

“Decentralized WSD Strategies for Climate Resilience in Tier-II Indian Cities: A Socio-Economic Review”

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Abstract— Rapid urbanization in Tier-II cities in India poses challenges to sustainable water management, notably in the context of climate change. The proposed decentralized Water Sensitive Design (WSD) interventions, including rainwater harvesting, decentralized wastewater treatment, and lake restoration, as potential and feasible alternatives to enhance urban resilience. Yet, the socio-economic ramifications of these strategies, and how the strategies fit within Sustainable

Development Goals (SDGs) are under-explored. The study assesses climate-resilience potential and socio-economic impacts of decentralized waste settlement disposal (WSD) in four Tier-II cities (Indore, Bhubaneswar, Coimbatore, and Udaipur). This research utilizes a qualitative, exploratory design to synthesize data from a systematic literature review and comparative case analysis. Using data from peer-reviewed literature, government reports, and case studies, the study analyzes the implementation of WSD interventions by these cities as well as the challenges they are facing. They holistically lead to better sanitation, better recharge of Cochin groundwaters, job creation, and some reduction of urban heat. But barriers, including fragmented governance, limited funding, and technical capacity, have kept them from scaling. The study calls for a more integrated approach to water-sensitive urbanism and presents a five-pillar framework for scaling up decentralized WSD in Tier-II cities. This research highlights the need for tailoring water management efforts to align with water targets of the SDG and provides critical insights for relevant stakeholders such as policymakers, urban planners, and development agencies engaged in developing urban futures resilient to climate impacts.

Keywords—Decentralized Water-Sensitive Design, Climate Resilience, Socio-Economic Impacts, Sustainable Development Goals, Tier-II Indian Cities, Urban Water Management

I. INTRODUCTION

India's cities are undergoing a dramatic transformation from rapid urbanization, rising climate variations, and increasing water insecurity (CWC, 2019; MoEFCC, 2020; World Bank, (2021). The growing challenge of building resilient and sustainable urban water systems is urgent, as around 377 million people currently live in urban areas, and this number is projected to rise above 600 million by 2036 (NIUA, 2020; Census of India, 2021; UNDESA, 2019; ADB, 2020).

However, urban water management in India still tends towards a centralized, sectoral, and reactive approach, and has been slow to catch up to fast spatial growth and increasing climatic shocks like urban flooding and prolonged droughts (Kumar & Singh, 2021; Jain et al., 2022; Mishra & Awasthi, 2021). Such a fragmented approach results in urban planning and hydrological cycle disjuncture, leading to groundwater over-extraction, untreated wastewater disposal into water bodies, and inadequate urban stormwater management (TERI, 2020; Das & Kumar, 2023; IWMI, 2018; NITI Aayog, 2019). In this respect, Water-Sensitive Design (WSD) is an innovative paradigm that integrates water management into urban planning through the emulation of the natural hydrological cycle with decentralized nature-based solutions (Wong & Brown, 2009; Brown et al., 2016; Chatterjee & Shaw, 2021; Sharma et al., 2022). Rainwater harvesting, green roofs, constructed wetlands, bio-swales, and decentralized wastewater reuse systems are core components of WSD—technologies which also provide co-benefits, including urban cooling and pollution reduction, biodiversity enhancement, and social-ecological resilience (Liao et al., 2017; UNEP, 2022; Rao & Deshpande, 2020; Ghosh et al., 2023). Established WSD practices on an international scale, within cities like Melbourne, Singapore and Amsterdam have seen these progressive principles embedded into urban development agendas through purposeful investment in blue-green infrastructure and integrated water governance, with resulting improvements in ecological health, flood mitigating capacity and urban liveability (Fletcher et al., 2015; Roy et al., 2020; Liu et al., 2021; Arup, 2022). While metropolitan areas like Chennai and Bengaluru have piloted some WSD interventions in India, Tier-II cities have received little attention in both policy and academic discourses (Vishwanath, 2021; CEPT, 2022; IISc, 2023). Tier-II Indian cities—like Indore, Coimbatore, Udaipur and Bhubaneswar—are fast-growing urban hubs with populations of 100,000 to 1 million, growing at a faster demographic rate than big metros (MoHUA, 2023; NIUA, 2021; UN-Habitat, 2020).

Limited institutional capability, stretched infrastructure, and municipal budgets add up to greater vulnerability in these cities to risks like water scarcity, flash floods, and sanitation crises (Singh et al., 2024; GIZ, 2021; Bhattacharya et al., 2021; WRI India, 2022). Despite these challenges, their mid-sized, under-explored, citizen-engaged, and transitional development context can also serve as a unique opportunity to pilot decentralized, low-cost, and community-driven WSD models targeted to the local socio-ecological contexts (Patel et al., 2020; UNDP India, 2023; Agarwal et al., 2022; Dasgupta & Narain, 2021). These cities might act as testing sites for mainstream WSD in India's urban climate adaptation and sustainable development strategies.

