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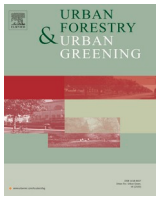

Original article

The intersection of justice and urban greening: Future directions and opportunities for research and practice

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ABSTRACT

The global uptake of green infrastructure in urban settings holds considerable promise for fostering both social and ecological benefits. Recognizing the imperative to ensure equitable distribution of these advantages, this paper draws on the rich traditions of justice considerations within urban studies to inform research on urban greening. Focusing on three key trends - reconceptualizing the 'urban' category, acknowledging the role of historical processes in shaping contemporary uneven and unjust geographies, and considering power dynamics in infrastructure development - we propose five tenets for advancing justice-focused urban greening research. These tenets encourage researchers to act as knowledge brokers, practice reflexivity, recognise the complex dimensions of justice which diversity of scale might reveal, embrace uncertainty, and cultivate a "modest imaginary" concerning infrastructure projects.

1. Introduction

Cities are at the forefront of advancing national and international sustainability goals (Bestill and Bulkeley, 2006; Portney, 2013; Connolly, 2019), with a notable surge in the adoption of concepts like nature-based solutions, ecosystem services, and green infrastructure over the past two decades (Escobedo et al., 2019). These terms broadly refer to the practice of addressing complex socio-natural problems by leveraging and improving networked landscape features to produce benefits for human societies and improve sustainability (Escobedo et al. 2019). Fang et al. (2023) distinguish ecosystem services as benefits derived from nature, green infrastructure as a strategic planning term for a network of natural spaces, and nature-based solutions as focused interventions for specific challenges such as climate change adaptation.

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Despite originating from different fields, these terms have mutually influenced their development (Fang et al., 2023). Aligning with the special issue's theme and acknowledging their collective purpose to underscore the urgency of identifying practices that improve ecological outcomes and quality of life (Escobedo et al., 2019), we use the terms green infrastructure (GI) as the physical 'interconnected networks of green space' (Fang et al., 2023) and "urban greening" defined as the implementation of urban green infrastructure.

Unlike most grey infrastructure, green infrastructure can simultaneously provide multiple ecosystem services, such as flood and heat mitigation, carbon storage and sequestration, and opportunities for recreation and improvement in mental and physical health (Gaffin et al., 2012; Elmqvist et al., 2016; Wolch et al., 2014). The potential benefits of green infrastructure are therefore social, environmental, and economic (Sowińska-Świerkosz & Garcia, 2022), which arguably makes green infrastructure a cost-effective and efficient response to today's multi-faceted challenges (European Commission, 2015; McPherson, 1992; Mees and Driessen, 2011). Cross-sectoral applicability and multifunctionality make urban green infrastructure an important part of a systems-based approach to urban sustainability and transformations (Frantzeskaki et al., 2021).

Despite these benefits, numerous challenges remain in both the conceptualization and implementation of urban green infrastructure. Some argue that green infrastructure reinforces an anthropocentric and western framing of nature in dichotomous opposition to society (Welden et al., 2021), a perspective that conflicts with the worldviews of many Indigenous communities (Malanidis & Hagerman, 2022). Within sustainability science more broadly, this dichotomy is increasingly questioned, as seen in the growth of relational approaches to understanding nature-human connections and the recognition of deep co-dependence between societies and nature (Bennett and Reyers, 2022; Folke et al., 2021; Haider et al., 2021; Ruckelshaus et al., 2020; West et al., 2020, 2018). This has led to a shift away from seeing urban nature as providing benefits produced *by* ecosystems *for* people, toward instead understanding its benefits as co-produced by a relational interplay of people and nature (Chan et al., 2018; Palomo et al., 2014; Pascual et al., 2017; Reyers and Selig, 2020). Consequently, meaningful inter- and transdisciplinary collaborations become imperative, involving diverse worldviews and knowledges, while recognizing a wide variety of values associated with urban nature (Pascual et al., 2023).

