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URBAN ECOSYSTEM SERVICES FOR CLIMATE CHANGE ADAPTATION IN DWARKA, DELHI: INSIGHTS FROM GLOBAL CASE STUDIES

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ABSTRACT

Rapid urbanisation and climate change are intensifying environmental risks in metropolitan regions, particularly in cities of the Global South. Indian cities such as Delhi are increasingly exposed to extreme heat, urban flooding, air pollution, and declining environmental quality, highlighting the urgent need for effective climate change adaptation strategies. Urban ecosystem services (UES), including regulating, provisioning, cultural, and supporting services, are increasingly recognised as a critical framework for ecosystem-based adaptation (Elmqvist et al., 2015; Kabisch et al., 2017). This study examines the role of urban ecosystem services in climate change adaptation within Dwarka Sub-City, Delhi, informed by insights from global case studies across Europe, North America, and Asia. International case studies demonstrate that regulating services such as microclimate cooling, air-quality regulation, and stormwater retention provide the strongest adaptation benefits, particularly in high-density urban environments (Larondelle and Lauf, 2016; Plieninger et al., 2022; Wang et al., 2016). Comparative analysis with global case studies underscores the importance of integrating UES into urban planning frameworks through sector-wise ecosystem service budgeting, urban tree-canopy targets, rooftop greening incentives, and coordinated blue-green infrastructure development (Zari et al., 2020; Brandt et al., 2016). The study contributes to urban climate governance literature by demonstrating how UES can function as an operational planning framework for climate adaptation in Indian metropolitan contexts. By contextualising global best practices within local socio-ecological and institutional conditions, the research offers transferable insights for rapidly urbanising cities facing similar climate challenges. Embedding UES-based strategies into statutory planning and participatory governance mechanisms is essential for strengthening long-term urban resilience in climate-stressed Indian cities.

Keywords: Urban Ecosystem Services, Climate Change Adaptation, Ecosystem-Based Adaptation, Global South Cities, Dwarka Sub City

INTRODUCTION

Rapid urbanisation combined with accelerating climate change has emerged as one of the most pressing challenges of the twenty-first century. Cities across the globe are increasingly exposed to climate-induced risks such as extreme heat events, flooding, air pollution, water scarcity, and declining environmental quality. These challenges are particularly acute in rapidly growing metropolitan regions of the Global South, where urban expansion often outpaces infrastructure provision, governance capacity, and environmental planning Seto et al. (2014); Intergovernmental Panel on Climate Change (2022). Indian cities exemplify this condition, facing compounded pressures from population growth, land-use transformation, climate variability, and socio-economic

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inequalities. Urban areas alter natural ecosystems profoundly through land cover change, replacement of permeable surfaces with impervious materials, fragmentation of green and blue spaces, and increased anthropogenic heat and emissions. These transformations weaken the capacity of urban ecosystems to deliver critical ecosystem services, thereby amplifying climate vulnerability Elmqvist et al. (2015). At the same time, there is growing recognition that urban ecosystem services (UES) the benefits humans derive from urban ecosystems can play a central role in climate change adaptation and resilience building when integrated into planning and governance frameworks Gómez-Baggethun et al. (2013); Kabisch et al. (2017).

Urban ecosystem services encompass regulating services (such as microclimate regulation, air purification, storm-water management, and carbon sequestration), provisioning services (food, water, biomass), cultural services (recreation, aesthetic value, mental health, social cohesion), and supporting services (biodiversity, soil formation, and hydrological cycles) Millennium Ecosystem Assessment (2005); The Economics of Ecosystems and Biodiversity (2011). In the context of climate change, regulating services are particularly critical, as they directly mitigate climate hazards such as urban heat islands (UHI), flooding, and pollution Bowler et al. (2010). However, provisioning and cultural services also contribute indirectly by enhancing food security, livelihoods, health, and social resilience Kabisch et al. (2015).

