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From Environmental Justice to Multispecies Equity: Rethinking Sustainable Urban Infrastructure Planning Through Well-Being, Climate Resilience, and Ethical Governance

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ABSTRACT

Urban green and blue infrastructure are routinely promoted as a pathway toward climate resilience, public health, and sustainable development. Yet increasing environmental amenities does not necessarily reduce inequality, and projects that improve aggregate ecological indicators may reproduce exclusion, displacement, or biodiversity loss. This critical integrative review updates Liotta and colleagues' multidimensional environmental justice approach using a bounded corpus of Scopus-exported studies through October 2026. We synthesize developments in spatial accessibility, cumulative environmental burdens, heat exposure, social segregation, health and lived experience, green gentrification, participatory governance, historical repair, and multispecies justice. Four comparative evidence tables distinguish conceptual propositions, empirical findings, analytical instruments, and planning implications. The synthesis identifies five interlocking limitations in conventional greening appraisal: reliance on land-cover proxies, neglect of heterogeneous needs, insufficient temporal and housing-market analysis, weak institutional accountability, and anthropocentric valuation. We advance a justice-centered decision framework that separates environmental provision from realized benefit, embeds multidimensional distributional assessment within participatory and reparative institutions, and treats ecological integrity as a substantive constraint rather than an interchangeable benefit. Contradictory findings across cities are interpreted as evidence of institutional, historical, and ecological contingency rather than universal planning failure. We outline testable propositions concerning multimodal access, displacement moderation, community decision authority, historical path dependence, and ecological safeguards. The review argues that sustainable infrastructure should be evaluated not by greening volume alone, but by who benefits, who remains protected over time, whose knowledge shapes decisions, and whether urban transformation sustains nonhuman life. These criteria offer an accountable basis for policy assessment.

***Keywords*:** *environmental justice; sustainable urban infrastructure; urban green infrastructure; multispecies justice; green gentrification*

1. INTRODUCTION

Urban green and blue infrastructure have become central to urban climate adaptation, biodiversity policy and health-oriented development. Liotta et al. (2020) made this paradox operational by demonstrating that prioritizing neighborhoods with the least green-space access produces different investment geographies from prioritizing reductions in multidimensional well-being inequality. Recent evidence pushes the argument further: ecological amenities must be understood as historically produced, politically negotiated and temporally unstable distributions of opportunity rather than as neutral inventories of green land (Venter et al., 2023; Anguelovski et al., 2026).

The methodological consequences are substantial. New comparative and multiscale approaches show that large nominal green-space endowments can coexist with unequal access or uneven functional performance (Fei et al., 2025; Cao et al., 2025). The normative object of assessment must consequently shift from the supply of green assets toward the distribution, governance and durability of their realized contributions. The contemporary literature creates an additional tension between human well-being and ecological integrity. Earlier spatial equity work often conceptualized nature as a means to improve health, recreation or ecosystem-service provision. Emerging multispecies scholarship questions the assumption that ecosystems warrant protection only through human benefits and advances reciprocity, ecological agency and intrinsic value as relevant planning considerations (Sobhani, 2026). Design-for-nature scholarship similarly exposes the divergence between landscape design focused on human experience and ecology focused on habitat continuity and species survival (Catalano et al., 2021). A review that merely adds biodiversity as another numerical indicator would miss the deeper ethical change: some ecological obligations should constrain projects even where an exclusively human welfare calculation would favor development.

This article synthesizes the supplied Scopus-exported literature through October 2026 alongside the foundational paper by Liotta et al. (2020). Our contribution is an integrative framework linking distributive outcomes, procedural authority, reparative responsibilities, temporal resilience and multispecies obligations. Rather than conducting a pooled statistical meta-analysis of incompatible study designs, we compare their concepts, evidence, assumptions and implications to develop testable propositions for sustainable infrastructure planning.

2. Review approach, corpus and evidentiary limits

The corpus was bounded deliberately by the two documents provided for this review: the published article of Liotta et al. (2020) and the supplied RIS/TXT extraction of Scopus records dated 13 October 2026. No additional publications were sought externally. The export contains 96 bibliographic records spanning empirical spatial analyses, reviews, modeling studies, policy discussions and conceptual interventions. Peripheral material on broader innovation or income inequality was not promoted into direct evidence of green-infrastructure effects. The review is therefore source-bounded and integrative, not an exhaustive census of worldwide scholarship or a formally preregistered systematic review.