Similarly, the implementation of urban green infrastructure has, at times, been criticized for being inattentive to the plurality of lived experiences impacting and impacted by that infrastructure, particularly in dense and diverse urban contexts. Urban green infrastructure is implemented in landscapes that are highly unequal in the distribution of environmental harms, benefits and burdens (Venter et al. 2020; Ferguson et al., 2018), inequalities that can be exacerbated by green infrastructure projects (Meerow and Newell, 2017; Hoover et al., 2021; Shokry et al. 2020). Outcomes of green infrastructure interventions are mediated by multi-scalar power relations, market forces, social structures, gender relations and governance contexts (Finewood et al. 2019; Kotsila et al., 2021; Grabowski et al., 2023). The use of green infrastructure in cities is often embedded in development paths that reinforce existing power structures, resulting in negative social impacts such as "displacement; resource, territorial, or community loss through nature commodification; and compromised long-term livelihoods" (Anguelovski and Corbera, 2023; see also: Kosoy and Corbera, 2010; Kull et al. 2015; Gabriel, 2016; Anguelovski et al., 2020; Walker, 2021). These critiques point to the need to center issues of equity and justice in both the research and practice of urban greening (Hobbie & Grimm, 2020, Keeler et al., 2019; Cousins, 2021; Sekulova et al., 2021). We use the term equity to refer to the fairness of distributions of *contemporary* benefits and burdens across groups, and the term justice to refer to the repair and remediation of *structural and historical forms* and impacts of inequities.

Recent work on the social dimensions of infrastructure has provided insight into the ways that contemporary and historic processes shape how infrastructure distributes benefits and burdens, as well as the role that infrastructure plays in reinforcing inequalities and injustices. Work concerned with how green infrastructure intersects with segregated urban landscapes builds on research into the way that infrastructure projects are always embedded in power relations more generally (Kaika, 2017). The US highway systems, for example, concretized patterns of urban racial segregation in service of a real estate industry that leveraged racial animus to produce highly segregated geographies that benefitted white communities while negatively impacting communities of color (Nall, 2018). Likewise, hydroelectric infrastructure projects in India have not only produced energy for development but have served as tools to shore up territorial state power (Gergen and McCreary 2022). These are but two examples of the myriad ways that infrastructure projects have the power to disrupt or calcify social, economic, and political inequalities. Thus, green infrastructure research that aims to advance justice must contend with the way all types of infrastructure projects are embedded in complex and multifaceted power relations and are always interacting with a social and natural landscape that is a byproduct of these power relations. Such an approach requires robust interdisciplinarity achieved through the disciplinary training of the researchers involved while also aiming to learn from and respond to the insights and contributions of other disciplinary fields. In this paper, we aim to practice that deep interdisciplinary integration to consider how insights from the field of urban studies might inform justice-oriented research on green infrastructure.

An overarching theme that we pull through from the field of urban studies, critical planning studies and other urban-oriented fields, is that justice-oriented research should not only *study* equity and justice, it should also integrate equity and justice principles *into the research process*. For researchers, that means attention to power dynamics that play out between researchers and communities and the way historic forms of exclusion shape contemporary power dynamics, including the researchers' own positionality (often referred to as "reflexivity"), as well as attention to the impact and use of the research at every stage. In other words, both research "findings" *and* the ways research is carried out can actively shape the impacts of that research. This paradigm challenges a traditional scientific approach that aims for a sharp separation between researchers, their values, and the "facts" and processes they study (referred to as the fact/value dichotomy). As Fischer (2000) notes: "the attempt to separate facts and values has facilitated a technocratic form of…analysis that emphasizes the efficiency and effectiveness of means to achieve politically established goals" (131). This technocratic approach, he argues, has largely reproduced existing social structures and is, by extension, unlikely to provoke social change that will result in meaningful improvements to urban equity or justice.

In this conceptual paper, we identify key tenets to guide the research process in order to advance justice-oriented urban greening research. We advocate for an approach that recognizes the situated nature of research within broader social, political, and economic structures. Such an approach integrates the principles of equity throughout the process, from site and topic selection, to research question design, research process, and ultimately circulation of findings. We believe that such an approach to green infrastructure research is necessary to meaningfully challenge systemic and historic inequalities. This paper is organized into the following sections. First, we draw insights from the field of urban studies to redefine how we conceptualize urban greening and equity. Then, putting these insights in conversation with lessons learned from our own research with under-resourced communities across diverse global contexts, spanning the Global North and South, we put forth a set of tenets to guide equity-oriented, justice-seeking urban greening research. In doing so, our aim is that these tenets might serve as guide for urban greening scholars working to advance a justice-oriented focus in their own research.

2. Lessons from urban studies

This section delineates emergent trends in the field of urban studies and key case studies to derive insights relevant to the intersection of green infrastructure, equity and justice. Relevant trends include the optimal scale for comprehending processes shaping urban space, acknowledging the relational dynamics between urban and non-urban spaces and processes, and contemplating the implications of these perspectives for identifying the root causes and consequences of injustice.

2.1. Trend 1. from urban to urbanization: process, scale, and justice

The field of urban political ecology has long explored the socio-ecological processes that link the urban and the rural (Cronon, 2009; Heynen, 2014; Swyngedouw, 1996). This approach directs attention to the interconnected social and ecological dimensions that may shape, but are not contained by, the city itself. Angelo and Wachsmuth (2015) argue for an approach that is concerned with the social and natural processes "not of the city but of urbanization" (p. 16). In so doing, they join a chorus of urban scholars attempting to reorient analyses of urban social relations away from the "container" of the city and toward the social and ecological processes that shape urban life.

