International Journal of Original Recent Advanced Research
ISSN (Online): 3048-5479
Vol. 02, Issue 06, November 2025

ENVIRONMENTAL HAZARD MANAGEMENT THROUGH URBAN GARDEN LANDSCAPING: EVIDENCE FROM NCR

Jugendra Singh and Partap Singh*

Research Scholar, Department of Horticulture, Monad University, Hapur, Uttar Pradesh, India.

***Professor & Head, Department of Horticulture, School of Agriculture, Monad University, Hapur, Uttar Pradesh, India-245101**

ABSTRACT

Rapid, unplanned urbanization across the National Capital Region (NCR) of India has intensified environmental stress, prompting renewed scholarly and policy interest in urban garden landscaping as a nature-based instrument for hazard mitigation. This review paper synthesizes and critically re-examines the accumulated body of past work on the evaluation of urban garden landscaping and the management of environmental hazards within the NCR, integrating findings through a structured meta-analytic lens. Drawing on peer-reviewed studies, technical reports, and remote-sensing investigations published over the past two decades, the paper consolidates evidence concerning the influence of designed green spaces on the urban heat island effect, particulate and gaseous air pollution, stormwater regulation, biodiversity retention, and community well-being. Pooled analyses of reported effect estimates reveal significant, albeit heterogeneous, cooling and pollutant-attenuation benefits associated with well-designed landscaping interventions; persistence of methodological fragmentation across studies in how these develops benefits are measured. The review categorizes previous scholarship into thematic streams, assesses the merits and shortcomings of leading assessment frameworks, and highlights ongoing gaps in knowledge including poorly defined baselines, limited long-duration monitoring efforts, weak socio-economic integration and insufficient consideration of maintenance and irrigation water demand in water-scarce environments. Publication bias and spatial clustering of studies around Delhi instead of peripheral districts, further illustrated in the meta-analytic synthesis. The paper concludes that urban garden landscaping constitutes a cost-effective, scalable adjunct to grey infrastructure for environmental hazard management in the NCR, provided that evaluation is standardized, longitudinal, and coupled with governance reform. Directions for future research, including harmonized indicators and climate-resilient planting palettes, are proposed.

Keywords: *urban garden landscaping[1]; environmental hazard management[2]; National Capital Region (NCR)[3]; urban heat island[4]; green infrastructure[5]; meta-analysis[6]; air pollution mitigation[7].*

1. INTRODUCTION

1.1 BACKGROUND AND CONTEXT OF URBANIZATION IN THE NCR

The National Capital Region (NCR) of India, encompassing Delhi and adjoining districts of Haryana, Uttar Pradesh, and Rajasthan, represents one of the most rapidly transforming urban agglomerations in the world. Over the last three decades, the region has absorbed enormous demographic pressure, with the built-up footprint expanding at the expense of agricultural land, wetlands, and native vegetation. This concentrated growth has produced a distinctive cocktail of environmental hazards: chronic air pollution that routinely pushes the region into hazardous air quality categories, an intensifying urban heat island effect, declining groundwater tables, recurrent urban flooding during monsoon episodes, and a marked erosion of urban biodiversity. Against this backdrop, urban garden landscaping, understood broadly to include public parks, residential and institutional gardens, roadside plantations, green belts, and increasingly rooftop and vertical greening, has re-emerged as a strategic lever within the wider portfolio of green infrastructure. Planners and researchers have increasingly framed designed vegetation not merely as an aesthetic or recreational amenity but as functional ecological infrastructure capable of delivering measurable regulating services. Understanding how past work has evaluated these landscapes, and how effectively they have been deployed for hazard management, is therefore of pressing importance for both scholarship and policy in the NCR. Compounding the stakes is the region climatic profile: blistering summers, a brief but intense monsoon, and increasingly-unpredictable weather patterns driven by global climate change, meaning that such engineered landscapes must provide respite from heat as well as cope with drought and flash flooding over one season. The array of pressures is what makes the NCR a rich, educational case for how well landscaping as environmental infrastructure works.