URBAN ECOSYSTEM SERVICES AND CLIMATE CHANGE ADAPTATION

Climate change adaptation in cities has traditionally focused on engineered or “grey” infrastructure solutions such as drainage systems, flood barriers, cooling technologies, and air-conditioning. While such approaches remain important, they are often costly, energy-intensive, and limited in addressing multiple risks simultaneously. In contrast, ecosystem-based adaptation (EbA) approaches emphasise the use of ecosystems and ecosystem services to reduce climate risks while delivering co-benefits for biodiversity, health, and social well-being European Commission (2015); Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (2019). Global research demonstrates that urban green and blue infrastructure—parks, urban forests, wetlands, lakes, green roofs, street trees, and riparian corridors—can significantly reduce land surface temperatures, improve thermal comfort, absorb storm-water, enhance air quality, and reduce energy demand Gill et al. (2007). For example, studies in European and North American cities show that tree canopy cover and green spaces can lower surface temperatures by several degrees Celsius during heat waves, thereby reducing heat-related morbidity and mortality Bowler et al. (2010). Similarly, urban wetlands and blue spaces have been shown to reduce flood risk by retaining and slowing storm-water runoff Kabisch et al. (2017). Beyond biophysical benefits, urban ecosystem services also support social and cultural dimensions of adaptation. Access to green spaces is linked to improved mental health, physical activity, social cohesion, and overall well-being, which are critical for adaptive capacity in climate-stressed environments Kabisch et al. (2015). Provisioning services such as urban agriculture and rooftop gardening can enhance food security, reduce dependence on external supply chains, and build community resilience, particularly during climate-related disruptions Thapa et al. (2021).

INSIGHTS FROM GLOBAL CASE STUDIES

Over the past decade, a substantial body of literature has emerged documenting urban ecosystem services and their role in climate adaptation across different geographical contexts. Studies from European cities such as Berlin, Copenhagen, and Barcelona have developed spatially explicit ecosystem service assessments to identify mismatches between service supply and demand and inform urban planning interventions Larondelle and Lauf (2016). Research in Asian megacities such as Beijing, Shanghai, and Bengaluru highlights the role of green-blue infrastructure in mitigating urban heat islands and managing storm-water under monsoon conditions Zhang et al. (2021). In arid and semi-arid cities like Phoenix, USA, comparative studies of urban trees and lawns reveal trade-offs between cooling benefits and water consumption, emphasising the need for context-specific ecosystem service planning Wang et al. (2016). Small island and coastal cities, such as Port Vila in Vanuatu, demonstrate how ecosystem-based adaptation and participatory governance can enhance resilience to climate extremes through integrated ridge-to-reef planning Pedersen et al. (2020). Collectively, these global case studies underscore that while ecosystem services offer powerful adaptation potential, their effectiveness depends on local climate, urban form, governance structures, and socio-economic conditions. Despite these advances, most of the empirical UES-adaptation research remains concentrated in the Global North or selected Asian contexts, with relatively limited evidence from Indian metropolitan regions. Where studies do exist in India, they often focus on isolated aspects such as urban heat islands, green cover change, or air pollution, without integrating ecosystem service supply–demand analysis, social perception, and governance dimensions in a single framework Chakraborty and Lee (2019).

THE INDIAN URBAN CONTEXT AND RESEARCH GAPS

Indian cities face distinctive climate adaptation challenges due to their tropical and subtropical climates, monsoon-driven rainfall variability, high population densities, and socio-economic inequalities. Rapid urban expansion has led to widespread loss of wetlands, green spaces, and agricultural land, undermining ecosystem services that once buffered climate risks Nagendra et al. (2018). The intensification of urban heat islands in Indian cities such as Delhi, Ahmedabad, and Hyderabad has resulted in increased heat-related health impacts and energy demand Chakraborty and Lee (2019); Intergovernmental Panel on Climate Change (2022).

At the same time, governance and planning systems in Indian cities often struggle to mainstream ecosystem-based approaches. Urban planning frameworks frequently prioritise built infrastructure and land monetisation over ecological functions, while environmental considerations are addressed in a fragmented or project-based manner Mahadevia et al. (2018). There is also limited incorporation of community perceptions and local knowledge in ecosystem service planning, despite evidence that social acceptance and participation are critical for long-term success Kabisch et al. (2017). A key gap in the literature lies in the lack of fine-scale, sector-level assessments of urban ecosystem services in Indian metropolitan contexts. Many Indian cities, including Delhi, are spatially heterogeneous, with planned sub-cities, informal settlements, institutional zones, and peri-urban areas coexisting within the same metropolitan region. Aggregated city-level analyses often mask local disparities in ecosystem service availability and climate vulnerability, limiting their usefulness for actionable planning.