This insight has two related implications for urban green infrastructure and justice. First, it invites reflection on what the term "urban" is meant to signal. In the literature on urban greening, the category of what constitutes the "urban" remains relatively under-examined. It often appears as a way to signal characteristics of the built environment or to draw attention to the complexity and significance of the interaction between human and natural processes. Drawing on the field of urban studies, however, we propose refining the object of analysis of "urban green infrastructure" to "urbanization and green infrastructure." Where "urbanization" refers to dimensions of "urbanization processes that exceed the confines of the traditional city" (Angelo and Wachsmuth, 2015; Wachsmuth et al., 2016) and turns attention to the characteristics of urbanizing societies rather than the city itself. This approach has natural alliances with the study of ecological processes, which seldom conform to human-made delineations of space or scale such as the "city," "state," or "country." Indeed, the complexity of nested scales of governance poses challenges to effectively governing and regulating nature that traverses state lines or county boundaries (Bodin, 2017).

Second, this reorientation draws attention to the scale at which we identify relevant relations and processes, with important implications for equity- and justice-related considerations. The scale of focus can dramatically change outcomes. In some cases, broadening the scale of consideration can reveal important global inequalities. For example, the climate footprint of some regions versus the unevenly borne impacts of climate change in others (Harlan et al. 2015). In other cases, broadening the scale of consideration from local to regional or global scales can also elide important localized ways that inequalities play out and may inadvertently intensify them. Residents in Turkey Creek, Mississippi (USA) raised this issue when they raised concerns about wetland mitigation programs that allowed developers to fill in wetlands in ways that impacted their community while offsetting their impact by buying wetland mitigation credits elsewhere. Turkey Creek is a small, Black community in Gulfport, Mississippi settled by formerly enslaved people during Reconstruction. The neighborhood was hit hard by Hurricane Katrina, in part because so much of the wetland that would historically absorb storm surge had been filled in for the development of strip malls, roads and other urban development. Residents argued that although the purchase of wetland credits elsewhere in environments that may afford greater ecological benefits at the global scale, by prioritizing the global impact over the local impact, this practice further contributed to the degradation and inhabitability of their neighborhood (Derickson, 2018). Turkey Creek is not alone, of course; research has shown in the United States that communities of color are disproportionately likely to live in low-lying areas and thus likely to be more vulnerable to the impacts of climate induced rain events and poor stormwater infrastructure (Hendricks & Van Zandt, 2021; Katz, 2021; Maantay & Maroko, 2009). At the same time, they are less likely to be able to afford to evacuate or make repairs on damaged homes (Fitzpatrick and Spialek 2020). This suggests that some patterns and relations that are of concern with respect to equity and justice are only discernible at the local or neighborhood scale and that attempting to address large-scale issues (such as global climate change) cannot be done equitably without careful attention to local-scale issues (such as neighborhood flooding). The case of Turkey Creek also illustrates the limits of equity-only approaches that do not account for historic injustices. While it may be the case that the neighborhood was not disproportionately impacted as compared to other neighborhoods (and therefore not raising equity concerns), the justice lens, which emphasizes structural and historic forms of inequality, allow an understanding of Turkey Creek, as a culturally significant place for people who have been historically disadvantaged, elevating the urgency of protecting this particular neighborhood from flooding.

Crucially, however, it is not necessarily the neighborhood scale at which these relations become visible. Attention to regional scales can also yield important insights for equity and justice. In Atlanta, Georgia (USA), residents founded the West Atlanta Watershed Alliance after they determined that efforts to highlight the impacts of urban development and environmental change were best illustrated by taking a watershed approach. This approach revealed how upstream dynamics were impacting downstream communities, emphasizing equity dimensions implicated in a watershed approach. Similarly, Gullah/Geechee people in the Southeastern United States have established Gullah/Geechee Nation, which spans 4 states, to illuminate the particular environmental challenges that impact their community as distinct from others. Xie et al. (2019) underscore the necessity of multi-scale analysis in their examination of the planning and implementation of the prominent Chongming Eco-Island development project in Shanghai, China. Their multi-scalar approach revealed the underlying rationale and inherent inequalities within the ecological construction process. The substantial coastal reclamation in Chongming over recent decades responds to Shanghai's growing demand for development land, while extensive afforestation across the island serves the dual purpose of counteracting the continuous loss of green lands in Shanghai's central area and showcasing the city and nation's dedication to ecological construction. The expeditious implementation, however, propelled by numeric targets set by the Municipal Government, has led to a mono-species plantation, detrimentally impacting both the local ecology and community (Xie et al., 2019; 2022).