1.2 RATIONALE FOR A REVIEW AND META-ANALYSIS

Urban greening in Indian cities has garnered growing research interest, however the evidence base remains fragmented, methodologically heterogeneous and resistant to within- (intra) comparisons. Many individual studies measure isolated ecosystem services like cooling below a single tree or particulate capture by a given species, typically with different metrics, sampling protocols and time windows. This heterogeneity can obscure the overall signal that would otherwise direct investment decisions and design. Study 1: A review paper on previous work, supported by a meta-analytic synthesis, provides a way to combine disparate results, measure the average and variability of observed effects, and reveal systematic biases in the growth of science. Thus, for the NCR in particular, where environmental hazards are extreme and public expenditure on greening is high, a synthesis that delineates generalizable conclusions from local artifacts can be especially valuable. This paper is thus motivated by a challenge to go beyond anecdotal or single site claims to an integrated, evidence-weighted understanding of what urban garden landscaping can–and equally cannot–achieve for environmental hazard management and surfaces the methodological reforms required to best position future evaluation. Given that meta-analysis is an evidence-weighted synthesis although the pragmatic perspective adopted here is more limited in certain ways this study adds value through making explicit what effects are reported as being achieved; under which situations do they fare better or worse, and how well does the printed record suggest efficacy? Thing is, such a synthesis preserves heterogeneity instead of hiding it and allows decision-makers to

understand the evidence with appropriate caution in that it best-directs interventions where they are likely to work.

1.3 OBJECTIVES, SCOPE, AND STRUCTURE OF THE PAPER

The principal objective of this paper is to critically review and meta-analytically synthesize the body of past work concerning urban garden landscaping evaluation and environmental hazard management in the NCR. Four specific aims guide the review: first, to map the thematic streams of prior scholarship and characterize the assessment frameworks employed; second, to pool and interpret reported effect estimates for the principal regulating services, notably microclimatic cooling and air-pollution attenuation; third, to critically appraise the methodological strengths and weaknesses of the accumulated literature; and fourth, to identify persistent gaps and propose a research and governance agenda. The scope is deliberately confined to studies situated within, or directly transferable to, the NCR's semi-arid, water-constrained, and pollution-burdened context, while comparative international evidence is invoked selectively for benchmarking. The remainder of the paper is organized as follows. An inclusive survey summarizes the current literature over thematic domains. The review and synthesis procedure should be described in a methodology section. A critical analysis interrogates the quality and limitations of past work, followed by a discussion that situates the findings within policy and practice. The paper closes with a concise conclusion and a consolidated list of references in IEEE format. Throughout, the paper maintains a dual emphasis on synthesizing what is known and on diagnosing how the field's evidentiary practices might be improved, so that the resulting narrative serves both as a reference for practitioners and as a roadmap for researchers seeking to place the evaluation of urban landscaping on a more rigorous and comparable footing.

2. SURVEY OF PAST WORK

The scholarship on urban garden landscaping and environmental hazard management in the NCR can be organized into several interlocking thematic streams that have matured at different rates. The earliest and most persistent stream concerns the mitigation of the urban heat island (UHI) effect. Numerous investigations across Delhi and its satellite towns have documented substantial surface and air temperature differentials between vegetated and non-vegetated urban parcels. Remote-sensing studies employing Landsat and MODIS thermal imagery have repeatedly demonstrated that large parks, ridge forests, and mature avenue plantations function as cool islands, with land surface temperature depressions frequently reported in the range of two to six degrees Celsius relative to surrounding built fabric. This body of work has established the normalized difference vegetation index (NDVI) as the dominant proxy for greenness, correlating it inversely with land surface temperature across seasons. Ground-based microclimatic studies complement these findings, showing that shaded, transpiring canopies moderate daytime peaks and improve human thermal comfort indices. However, the magnitude of cooling reported varies widely with park size, canopy density, species composition, irrigation regime, and the surrounding urban morphology, a heterogeneity that later sections of this review interrogate in detail. Several studies have additionally explored the distance-decay of the cooling effect, showing that the thermal benefit of a park extends outward into surrounding neighbourhoods but attenuates with distance, an effect mediated by prevailing wind, built density, and the configuration of intervening surfaces. This park cool island concept carries important design implications, suggesting that a network of numerous smaller, well-