Our analytical extraction considered geographical context, study design, justice construct, principal indicators, reported contribution, plausible mechanisms and limitations inferable from the abstract. Where an abstract reported a model performance or numerical association, the review preserves its geographic and methodological setting. It does not infer unavailable sample details, confidence intervals, robustness diagnostics or journal issue pagination. This restraint matters because sophisticated spatial modeling can lend a false appearance of causal precision

when it is applied to observational neighborhood data.

The synthesis proceeded through iterative conceptual comparison rather than frequency counting. Contradictory findings were retained because disagreement across cities often identifies causal contingencies rather than research failure. Four tables summarize the conceptual architecture, evidence patterns, methods and planning implications. They are interpretative evidence maps, not quantitative meta-analytic estimates.

The limits of this approach must remain visible. Moreover, abstracts differ in reporting detail and publication type. This paper avoids false PRISMA claims and does not estimate publication bias. A future systematic update would require registered eligibility criteria, full-text risk-of-bias evaluation, explicit database coverage and standardized outcome extraction.

3. From spatial access to multidimensional justice

The strongest continuity with Liotta et al. (2020) is their insistence that distributional targets must be assessed for other components of well-being. This insight is not an argument against access standards. Rather, it establishes that access standards are diagnostically incomplete when the policy objective is to reduce disadvantage across people, not simply to spread facilities evenly across territory.

More recent measurement research refines the diagnosis by separating provision, accessibility and functionality. Zhang et al. (2025) model variations in park accessibility across walking, cycling and public transit, finding especially marked inequity for older residents. Cao et al. (2025) integrate block-scale supply-demand indicators with residential-level multimodal catchment analysis, demonstrating that aggregation levels and travel assumptions generate different equity diagnoses. Such findings undermine the idea of a universal catchment radius adequate for every population. Distributional justice consequently requires person-sensitive accessibility rather than an undifferentiated nearest-distance metric.

Differences also arise between visible greenery, accessible recreation and cooling performance. Spatial studies using visible, functional and accessible metrics underscore that conclusions can depend on which environmental dimension is observed (Lee et al., 2026). Li et al. (2026) add temporal heat hotspots to green-space assessment, finding that socially disadvantaged communities may improve in nominal green-space access while simultaneously experiencing increasing heat exposure. This is not necessarily a contradiction in the data; it reveals that a park's existence and its protection against a specific climate hazard operate through different spatial and temporal mechanisms.

Multidimensional environmental burden is the counterpart to unequal amenities. Hölzl et al. (2021) combine air pollution, noise, heat stress and green-space scarcity to identify overlapping burdens in Berlin, while Bonilla et al. (2023) investigate air-quality inequality alongside economic and social disadvantage in Bogotá and simulate alternative mitigation policies. Yet composite indices introduce another dilemma: weighting and normalization embed judgments concerning the relative significance of risks. Transparent sensitivity analysis and deliberative weighting are therefore substantive elements of justice, not optional technical appendices.

The institutional scale of analysis also changes what counts as an unjust outcome. Richards et al. (2023) assess multiple contributions of urban nature in Christchurch and document disadvantages across carbon stock, runoff retention, shade, recreation and other functions in vulnerable neighborhoods. Tardieu et al. (2021) show that soil-sealing trajectories poorly represent changes in several ecosystem services across the Paris metropolitan region. Taken together, the studies caution against replacing one narrow indicator with another apparently comprehensive but equally partial proxy. A multidimensional framework needs distinct outcome families, visibility of trade-offs and

explicit attention to spatial spillovers. A composite score may help ranking, but it should never erase the underlying distribution of benefits and harms.

Measurement design is also shaped by the normative meaning assigned to inequality. Yan et al. (2024) survey changing research emphases across park equity scholarship, including vulnerable groups and health; the diversity they identify should be treated as theoretical plurality, not merely methodological fragmentation. Each objective can support different, defensible intervention rankings under identical data.

Data quality limits even highly resolved analyses. New spatial indicators can mitigate some problems, but data sophistication should not mask limitations in representativeness. Ground-truthing sites and integrating user testimony provide necessary checks on remote measurements.

Table 1 consolidates the ethical dimensions identified across the corpus and explains how each changes infrastructure appraisal, priority setting and accountability.