DWARKA SUB-CITY, DELHI AS A CRITICAL CASE

Dwarka Sub-City, located in the south-western part of the National Capital Territory of Delhi, represents a planned urban development characterised by multiple residential sectors, institutional areas, transport corridors, and residual open spaces. Conceived as a self-contained sub-city, Dwarka has experienced rapid population growth, high-density housing development, and increasing pressure on infrastructure and environmental resources. Delhi is widely recognised as one of the most climate-vulnerable megacities in India, facing severe heat waves, deteriorating air quality, water scarcity, and periodic urban flooding. Dwarka reflects many of these challenges, including rising surface temperatures, uneven distribution of green spaces, storm-water drainage issues during monsoon periods, and limited integration of ecosystem services into sector-level planning. At the same time, Dwarka retains significant potential for ecosystem-based adaptation through existing parks, road-side green belts, lakes, vacant plots, and extensive rooftop areas suitable for greening and urban agriculture. Studying Dwarka provides an opportunity to examine how urban ecosystem services perform within a planned Indian sub-city, how their benefits and deficits are distributed spatially, and how insights from global case studies can inform local climate adaptation strategies.

AIM AND CONTRIBUTION OF THE STUDY

Against this backdrop, this study investigates urban ecosystem services for climate change adaptation in Dwarka, Delhi, drawing insights from global case studies and applying them within an Indian metropolitan context. It bridges worldwide knowledge and local practice by translating lessons from international case studies into context-specific recommendations for Dwarka. By positioning urban ecosystem services as a strategic framework for climate adaptation, the study contributes to broader debates on sustainable urban development and resilience in climate-stressed cities of the Global South. Dwarka Sub-City is a planned urban satellite neighbourhood located in southwest Delhi, comprising 29 sectors spanning residential, commercial, institutional, recreational, and transport nodes. It is a high-density residential area with expanding built-up land, declining per-capita green cover, recurrent heat stress, drainage vulnerability, and severe air pollution episodes. Dwarka therefore represents a relevant testing ground for urban climate adaptation using urban ecosystem services, particularly regulating, cultural, and provisioning services.

RESULTS AND DISCUSSIONS

ECOSYSTEM SERVICE CATEGORIES & INDICATORS

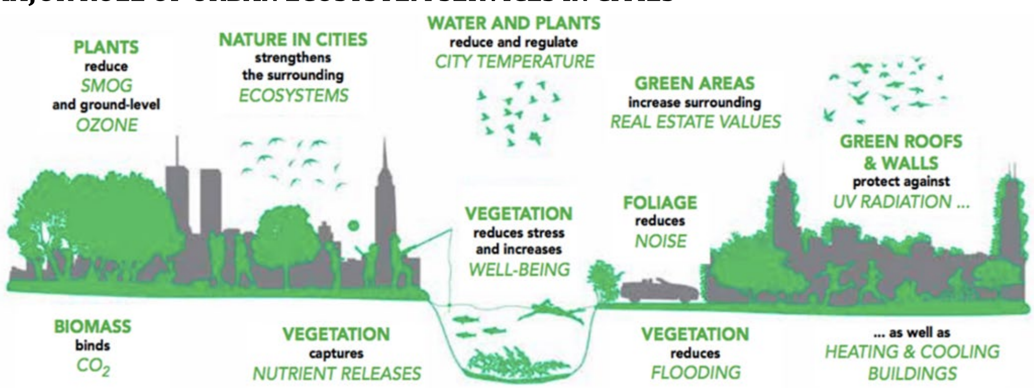
The study evaluates UES across four categories as defined by Millennium Ecosystem Assessment (2005) and The Economics of Ecosystems and Biodiversity (2011)

Category	Indicators & Metrics (Dwarka-specific relevance)
Regulating	Land Surface Temperature (°C), NDVI, tree canopy %, stormwater retention estimate, pollutant reduction potential
Provisioning	Rooftop agriculture space (m^2), food yield potential, accessible water resources
Cultural	Green space accessibility (walking distance & time), recreational ratings, perceived well-being
Supporting	Vegetation diversity index, soil permeability, biodiversity presence proxies

Indicators were selected based on data availability, policy relevance, and climate adaptation value.