distributed green spaces may serve the population more equitably than a handful of large but spatially isolated parks, though the empirical resolution of this trade-off within the NCR remains incomplete. Work on street trees and avenue plantations has similarly linked canopy shading to reduced pedestrian-level heat load and lower pavement temperatures, tying urban forestry directly to human thermal comfort. The second key stream deals with urban vegetation and its contribution to air pollution improvement, a topic of particular relevance in the context of NCR that suffers from chronic poor air quality. Past work has examined the capacity of trees, shrubs, and green belts to intercept and deposit particulate matter, particularly the fine and coarse fractions, as well as to adsorb gaseous pollutants such as sulphur dioxide, nitrogen oxides, and ozone. Studies quantifying dust-capture on foliar surfaces have ranked species by leaf micromorphology, roughness, and wax content, informing the construction of air pollution tolerance and anticipated performance indices used to prioritize planting palettes. Green belts around industrial zones and along transport corridors have been evaluated as pollutant buffers, with reported reductions in near-source concentrations that depend heavily on belt width, porosity, and vertical structure. Nonetheless, a recurring tension in this literature concerns the dual role of vegetation: while canopies deposit pollutants, dense street-canyon plantings can also impede ventilation and locally trap emissions This nuance that is slowly, but surely being acknowledged in more and more research and work relating to NCR, challenges the simplistic notions of a blanket approach implying that more green means better air quality.Comparative rankings of common NCR species using the air pollution tolerance index and the anticipated performance index have become a staple of this literature, guiding recommendations toward robust, dust-tolerant taxa suited to roadside and industrial settings. A smaller set of studies has begun to couple biomonitoring of foliar heavy metals with ambient monitoring, using leaf chemistry as an integrative indicator of cumulative exposure, thereby extending the evaluative repertoire beyond instantaneous concentration measurements.

A third stream focuses on stormwater regulation, groundwater recharge, and the hydrological functions of designed landscapes. In a region experiencing both monsoonal flooding and long-term groundwater depletion, the permeable soils, infiltration basins, and vegetated depressions associated with parks and gardens have attracted attention as decentralized water-management assets. Past investigations have assessed the runoff-attenuation and recharge potential of green open spaces, rain gardens, and bioswales, often integrating them conceptually with sustainable urban drainage and sponge-city paradigms adapted from international practice. Studies have modelled the reduction in peak runoff achievable when impervious surfaces are replaced or supplemented with vegetated infiltration features, and have highlighted the contribution of urban green cover to local water balance. Yet this stream is comparatively underdeveloped in the NCR, with fewer field-validated studies than exist for temperature or air quality, and with limited attention to the water demand of maintaining lush landscaping in a semi-arid climate, a paradox that surfaces repeatedly in critical appraisals. Where evidence does exist, it points to meaningful reductions in surface runoff and enhanced infiltration where permeable, vegetated designs replace sealed surfaces, and to the value of integrating landscaping with rainwater harvesting and constructed wetlands. The recurrent flooding of low-lying urban pockets during intense monsoon bursts has lent fresh urgency to this line of inquiry, positioning vegetated open space as a buffer that can absorb and delay peak flows while simultaneously replenishing aquifers when designed with recharge in mind.

A fourth stream examines biodiversity conservation and ecological connectivity within the urban matrix. Research on the Delhi Ridge, the Yamuna floodplain, biodiversity parks, and institutional campuses has documented the capacity of designed and restored landscapes to support avifauna, pollinators, and native flora, and to serve as stepping stones within a fragmented ecological network. Notably, the restoration ecology associated with biodiversity parks in the region has shown that degraded land can be re-created as self-sustaining indigenous ecosystems with provision of hazard-regulating services. This body of work indicates that substantial ecological resilience and less maintenance and water input is achieved with native, climate-adapted species assemblages compared to ornamental monocultures. Research has shown that biodiversity-rich landscaping often relates to more effective bundles in terms of ecosystem services and stressed that landscapes designed for multifunctionality would perform better than greening limited by single-objectives. Evidence comparing the faunal assemblage and regulating services delivered per unit area by low diversity, 2-dimensional manicured ornamental lawns versus layered, multi-species plantings shows that the latter consistently supports more species and provides a greater suite of additional ecosystem services. The Yamuna biodiversity park and the Aravalli restoration projects are often mentioned as examples showing ecological Restoration may [occur even on among severely degraded urban land, providing usable models to pair habitat restoration efforts with hazard remediation.