As these examples illustrate, there is no single scale that is inherently better for making visible the justice and equity dimensions of various environmental impacts. This means that for researchers interested in urban greening, the proper scale of analysis (i.e. local, regional, global), has to be understood as not pre-given or self-evident. Researchers should consider how the selected scale of analysis illuminates some equity issues while potentially eliding others, as well as consider the different insights that different scales might reveal. Following insights from the field of urban studies, researchers should conceptualize the urban as a set of relational processes that play out across scales to better understand the justice and equity dimensions of urban greening projects.

2.2. Trend 2. From ahistorical to historically rooted

The proliferation of user-friendly tools to visualize spatial data has led to an explosion of research into the relationship between environmental outcomes and social data in cities (e.g., Schüle et al., 2019; Schwarz et al., 2015; Venter et al., 2020). While these maps offer insight into the geographies of environmental injustice, these "snapshots" of inequality in the distribution of ecosystem benefits and burdens cannot tell the whole story of how these dynamics arose nor, importantly, point to the kinds of intervention that will be most effective at creating equitable outcomes. The field of urban studies widens the lens beyond

contemporary distribution of benefits and burdens (ie, the realm of equity) to include an accounting of the broader historic processes that contributed to the distributions of people, groups, wealth and power throughout the city (ie, the realm of justice). Green infrastructure researchers interested in promoting justice must contend with the way that these socio-natural landscapes are byproducts of discriminatory systems and consider whether and how green infrastructure interventions could entrench these discriminatory patterns.

Pulido (2000) significantly transformed understanding of the process by which these distributions of environmental burdens were produced in US cities. Her analysis incorporated an understanding of housing market dynamics—suburbanization, redlining, and highway construction—that facilitated uneven mobility along racial lines in the mid-20th century, demonstrating how policy and planning decisions that led to mobility and choice for white people and constrained choices for people of color also functioned to produce uneven geographies of urban nature. By integrating an analysis of unjust contemporary distributions with historic housing market dynamics, Pulido showed that geographies of environmental injustice are not simply a function of the siting of hazardous land uses, but rather are shaped by a range of interrelated urban processes that reflect and reproduce social, political, and economic inequalities.

Because contemporary distributions of environmental benefits and burdens in urban spaces are shaped by historic processes that created racially segregated cities and their geographies (Schell et al. 2020), investments in green infrastructure can reproduce or intensify urban inequality if they fail to center a reparative approach. For example, sites that are identified as "valuable nature" worth investing in and improving on may have been produced in concert with processes of racialized exclusion. Heck (2021) shows that the distribution of water quality standards for rivers in St. Louis, Missouri (USA) reflects the city's historic racial and environmental geographies in which water bodies in predominantly white neighborhoods were managed for recreation while those in Black and immigrant communities were managed for industrial activity. Today the bodies of water that historically flowed through the city's segregated white neighborhoods are managed to higher water quality standards than those for water bodies in the city's majority-Black neighborhoods, reflecting the city's racialized environmental history. A reparative, justice-oriented approach to green infrastructure takes into account and aims to mitigate these historically produced disparities in water quality.

Similarly, historic ecological systems may have been destroyed or transformed as part of economic, social, and political projects with positive outcomes for some and devastating consequences for others. For example, research on New Deal efforts to manage nature in the southeastern United States demonstrates how swamplands were characterized by government officials as undesirable, dangerous, and unworthy of environmental protection, despite their importance to independent Black communities that found spaces of refuge in these swamplands. This characterization was used to justify the eradication of Black communities through flooding that resulted from dam construction (Vickers, 2022). Attention to justice dimensions in urban greening requires that the highly unequal conditions that produced contemporary urban environments be accounted for in future investments.

South Africa's history of racial segregation entrenched during Apartheid also highlights the importance of history, efforts to repair, and the complexities of such efforts. During the Apartheid era, population groups categorized as "Africans," "Indians," and "Coloured" were restricted to different residential areas through the notorious Group Areas Act and related legislations. These residential areas are usually separated through buffer zones or vacant land which contain natural ecosystems providing green infrastructure functions in the city-region (Strauss, 2019). Reforms in the post-apartheid era—from the Reconstruction and Development Programme in 1994 to more recently the National Spatial Planning and Land Use Management Act 16 of 2013—have sought to address historical disadvantage and achieve environmental equity. For example, the City of Johannesburg led aggressive tree-planting and park development in historically disadvantaged neighborhoods (Schäffler and Swilling, 2013). However, Venter et al. 2020 show that inequities in neighborhood greenness have been maintained or entrenched since Apartheid for Black African, Indian, and Coloured residents across urban areas in South Africa. In addition, the type of urban nature promoted in public spaces is still influenced mainly by colonial and apartheid-era norms, with little to no recognition of African identities and needs (Shackleton & Gwedla, 2021).

