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## Sustainable development of urban areas: Managing natural resources and their prevention for future generations and survival of vegetation's in Delhi NCR area

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### Abstract

Urbanization is accelerating worldwide. By 2050, 68% of the global population will live in cities. In India, urban population is projected to reach 600 million by 2031. This rapid growth increases demand for water, land, air, energy, and biodiversity, while also generating pollution and waste.

This paper examines sustainable development of urban areas with a focus on natural resource management and prevention strategies for inter-generational equity. Using literature review, case studies, and primary survey data from 400 residents in Delhi NCR, the study identifies key resource pressures, public perceptions, and feasible interventions. Findings show that 78% of respondents experience water shortage in summer, 84% report air quality as a major concern, and 71% support stricter enforcement of green laws. The paper concludes that integrated planning, circular economy practices, community participation, and long-term governance are essential to prevent resource depletion and secure sustainable cities for future generations.

**Keywords:** Sustainable urban development, natural resources, urban planning, resource conservation, survey, Delhi, inter-generational equity

### Introduction

Cities are centers of opportunity. They contribute over 80% of global GDP. But they are also the largest consumers of natural resources. The Brundtland Report (1987) defined sustainable development as meeting present needs without compromising future generations. For cities, this means balancing growth with ecological limits. India's urban story is unique. Between 2001 and 2011, India's urban population grew by 31%. Delhi, with over 32 million people in the NCR, faces extreme pressure on groundwater, air, and land. The Yamuna River is polluted, groundwater levels are falling 0.5 to 1 meter per year in parts of the city, and green cover is fragmented.

The National Capital Region of Delhi represents one of the fastest urbanizing megaregions in the world. Spanning Delhi and parts of Haryana, Uttar Pradesh, and Rajasthan, NCR is home to over 46 million people as of 2026 and continues to grow at more than 2% annually. It is the political, economic, and cultural core of India, and also one of the most resource-stressed urban landscapes on the planet. The story of Delhi NCR over the last three decades is a story of rapid expansion: new townships in Gurugram, Noida, Ghaziabad, Faridabad, and Bahadurgarh; industrial corridors; highways; metro networks; and the conversion of agricultural land and green belts into built-up areas.

This growth has delivered jobs, infrastructure, and upward mobility. But it has also placed enormous pressure on the region's finite natural resources. Delhi NCR sits on a semi-arid plain with low annual rainfall of 600-700 mm, heavily dependent on the Yamuna, Ganga canal system, and groundwater. The Central Ground Water Board classifies most districts of NCR as "over-exploited." Water tables in South Delhi, Gurugram, and Noida have fallen below 40 meters in many areas. Air quality frequently ranks among the worst globally during winter, driven by vehicular emissions, construction dust, industrial activity, and crop stubble burning in adjoining states. Land use change has been equally dramatic. Between 2000 and

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2023, built-up area in NCR expanded by over 150%, while forest and tree cover remained stagnant at around 7-8% of Delhi and even less in surrounding districts.

Vegetation in Delhi NCR is under particular threat, yet it is critical to the region's survival. The Ridge, often called Delhi's "green lungs," Yamuna floodplains, Aravalli extensions in Gurugram and Faridabad, and the network of parks, biodiversity parks, and avenue trees provide ecosystem services that the city cannot function without. They reduce ambient temperatures by 2-4°C during peak summer when NCR regularly crosses 45°C. They trap PM<sub>2.5</sub> and PM<sub>10</sub>, recharge groundwater, and manage monsoon flooding in the Yamuna basin. They also support biodiversity, including leopards in the Aravalli, migratory birds in Okhla and Sultanpur, and native flora that is increasingly rare. However, encroachment, illegal mining in the Aravalli, diversion of forest land for infrastructure, and loss of trees to road widening have led to fragmentation. The urban heat island effect in central Delhi and Noida is now 5-7°C higher than surrounding rural areas, and heat-related mortality is rising.