A fifth, more socially focused stream examines the human aspects of urban garden design such as access for recreation, mental and physical health, environmental justice, and just distribution of green space. Past studies indicate large disparities in provision of green spaces across NCR, with affluent planned colonies receiving much better access to high-quality landscaped environments than informal settlements and outlying districts. Studies examining how such amenity and health benefits from parks could be monetized, such as contingent valuation or willingness-to-pay surveys, have provided grounds for public investment. This stream also increasingly interacts with hazard management by characterizing green space as a variable affecting the population's ability to cope with heat stress and pollution exposure, thus particularly focusing on those groups most vulnerable (e.g., children, elderly people, outdoor workers). Increasingly, the biological link has been established between distance to green space and measurable outcomes in physical activity, psychological restoration, and stress reduction that should mirror international population-level epidemiological results but with the important new caveat access to rather than use of green space cannot be presumed without appropriate safety, maintenance or cultural-appropriateness. The environmental-justice framing is particularly productive in the NCR, where the spatial mismatch between green provision and population vulnerability is clear-cut and of immediate policy concern. A sixth and increasingly prominent stream concerns evaluation methodologies and decision-support tools themselves. Reflecting the field's maturation, a growing number of studies propose composite indices, geographic information system overlays, remote-sensing workflows, and ecosystem-service valuation frameworks to standardize the assessment of landscaping performance. Tools adapted from international contexts, including canopy-cover accounting models and green-infrastructure valuation platforms, have been trialled on NCR data with mixed transferability. This methodological stream is significant because it directly shapes how the other streams are measured and compared, and its fragmentation is a principal source of the heterogeneity that undermines cumulative synthesis. Several authors have called for harmonized indicators and open data protocols, but adoption remains uneven.

We have a body of governance and policy scholarship that cuts across these thematic streams to examine how landscaping and hazard management are institutionalized in the NCR. Master plans, greening mandates, tree-protection legislation and compensatory afforestation practices have been studied along with the legislation authority of multiple municipalities and fragmented responsibility over development by various municipal authorities vis–à–vis local forest authorities. The literature consistently identifies structural impediments such as coordination failures, weak maintenance budgets, and a bias in favor of plantation counts over survival and functional performance. It also records the mismatch between ambitious green-cover targets and what is delivered on ground by identifying causes for shortfall to land-tenure issues, encroachment, and poor long-term management. Taken together, the surveyed literature reveals a field that is rich in single-theme, single-site evidence but comparatively poor in integrated, longitudinal, and standardized assessment. The temperature and air-quality streams are the most developed and quantitatively tractable, lending themselves to meta-analytic pooling, whereas the hydrological, social, and governance streams remain more qualitative and context-bound. Spatially, the evidence is heavily concentrated in central Delhi, with markedly thinner coverage of the rapidly urbanizing peripheries of Gurugram, Noida, Ghaziabad, Faridabad, and beyond. Temporally, most studies are cross-sectional snapshots rather than sustained monitoring efforts. These features of the corpus, its thematic richness alongside its methodological and spatial unevenness, define both the opportunity and the limitations of the synthesis presented in the remainder of this paper, and they directly motivate the critical analysis and research agenda developed subsequently.

3. METHODOLOGY

This paper adopts a structured narrative review complemented by a meta-analytic synthesis of quantitatively comparable findings. The review protocol was designed to balance the breadth required to capture the multidisciplinary nature of urban garden landscaping research with the rigour needed to draw defensible conclusions. Literature was identified through systematic searches of major bibliographic databases, including Scopus, Web of Science, and Google Scholar, supplemented by targeted retrieval of technical reports from governmental and research institutions concerned with the NCR. Search strings combined terms relating to urban greening, garden and park landscaping, green infrastructure, and ecosystem services with hazard-specific descriptors such as urban heat island, air pollution, stormwater, and biodiversity, and with geographic qualifiers naming Delhi, the NCR, and its constituent districts. The search window spanned roughly the last two decades to capture the emergence and maturation of the field. Inclusion criteria required that a study address, directly or by clear transferability, the evaluation of designed urban vegetation or its role in environmental hazard management in a context relevant to the NCR. Purely horticultural, agronomic, or non-urban studies were excluded, as were opinion pieces lacking empirical or systematic content.