II. SIGNIFICANCE OF THE STUDY

An easy In contrast, although the discourse on water sensitive urbanism elsewhere has gained substantial traction, in India, literature and policy applications are disproportionate and predominantly focused on gradients within large metropolitan agglomerations with two of the three examples focused on them (Jain et al., 2022; D'Souza et al., 2024; Singh & Narain, 2021; IISc, 2023). This asymmetry has led to a significant knowledge gap on how decentralized Water-Sensitive Design (WSD) strategies can be responsibly tailored to the socio-institutional realities of Tier-II cities (NIUA, 2020; Dasgupta et al., 2022; Bhat et al., 2023). There are two salient reasons why this review is important. A. It first assesses the potential for climate resilience of decentralized WSD systems, specific to mid-sized Indian cities, where the geography of the centralized infrastructure model tends to be spatially incompatible and financially unviable (ADB, 2019; Prasad et al., 2020; Tiwari & Shah, 2021; UN-Habitat, 2020). To cite the most prominent of such examples, many of the large sewage treatment plants (STPs) constructed in cities like Kanpur and Varanasi under a low-density, capital-oriented paradigm to service their wastewater do not deliver the expected performance criteria, which results in environmental pollution in and around human settlements (CPCB, 2021; NGT, 2022; CSE, 2023). Second, this review critically reflects on the socio-economic co-benefits of decentralised WSD approaches, which is one aspect of WSD that remains under-theorized in both academic and policy discourse (Chowdhury et al., 2017; World Bank, 2021; Rao & Deshpande, 2020; Pandey et al., 2022).

These overlapping advantages involve better public health through lower pollution levels, improved livelihoods through nature-based solutions (NbS), amplified social equity in the peri-urban areas, and even environmental justice ramifications in susceptible populations (UNDP India, 2023; Joshi & Bhattacharya, 2021; Ghosh et al., 2023).

Tier-II cities, however, face multiple systemic challenges that impact the adoption and scaling of decentralized WSD:

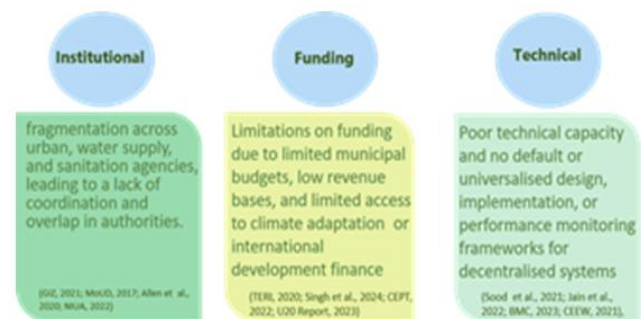


Figure 1: Key institutional, funding, and technical barriers hindering the implementation of decentralized water-sensitive design systems in Indian cities.

Despite an increasing number of decentralized systems, limited community engagement remains true; in fact, awareness towards water-sensitive solutions is extremely low, mostly found in peri-urban and informal settlements, where confidence in the capacity of municipalities is low (Chatterjee and Shaw, 2021; Joshi et al., 2020; Agarwal et al., 2022; WRI India, 2023).

Here, “decentralized” describes locally embedded, modular approaches to urban water management, such as household-level rainwater harvesting (HRH), community-scale greywater reuse, or the establishment of neighborhood wetlands that operate autonomously or semi-independently from centralized networks (UNEP, 2022; Brown et al., 2016; Sharma et al., 2022).

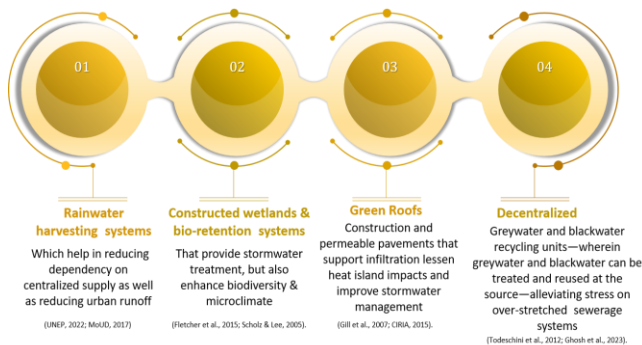
Drawing on a systematic review of peer-reviewed articles, government publications, urban climate action plans, and case study documentation from 2015 to 2025, this study provides grounded insights into the enabling conditions as well as the ongoing bottlenecks that shape the feasibility and equity of decentralized WSD pathways across India's smaller urban centres (NIUA, 2021; IISc-Bengaluru, 2024; NMCG, 2022).

III. LITERATURE REVIEW

A. Conceptual Foundations of Water-Sensitive Design

Water-Sensitive Design (WSD) is a transformative approach to urban water management (Wong & Brown, 2009; Brown et al., 2016; Sharma et al., 2022) that combines hydrological planning with ecological sustainability, participatory urban design, and socio-technical innovation. With the basic concept of Integrated Urban Water Management (IUWM) at its core, WSD aims to capture, infiltrate, and reuse rainwater on-site to take advantage of decentralized and nature-based solutions by mimicking the natural hydrological cycle (Chocat et al., 2007; Liao et al., 2017; Mitchell, 2006; Rauch et al., 2005).

Key elements include:



The fundamental tenet of WSD is to consider water as an asset, as a natural landscape element that is incorporated into urban environments to produce co-benefits in resilience, public health, urban cooling, amenity value, and equity (Fletcher et al., 2015; UNEP, 2022; Roy et al., 2020).

B. Global Evidence on Decentralized WSD Systems

WSD approaches have had increasing exposure worldwide in cities that champion resilience, ecosystem health, and community co-benefits:

- Community-scale treatment wetlands, rain gardens, and precinct-scale stormwater reuse measures in Melbourne, Australia, in the Cooperative Research Centre for Water Sensitive Cities, significantly increased urban water security and ecosystem life (Fletcher et al., 2013; Wong & Brown, 2009; Sharma et al., 2020).
- Singapore's ABC Waters Programme turned utilitarian canals into multifunctional public spaces and improved stormwater quality and urban flood risk while contributing towards fostering citizen engagement (PUB Singapore, 2021; Lien & Hang, 2020; Surbana Jurong, 2019).