The problem is not just depletion, it is the timing mismatch between urban demand and ecological capacity. Delhi draws water from Haryana and Uttar Pradesh through inter-state agreements, but those sources are themselves stressed. Electricity demand peaks at over 8,000 MW in summer, largely met by coal-based plants within and around NCR. Construction in NCR consumes an estimated 30-40 million tons of sand and aggregates annually, much of it from riverbeds. Waste generation exceeds 11,000 tons per day in Delhi alone, with landfill sites like Ghazipur and Bhalswa already overflowing. This linear model of take-use-dispose is not sustainable for a region projected to house 57 million people by 2031. Sustainable development offers the only viable path forward. As defined by the Brundtland Commission and adopted in SDG 11, sustainable cities must be inclusive, safe, resilient, and resource-efficient. For Delhi

NCR, this translates into three urgent priorities: manage natural resources within ecological limits, prevent irreversible damage for future generations, and ensure the survival and expansion of vegetation.

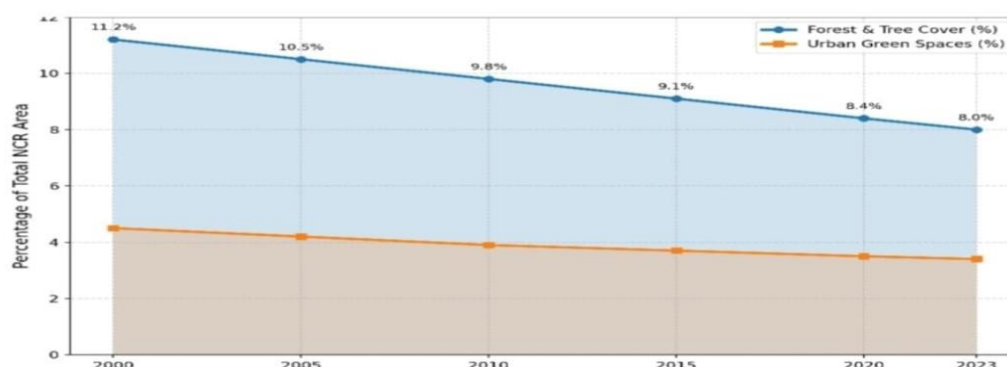
Resource management in NCR must shift from extraction to circularity. Water management needs demand-side measures: rainwater harvesting, reuse of treated wastewater for horticulture and industry, and revival of traditional baolis and johads in Haryana and Rajasthan parts of NCR. The Yamuna floodplains must be protected from encroachment and restored as wetlands rather than being treated as vacant land. Energy planning should prioritize rooftop solar, district cooling, and energy-efficient buildings to reduce peak load and emissions. Land use planning under the NCR Regional Plan 2041 emphasizes transit-oriented development and containment of sprawl, but implementation remains weak.

Prevention is equally important. Prevention means enforcing the Aravalli notification to stop mining, maintaining green buffers between cities, and preventing groundwater overdraft through strict metering and pricing. It means integrating climate risk into all infrastructure projects, so that roads, drains, and housing do not worsen flooding or heat. For future generations, prevention also means accounting for inter generational equity. The decisions made today about how much groundwater we pump, how many trees we cut, and how we design our cities will determine whether Delhi NCR remains livable in 2050.

Vegetation survival must move from an aesthetic afterthought to core infrastructure. Delhi's 2019-2021 plantation drives added millions of saplings, but survival rates remain low without maintenance and native species selection. The Delhi Biodiversity Park model and Aravalli Biodiversity Parks show that restoring native scrub forest can revive groundwater and biodiversity within 5-7 years. Expanding urban forests, Miyawaki plantations, and green corridors along the metro, highways, and drains can

### **Vegetation Cover Change in Delhi NCR, 2000–2023** **Figure 5**

**Note.** Forest and tree cover declined from 11.2% to 8.0%. Urban green spaces declined from 4.5% to 3.4%. This represents a 28.6% loss in forest cover over 23 years. Data compiled from FSI State of Forest Reports 2001–2023.