IDENTIFIED COMPONENTS OF URBAN ECO SYSTEM SERVICES

MAJOR ROLE OF URBAN ECOSYSTEM SERVICES IN CITIES



Source: Https://Www.Cocity.Se/Om-Oss/Urban-Ecosystem-Services

CASE STUDY ANALYSIS TABLE 1

Table 1

Paper (author, year)	Location / scale	Aim / research question	Methods & sample	Ecosystem service(s) focus	Key findings (summary)	Adaptation / planning implications
Wang et al., 2016 — *Cooling & energy saving potentials of shade trees & urban lawns in a desert city*	Phoenix, Arizona (city / street-canyon scale)	Quantify cooling and building energy savings from shade trees vs. urban lawns	Numerical single-layer urban canopy model with tree representation; driven by 2012 meteorological data; model validation with tower measurements.	Regulating (thermal comfort, cooling); trade-offs with water use	Shade trees provide larger cooling and building energy savings than lawns; lawns cool via ET (needs irrigation) while trees cool mainly by shading; combined vegetation gives diminishing returns.	Prioritise shade trees in arid cities for UHI mitigation and energy savings; consider water–energy tradeoffs and irrigation strategy; use tree metrics (crown radius, vegetation fraction) as planning levers.

Zhang et al., 2021 — *ES supply–demand in PRD urban agglomeration*	Pearl River Delta (multiple cities, regional scale)	Assess how urbanization (2000–2015) altered spatial balance of ES supply & demand and derive planning recommendations	Spatial analysis of four ES (water yield, grain, carbon, recreation); supply/demand mapping; sensitivity analysis to urbanization indicators (POP, GDP, ALP)	Provisioning (grain), regulating (water yield, carbon sequestration), cultural (recreation)	Rapid urbanization increased ES deficits and spatial mismatch; population density, GDP and artificial land proportion are key drivers of ES imbalance; grain & carbon services showed major deficits.	Region-scale planning: control artificial land expansion, water-saving for high-consumption sectors, ecological restoration for carbon, protect agricultural supply areas; tailor strategies by development stage.
Mabon & Shih, 2021 — *Urban greenspace as adaptation in subtropical Asian cities*	Three subtropical Asian cities (Hanoi, Taipei, Fukuoka) — comparative governance study	Explore competences (skills, institutional arrangements) needed to enact climate adaptation via greenspace in subtropical Asian contexts	Policy & document review + stakeholder interviews across three cities; qualitative comparative analysis	Governance & social dimensions of greenspace (justice, participatory, planning) — a socio-institutional lens rather than specific ES types	Institutional fragmentation and the need for cross-boundary actors are bigger barriers than technical knowledge; opportunities for civil society and justice differ by city.	Strengthen cross-sectoral coordination, data translation (knowledge brokers), inclusive participation to avoid green climate gentrification; localise international NBS concepts to context.
Plieninger et al., 2022 — *Perceptions of lake ecosystem services (Bengaluru)*	Two study areas near Bengaluru, India (village / household scale)	Elicit local perceptions of ecosystem services/disservices from lakes and how drying affects perceived ES	Photo-elicitation questionnaire + stratified random household interviews; N = 536 households; Likert scales and open questions	Provisioning (water), regulating (flood, water purification), cultural (sense of place, aesthetics), disservices	People perceive multiple provisioning, regulating and cultural services from lakes; dry vs water-filled states strongly change perceived service importance; disservices (health, dumping) important.	Include local perceptions in lake restoration planning; manage disservices (waste, vector control); link socio-cultural values into management and governance approaches.
Thapa et al., 2021 — *Assessment of urban rooftop gardens in Nepal*	Kathmandu & Dhulikhel, Nepal (household / rooftop scale)	Assess species diversity, nutritional supply and constraints of rooftop gardening	Semi-structured household survey (N = 103), key informant interviews, 2 FGDs; diversity indices (Shannon)	Provisioning (food / nutritional supply), cultural (livelihoods), regulating (microclimate benefits referenced)	Rooftop gardens supply many edible species (43 edible species reported); positive attitudes but barriers include technical knowledge, load concerns and limited support.	Promote training, extension services, structural assessments for roofs, crop calendars and policy support to scale rooftop agriculture for urban food security.