- Floating communities, decentralized sewage treatment, and multi-use water squares are part of the circular water agenda for Amsterdam to combat water logging and adapt to climate change (Daamen & Louw, 2021; Roy et al., 2020; UNESCO-IHE, 2018).
- The US city of Portland pioneered green streets and bioswales, showing how decentralized infrastructure could often be much cheaper than gray approaches (EPA, 2015; Brand et al., 2021).

This enables: regulatory reforms coupled with inter-departmental coordination; strong public-private partnerships and sustained funding through climate adaptation budgets or utility fees (Ferguson et al., 2013; UN-Habitat, 2020; OECD, 2021).

C. WSD in India: Emerging Trends and Knowledge Gaps

In India, historical and cultural antecedents of decentralized water management are apparent in systems such as baolis (stepwells), johads, and community tanks, which formed significant parts of the regional hydrological resilience and planning towards community access to water. However, these indigenous practices were displaced gradually with the colonial centralization, engineering-driven urban planning, and piped water systems (Agarwal & Narain, 1997; Singh et al., 2018; Narain & Pandey, 2012; Tiwari & Joshi, 2021). In India, WSD concepts are emergent (albeit fragmented) and linked to frameworks in academic literature, master plans led by consultants or interventions with funding provided by donors (Khosla et al., 2020; CWMI, 2019).

Examples include: Recent urban interventions aligned with WSD include:

- Jakkur Lake, Bengaluru: The success here has been attributed to synergy between a community-supported sewage treatment plant, constructed wetlands, and restored lake area to simultaneously improve water quality, fishery livelihoods, and biodiversity (Ramachandra et al., 2019; ATREE, 2021; Mughal, 2022). This is exemplary of hybrid grey-green infrastructure enabled through collaborative governance (Narasimhan et al., 2020).
- Water Body Restoration in Chennai: Jointly done by civic bodies, NGOs, and resident groups, rejuvenated tanks and temple ponds serve the dual purpose of helping buffer floods and recharging groundwater. Many of these have received support under the Smart Cities Mission as part of urban resilience goals (Kumar & Srinivasan, 2021; CSE, 2023; TNUISL, 2020; Iyer & Mahalingam, 2022).

- c. Wastewater reuse systems in Pune: In peri-urban and informal settlements, decentralized greywater recycling with small-scale treatment units has appeared promising in terms of possibilities for recycled water in toilets and gardening, with community management and NGO facilitation of this (Patel et al., 2020; WaterAid India, 2022; Dalberg, 2021; Anjaria & Bhagat, 2022)

D. Despite these promising examples, WSD uptake faces multiple systemic challenges:

- a. Policy Disconnects: Although national schemes like AMRUT, Swachh Bharat Mission (SBM), and Smart Cities Mission mention water-sensitive strategies here and there, they fail to present concrete measures such as implementation frameworks, design guidelines, or performance indicators for decentralized systems (MoHUA, 2021; NITI Aayog, 2022; NIUA, 2020; CEEW, 2021). For example, AMRUT 2.0 is about reuse but is not integrated with stormwater management or landscape design.
- b. Monitoring Gaps: There are very few or no impact assessments conducted between the decentralized systems and positive outcomes (Jain et al, 2022; CEPT, 2022; Saci WATERS, 2021; NMCG, 2023). Many systems with a lack of accountability fail due to poor O&M (WWF India, 2021).
- c. Hydro-Ecological Blindness: In both urban master plans and new cities, administrative rather than hydrological boundaries are used, cutting out basin/ watershed scale planning or infiltration zones (TERI, 2020; IISc, 2023; NIUA, 2021; WRI India, 2023). Infrastructure projects tend to encroach on wetlands or recharge areas, undermining resilience further.

WSD in India, then, is predominantly project-based and non-systemic, largely stemming from funding mechanisms with an external origin, such as CSR and pilot studies, rather than a foundational part of an endogenous, city-wide planning frame (FICCI, 2021; UNDP India, 2023). Scaling decentralized WSD remains a challenge without stronger policy alignment with, and capacity building and interdepartmental convergence towards the centers of WSD.

E. Socio-Economic Dimensions of Decentralized WSD

WSD literature generally focuses on hydrologic performance, climate resiliency, and urban ecoristorical ecosystem service provision, with less attention paid to the socio-economic nexus despite its importance to sustainability in resource-poor, rapidly urbanizing cities in the Global South (Fletcher et al., 2015; Kumar & Narain, 2021; UN-Habitat, 2020; Trémolet et al., 2010).

a. Public Health

Decentralized greywater and blackwater systems can have a major impact on improved sanitation access, water quality, and public health outcomes, particularly in low-income or peri-urban settlements that have historically been neglected by conventional sewerage systems (World Bank, 2021; Chowdhury et al., 2017; ADB, 2020). †Ramachandra et al., 2019; Gupta et al., 2022 Methodology in addressing fecal contamination and vector-borne disease risks from domestic wastewater in Bengaluru, Pune, and Hyderabad Constructed wetlands and bioswales also mitigate pathogen loads, heavy metals and suspended solids from stormwater runoff (UNEP, 2022; Sharma & Kumar, 2019).