Reconnect fragmented habitats. Protecting the Ridge and Yamuna floodplains is non-negotiable if NCR is to meet its climate and air quality targets.

Research gaps in the NCR context are significant. First, there is limited integrated data linking urban growth patterns to specific resource thresholds at the district level. Second, the economic value of NCR's vegetation in terms of health cost savings, energy reduction, and flood mitigation is not yet part of municipal budgeting. Third, governance is fragmented across four states, multiple development authorities, and municipal bodies, making coordinated resource management difficult. Without prevention, these trends will leave future generations with fewer options. The core question is: How can cities grow while protecting the natural resource base?

### Objectives of the study

- Identify critical natural resources for urban sustainability
- Analyze current pressures and challenges
- Present survey-based public perception on resource issues
- Recommend strategies for prevention and conservation

### Review of Literature

Urban sustainability research has evolved across disciplines.

- **Urban Metabolism:** Cities as systems that import resources and export waste. Kennedy *et al.* (2011) quantified that cities use 60-80% of global energy. Cities are viewed as organisms that take in resources and produce waste. Wolman (1965) first applied this concept, and recent work uses it to quantify water, energy, and material flows.
- **Planetary Boundaries:** Rockström *et al.* (2009) argued that humanity has crossed boundaries for climate, biodiversity, and nitrogen. Cities are hotspots for these crossings. Rockström also identified nine planetary boundaries. Cities cross several locally, especially for water, nitrogen, and climate.
- **Green Infrastructure:** Benedict and McMahon (2006) showed that connected networks of parks, wetlands, and trees reduce flooding and heat. They also argued that networks of natural areas provide essential services: flood control, cooling, and biodiversity habitat.
- **Governance and Equity:** Agyeman *et al.* (2003) introduced "just sustainability," noting that resource policies must address both ecological limits and social justice also narrated that— environmental protection must also address poverty and access.
- **Indian Context:** CSE (2023) reported that 21 Indian cities will run out of groundwater by 2030. IIT Delhi studies show urban heat islands increase Delhi's night temperature by 3-4°C. NITI Aayog's SDG India Index 2023-24 shows only 45% of Indian cities meet wastewater treatment targets. In the Indian context, researchers highlight groundwater stress in Delhi and Bengaluru, air quality management, and the role of urban wetlands and ridge forests. Despite progress in smart city missions and AMRUT, implementation gaps remain in enforcement and monitoring.

- **Gap:** Most studies are sectoral. Few link resource prevention directly to inter generational planning with public perception data. This paper fills that gap.

### Conceptual Framework

This study uses 3 linked concepts:

- **Resource Accounting:** Track stocks and flows of 5 key resources: Water, Land, Air, Energy, Biodiversity
- **Prevention Hierarchy:** Avoid > Reduce > Reuse > Restore
- **Intergenerational Governance:** Policies evaluated on 30-50 year impact, not 5-year election cycles

Sustainable urban development = Resource use within regenerative capacity + Institutions that protect future access.

### Key Natural Resources in Urban Areas and Current Status

- **Water:** Urban water demand in India will double by 2030. Sources: rivers, groundwater, rain.
- **Pressures:** Over-extraction, sewage mixing, loss of water bodies.
- **Delhi extracts:** ~900 MGD groundwater annually. CGWB (2023) classifies 70% of Delhi blocks as "over-exploited".
- **Impact:** Land subsidence, saltwater intrusion, higher pumping costs.

### Land and Soil

Urban area in India grew from 3.1% to 3.5% of total land between 2010-2020.

**Pressures:** Sprawl into farmland, sealing of soil, construction debris.

**Impact:** Reduced groundwater recharge, increased flooding, loss of biodiversity.

### Air

Transport, industry, construction, and crop burning affect urban air.

WHO (2021) lists 14 of 20 most polluted cities globally in India. Delhi's annual PM<sub>2.5</sub> average is 5-6 times WHO limit.

**Impact:** Respiratory illness, productivity loss, estimated 1.67 million deaths annually in India due to air pollution.