These initiatives illustrate the way that even policies that aim to address spatial inequities in urban nature do not always turn out as envisioned. Plans must contend with the histories of discriminatory policies and practices that produced underlying inequalities, and be attentive to the ways that contemporary efforts might reproduce or undermine the structures driving inequities in urban greenspace. This is true for new greenspace developments, as well as changes to existing urban nature. In many places around the world, greenspace may be perceived as more than a provider of ecosystem services or nature-based solutions, but as sacred spaces that are rooted in cultural memory (Cloud & Redvers, 2023).

Attention to the historical processes that created the uneven distribution of environmental benefits and burdens in urban nature reorients urban greening research and practice from a field focused on making improvements relative to contemporary baselines toward an approach that centers justice and reparations for past harms (Anguelovski and Corbera, 2023; Grabowski et al. 2023). Recently, there have been notable efforts from green infrastructure researchers to incorporate historical analyses grounded in rich archival data to show how inequalities in urban green infrastructure were produced (e.g., Carmichael and MacDonough, 2018; Grove et al., 2018; Locke et al., 2021; Roman et al., 2018). This work contributes to such a reorientation within the field of urban greening, though more work drawing on a historically grounded approach is needed. Importantly, this reorientation means drawing on strong interdisciplinary collaborations and community partnerships to contextualize this history (Ehrman-Solberg et al., 2020; Keeler et al., 2020).

2.3. *Trend 3. From identifying inequalities to the making of the racial wealth gap*

A final trend of note in the field of urban studies is the attention to the wealth creation that occurs through investments in the built and natural environments. While there has long been a focus on the role of policies and practices in creating underserved places and neighborhoods, there is growing attention to the way that investments in high-quality environments function to create wealth for some while explicitly leaving out others (Park and Pellow, 2013).

Work on the management of urban nature in Minneapolis, MN shows, for example, that the use of racially restrictive covenants that barred non-white people from buying property were used by developers who were also lobbying city officials to develop parkland adjacent to their new developments (Walker et al., 2022). Developers would gift swampy property to the Park Board with the expectation that the city

would dredge the swamp to create a lake, increasing the value of developers' landholdings. Today, these human-made or managed lakes and streams are highly valued ecosystems within the park system. Not only did developers profit from these discriminatory investments in urban nature, but also individual homeowners reaped the benefits of racist real estate practices as well. While these real estate industry tools have long been outlawed, Walker et al. (2022) show that their effects endure, resulting in a highly racially segregated city, where majority white neighborhoods enjoy higher property values and greater proximity to high quality urban nature.

Contemporary work on the relationship between investments in urban nature and gentrification and displacement reflect this dynamic (Gould and Lewis, 2016). Urban greening is increasingly embedded in the profit-seeking of the real estate market, driven by both private developers and by growth-oriented public sector initiatives (Anguelovski et al., 2019; García-Lamarca et al., 2022). This phenomenon, known as "green gentrification," refers to the process in which sustainability initiatives and investments in urban green infrastructure are linked to increases in property values and cost of living that drive the displacement of low-income residents and an influx of new, higher-income residents (Klein et al., 2020). As a result, the "added value" of sustainability initiatives is captured not only by the public sector and by private developers (Angelo, 2019; McClintock, 2018a), but also by the new higher income residents who are able to afford the rising costs of living. These residents are often disproportionately white non-immigrants, while those who are displaced are disproportionately immigrant, non-white, and other marginalized and disenfranchised groups, leading to a deepening of the racialized inequalities in access to wealth and the re-entrenchment of an urban ecosystem structured by racial capitalism (Anguelovski et al., 2019; McClintock, 2018b).

Integrating these observations from the field of urban studies suggests three key issues confronting the integration of justice and equity concerns into the field of urban greening. First, it suggests that such approaches will need nuanced and holistic approaches to use systems frameworks across spatial and temporal scales. It is not sufficient to consider the boundaries of a city as the container for the concerns of "urban" green infrastructure. Instead, such analyses should take a relational approach that engages with the process of urbanization across scales. Second, the field of urban studies illustrates the need for historically attuned, multiscale analyses of contemporary distributions of benefits and burdens to better understand the equity implications of future investment. Finally, urban planning for justice, equity and sustainability will need to take stock of the complex interplay between states, markets, and social processes to identify opportunities for maximizing equitable outcomes and promote system change.