b. Livelihoods and Green Jobs

Due to the installation of green infrastructure associated with WSD interventions, there is substantial potential for job creation in construction, operation, and maintenance in this sector. For instance, decentralized STPs, community-led rain gardens, urban wetland restoration, and green roof retrofitting projects in Indian cities have catered to local employment for masons and gardeners (Chatterjee & Shaw, 2021; UNDP India, 2023; NIUA, 2021; SaciWATERS, 2022). From Indore and Bhubaneswar, there is evidence of successful linking of WSD with skill development schemes and MGNREGA for Lake and Canal rejuvenation (GIZ, 2021; KPMG, 2022).

c. Urban Equity

Decentralized WSD is a means to rectify historic spatial inequities in water and sanitation access by focusing on unplanned settlements, slums, and peri-urban geographies underserved by centralized infrastructure (UN-Habitat, 2020; NIUA & WRI India, 2021). But without pro-poor geographies, the profits of WSD can also be appropriated by privileged enclaves or commercial developments, such as those encountered in Pune, Gurugram or parts of Delhi NCR (Patel et al., 2020; D'Souza et al., 2024; Anjaria, 2021; Coelho & Raman, 2020).

d. Community Participation

It is imperative that such decentralised systems be sustainable and functional, which also hinges on participatory governance and local stewardship (Ferguson et al., 2013; ICLEI South Asia, 2020). International examples—from Colombia to the Philippines—demonstrate that co-production models enhance system maintenance, user satisfaction, and cost recovery (Ferguson et al., 2013; GIZ, 2019).

In Indian context, however, engagement is majorly top-down with a restricted ownership from communities (especially women, lower castes and tribal communities) due to socio-institutional barriers (Das & Kumar, 2023; Joshi et al., 2020; Ray & Bhatt, 2021).

IV. TIER-II CITIES: UNIQUE CHALLENGES AND OPPORTUNITIES

Tier-II cities (those with population between 100,000 and 1 million) are increasingly sites for urbanization, but these cities lack the institutional, financial and technical capacity for adopting Water-Sensitive Design (WSD) in scale (MoUD, 2017; GIZ, 2021; World Bank, 2022; Dasgupta & Somanathan, 2021). These cities are the frontline of climate effects, demographic pressures, and infrastructure shortfalls, but they also hold significant possibilities for reimagined decentralized planning.

A. Challenges

- a. **Institutional Fragmentation** Water, sanitation, drainage, and urban planning responsibilities are spread across various parastatal and municipal agencies which suffer from poor coordination, data silos and a lack of integrated WSD vision (MoUD, 2017; GIZ, 2021; Jain et al., 2022; IIHS, 2020). Udaipur and Bhubaneswar case studies show how fragmented mandates delay project execution and monitoring (NIUA, 2022).
- b. **Funding Constraints** Municipal budgets are insufficient and dependent on transfers from the center and the state. Limited capacity exists to mobilize climate-resilient financing or to engage with blended finance models at the urban water and sanitation delivery (WSD) infrastructure level (TERI, 2020; Singh et al., 2024; NIUSA & ADB, 2023; IISD, 2021). We also observe low revenue collection and own-source income, which limits investment in decentralized green infrastructure.
- c. **Technical Gaps** Personnel shortages of trained professionals—particularly engineers, landscape planners, and GIS specialists—deter decentralized system design, monitoring, and maintenance (Sood et al., 2021; NIUA, 2022; WRI India, 2022). The technical training courses being run under AMRUT and Smart Cities have had minimal reach beyond non-metro regions.

- d. **Defence of weak Community Involvement** It is well known that the urban poor settlements, peri-urban villages, and informal colonies are often past the official planning maps and absent from deliberative and decision-making procedures (Chatterjee & Shaw, 2021; Anand & Teltumbde, 2021; Kundu et al., 2023). As a result, the levels of trust, uptake, and stewardship of WSD systems are low.

B. Opportunities

- a. **Scale advantage** Tier-II cities benefit from more manageable spatial scales, fewer legacy infrastructures, and greater flexibility to combine decentralized, low-cost, and modular WSD approaches compared to megacities (ADB, 2019; Sharma et al., 2022; OECD, 2021). This follows the potential for early adoption of nature-based solutions (NbS), and hybrid infrastructure.
- b. **A Leadership of Proactivity** Cities like Indore, Bhubaneswar, Surat and Coimbatore, for example, have made success of solid waste management, slum upgrading and green urban planning with innovative use of donor partnerships, smart city frameworks and municipal entrepreneurship (GIZ, 2021; UNDP India, 2023; Battacharya & Rastogi, 2020; Sinha et al., 2023).
- c. **Civic Innovations** Citizen dashboards, mobile applications, and real-time water monitoring systems are on the rise to bridge capacity gaps between the bottom-up and top-down approaches — potentially allowing municipal bodies and NGOs to build participatory and co-creative solutions (NIUA, 2021; ICRIER, 2022; TISS Urban Action Lab, 2023). Indore, Vadodara, and Warangal and these tools have been piloted across cities successfully.

V. RESEARCH METHODOLOGY

A. Research Design

This study uses a qualitative, exploratory research design, combining a systematic literature review and a comparative case analysis to assess the climate-resilience potential and socio-economic implications of decentralized Water-Sensitive Design (WSD) interventions in Tier-II Indian cities. The research is based on peer-reviewed academic literature, as well as grey literature, including government reports, policy briefs, and planning frameworks, published in the years 2015 to 2025.

The theme is situated between water-sensitive urbanism, decentralized infrastructure, and inclusive urban development.

An interpretive, inductive analytical approach facilitates the discovery of emergent patterns and thematic insights within a diverse body of literature. This perspective also enables contextual examination of place-specific dynamics, highlighting:

- a. What decentralized WSD strategies are being used
- b. What socio-economic output do they produce?
- c. And how does that delivery align with the Sustainable Development Goals (SDGs) and national urban development missions?