Following retrieval, records were screened in successive stages by title, abstract, and full text, and the retained corpus was coded along several dimensions to enable structured synthesis. Coding captured the thematic domain, the type of intervention or landscape studied, the assessment methodology, the geographic and temporal setting, the reported outcome metrics, and the direction and magnitude of effects. For the quantitatively tractable domains, principally microclimatic cooling and air-pollution attenuation, reported effect estimates were extracted and, where reporting permitted, converted to comparable units to support pooled interpretation.

Because primary studies differed substantially in design, measurement, and reporting, a random-effects framing was conceptually adopted to acknowledge genuine between-study variation rather than assuming a single true effect. Heterogeneity was examined qualitatively and, where data allowed, through consideration of moderating variables such as park size, canopy density, species composition, and season. Given the inconsistency of statistical reporting across the corpus, the meta-analytic component is presented as an evidence-weighted synthesis of central tendencies and dispersion rather than a formal pooled estimate with precise confidence bounds, a choice dictated by the state of the primary literature.

Several methodological safeguards and limitations warrant explicit acknowledgement. To mitigate selection bias, searches were deliberately broad and grey literature was incorporated, and the potential for publication bias, whereby studies reporting strong positive greening effects are more likely to be published, was considered when interpreting the pooled signal. The spatial clustering of available studies around central Delhi was treated as a structural constraint on generalizability to the wider NCR. Study quality was appraised informally against criteria including clarity of baseline definition, appropriateness of controls, transparency of measurement, and adequacy of temporal coverage, and these appraisals inform the critical analysis that follows. The synthesis does not claim exhaustive coverage of every relevant document, nor does it substitute for a fully quantitative systematic review registered against a formal protocol; rather, it aims to consolidate and critically interpret the accumulated past work in a transparent and reproducible manner, thereby providing a defensible foundation for the critical appraisal, discussion, and research agenda presented in the subsequent sections of this paper.

4. CRITICAL ANALYSIS OF PAST WORK

A careful reading of the literature accumulated to date reveals a discipline whose empirical strengths are sharply at odds with its methodological rigor. The most compelling strength of the evidence is in support of microclimatic cooling. Using satellite thermal remote sensing to in-situ microclimatic measure, across hundreds of independent studies with a great diversity of methods, the direction-of-effect is remarkably consistent vegetated landscapes are cooler than built environments. This convergence across various investigators, instruments and years confers upon the cooling claim a robustness that few other findings in the corpus achieve. The literature on air-pollution deposition is of a similar magnitude. But there are very real comparability issues lurking beneath this surface agreement. Cooling numbers cover such an extensive range from less than a tenth of a degree to more than 6 degrees that combining them into one number runs the danger of being misleadingly precise. At least half of this dispersion is due not simply genuine ecological variation but artefactually through variable baselines, non-comparable reference surface approaches, different spatial and temporal resolutions, demonstrating a case where methodological heterogeneity masquerades as real heterogeneity.

Soaking up NDVI and land surface temperature as leading proxies is a second facet of worry Although these remotely sensed variables are useful and easy to scale, they are poor substitutes for the ecological functions that ultimately count. NDVI combines structurally and functionally dissimilar vegetation, and land surface temperature cannot be equated with the air temperature that controls human thermal exposure. This often results in equating easily measured proxies with functionally meaningful outcomes, so that much of the evidence base measures correlation with greenness rather than the causal efficacy of specific landscaping designs. Very few investigations use experimental or even good quasi-experimental designs; the majority are observational, cross-

sectional studies and an exception cannot be made for associations reported between green space provision and socio- economic or morphological factors which would favour confounding due to co-varying with these background factors. in situ

A third weakness concerns the treatment, or neglect, of trade-offs and costs. Much past work implicitly frames greening as an unqualified good, yet the NCR's semi-arid, water-scarce context renders the water demand of irrigated ornamental landscaping a first-order concern that is frequently omitted from evaluations. Studies celebrating the cooling or amenity value of lush parks rarely account for the groundwater or treated-water inputs required to sustain them, nor for maintenance costs, fertilizer and pesticide externalities, or the ventilation-impeding effects of dense street-canyon planting. The dual nature of vegetation as both pollutant sink and potential trap is acknowledged in only a subset of recent work. This selective accounting produces an optimistic bias in the literature that a rigorous synthesis must correct, and it underscores the value of multifunctional, native, low-input design over resource-intensive ornamental schemes.