3. Tenets for justice-oriented urban greening research

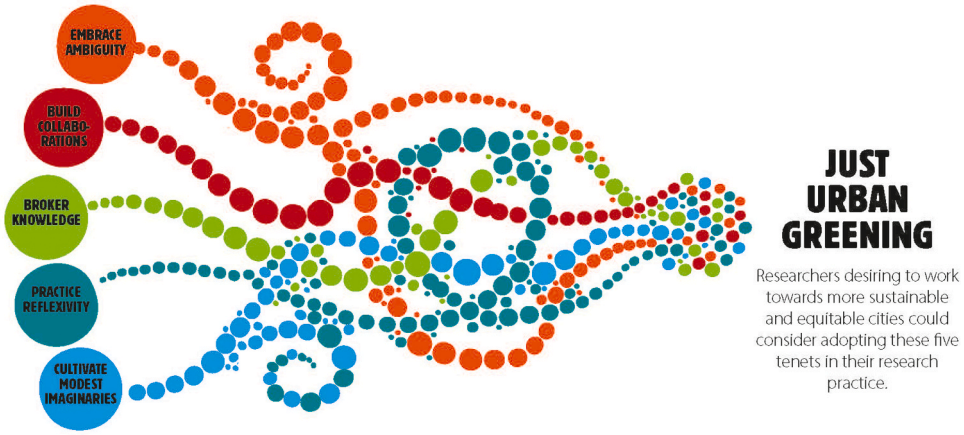
Advancing justice and equity-oriented urban greening research necessitates not only innovative ideas but also novel strategies for translating the ideas into actionable initiatives. In this section, we consider the implications of the above emerging trends in urban studies for research on urban greening, drawing on our own geographically and culturally diverse research sites and community collaborations. We delineate five tenets guiding equity- and justice-oriented urban greening research that have helped facilitate effective, inter- and transdisciplinary projects, offering insights for researchers.

4. Tenet 1. Situating green infrastructure research in an ecosystem of power

Following Fischer, an approach to equity-oriented, justice-seeking urban greening research requires what Derickson (2021) has called a "thick" conception of knowledge production that situates researchers, their institutions, their practices and relationships in an "ecosystem" of power and social change. Researchers have used the term "reflexivity" to describe the process of determining one's relationship to the social and power structures they interface with in the course of their research. Reflexivity includes looking at how the researcher's own experience serves as an entry point for their research; or how the researcher's gender, race, caste or class position influences research; and even the disciplinary training of the researcher that determines choice of study subject and methods (Knaggård et al. 2018).

Reflexivity has long been associated with the social sciences, but today reflexivity is finding increasing acceptance in the natural sciences. Even conservation science conducted in the past using purely biological methods has witnessed a paradigm shift. There has been a growing recognition of the need for reflexivity among researchers and practitioners of conservation science to aid conservation (Pienkowski et al., 2022, Beck et al. 2021). Urban greening research, too, is beginning to center the need for reflexivity among researchers with regard to their questions and methods and the implications of this for justice. For example, Langemeyer and Connolly (2020), in their discussion of recognitional and procedural justice in urban ecosystem services research, point to the need of a multiplicity of worldviews and lived experiences in shaping our understanding of the value of urban nature. Being a reflexive sustainability researcher requires consistent reflection on the interlinked social and ecological questions they are asking and the methods they are using as well as what the relevance of that research, not only within academia but also for society (Knaggård et al. 2018, Nastar, 2023). According to Nastar (2023: pp4):" […] reflexivity is also helpful for sustainability researchers to become more aware of values, worldviews, and power relations shaping their ways of knowing and conducting research." Thus, reflexivity requires that sustainability researchers question their own beliefs and positions and explore new ways of both knowing and doing research. Reflexive sustainability researchers should be concerned with ensuring that solutions for sustainability challenges prioritize equity and are inclusive. Further, sustainability researchers cannot conduct research in a social and political vacuum—rather, they have to be cognizant of power relations in society that influence their research and its outcomes (Nastar, 2023).

Researchers aiming to be more reflexive will have to engage with the power-laden geographies of research and the complex dimensions of equity which play out across a diversity of scales. This is especially true for research conducted in the rapidly urbanizing Global South. When it comes to studies on equity and justice in the context of urban greening, there are far fewer studies focused on the Global South (and even fewer led by researchers *from* the Global South). This is concerning as inequities are often more pronounced in the Global South. Similarly, collaboration among researchers from the Global South is important in this context to facilitate shared learning among researchers from countries facing similar challenges related to urban greening and justice (Lechner et al., 2020). Urban greening researchers from the Global North who are often better financed could make more effort to collaborate with researchers from the Global South who work with local communities or practitioners.