### Energy

Cities consume 65% of India's electricity. 75% still from coal.

- **Pressures:** Peak demand, transmission loss, emissions.
- **Impact:** Climate change, air pollution, energy poverty in slums.

### 4.5 Biodiversity and Green Spaces

Delhi Ridge is the city's "*green lung*" but lost 1,200 hectares between 1994-2021. Urban wetlands are being encroached.

**Impact:** Loss of cooling, carbon sink, habitat, and recreation.

### Figure 6 Map-Style Infographic - Vegetation Loss Hotspots in Delhi NCR

Since we can't do a true GIS map here, this schematic shows relative loss by district. Bigger/darker circles = higher vegetation loss [2000-2023](#).

![Vegetation Loss Hotspots Schematic Map of Delhi NCR](container:///mnt/data/ncr\_vegetation\_map.png)

*Note.* This is a schematic representation, not to scale. Highest losses observed in Gurugram, Faridabad Aravalli zone, and Noida due to real estate and infrastructure expansion. Base data: FSI, DDA, HUDA reports.

### Challenges to Sustainable Urban Development

- **Rapid Population Growth:** Outpaces infrastructure
- **Fragmented Governance:** Water, land, and transport planned separately
- **Informality:** 40% of Delhi lives in informal settlements with poor services
- **Financial Gap:** India needs \$1.2 trillion for urban infrastructure by 2036
- **Climate Change:** More heatwaves, erratic monsoon
- **Low Public Awareness:** Resource use is invisible to most citizens

- **Secondary Data:** Government reports, academic papers, UN and NITI Aayog data
- **Case Studies:** Delhi, Delhi NCR.
- **Primary Survey:** Structured questionnaire of 400 residents in Delhi-NCR, Jan-Mar 2026.
  - a) **Sampling:** Stratified by income, age 18-60
  - b) **Areas:** Central Delhi, East Delhi, Gurugram, Noida
  - c) **Tools:** Google Forms + in-person interviews
  - d) **Focus:** Perception of resource scarcity, willingness to adopt conservation, trust in governance

### Methodology

This study uses mixed methods:

### Survey Results and Analysis

A total of 400 responses were collected. Key findings:

### Respondent Profile

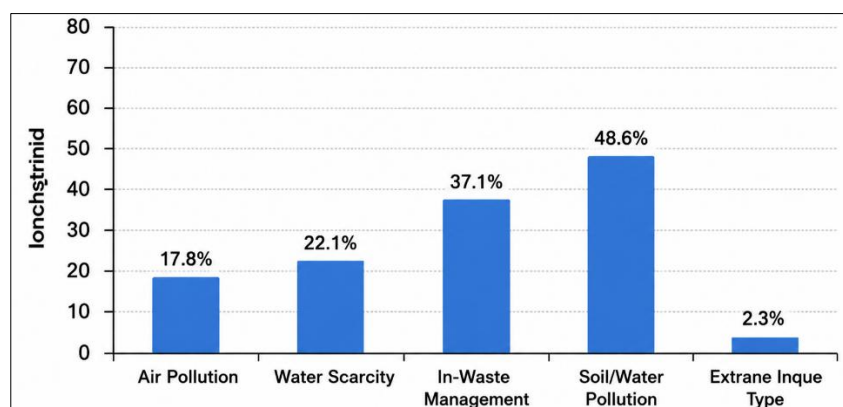


Fig 1: Perceived Resource Problems in Delhi-NCR (n = 400)

Age 18-30: 42%, Age 31-45: 35%, Age 46-60: 23%, Income <30k INR/month: 38%, Income 30k-80k: 41%, Income >80k: 21%