Table 1. Justice constructs and their operational consequences

Justice dimension	Normative object	Common evidence	Analytical blind spot	Planning response	Ref.
Multidimensional distribution	Cumulative disadvantage	Income, health, access, hazards	Indicator weights encode values	Prioritize inequality reduction, test weights	Liotta et al. (2020)
Accessible opportunity	Usable services across travel modes	Network time, catchments, mobility	Nominal proximity is not realized use	Profile walking, cycling and transit	Zhang et al. (2025); Cao et al. (2025)
Thermal justice	Protection where heat exposure is highest	Heat hotspots across years	Annual green totals miss changing risk	Co-target cooling and thermal vulnerability	Li et al. (2026)
Historical and reparative justice	Repair accumulated sociospatial harm	Segregation, historical exclusion	Present deprivation omits responsibility	Trace causes and govern reparations	Anguelovski et al. (2026)
Procedural justice	Effective influence over decisions	Co-design and governance arrangements	Participation can be symbolic	Share decision authority and budgets	Bellè & Deserti (2024); Chapman et al. (2024)
Multispecies justice	Intrinsic ecological interests	Habitat and ecological agency	Human utility erases nonhuman claims	Set ecological safeguards	Sobhani (2026)

4. Social-spatial structures, historical legacies and cumulative burdens

Spatial inequality is not simply an accidental mismatch between park sites and residential populations. Tivadar and (2026) formalize a theoretical connection between spatial segregation and environmental inequality and examine tree-canopy disparities across 97 French urban areas. Environmental quality may align with or partially counterbalance residential sorting. This distinction prevents planners from treating segregation indices as a complete substitute for environmental measurement.

Comparative cases illustrate both recurring patterns and local contingency. In affluent Oslo, poorer districts and neighborhoods with more immigrant residents have lower blue-green exposure and higher air-pollution burdens despite substantial citywide nature availability (Venter et al., 2023). In Japan, Chen et al. (2023) identify relationships between urban form and green-space equity across shrinking cities, reminding us that

inequity is not confined to expanding megacities. In Changsha, Cao et al. (2024) relate landscape quality and residential differentiation to unequal greening and possible green gentrification. Taken together, these studies challenge two presumptions: that environmental inequality disappears when a city is green overall, and that it can be explained by growth rate or density alone.

The newest conceptual scholarship makes historical responsibility unavoidable. Anguelovski et al. (2026) interpret contemporary unequal ecologies as products of dispossession, racialized exclusion and accumulated socioecological damage and propose ecologies of repair rather than distributional correction alone. This is analytically stronger than simply adding historical variables to a regression because it invites investigation of causal pathways linking land control, public investment, displacement and ecological degradation across generations.

Soil contamination illustrates how these histories become materially embodied. Maciejewska and Ulanicka-Raczyńska (2023) identify planning-related contamination risk and health-safety concerns in Warsaw brownfields, while Judelsohn et al. (2026) connect lead-contamination patterns in Buffalo with segregation and describe residents' experiences of policy inertia. The choice between quick beautification and costly cleanup is therefore not merely an engineering sequencing problem: it involves the allocation of hidden risks, the credibility of public institutions and the right of affected communities to meaningful information.

Spatially concentrated environmental disadvantage may extend beyond a city's administrative boundary. Jia et al. (2023) propose identifying ecological-security patterns through ecosystem-service supply-demand scarcity across urban agglomerations. Administrative convenience should not determine the ethical perimeter of assessment.

The spatial equity literature also shows how the selected unit of analysis shifts with the research question. Zhang et al. (2024) operationalize daily accessible greenery through street views, building visibility and activity-related accessibility rather than a single park-distance measure. Xue et al. (2025) report that regional-level improvements in economic and ecosystem-service benefits in Ordos conceal contrasting district- and grid-level trajectories. Tivadar (2025) likewise examine both canopy exposure and hazardous industrial sites, showing why an assessment restricted to amenities fails to capture environmental inequality fully. Together, these works support cross-scale reporting that preserves neighborhood variation instead of inferring uniform benefit from citywide trends.

Table 2 compares geographically diverse empirical studies, highlighting where study design and context qualify otherwise similar claims about unequal environmental benefits.

Table 2. Cross-context empirical evidence and interpretative implications

Setting	Design or focus	Reported central finding	Interpretation	Important limitation	Ref.
Paris, France	Multidimensional targeting simulation	Priority areas shift under well-being criteria	Access deficits ≠ greatest equity gain	Simulated, not observed new projects	Liotta et al. (2020)
Oslo, Norway	Socio-spatial exposure mapping	Disadvantaged districts have lower blue-green access and higher pollution	Green cities can remain unequal	Observational association	Venter et al. (2023)
Berlin, Germany	Multiple environmental-burden mapping	Vulnerable groups experience	Single-hazard indicators miss cumulative risk	Area-level inference	Hölzl et al. (2021)