5. Tenet 2. Explicitly building on transdisciplinarity and the co-production of knowledge

Research on green infrastructure is closely intertwined with transdisciplinarity and the co-production of knowledge (Nastar, 2023). Given the complex nature of sustainability research, transdisciplinary approaches are essential. Transdisciplinary research, as outlined by Lang et al. al. (2012), entails both problem-oriented knowledge production and collaborative knowledge-building involving both academic and non-academic stakeholders. Lang et al. (2012) propose three "phases" of transdisciplinary research: first, framing the problem and assembling a collaborative research team; second, co-producing solution-oriented and transferable knowledge through collaborative research"; and third, "(re-)integrating and applying the produced knowledge in both scientific and societal practice" (Lang et al. 2012: 27).

Engaging in transdisciplinarity, involving collaboration with members from diverse disciplines or external to academia, poses notable challenges. Shackleton et al. (2022) highlight the considerable time investment required, with challenges emerging from defining problems to finding implementable solutions due to the multiplicity of perspectives involved (Knaggård et al. 2018). Furthermore, there may be inadequate institutional or financial support for undertaking transdisciplinary research. Social and psychological obstacles further complicate matters, including unequal power dynamics among involved actors and potential biases favoring scientific knowledge over indigenous knowledge systems, exemplifying issues such as patriarchal structures and exclusion based on norms of caste, class, and race (Nastar, 2023).

In the realm of urban greening, transdisciplinarity and co-production of knowledge play pivotal roles. The generation of knowledge on urban greening requires collaborations that extend beyond disciplinary boundaries and offer researchers an opportunity to improve the quality and practicality of their work by transcending the silos of their disciplinary training (Franzetskaki et al., 2016). To advance collaborative, justice-oriented knowledge production, it is imperative that communities potentially affected by green infrastructure projects are involved in research or implementation as partners or co-producers of knowledge. Given the dynamic complexities of urbanization, research on urban greening requires practitioners, policy-makers, community organizers, and activists to be included throughout the research process. This co-production method, in turn, re-orients urban greening research toward a wider audience. Techniques for sharing the research beyond collaborators, such as sharing results via photo exhibitions with the wider public, writing about the research in accessible outlets like newspapers or online media, using the local language, and designing multi-lingual educational materials for schools, serve as examples of engaging broader audiences. Through co-production and the creation of creative, widely accessible research products, the knowledge generated in green infrastructure research may resonate throughout the broader ecosystem of knowledge and practice. Researchers in this domain should perceive themselves as knowledge brokers, acting as the bridge between urban planners, the community, policy makers and scientists (Franzetskaki et al., 2016).

6. Tenet 3. Recognizing researchers as knowledge brokers

The relationship between science and knowledge creation is in flux as social-ecological change necessitates examining established models of knowledge mobilization, negotiation, synthesis, and dissemination that have contributed to the marginalization of other modes of knowing (Chilisa, 2017; Marshall et al. 2018). This poses a challenge to conventional science and research and calls for a deeper examination of our professional responsibilities, as well as the investigation of engaged and activist research methodologies (Lotz-Sisitika et al., 2016). In this context, the traditional lines between the researcher as *producer* of knowledge and *broker, translator,* or *mediator* of knowledge are both questioned and blurred. This means embracing the role that researchers play in connecting practitioners, communities, and stakeholders to new fields, frameworks, methods and ideas (Bielak et al., 2008; Scodanibbio et al., 2023). As researchers we have often been trained to see these effects as accidental byproducts of the "real" work of objective research. Our own experiences suggest, however, that sustained engagement with various communities of practice in the knowledge broker role is a central contribution of urban greening researchers to promoting equity and justice. Moreover, playing the knowledge broker role enhances our understanding of the nuanced socia-lecological and historical context in which green infrastructure projects are situated.

7. Tenet 4. Embracing ambiguity between research and outcomes

While urban greening research has grown increasingly interdisciplinary, engaged, and critical (Anguelovski et al., 2020; Anguelovski and Corbera, 2023; Grabowski et al., 2017; Mason et al., 2019), the practice and implementation of urban green infrastructure remains largely rooted in the technological and technocratic approach to infrastructure implementation (Finewood et al., 2019). The conventional thinking in urban greening research assumes that more and better