VI. CASE SELECTION CRITERIA

In order to ground the analysis, four Tier-II Indian cities were selected on the basis of their relevance for implementation of decentralized WSD—Indore, Bhubaneswar, Coimbatore, and Udaipur. The selection was guided by the criteria below:

A. Diversity in Geo and Eco systems

The selected cities illustrate India's hydroclimatic and ecological diversity and enable cross-city comparisons across varied environmental contexts:

- a. *Indore (Madhya Pradesh)*: Semi-arid context, concerned by seasonal water crisis and rapid peri-urban expansion.
- b. *Bhubaneswar (Odisha)*: Coastal city prone to tropical cyclones and periodic urban flooding.
- c. *Coimbatore (Tamil Nadu)*: A tropical, inland city with a long legacy of tank-based water management systems.
- d. *Udaipur (Rajasthan)*: Largely arid-hilly city historically dependent on artificial lakes and catchment systems.

This diversity aids in assessing how WSD strategies adapt to different hydrological, climatic, and socio-environmental contexts (Sharma et al., 2022; TERI, 2020; CEEW, 2021; WRI India, 2023).

B. Alignment with the Smart Cities Mission (SCM)

All four cities were among the first cities to join the Government of India's Smart Cities Mission (SCM). Their engagements have cultivated:

- a. An institutional capacity for integrated urban planning,
- b. Water-sensitive infrastructure investment support,
- c. Public record to assess progress.

C. DC-WSD intervention areas under SCM are as follows:

- a. Green corridors (Coimbatore, Indore),
- b. Lake rejuvenation projects (Udaipur, Bhubaneswar),
- c. Decentralized wastewater treatment systems (Indore, Coimbatore)

These programs give concrete ground for assessing the institutional, infrastructural, and social sectors of decentralized WSD deployment to practise (MoHUA, 2021; NIUA, 2022; Bhattacharya & Sanyal, 2021; GIZ, 2023).

D. Public documentation availability:

In other words, these cities declared some additional transparency and availability.

- a. Annual reports,
- b. Dual (quantifiable/qualitative) — City Indicators (e.g. AMRUT Service Level Benchmarks).
- c. Open Data portals and dashboards (e.g., Indore Smart City portal, Coimbatore Water Atlas)
- d. City Development Plans and Environment Improvement Action Plans (including integrated plans).

Assessments and case briefs for these cities have been published by sources such as NIUA, CEPT University, MoHUA's ClimateSmart Cities Alliance and GIZ Urban Resilience Program (NIUA, 2021; CEPT, 2022; GIZ, 2023; IIHS, 2020; CPR, 2021).

E. Emerging evidence of decentralized and community-led water initiatives:

- a. Indore: Community-based greywater recycling in informal settlements, integrated stormwater-sewer planning (World Bank, 2022; UNDP India, 2023)
- b. Bhubaneswar: Rejuvenating urban tanks through multi-stakeholder engagement (GIZ, 2021; CPR, 2023)
- c. Institution to land in Coimbatore: Rejuvenating peri-urban tanks with resident associations and NGOs (WRI India, 2022; Sood et al., 2021)
- d. Citizen-academia Lake monitoring and revival initiatives (INTACH, 2020; Rao & Chauhan, 2023); Udaipur.

These are early-stage transitions toward water-sensitive urbanism, often funded by donor agencies, social corporate responsibility (CSR) programs, and community-based organizations.

VII. DATA SOURCES

This research relies on a comprehensive and triangulated approach to secondary data, combining academic literature with policy reports, institutional documentation, and grey literature to capture the multi-scalar dimensions of decentralized Water-Sensitive Design (WSD) in Tier-II Indian cities. Key data sources include:

A. Peer-Reviewed Academic Literature (2015–2025)

Scholarly literature was accessed through Scopus, Google Scholar, and SpringerLink, focusing on themes of:

- a. WSD and nature-based solutions (Brown et al., 2009; Sharma et al., 2022),
- b. Decentralized wastewater management (Chowdhury et al., 2017; Singh & Narain, 2023),
- c. Urban climate resilience and socio-economic impacts (Ferguson et al., 2013; Anand et al., 2021).

Academic syntheses and meta-reviews were also referenced to identify emerging gaps and research frontiers in WSD (Narayanan et al., 2020; Mukherjee & Roy, 2022).

B. Government and Municipal Reports

- a. DPRs (DPRs) for water-based interventions (CEPT, 2022),
- b. AMRUT city score cards & Performance Dashboards (MoHUA, 2022),
- c. State urban water and sanitation policies (Government of Tamil Nadu, 2020; ULB Indore, 2023).
- d. City-level documents were essential tools for tracking institutional intent and implementation:
- e. City Development Plans & Smart City proposals (MoHUA, 2018; NIUA, 2021),

Such information, including technical project details, institutional frameworks, and financial allocations, can be crucial for case-level comparison (World Bank, 2022; UN-Habitat India, 2023).

C. Reports by National and International Agencies

The following organizations provided data and insights:

- a. *National Institute of Urban Affairs (NIUA)*: Smart Cities, WSD and urban equity casebooks and policy briefs (NIUA, 2021; 2023),
- b. *UNDP India and World Bank*: Report on decentralized systems, progress on SDGs, urban livelihoods (UNDP, 2022; World Bank, 2021),

- c. *Asian Development Bank (ADB) and GIZ*: Communication on climate financing, water resilience and city pilot projects (ADB, 2020; GIZ, 2023),

The Energy and Resources Institute (TERI): Urban climate vulnerability reports and water-energy nexus studies (2020; 2023).