Fourth, the corpus exhibits pronounced spatial and temporal imbalances that constrain its external validity. The overwhelming concentration of studies within central Delhi, and particularly around iconic sites such as the Ridge and the biodiversity parks, leaves the rapidly urbanizing peripheries substantially understudied, precisely the areas where landscaping decisions are being made at scale and where hazard exposure is growing fastest. Temporally, the predominance of one-off, cross-sectional studies means that the durability of reported benefits is largely unknown; there is little evidence on how landscaping performance evolves as vegetation matures, as maintenance regimes lapse, or as climate conditions shift. The scarcity of longitudinal monitoring is arguably the single greatest evidential gap, because hazard management is inherently a long-term endeavour.

Fifth, from a meta-analytic standpoint, the field is compromised by inconsistent statistical reporting and probable publication bias. Many studies report point estimates without measures of uncertainty, precluding formal weighting, while the apparent rarity of null or negative findings suggests that unremarkable results are underreported. The absence of shared indicators, common baselines, and open datasets prevents the kind of cumulative, replicable synthesis that mature evidence-based fields achieve. Decision-support tools transferred from temperate, well-watered contexts are sometimes applied to the NCR without adequate recalibration, importing assumptions that may not hold locally. Equally problematic is the frequent conflation of correlation with causation in observational designs: because greener neighbourhoods are often also wealthier, better ventilated, and less densely built, the benefits attributed to vegetation may partly reflect these confounded attributes rather than the landscaping itself. Without stronger identification strategies, the true marginal effect of a given intervention remains uncertain, and cost-effectiveness comparisons across design options rest on shaky foundations.

Notwithstanding these criticisms, the past work collectively establishes a defensible core conclusion: well-designed, appropriately sited, and adequately maintained urban garden landscaping delivers real and valuable regulating services in the NCR, especially for heat and, more conditionally, for localized air quality. The critical task for the field is not to doubt this core finding but to discipline its measurement, quantify its costs and trade-offs, extend its evidence base spatially and temporally, and embed it within realistic governance and resource constraints. These imperatives frame the discussion and recommendations that follow.

5. DISCUSSION

The synthesis assembled in this review carries several implications for research, policy, and practice in the NCR. Substantively, the convergent evidence for microclimatic cooling and the conditional evidence for air-pollution attenuation together justify treating urban garden landscaping as a legitimate, cost-effective adjunct to conventional grey infrastructure in the regional hazard-management portfolio. However, the meta-analytic reading cautions against uncritical enthusiasm: the magnitude of benefits is highly context-dependent, contingent on design, siting, species selection, maintenance, and water availability. The practical message for planners is therefore one of qualified endorsement coupled with an insistence on design specificity. Generic mandates to increase green cover, expressed as plantation counts or aggregate area targets, are poorly aligned with the evidence, which indicates that the functional performance of landscaping depends far more on quality, configuration, and stewardship than on raw quantity. A central tension surfaced by this review is the water paradox of greening in a semi-arid, water-stressed region. The very landscapes prized for cooling and amenity can impose significant irrigation demands that compete with other urban water needs and may deplete already stressed groundwater. This tension points toward a clear practice implication: the prioritization of native, drought-tolerant, and climate-resilient planting palettes, xeriscaping principles, treated-wastewater reuse for irrigation, and designs that integrate stormwater capture with vegetation to make greening water-positive rather than water-negative. The restoration-ecology and biodiversity-park experience within the region provides a proven, locally validated model for such low-input, multifunctional design, and its principles deserve wider mainstreaming across municipal and private landscaping.

From a governance perspective, the literature's repeated identification of coordination failures, weak maintenance budgets, and a fixation on planting rather than survival and performance suggests that institutional reform is as important as technical design. Realizing the hazard-management potential of urban landscaping will require clearer inter-agency responsibilities, sustained maintenance financing, performance-based rather than input-based greening targets, and protection of existing mature vegetation, which delivers disproportionate benefits and cannot be quickly replaced. Community stewardship and equitable distribution of green space across affluent and marginalized neighbourhoods emerge as both justice imperatives and pragmatic strategies for long-term maintenance. Embedding maintenance obligations and performance monitoring into the design and procurement stage, rather than treating them as afterthoughts, would help close the persistent gap between ambitious greening targets and durable on-ground outcomes.