Setting	Design or focus	Reported central finding	Interpretation	Important limitation	Ref.
		overlapping burdens			
Miami-Dade, USA	Multiyear green space and heat mapping	Access improvements can coexist with higher heat exposure	Climate exposure must be measured directly	Local and climate-specific	Li et al. (2026)
28 cities, North America and Europe	Spatial longitudinal comparative model	Greening associated with later gentrification in 17 cities	Benefits can change social recipients	Not universal causal effect	Anguelovski et al. (2022)
Christchurch, New Zealand	Nine contributions of nature assessed	Vulnerable areas disadvantaged in several ecosystem contributions	Multiple ecosystem functions matter	Place-specific vulnerability index	Richards et al. (2023)
Buffalo, USA	Mixed methods, soil contamination	Lead patterns mirror segregation and policy inertia	Historical harms persist materially	No universal project effect	Judelsohn et al. (2026)
Amsterdam, Netherlands	Participatory GIS and demand-supply maps	Different groups face different functional mismatches	Demand is heterogeneous	Participation and modeled demand limitations	Schrammeijer et al. (2022)

5. Climate adaptation and the temporal redistribution of risk

Urban climate policy often measures success through vegetation expansion or average reductions in land-surface temperature. Li et al. (2026) explicitly incorporate high-temperature hotspots and repeated observations, finding divergent trajectories in accessibility and thermal exposure across socioeconomic communities. Climate equity requires the joint evaluation of exposure, sensitivity and adaptive capacity over time.

Heat mitigation services also have differentiated spatial footprints. Xu et al. (2025) examine the equity of heat-mitigation ecosystem services in Singapore, while Petzold et al. (2023) review greening responses to climate-related heat risk from a social-geographical perspective. Together with Zhang et al. (2025), these contributions suggest that heat-oriented investment criteria should not mechanically prioritize the least vegetated parcel. They should identify the combination of thermal need, likely cooling reach, pedestrian routes, vulnerable users and implementation feasibility. A tree canopy intervention near transit stops may contribute to a different set of opportunities than a remote park of equivalent area.

The time dimension extends beyond changing weather. Tree planting generates benefits gradually as canopy matures, whereas land acquisition, rents and neighborhood reputations may change earlier. More intense storms can alter drainage priorities, and patterns of use can change during health crises. An apparently equitable opening-day distribution may not remain equitable over the asset's life cycle.

Climate resilience introduces tensions between the speed of delivery and procedural legitimacy. An explicit distinction between modeled benefits and experienced protections prevents climate adaptation from becoming a technocratic substitute for justice.

Climate priorities can be distorted by the scale at which thermal outcomes are measured. Surface temperature is not identical to the air temperature, radiant load

or physiological heat stress people experience. Equally, cooling effects may extend beyond the park boundary under particular meteorological conditions. Such refinement should enhance rather than displace distributional transparency.

Resilience also concerns failure, maintenance and recovery. Flood-retention facilities may shift water accumulation onto downstream households unless hydrological networks are considered. This life-cycle perspective links climate policy to environmental governance and makes accountability possible after a project has disappeared from political attention.

6. Needs, preferences, health and the lived experience of urban nature

Equal proximity does not imply equal value. Schrammeijer et al. (2022) combine participatory mapping with spatial and statistical methods in Amsterdam to distinguish demand and supply for relaxing, meeting others, walking and cooling. The results identify function-specific mismatches and potential trade-offs between social activities. Ta et al. (2022) use a choice experiment in the Paris metropolitan region to show that residents value green-space attributes and travel time differently by urban context. A universal model of park demand therefore risks interpreting difference as deficiency: a small, nearby garden may be highly valued in a dense center while larger landscapes may be more important to some suburban users.

The implication is not that subjective preferences should entirely determine investment. Preferences themselves can reflect exclusion, adaptation to scarcity or expectations shaped by past neglect. A defensible planning process must therefore distinguish stated preferences from the conditions under which preferences were formed. Demand-based allocation without a minimum rights-based floor could redirect funds toward politically vocal, mobile or affluent populations. Conversely, an exclusively needs-based algorithm can disregard legitimate local identities and attachments. Justice requires a dialogue between guaranteed entitlements and contextual pluralism.

Health evidence shows how consequential contextual differentiation can be. Singh et al. (2025), analyzing a Canadian perinatal cohort, report associations between green or blue exposure and some depression and anxiety measures, with temporal variations across pregnancy and postpartum periods. Health-related equity indicators should specify the population, exposure pathway and outcome rather than subsuming every health claim under 'well-being'.