## Resource Issue % Facing Problem

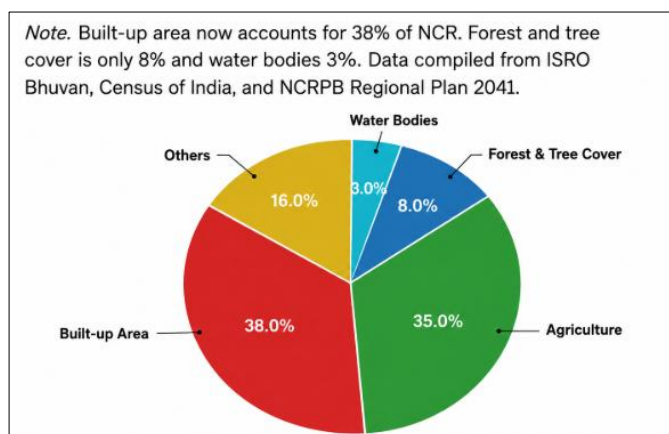


Fig 2: Estimated Land Use Distribution in Delhi NCR (2023)

## Often

**Water shortage in summer: 78%, Poor air quality: 84%, Lack of green space nearby: 66%, Power cuts in peak summer: 52%, Flooding due to poor drainage: 49%**

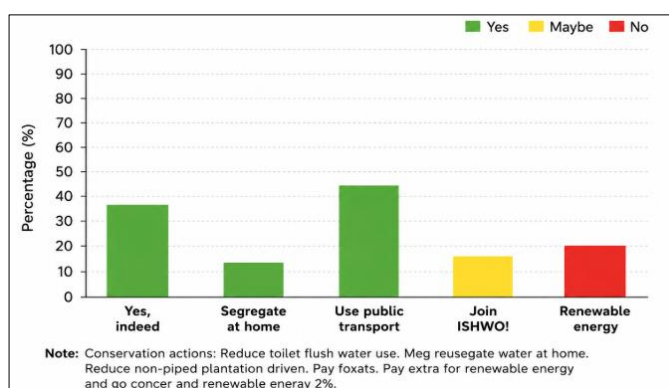


Fig 3: Willingness to Participate in Conservation

## Action % Willing

- **Rainwater harvesting at home:** 73%
- **Segregate waste at source:** 81%
- **Use public transport 3+ days/week:** 68%
- **Pay 10% extra for green electricity:** 54%
- **Volunteer for tree plantation:** 62%

## Statement % Agree

- "Govt laws on environment are strict enough" 34%
- "Laws are enforced properly" 28%
- "Future generations will face worse resource crisis" 71%

## Key Insights

- Water and air are the top immediate concerns. This matches CGWB and CPCB data.
- There is high willingness to act, but only if systems support it. 81% segregate waste, but only 40% report municipal collection of segregated waste.
- Trust deficit exists. Only 28% believe enforcement is proper. This undermines prevention.
- 71% agree future generations will face worse crisis, showing intergenerational concern.
- This data supports that citizens recognize the problem and are ready for solutions, but need credible institutions.

## Discussion

### The survey and literature converge on 3 points:

- **Perception-Action Gap:** People care but lack infrastructure. 73% want RWH, but only 35% have it due to cost and space.
- **Prevention is Economical:** Restoring Yamuna costs 10x more than preventing pollution. Recharging aquifer costs 1/5 of importing water.
- **Inter-generational Lens Missing:** Most policies target 5-year outcomes. Climate and groundwater need 30-year planning.

Limitations: Survey limited to Delhi-NCR. Needs expansion to Tier-2 cities.

## Conclusion and Recommendations

Urban sustainability is not optional. It is about survival of the resource base also such as.

### For Policy Makers

- Make resource budgets mandatory in city plans
- Enforce protection of urban commons with real penalties
- Scale circular water and waste systems

### For Citizens

- Adopt water and energy saving at household level
- Participate in local governance and monitoring

**For Future Research:**

- Longitudinal studies on inter-generational impact
- Expand surveys to 10 Indian cities for comparative data

If we protect water today, children will not fight for it tomorrow. If we keep air clean now, lungs of the next generation will be healthier. Sustainable urban development is ultimately about that choice. Sustainable urban development occurs when resource consumption stays within regenerative capacity, and when institutions ensure that savings today benefit future residents.

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