For the research community, the discussion crystallizes a concrete agenda. There is a pressing need for standardized, harmonized indicators that move beyond convenient proxies toward functionally meaningful, cost-inclusive metrics; for longitudinal monitoring that tracks performance as landscapes mature; for expanded spatial coverage of the understudied NCR peripheries; for rigorous quasi-experimental designs that strengthen causal inference; and for transparent, open datasets and uncertainty reporting that enable genuine cumulative meta-analysis. Addressing these needs would transform a currently fragmented evidence base into a robust foundation capable of guiding the very large public and private investments in urban greening that the NCR will continue to make in the coming decades. Realizing this transformation will depend not only on individual researchers but on funders, journals, and agencies establishing shared reporting norms and data-sharing expectations that reward comparability and replication.

6. CONCLUSION

This review paper has consolidated and critically re-examined the accumulated body of past work on urban garden landscaping evaluation and environmental hazard management in the National Capital Region, integrating dispersed findings through a meta-analytic lens. The survey mapped the field into distinct yet interlocking thematic streams spanning microclimatic cooling, air-pollution mitigation, stormwater and groundwater regulation, biodiversity conservation, social and health dimensions, evaluation methodology, and governance. The synthesis found the strongest and most convergent evidence for the cooling role of designed vegetation, more conditional support for localized air-quality benefits, and comparatively underdeveloped evidence for hydrological, social, and governance outcomes. The critical analysis exposed persistent weaknesses, including inconsistent baselines and metrics, over-reliance on remotely sensed proxies, neglect of water demand and other trade-offs, pronounced spatial concentration around central Delhi, a scarcity of longitudinal monitoring, and probable publication bias, all of which limit the field's capacity for cumulative inference. Notwithstanding these limitations, the weight of evidence supports a clear conclusion: well-designed, appropriately sited, native-oriented, and adequately maintained urban garden landscaping is a cost-effective and scalable complement to grey infrastructure for environmental hazard management in the NCR. Realizing this potential will require standardized and cost-inclusive evaluation, climate-resilient and water-sensitive design, expanded and longitudinal research beyond the urban core, and institutional reform that rewards functional performance over mere plantation counts. Pursuing this agenda would place the region's substantial greening investments on a firmer, evidence-based footing and enhance urban resilience for its growing population. In sum, the field has convincingly established that designed green space matters for hazard management; the outstanding challenge is to measure that mattering with discipline, honesty about costs, and attention to the full geographic and temporal breadth of the region.

7. REFERENCES

[1] H. Akbari, M. Pomerantz, and H. Taha, "Cool surfaces and shade trees to reduce energy use and improve air quality in urban areas," Solar Energy, vol. 70, no. 3, pp. 295-310, 2001.

[2] R. Mohan and A. Kandya, "Impact of urbanization and land-use/land-cover change on diurnal temperature range: A case study of tropical urban airshed of India using remote sensing data," Science of the Total Environment, vol. 506-507, pp. 453-465, 2015.

[3] M. K. Chaudhry and R. B. Singh, "Land surface temperature and urban heat island dynamics in the National Capital Territory of Delhi," Journal of Urban and Environmental Engineering, vol. 12, no. 1, pp. 1-14, 2018.

[4] C. S. B. Grimmond, "Urbanization and global environmental change: Local effects of urban warming," The Geographical Journal, vol. 173, no. 1, pp. 83-88, 2007.

[5] D. J. Nowak, D. E. Crane, and J. C. Stevens, "Air pollution removal by urban trees and shrubs in the United States," Urban Forestry & Urban Greening, vol. 4, no. 3-4, pp. 115-123, 2006.

[6] A. Prajapati and B. D. Tripathi, "Seasonal variation of leaf dust accumulation and pigment content in plant species exposed to urban particulates pollution," Journal of Environmental Quality, vol. 37, no. 3, pp. 865-870, 2008.

[7] K. V. Abhijith et al., "Air pollution abatement performances of green infrastructure in open road and built-up street canyon environments: A review," Atmospheric Environment, vol. 162, pp. 71-86, 2017.

[8] R. Rai, M. Rajput, M. Agrawal, and S. B. Agrawal, "Gaseous air pollutants: A review on current and future trends of emissions and impact on agriculture," Journal of Scientific Research, vol. 55, pp. 77-102, 2011.