Lived experience also challenges purely spatial claims about environmental improvement. Meenar et al. (2025) map emotional experiences in Camden parks and report that historical environmental injustice and site-specific attributes shape respondents' reactions. The finding complicates both celebratory biophilic urbanism and purely negative accounts of under-resourced spaces. Environmental quality is partly experienced through safety, social memory, belonging and local use practices. Research therefore needs methods that can register attachment, ambivalence and disagreement rather than assuming that positive vegetation metrics translate straightforwardly into positive experience.

Experiential evidence should complement rather than displace physical indicators. Interviews, participatory geographic information systems, observations and environmental monitoring answer different questions. It also makes procedural accountability testable, because planners can compare expressed needs with their eventual incorporation into project specifications.

7. Green gentrification

The clearest challenge to 'more greening equals more justice' comes from displacement dynamics. Anguelovski et al. (2022) analyze green gentrification across 28 European and North American cities and identify a positive relationship between earlier greening and later gentrification in 17 cases. Planning evaluation must therefore

ask who occupies a neighborhood when benefits mature, not just who resides there at project announcement.

Kronenberg et al. (2021) frame unintended consequences through interactions among infrastructure, institutions and perceptions. Trade-offs are not exceptions to otherwise straightforward green policy. They are normal features of multifunctional socioecological systems in which benefits cannot all be maximized simultaneously. It follows that a review of 'best practices' without identifying losers and institutional conditions will systematically overstate transferability.

The distinction between investment placement and benefit retention matters for reparative policy. The cited literature motivates these responses, but it does not establish a universally effective policy package; intervention evaluations remain necessary.

A second unintended-consequence problem concerns ecological simplification. Infrastructure that looks visibly green may provide low biodiversity support, high irrigation demand or limited thermal performance. Catalano et al. (2021) advocate design for nature across building, city and landscape scales, and the broader discussion of ecosystem-service indicators shows why functional quality cannot be inferred directly from vegetated area (Tardieu et al., 2021). Conversely, conservation rules that exclude community use can recreate older patterns of enclosure. Both problems require explicit negotiation between ecological obligations and social entitlements.

These tensions suggest a dynamic counterfactual for evaluating investment. To assess that counterfactual, studies need longitudinal housing, demographic, ecological and health information alongside project implementation records. Cross-sectional correlations remain valuable for diagnosing unevenness but are not sufficient to identify the full causal chain between greening, changes in residential composition and subsequent benefit capture.

Further reviews and place-specific analyses warn against assuming that nature-based interventions share the same social meaning across settings. Nickayin et al. (2023) address the relationship between just cities, nature-based solutions and socioenvironmental inequality, while. Pellerey et al. (2026) investigate the possible divergence between greater greenery, participation and justice. Their titles and abstract-level contributions do not establish the magnitude of any shared causal effect, but they sharpen what future evaluations must test.

8. Governance: from participation to reparative and multispecies obligations

Participatory planning is often presented as the solution to technocratic bias, yet inclusion depends on authority, not simply attendance. Bellè and Deserti (2024) examine urban greening plans through ecological, public and property-related dimensions and emphasize co-production. Chapman et al. (2024) develop an approach for monitoring and evaluating co-governance in equitable urban greening. Without the capacity to alter priorities, a consultation exercise may legitimate a predetermined investment map rather than democratize it.

The strongest form of procedural justice also acknowledges differentiated knowledge. Historical environmental harms intensify this obligation, because marginalized communities may reasonably mistrust new sustainability promises. Participatory mapping or choice experiments are useful instruments only if their results influence land acquisition, design and ongoing management.

Reparative governance goes further by making past and continuing institutional harm part of the policy objective. Anguelovski et al. (2026) argue for ecologies of repair, while studies of soil and contamination demonstrate how the built environment retains traces of earlier zoning, segregation and disinvestment (Judelsohn et al., 2026; Maciejewska & Ulanicka-Raczyńska, 2023). A reparative planning

process should therefore identify responsibility, restoration priorities and mechanisms for durable community control. Allocating an equal quantity of new greenery everywhere may be formally even-handed but reparatively inadequate when harms have been accumulated asymmetrically for decades.

A further shift appears in multispecies justice. Sobhani (2026) contests market-based instrumentalization of nature and proposes governance organized around interdependence, reciprocity, care and ecological agency. Such a shift produces difficult decisions. Wetlands, deadwood or spontaneous habitats may be ecologically valuable even when they are not preferred recreational landscapes. Planning institutions must recognize that legitimate environmental interests include those that cannot be represented by conventional willingness-to-pay studies.

Operationalizing multispecies justice requires more than adding a biodiversity column to an optimization matrix. This approach is normative synthesis rather than a validated universal formula, and its institutional feasibility remains an empirical question.