D. SDG Localization Documents and Urban Resilience Frameworks

- a. *Global goals were consulted to benchmark city-level alignment.*
- b. *Voluntary Local Reviews (VLRs) & SDG city monitoring reports (UN-Habitat, 2021; NITI Aayog, 2022),*
- c. *Climate Smart Cities Alliance toolkits & resilience plans (MoHUA-NIUA, 2020; IIHS, 2021),*

City-level budgetary allocations for water and climate adaptation schemes, especially for SCM, AMRUT, and state climate missions (CEPT, 2022; CEEW, 2023);

E. Grey Literature and Think Tank Publications

- a. Grey literature addressed contextual and qualitative gaps, in particular on community-driven initiatives and peri-urban practices:
- b. CPR, IIHS, and WRI India Working papers and Policy briefs (WRI, 2023; CPR, 2022);
- c. NGO's report on documenting informal water systems and citizens' participation (WaterAid India, 2022; CSE, 2023),

Conference proceedings and practitioners' blogs give real-time insights (e.g., INTACH, 2021; Urban Voices India, 2024).

F. Triangulation and Reduction of Bias

A triangulation method was employed to validate where data sources had varying scope or consistency:

- a. Academic findings with institutional reports,
- b. Assessments on ground versus city performance data,
- c. Narrative reporting with spatial, or budgetary signals (UNDP India, 2022; Joshi et al., 2023)

This enhanced accuracy, mitigated reporting bias, and fortified cross-validation across datasets.

VIII. ANALYTICAL FRAMEWORK

To structure the comparative analysis of the selected cities, the following analytical dimensions were used:

Dimension	Description
Type of WSD Intervention	Categorization based on infrastructure typology: rainwater harvesting, wetlands, green roofs, etc.
Level of Decentralization	Degree to which systems operate independently of central municipal networks (fully/partially decentralized).
Socio-Economic Impacts	Impacts on health (e.g., sanitation, waterborne disease), livelihoods (job creation, informal sector), and inclusion (access in low-income areas).
Institutional and Financial Enablers	Presence of enabling policy, municipal leadership, PPPs, or donor financing.
Barriers to Implementation	Challenges such as policy fragmentation, technical capacity, funding gaps, or low community uptake.
Alignment with SDGs	Assessment of how interventions contribute to SDGs 6, 11, and 13 through direct or indirect indicators.

Figure 3: This framework provides the foundation for the city-wise comparative matrix presented in the subsequent section.

IX. CASE STUDIES OF DECENTRALIZED WSD IN TIER-II INDIAN CITIES

A comparative case analysis of four Tier-II Indian cities—Indore, Bhubaneswar, Coimbatore, and Udaipur—to evaluate their decentralized Water-Sensitive Design (WSD) initiatives, socio-economic outcomes, and alignment with SDG goals. Each city is analyzed using the framework established in Section 3.

A. Indore (Madhya Pradesh)

Indore has led the way nationally in urban water body rejuvenation, citizen-driven sanitation reforms, and decentralized wastewater management. More than 150 decentralized STPs have been set up at residential, commercial, and institutional sites (Indore Municipal Corporation, 2023; CPCB, 2022).

Major initiatives include:

- Phytoremediation and wetland systems for Khan and Saraswati River rejuvenation (GIZ, 2022; NEERI, 2023)
- Restoration of 20+ lakes (CEPT, 2022) undertaken under AMRUT and Smart Cities Mission
- Decentralised rainwater harvesting is mandatory in new construction, including slum redevelopment areas (MoHUA, 2021).

In terms of socio-economic outcomes, we have:

- More than 30% reduction in vector-borne disease incidence in informal wards (PHED, 2023),
- 10–15% rise in groundwater levels near recharge zones (IIT Indore, 2022),

- Livelihood creation for ~5,000 workers involved in decentralized waste and sanitation services (UNDP India, 2022; ADB, 2023).

Strong local governance, inter-agency coordination, and the support of agencies such as ADB, GIZ, and NIUA have been key to success (World Bank, 2022; NIUA, 2023)

B. Bhubaneswar (Odisha)

The focus on this strategy is guided by the coastal nature of the city and its susceptibility to cyclonic disturbances, and it has seen them incorporate WSD into an overall climate-resilient infrastructure plan across Bhubaneswar. The Smart City Plan stresses the following:

- Green-blue corridors, bioswales, and rain gardens along arterial roads (NIUA, 2021),
- Restoration of natural stormwater drains through bio-engineering and check-dams (IUDX, 2022)
- “Jaladhara” rainwater harvesting in 500+ public buildings (BMC, 2022; CSE, 2023).

The heritage–water integration via retrofitting Khandagiri and Kapileshwar stepwells for reuse is a unique modelling of hybrid ecological–heritage infrastructure (INTACH, 2022; ASI, 2021).

C. Socio-economic impacts :

- Water security in the drought season for 20,000+ peri-urban households (WaterAid India, 2022),
- Jobs created through urban water maintenance programs as part of NULM and Mission Shakti (UNDP India, 2023),
- Co-benefits in eco-tourism and urban heat mitigation.

But, lack of integrated greywater-stormwater reuse and an ineffective data management system obstruct long-term scalability (GIZ, 2023; Das & Kumar, 2024).