Pedara / Pedersen Zari et al., 2020 — *Devising urban EbA projects: Port Vila, Vanuatu*	Port Vila, Vanuatu (island capital; ridge-to-reef scale)	Develop and prioritise urban ecosystem-based adaptation (EbA) project concepts and implementation plans	Mixed spatial & non-spatial methods: LUCI & hydrological modelling, ESRAM mapping, climate scenarios, stakeholder & participatory workshops; produced 5 EbA project plans	Terrestrial–freshwater–coastal services (flood mitigation, erosion control, coastal protection, home gardens, urban trees)	Identified priority EbA projects (riparian regeneration, coastal vegetation restoration, home-garden intensification, urban trees, sustainable housing); modelling showed lowlands vulnerable to flood/sediment and nutrient delivery to reefs.	Use participatory planning + ridge-to-reef modelling to design EbA; include governance capacity building, financing options, monitoring plans, and community governance to implement EbA in small islands.
Landuse / Mamminasata, 2020 — *Land use change, spatial interaction & sustainable dev.*	Mamminasata Metropolitan area, South Sulawesi, Indonesia (metropolitan / suburban scale)	Analyse spatial integration, spatial interaction and impacts on land-use change, economic growth and environmental quality	Comparative multi-temporal analysis (2001, 2015, 2019); surveys, observations, gravity model for spatial interaction; path analysis; sample ~400 respondents	Urban expansion impacts (land-use change, environmental degradation) — focus on socio-economic drivers	Spatial integration and agglomeration drive peri-urban land conversion, suburban service center formation, and environmental degradation; transport/connectivity key.	Policy needs for sustainable metropolitan planning: protect agricultural land, manage sprawl, coordinate multi-level governance, incorporate transport planning and carrying-capacity considerations.
Larondelle & Lauf, 2016 — *Multi-scale UES supply-demand net balance method*	Case examples / methodological paper (urban areas)	Present a transferable multi-scale method to quantify supply, demand and net balance of urban ecosystem services (UES)	Multi-scale spatial analysis combining ecological indicators and socio-economic demand; normalization & aggregation across scales	Multiple UES (provisioning, regulating, cultural) — method designed to capture heterogeneity within land-cover classes	Method shows fine-scale green patches can deliver substantial local benefits and reveals limits of supply under rising demand; multi-scale approach helps identify under-supplied areas.	Method is transferable to planning: identify undersupplied areas, prioritize services by local context (heat, water, air); warns about uncertainties where empirical parameters borrowed from other contexts.

CASE STUDY ANALYSIS TABLE 2

Table 2

Paper (file)	Location / case	Methods (short)	Ecosystem-services focus (P=provisioning / R=regulating / C=cultural / D=disservices)	Key findings (summary)	Adaptation / planning implications	Indicators / data used
Climate change adaptation policy and practice: major cities in Poland.	Major Polish cities (multi-city policy review).	Document & policy scoring; review of local strategies; compilation of EU-funded projects and participatory budget items.	**R & NbS focus** (policy and green infrastructure measures prominent); many listed projects coded as "green". **D**: shrinking urban green area trend.	Many local measures remain mitigation-lean (framed as mitigation rather than adaptation); >80% of projects labelled green, but implementation and budgets vary with weak upward trends. Green area contraction continues.	Need clearer differentiation between adaptation vs mitigation in plans; mainstream NbS with monitoring & allocation of funds; use participatory budgeting to scale local green projects.	Policy scoring metrics; counts and budgets of projects (2014–2020); land-cover trends; classification of projects (green/grey/soft).
Ecosystem services supply and demand response to urbanization — Pearl River Delta (Zhang et al., 2021).	Pearl River Delta, China (urban agglomeration analysis).	Spatial supply–demand modelling for 4 ES; regression analysis; Random Forest sensitivity analysis across urbanization gradients (2000–2015).	**P & R (water yield, grain, carbon)** and **C (local recreation)** examined. Urbanization ↓ ES supply and ↑ demand → intensified spatial imbalance.	Spatial imbalances worsen with urbanization — planning must integrate supply–demand accounting; different urbanization stages show different sensitivities (policy must be targeted).	ES supply maps (water yield, carbon, grain productivity, recreation); demand proxies (population density, GDP density, artificial land fraction); Random Forest sensitivity metrics; regression coefficients across zones.	
Cooling & energy saving potentials of shade trees and urban lawns (Phoenix numerical modelling).	Phoenix, Arizona (arid/desert city numerical case).	Urban canopy model (single-layer UCM) with stochastic tree radiative exchange; Monte Carlo simulations; energy and water trade-off analysis.	**R** dominant (shading reduces air & surface temps): shade trees provide larger energy savings than lawns; trade-off exists between water use and cooling (lawns evapotranspire but require irrigation).	For arid cities prioritise shade trees (xeric species) where water is scarce; integrate tree planting into energy-saving strategies but account for water-energy trade-offs. Use UCM outputs to target planting locations for	Modeled LST/air temp reductions; building cooling load changes; water demand for vegetation; Monte Carlo uncertainty ranges.	

