards for drainage, road design, housing layouts, and public space development. Dedicated financing through green bonds, AMRUT-linked funds, climate adaptation grants, PPPs, and CSR partnerships should be expanded. Capacity building for municipal engineers, planners, and environmental officers is essential to improve project design and long-term maintenance. Finally, citizen participation, ward-level monitoring, and community stewardship must be strengthened to ensure that green infrastructure remains functional, inclusive, and locally supported.

Conclusion

Green infrastructure has become increasingly important for strengthening urban resilience in India, where cities face growing exposure to climate-induced and development-related stresses such as flooding, heat waves, water scarcity, air pollution, and ecological degradation. As India's urban population expands rapidly and a substantial share of future infrastructure is yet to be built, the country has a unique opportunity to avoid repeating unsustainable urbanization patterns by embedding green and blue-green systems into city planning from the outset. Urban forests, lakes, wetlands, parks, permeable landscapes, river buffers, and other nature-based assets can significantly reduce disaster risks, improve environmental quality, support public health, and enhance the adaptive capacity of urban communities. National and city-level initiatives such as AMRUT 2.0, river-sensitive planning frameworks, the River Cities Alliance, and Heat Action Plans indicate that the policy foundation for green infrastructure is gradually strengthening in India. However, major challenges remain in the form of land encroachment, fragmented institutions, weak planning integration, inadequate municipal finance, and limited technical capacity. Therefore, the future of resilient urban development in India depends on treating green infrastructure not as a decorative amenity but as essential urban infrastructure. A policy shift toward integrated planning, ecological zoning, dedicated financing, institutional coordination, and citizen participation is necessary to fully realize its resilience benefits. In the long term, mainstreaming green infrastructure can help Indian cities become safer, healthier, more inclusive, and more climate-resilient.

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