D. Coimbatore (Tamil Nadu)

Capitalizing on its historical tank system and semi-arid ecosystem, Coimbatore promotes decentralized water resilience. Restoration of the Noyyal river and 8 connected tanks through in-situ treatment and with the use of bioengineering forms the crux of its strategy (TNULB, 2021; EFI, 2022).

Examples of decentralized interventions include:

Rooftop rainwater harvesting requirement in residential and industrial estates (Corporation of Coimbatore, 2023), Bioretention basins and permeable pavements in flood-prone wards (Siruthuli, 2021), Community-managed STPs with industrial wastewater reuse (TNPCB, 2022).

E. Socio-economic impacts:

- a. ~18%, lower in flood insurance claims companies from low-lying zones (IRDAI, 2023),
- b. ~6,000 residents engaged in lake and canal stewardship, including youth and women (EFI, 2022, UN Women India, 2023),
- c. Restored wetlands nourish local fisheries and farms.

Technical fragmentation, constrained real-time water quality data, and funding restraints through CSR/NGO collaborations are the continuations of the barriers (Sood et al., 2021; WRI India, 2023).

F. Udaipur (Rajasthan)

The water scarcity and seasonal rainfall here have shaped WSD efforts that foster low-tech reuse and eco-hydrology innovations. Key projects include:

- a. Floating wetlands in Pichola and Fateh Sagar lakes for treating surface runoff and enhancing oxygenation (ICLEI-SA, 2022; INTACH Udaipur, 2023),

- b. Eco-sanitation systems & decentralisation reuse in low bathrooms (Arghyam, 2022),
- c. Pervious pavements and bioswales incorporated in old city wards and heritage zones (Smart City Udaipur, 2023)

G. Socio-economic outcomes:

- a. Enhancement in urban tourism aesthetics and traveller perception of cleanliness (Tourism Dept. Rajasthan, 2023),
- b. Decrease in the number of flooding incidents by 25% after infrastructure retrofitting in 2022–24 (UN-Habitat India, 2024),
- c. Improved resilience in slum-rehabilitated colonies like Savina and Hiran Magri.

Remaining constraints are awareness of citizens, seasonal variability, and O&M financing for localized systems (GIZ, 2022; Dasgupta et al., 2023).

Table 1: A peer-reviewed study, a national/international development agency report, or a government publication.

City	Indore	Bhubaneswar	Coimbatore	Udaipur
WSD Intervention Type	Decentralized STPs, lake rejuvenation, RWH, bioremediation wetlands	Percolation ponds, green corridors. Jaladhara recharge program, heritage-linked water reuse	Urban wetlands, bioretention swales, lake restoration, community-managed reuse in industrial	Floating wetlands, bioswales, decentralized eco-sanitation, pervious streetscapes in heritage precincts
Decentralization Level	High	Medium	Medium-High	Medium
Socio-Economic Impacts	Improved public health, sanitation in informal settlements, jobs in wastewater sector, aquifer recharge	Livelihood generation, access to water in dry months community participation, tourism enhancement	Urban flood resilience lake-stewardship initiatives, improved water quality, civic environmental literacy	Slum rehabilitation, aesthetic improvement, tourism revenue, urban heat mitigation
Key Enablers	GIZ support, DB projects. strong municipal leadership	Smart City Mission. NIUA-INTACH integration	NGO partnerships (Siruthuli, EFI). academic engagement (Anna University, PSG)	ICLEI-SA support, Smart Heritage, District planning, NGO co-design
Barriers	Inter -agency overlap, limited GIS-linked monitoring	Lack of integrated greywater reuse planning	Budgetary constraints, weak municipal convergence mechanisms	Seasonal rainfall dependency, public awareness gaps
SDG Alignment	SDG 6,11,13	S D G 6,11	S D G 6,13	S D G 6,11,13
Source	GIZ 2022; UNDP India (2022); IMC Reports(2023);adb (2020)	NIUA (2021); INTACH (2022); Bhubaneswar Smart city Ltd (2022);UN=Habitat (2023)	TNULB (2021);EF(2023);Siruthuli (2022);CPR(2020)	ICLEI-SA (2022);UMC(2023); Ministry of housing & Urban Affairs (MoHUA,2021);UNDP (2022).

X. DISCUSSION AND POLICY IMPLICATIONS

The preliminary comparative analysis of four Indian Tier-II cities, viz. Indore, Bhubaneswar, Coimbatore and Udaipur provides evidence that socially, institutionally and ecologically contextualized decentralized WSD strategies hold significant promise for climate-resilient urban water management. But the success of such initiatives depends on a number of interlocking factors — everything from governance and finance to community engagement and technical capacity.

A. General Insights From the Case Studies

Municipal Capacity and Political Leadership Are Important Enablers

- a. Cities such as Indore and Coimbatore that show strong municipal ownership and good inter-agency coordination have contributed substantially to the scaling up of decentralized WSD systems. For example, the consistent top ranking of Indore in the Swachh Bharat rankings correlates with its proactive approach toward decentralized STPs and lake restoration (IMC, 2023; UNDP, 2022). Conversely, cities with fragmented governance, as in the case of Udaipur, experience implementation bottlenecks even if innovative pilots may have already been conducted.
- b. Solutions Based on Nature (SbN) Must Be Adapted to Local Context The 4 cities show that WSD is not an “all or none” option. While percolation ponds and heritage-linked reuse that Bhubaneswar continues to rely on stand in contrast to industrial wetland systems in Coimbatore or floating islands in Udaipur. Design of, and public acceptance of, WSD interventions are shaped by the ecological and cultural contexts of which the interventions are to be deployed (INTACH, 2022; EFI, 2023).
- c. Socio-Economic Co-Benefits Remain Under- Valued in Planning WSD co-benefits—direct benefits such as improved public health, job creation, groundwater recharge, and tourism—are clear, even though they are often poorly represented/quantified in metrics for planning. Bhubaneswar and Udaipur, for instance, have harnessed water heritage and aesthetics as part of their tourism strategy, but such benefits have not yet made their way into formal cost-benefit analyses or climate investment plans (UN-Habitat, 2023; MoHUA, 2021).
- d. Data and Monitoring Infrastructure is a Persistent Gap Decentralized WSD at scale generally requires localized and distributed real-time data systems for hydrology, water quality, and asset performance.