A difficult institutional question concerns representation of absent constituencies. In conventional planning, their interests are often approximated through expert models or legal requirements. Ecological assessments can establish minimum habitat conditions, while tenant organizations and social services can identify housing insecurity. These are not perfect substitutes for direct representation, but they make the limits of stakeholder consultation visible. Transparent mandates, independent review and periodic reconsideration reduce the danger that ecological or community representation becomes captured by a single powerful organization.

Renewable energy and other low-carbon infrastructure demonstrate the wider relevance of the argument beyond parks. Urkidi Azkarraga et al. (2024) discuss environmental justice in renewable energy planning, bringing questions of space, governance and unequal burdens into decarbonization choices. Sustainable infrastructure may deliver widely shared climate benefits while generating concentrated local land-use conflicts. Extending green-infrastructure justice principles to energy transitions should nevertheless respect differences in service pathways, affected populations and legal regimes rather than presuming that parks and power facilities share identical policy tools.

9. An integrated justice-centered assessment framework

The reviewed scholarship supports a framework built around six linked questions: baseline injustice, beneficiaries, mechanisms, temporal distribution, ecological integrity and decision authority. The first stage maps cumulative deprivation rather than simply counting assets. It combines hazards, green and blue functions, accessibility, demographic sensitivities and the social history of sites. The third identifies groups able to access and retain these benefits. This separation prevents a modeled ecosystem service from being treated automatically as a realized human welfare gain.

At the prioritization stage, projects should be compared against more than one value function. Liotta et al. (2020) demonstrate how rankings depend on multidimensional inequality assumptions; Tivadar and Schaeffer (2026) show that spatial segregation places additional structure on between-group disparities. We therefore propose reporting a dashboard that preserves individual indicators alongside a transparent summary ranking. Where rankings change substantially, the result should trigger deliberation rather than be hidden behind a single optimization score.

An implementation stage evaluates whether procedural promises become material rights. These are not secondary social benefits appended to an engineering project. They govern whether investments translate into equitable, sustained outcomes. Cross-

jurisdiction service flows should also be accounted for where upstream ecological investments protect downstream populations or where fiscal costs and benefits accrue to different municipalities (Jia et al., 2023).

Monitoring must then observe distributions repeatedly rather than certifying a project at commissioning. Where baseline measurements are absent, studies should acknowledge the limitations of before-after comparisons. Where feasible, matched comparison areas, event-study designs or staged rollouts can improve causal identification, although these still require scrutiny of spillovers and selection effects.

Finally, the framework differentiates outcome improvement from governance legitimacy. Both outcomes merit reporting. Similarly, increasing public recreation cannot automatically compensate for losses of habitat integrity. These distinctions are central to moving beyond an omnibus sustainability index. The framework is therefore best understood as a structured decision protocol with multiple minimum conditions and contestable priorities, rather than as a single definitive score that settles ethical disagreement.

Several complementary strands extend the framework beyond distribution. Hamel et al. (2021) discuss mapping urban nature benefits using InVEST, Liu et al. (2022) demonstrate geographically explicit modeling of recreational supply and demand. These approaches can improve decision support, provided that model-derived benefit estimates are not equated with ethical legitimacy. Institutional evaluation must additionally ask whether the selected valuation boundaries acknowledge those who cannot express market preferences and whether relevant ecological effects are visible in the model.

Table 3 assesses the methodological approaches underlying these conclusions, including their measurement strengths, blind spots and implications for interpretation.

Table 3. Measurement strategies, capabilities and methodological risks

Method	Primary question	Typical inputs	Analytical strength	Key qualification	Ref.
Multidimensional index	Who is multiply disadvantaged?	Social and environmental dimensions	Evaluates cumulative inequality	Normative weights and substitutability	Liotta et al. (2020)
Multimodal catchment analysis	Who can practically reach parks?	Networks, residences, modal travel times	Accounts for route and mobility variation	Imperfect behavioral representation	Cao et al. (2025); Zhang et al. (2025)
Segregation-based inequality	How does residential sorting structure disparity?	Group shares and ecological exposures	Clarifies bounds and sorting effects	Does not establish historical cause	Tivadar & Schaeffer (2026)
Remote sensing with temporal exposure	Who is protected across hot periods?	Greenness, heat hotspot sequences	Integrates changing climate burden	Heat proxies differ from health exposure	Li et al. (2026)
Participatory GIS	What functions do residents need?	Mapped perceptions and spatial variables	Exposes function-specific demand	Participation-selection bias	Schrammeijer et al. (2022)
Discrete choice experiments	Which park features matter to whom?	Hypothetical attributes and travel costs	Measures preference heterogeneity	Hypothetical choice is not actual use	Ta et al. (2022)
Ecosystem-service mapping	Which ecological functions change?	Land cover, biophysical service models	Distinguishes services from sealing	Models subject to uncertainty	Tardieu et al. (2021)