				maximum cooling/energy benefit.	
Urban greenspace as adaptation in subtropical Asian cities (comparative: Hanoi, Taipei, Fukuoka).	Hanoi (Vietnam), Taipei (Taiwan), Fukuoka (Japan) — subtropical Asian governance comparison.	Qualitative: stakeholder interviews, policy & literature review; competence (skills/capacities) evaluation for greenspace adaptation.	**R & C** emphasis (greenspace for heat reduction, flood mitigation, wellbeing). Key constraint: institutional fragmentation & governance (not lack of technical policy). Equity risks (green gentrification) noted.	Build cross-sectoral competence, collaborative actors who work across institutions; embed justice/equity safeguards; localise best practices rather than direct transfer.	Governance/competence indicators (institutional linkages, participation levels, policy/legal frameworks); qualitative interview themes.
Assessment of rooftop gardens — Kathmandu & Dhulikhel, Nepal (green roofs, nutritional supply).	Kathmandu and Dhulikhel (Nepal) — household rooftop gardening survey.	Household survey (N=103), semi-structured questionnaires, key informant interviews, 2 FGDs; diversity indices (Shannon, Simpson).	**P (food & nutrition)** and **C** (satisfaction, recreation) strong; rooftop gardens supply local vegetables, increase biodiversity; constraints include technical knowledge, perceived roof load, policy support gaps. Shannon diversity: Kathmandu H≈3.58; Dhulikhel H≈3.04.	Promote training, municipal support, subsidies/loans, and technical guidance for safe rooftop systems; rooftop farming is a viable urban food security measure but needs governance & capacity building.	Survey metrics (area under cultivation, % rooftop used), diversity indices (Shannon, Simpson), costs (establishment & maintenance), satisfaction rates.
Land use change & spatial interaction — Mamminasata, South Sulawesi, Indonesia.	Mamminasata metropolitan area, South Sulawesi, Indonesia (core–periphery suburban dynamics).	Comparative land-use analysis for 2001/2015/2019; observations, surveys, documentation; path analysis and gravity model for spatial interactions.	Urban expansion/agglomeration → conversion of agricultural land, environmental quality degradation; spatial integration/interaction strongly influence suburban land-use change.	Recommend sustainable metropolitan planning, protect agricultural land, manage suburban growth with policies oriented to environmental protection and social equity. Use spatial interaction insights to guide infrastructure & land-use zoning.	Land-use change maps, path analysis outputs, gravity model metrics, socio-economic indicators across time slices.

ANALYSIS FROM THESE CASE STUDIES

Methods vary with the research question. Quantitative, spatially explicit supply–demand and modelling studies (Zhang; Larondelle previously) are best when planners need spatial targeting; household surveys (Nepal) show local provisioning & social acceptance; governance analyses (Poland; Mabon) reveal institutional obstacles.

- Context matters for which ES to prioritise. Arid cities: shading trees to save energy (Phoenix). Densifying Asian cities: governance & equity in greenspace rollout (Hanoi/Taipei/Fukuoka). Rapid urbanization: supply declines while demand rises (Pearl River Delta). Rooftops: local provisioning and biodiversity benefits (Kathmandu).
- Implementation needs cross-cutting measures. Technical models + social participation + governance capacity + financing (policy instruments) produce implementable results. Several papers flag the need for monitoring indicators to track outcomes.

CONCLUSION

The literature increasingly emphasizes the need for ecosystem-based adaptation and nature-based solutions in cities to cope with intensifying climatic pressures. However, translation of evidence into planning practice remains limited in rapidly developing nations such as India. This review demonstrates the potential for UES-based strategies to strengthen urban resilience through fine-scale spatial mapping, social value integration, and participatory governance. By applying these principles to Dwarka, the study contributes to global scholarship and provides a replicable adaptation framework for Indian metropolitan planning.

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