Similarly, as implemented through the Smart Cities program, cities such as Indore have started to digitize STP and stormwater infrastructure, but most cities do not have any integrated water information system (GIZ, 2022; Sood et al., 2021).

B. Toward a Scalable Framework for Tier-II Cities

Based on the comparative analysis, a scalable WSD framework for Tier-II cities should integrate the following five pillars:

Table 2: A five-pillar framework for decentralized WSD in Tier-II cities

Pillar	Description	Operational Instruments
Decentralized Governance	Establish ward-level water cells that integrate planning, operations, and monitoring	Urban Water Mission Cells, cross-department MoUs
Community-Centric Design	Co-create WSD projects with local communities, especially in informal settlements	Participatory planning workshops, CBO and SHG partnerships
Blended Finance Models	Mobilize municipal budgets, CSR funds and climate finance for decentralized WSD investments	Green Bonds, Public-Private Partnerships (PPPs), Viability Gap Funding (VGF)
Knowledge & Capacity	Build local technical capacity through city-university collaborations and modular toolkits	Urban WSD lab, training modules for engineers and para-workers
Monitoring & Metrics	Develop SDG-aligned performance indicators and open-access monitoring dashboards	SDG 6/11-linked KPIs, IoT-based sensors for water quality and recharge

C. Policy Implications and Recommendations

Mainstream Decentralized WSD in National Missions Programs such as AMRUT 2.0, SBM-U 2.0, and the Jal Jeevan Mission should integrate decentralized WSD typologies as explicit inclusions in their funding guidelines, technical standards, and performance monitoring frameworks (MoHUA, 2021; NITI Aayog, 2022). Internationally, aligning decentralization of urban water services with national urban water missions fosters bottom-up innovation while retaining accountability (UN-Habitat, 2023; ADB, 2020).

- a. Citywide Orchestration of Institutional Synergy
Cross-sectoral governance is needed for decentralized WSD. ULBs, Parastatal agencies such as PHED and SWM departments, and Smart City SPVs should create joint implementation platforms to co-develop water-sensitive plans (NIUA, 2021; GIZ, 2021). A precondition for these, according to the Indore and Bhubaneswar models, is that convergence through Urban Water Mission Cells while tapping inter-departmental MoUs, further supports coordination and minimizes time to procure projects (UNDP India, 2022; ICLEI-SA, 2022).
- b. Invest in demonstration pilot projects in tier-II and III cities
Pilot wards are identified in quickly urbanising towns for proof-of-concept WSD opportunities according to ecological and socio-economic contexts. Such pilots must be co-developed with the tacit knowledge partners (like NIUA, GIZ, and ICLEI) and must be funded by the municipal innovation funds and CSR platforms (TERI, 2023; Das & Kumar, 2023; Sood et al., 2021). International past experiences from Southeast Asia and Latin America indicate that demonstration-based scale-up is more effective than blueprint replication (World Bank, 2021; UNESCAP, 2022).
- c. Promote SDG-Based Reporting
Municipalities must use SDG-aligned urban water metrics, specifically SDG 6.3.1 (percentage of wastewater safely treated), 6.5.1 (proportion of a basin with integrated water resources management), and 11.5 (the number of lives lost due to water-related disasters), to report on socio-ecological outcomes (UNDESA, 2021; NIUA, 2020). IoT-based dashboards or open-data platforms can foster data transparency and inter-city learning (Chatterjee & Shaw, 2021; GIZ, 2022)

XI. CONCLUSION

The socio-economic analysis of decentralized Water-Sensitive Design (WSD) strategies presented in this study for the context of Tier-II Indian cities highlights the critical gap that exists in our understanding that could assist to reimagining urban water management (UWM) beyond a centralized paradigm. Based on an in-depth comparative analysis of Indore, Bhubaneswar, Coimbatore, and Udaipur, the study shows that decentralised, community-driven, and nature-based approaches hold resilient pathways to climate action provided those actions are geographically scalable, particularly in cities having institutional fragmentation and financial constraints.

The main messages highlighted that, despite tangible benefits of localized WSD interventions—from better sanitation or water quality to increased urban liveability and equity—the uptake is still episodic and uneven owing to systemic gaps in governance, finance, and monitoring. The five-pillar framework proposed here provides a pragmatic, flexible structure from which to design and embed decentralized WSD across India's urban continuum, particularly in the fast-growing secondary cities that continue to be neglected by national urban policy.

In the days to come, ensuring WSD principles as a cross-cutting theme in India's flagship urban missions and SDG localization efforts will be key. Just as critical is the necessity to embrace inclusive, cross-sectoral partnerships to enable local governments, civil society, and academia to co-create water-resilient futures grounded in socio-ecological justice. With India's urbanization, the Tier-II cities not only pose challenges but also offer opportunities to scale decentralized, sustainable, and climate-responsive urban water systems.

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