Method	Primary question	Typical inputs	Analytical strength	Key qualification	Ref.
Qualitative and mixed methods	How are harms experienced and governed?	Interviews, maps, institutional records	Captures legitimacy and historical mechanisms	Transferability requires contextual analysis	Meenar et al. (2025); Judelsohn et al. (2026)

10. Methodological disputes and unresolved theoretical tensions

The first unresolved dispute concerns aggregation. Liotta et al. (2020) explicitly examine inequality aversion and substitutability parameters, yet their example also illustrates how demanding the ethical choice of weights becomes when environmental, social and health dimensions are placed together. Present-day machine-learning and composite-indicator methods increase descriptive resolution without resolving this normative problem. A high predictive score is not a substitute for public justification of trade-offs; indeed, greater model complexity can make the grounds of prioritization harder to contest.

A second dispute concerns the appropriate unit of justice. Neighborhood averages cannot establish how benefits vary within households or among residents with different access needs. Equally, treating only individuals as beneficiaries can conceal shared public goods and collective claims over cultural sites. The solution is not necessarily to select one unit permanently, but to report linked assessments at person, neighborhood, and ecological-network scales, with clear explanations of where ecological inference becomes unavoidable.

Third, there is tension between egalitarian access and differentiated demand. Choice experiments and participatory mapping show that households and groups want different functions (Ta et al., 2022; Schrammeijer et al., 2022). Yet rewarding expressed demand can reinforce participation inequalities. This distinction is not fully operationalized by either distance-based standards or pure preference-optimization models, creating a genuine agenda for combined rights-based and preference-sensitive appraisal.

Fourth, there is tension between immediate redistribution and long-term protection. Green investments may be located in deprived areas, yet their eventual beneficiaries may differ because of displacement, demographic change or inconsistent maintenance (Anguelovski et al., 2022; Kronenberg et al., 2021). Static justice metrics fail when the social composition of the exposed population changes endogenously with investment. Dynamic models need explicit housing and institutional pathways, but richer models risk overparameterization and untestable assumptions. Empirical comparison should therefore favor parsimonious causal mechanisms accompanied by sensitivity ranges rather than performative forecasting precision.

Fifth, the expansion from human welfare to multispecies obligations introduces questions that cannot be solved empirically alone. Economic valuation and ecosystem-service accounting can characterize many human-facing benefits, but intrinsic ecological value is not commensurable with every other outcome (Sobhani, 2026). Neither guarantees consensus. Top-tier research should make these normative commitments explicit, compare their implications and identify institutional contexts in which competing approaches produce different decisions.

A related dispute concerns whether greenery should be measured principally as exposure, opportunity, ecosystem function or realized public value. Liu et al. (2026) highlight distributional contradictions in urban green-space provision and use, Mansur et al. (2022) argue for integrating multiple values into urban nature futures. Research must make that choice explicit rather than hide it in a composite index.

11. Research agenda and testable propositions

Future work should move beyond repeated demonstrations that income and greenery correlate. The central empirical question is when particular interventions reduce inequalities in realized well-being over time. This is supported conceptually by multiscale accessibility work and temporally explicit cooling analysis (Cao et al., 2025; Li et al., 2026). It should be tested with disaggregated travel data, seasonal environmental measurements and observed rather than assumed park use.

A second proposition is that anti-displacement institutions moderate the relationship between greening investment and the long-run distribution of benefits. The multinational evidence on green gentrification motivates longitudinal designs that jointly measure park investment, residential retention, housing affordability and changes in access (Anguelovski et al., 2022). Better designs combine administrative housing records, project timing and qualitative accounts of involuntary departure and neighborhood transformation.

A third proposition concerns co-governance: participation affects outcomes most strongly when affected groups obtain decision rights over site selection, operational rules and budgets rather than consultation opportunities alone. The possibility follows from contemporary greening-plan and co-governance research (Bellè & Deserti, 2024; Chapman et al., 2024). Such studies must also account for the fact that already well-organized communities may be better placed to secure participatory institutions.

A fourth proposition is that historical environmental damage predicts present-day infrastructure inequity above and beyond contemporary income and density. The emerging theory of ecologies of repair and empirical analyses of soil contamination provide strong motivation (Anguelovski et al., 2026; Judelsohn et al., 2026). A reparative intervention should then be evaluated against a historical counterfactual, not merely a contemporary citywide mean.