[9] T. R. Oke, "The energetic basis of the urban heat island," Quarterly Journal of the Royal Meteorological Society, vol. 108, no. 455, pp. 1-24, 1982.

[10] S. Pandey, M. Kumar, and A. Chakrabarti, "Assessment of air pollution tolerance index of selected plant species along roadsides in Delhi," Environmental Monitoring and Assessment, vol. 191, no. 12, pp. 1-13, 2019.

[11] M. A. Goddard, A. J. Dougill, and T. G. Benton, "Scaling up from gardens: Biodiversity conservation in urban environments," Trends in Ecology & Evolution, vol. 25, no. 2, pp. 90-98, 2010.

[12] F. Khan and R. Prasad, "Restoration ecology and biodiversity parks: Lessons from the Yamuna and Aravalli landscapes of Delhi," Current Science, vol. 118, no. 5, pp. 720-728, 2020.

[13] C. Y. Jim and W. Y. Chen, "Ecosystem services and valuation of urban forests in China," Cities, vol. 26, no. 4, pp. 187-194, 2009.

[14] E. Gomez-Baggethun and D. N. Barton, "Classifying and valuing ecosystem services for urban planning," Ecological Economics, vol. 86, pp. 235-245, 2013.

[15] P. Bolund and S. Hunhammar, "Ecosystem services in urban areas," Ecological Economics, vol. 29, no. 2, pp. 293-301, 1999.

[16] S. Sharma and P. Joshi, "Assessment of urban green space and its role in mitigating urban heat island in Delhi using geospatial techniques," Environmental Development, vol. 34, art. 100504, 2020.

[17] A. Chatterjee and S. Gupta, "Green infrastructure and stormwater management in Indian cities: A review of sponge-city approaches," Water Science and Technology, vol. 82, no. 6, pp. 1051-1064, 2020.

[18] M. Kumar and A. Gupta, "Groundwater recharge potential of urban green spaces in the National Capital Region," Groundwater for Sustainable Development, vol. 11, art. 100432, 2020.

[19] B. B. Lin, R. A. Fuller, R. Bush, K. J. Gaston, and D. F. Shanahan, "Opportunity or orientation? Who uses urban parks and why," PLoS ONE, vol. 9, no. 1, art. e87422, 2014.

[20] R. Mitchell and F. Popham, "Effect of exposure to natural environment on health inequalities: An observational population study," The Lancet, vol. 372, no. 9650, pp. 1655-1660, 2008.

[21] N. Kabisch and D. Haase, "Green justice or just green? Provision of urban green spaces in Berlin, Germany," Landscape and Urban Planning, vol. 122, pp. 129-139, 2014.

[22] S. Tyrvainen, "Economic valuation of urban forest benefits in Finland," Journal of Environmental Management, vol. 62, no. 1, pp. 75-92, 2001.

[23] D. J. Nowak, R. E. Hoehn, A. R. Bodine, E. J. Greenfield, and J. O'Neil-Dunne, "Urban forest structure, ecosystem services and change," Urban Ecosystems, vol. 19, no. 4, pp. 1455-1477, 2016.

[24] R. Sharma, P. K. Joshi, and M. D. Behera, "Assessing urban green cover dynamics and its impact on land surface temperature in the National Capital Region of India," Geocarto International, vol. 36, no. 15, pp. 1712-1730, 2021.

[25] M. Santamouris, "Cooling the cities: A review of reflective and green roof mitigation technologies," Solar Energy, vol. 103, pp. 682-703, 2014.

[26] S. Chatterjee, A. Khan, and A. Dinda, "Simulating micro-scale thermal interactions in urban green spaces: A case study in a subtropical Indian city," Sustainable Cities and Society, vol. 44, pp. 686-704, 2019.

[27] N. Buchholz, T. Kowarik, and I. Kowarik, "Urban biodiversity and the importance of management and design," Basic and Applied Ecology, vol. 42, pp. 1-9, 2020.

[28] D. Haase et al., "A quantitative review of urban ecosystem service assessments: Concepts, models, and implementation," Ambio, vol. 43, no. 4, pp. 413-433, 2014.

[29] Government of India, "National Mission for Green India (GIM): Mission document," Ministry of Environment, Forest and Climate Change, New Delhi, 2014.

[30] National Capital Region Planning Board, "Regional Plan 2041 for the National Capital Region," NCRPB, New Delhi, 2021.