A fifth proposition concerns cross-objective planning: projects selected through a hierarchy of ecological safeguards and social-justice targets will generate fewer destructive ecological trade-offs than projects ranked by a single monetized ecosystem-service benefit. Sobhani (2026) and Catalano et al. (2021) motivate this hypothesis, but neither supplied abstract provides a direct comparative test. Pilot projects can assess biodiversity composition, connectivity, public access and distributional change under alternative decision protocols. Monitoring is essential because apparent short-term compatibility between ecological restoration and recreation may weaken as visitation increases.

A sixth proposition concerns geographic transferability. De Souza and Torres (2021) call for stronger South–North dialogue and attention to heterogeneous Global South conditions. The aim should be conditional explanation—what works, for whom, under which institutional and ecological circumstances—rather than universalizing a single city's preferred indicator threshold.

Research on causal effects will need more careful treatment of intervention bundles. Future syntheses should state which outcomes are directly observed, which are estimated through proxies and which follow from normative argument.

A parallel challenge is the unequal geography of research itself. Well-documented metropolitan areas can support richly layered geospatial analyses, whereas cities with limited administrative records may not. De Souza and Torres (2021) highlight the need to strengthen dialogue across Global North and South. This approach can improve geographic diversity without lowering standards for transparent uncertainty or ethical engagement.

Table 4 translates the synthesis into researchable questions, candidate study designs and the evidence needed to test the proposed mechanisms.

Table 4. Research priorities derived from the synthesis

Research gap	Testable proposition	Recommended design	Key outcome	Policy significance	Ref.
Proximity vs realized access	Mobility-sensitive access changes priority rankings	Network scenarios and observed use	Group-specific travel and park use	Avoid false access equity	Zhang et al. (2025); Lee et al. (2026)
Static climate proxies	Longitudinal thermal exposure changes green-equity diagnosis	Panel heat and canopy mapping	Heat burden across social groups	Target actual climate protection	Li et al. (2026); Xu et al. (2025)
Benefit capture	Tenure safeguards moderate green gentrification	Longitudinal matched neighborhoods	Resident retention and affordability	Keep investments beneficial locally	Anguelovski et al. (2022)
Symbolic participation	Decision authority improves use and legitimacy	Comparative governance evaluation	Documented influence and satisfaction	Strengthen co-governance	Chapman et al. (2024)
Historical erasure	Past discriminatory land use predicts current burdens	Historical GIS plus exposure measures	Present inequity net of current income	Design reparative investment	Anguelovski et al. (2026)
Anthropocentric optimization	Ecological constraints alter project ranking	Decision experiments and biodiversity field audits	Habitat and social outcome trade-offs	Protect multispecies cohabitation	Sobhani (2026); Catalano et al. (2021)
Unequal evidence geography	Institutional conditions moderate transferability	North–South comparative field studies	Conditional intervention performance	Avoid universal thresholds	de Souza & Torres (2021)

12. Implications for planning practice and environmental policy

For practitioners, the review recommends replacing one-dimensional greening targets with a transparent, phased assessment. Baseline reports should show separate maps for environmental burdens, recreational access, ecosystem functions and socially differentiated vulnerability. This prevents superficially similar 'green' interventions from being evaluated against incompatible outcomes. It also creates clearer accountability because each project has explicit beneficiaries and mechanisms.

Project appraisal should require a distributional impact statement alongside conventional cost and ecological assessment. At implementation, agencies should align construction, contamination management and maintenance contracts with the social and ecological objectives specified in the appraisal. Monitoring should remain funded after capital delivery. Agencies should specify corrective actions when investments appear to intensify displacement, concentrate benefits or undermine habitats. The governance question is not whether all trade-offs can be eliminated, but whether they are visible, contestable, explained and revisited as evidence changes.

13. CONCLUSION

This review demonstrates that sustainable urban infrastructure cannot be evaluated solely through green space provision or aggregate environmental performance. Environmental justice requires integrating multidimensional well-being, spatial inequality, climate vulnerability, and meaningful public participation into planning decisions. The literature further highlights how historical segregation, green gentrification, and unequal benefit distribution may undermine otherwise

beneficial interventions. Advancing equitable infrastructure therefore demands context-sensitive assessments, anticipatory safeguards, reparative governance, and recognition of ecological integrity beyond human-centered benefits. Future research should prioritize longitudinal, participatory, and multidimensional evaluations to establish whether infrastructure investments deliver enduring social equity, climate resilience, and ecological sustainability across diverse urban contexts.

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