"facts" will lead to a better understanding of the world and better-informed and more successful decision-making (Owens, 2005). This approach frames the implementation of green infrastructure as primarily a knowledge problem in which, with sufficient information, the optimal type and placement of green infrastructure can be identified and implemented (Heckert and Rosan, 2016; Teisch, 2011; Zhu et al., 2019). In other words, the relationship between knowledge production and decision-making is conceived of as a rational, linear process of problem identification, fact gathering, and informed decision-making. Yet urban green infrastructure, like other forms of infrastructure, is situated within its sociopolitical context, reflects the values embedded in its design and implementation, and results in both intended and unintended services and dis-services to communities (Björkman and Harris, 2018; Grabowski et al., 2017). Even as the green infrastructure literature has become increasingly attuned to calls to center justice at multiple scales (Grabowski et al., 2023; Heckert and Rosan, 2016; Hoover et al., 2021), early efforts to integrate considerations of the social impacts of green infrastructure have continued to reflect the field's technocratic orientation, often relying on spatial overlay approaches to identify the "most equitable" solutions (e.g., Heckert and Rosan 2018). If not done carefully and as part of community-engaged and co-produced research, these approaches can reproduce, rather than subvert, the technocratic philosophical underpinnings of green infrastructure science by assuming that generating the "right" knowledge will advance the desired ends.

On the other hand, research that operates from a perspective that knowledge, rather than a set of abstract stand-alone propositions, is situated, relational, and continually (re)produced (Angelo and Wachsmuth, 2015; Haraway, 1988) challenges this technocratic perspective. From this perspective, knowledge, rather than being inherently actionable, only becomes actionable when in a context in which it can be mobilized (Celino and Concilio, 2010). This suggests that advancing justice-oriented urban greening requires a shift in the research process itself. In addition to seeing urban greening researchers as "knowledge brokers" operating within a broader "ecosystem of knowledge" (see sections above), we argue that advancing a more equitable and justice-oriented body of research and practice will entail those who are engaged in the research process becoming comfortable with uncertainty and unpredictability in the relationship between research and impact (Xie, 2021).

To advance a framework of uncertainty for green infrastructure research(ers), we draw John Kingdon's (Kingdon, 1984) multiple streams framework. This framework begins with an assumption of ambiguity in problem-definition. Ambiguity refers to the particular uncertainty that emerges from a multiplicity of valid and, sometimes conflicting, ways of defining a problem (Brugnach and Ingram, 2012). This assumption is well-suited for the challenge of integrating equity and justice in urban greening research because planning for green infrastructure is characterized by multiple potential goals and trade-offs (Chang et al., 2021; Choi et al., 2021) and because definitions of equity and justice are inherently relational and contextual (Young, 2002). Rather than a technocratic approach, Kingdon's multiple streams framework rejects a rational-actor approach to policy solutions and instead argues that for any given political problem, many different potential solutions exist (Hoefer, 2022). Kingdon argues that shifting knowledge, contexts, and social relations can and should shift preferences for policy solutions. From this perspective, the "right" policy solution to a particular policy problem is shifting and contextual, depending on the social and political context. Moments of alignment between problem, policy, and politics thus represent "windows of opportunity."

Drawing on Kingdon, we reframe the goals of urban greening research to include both 1) developing many potentially acceptable solutions to the challenges of equitable and just urban greening and, importantly, 2) developing the relationships that create new potential contexts in which windows of opportunity might emerge. Developing relationships with stakeholders that shape the context of green infrastructure implementation—engineers, urban planners, community organizers, policymakers, environmental justice activists—might allow researchers to engage with and consider how different stakeholders might define the problem of advancing equity and justice. In doing so, researchers might better understand the problem-definitions that are most salient to the stakeholders and communities with whom they have shared goals and political commitments (Knaggård, 2015). Embracing the ambiguity of multiple problem definitions might, in turn, suggest new research questions, directions, and innovations that might not be obvious when approaching the problem from only the researcher's perspective. Building relationships with multiple stakeholders creates new contexts for windows of opportunity to arise, in which a researcher's previous results or innovations might be particularly useful or lead to new insights when presented in the context of a stakeholder's specific challenges.

One example of a research initiative that embraces this ambiguity between research and outcome comes from the CREATE (Co-developing Research and Engaged Approaches to Transform Environments) Initiative. This research effort, begun in 2017 (and whose leadership includes co-authors Derickson and Walker), aimed to undertake community-driven research at the intersection of equity and the environment (CREATE Initiative, 2023). The project began with the goal of devoting research and resources to questions related to water quality and flooding, policy, and environmental justice, yet the Initiative's research agenda was transformed through engagement with community partners from local environmental justice activists, who repeatedly voiced concerns about housing, gentrification, and displacement as the most pressing environmental concerns facing their communities (Ehrman-Solberg et al. 2020). This represented a re-definition of the team's initial problem, prompting the team to pursue research into new questions related to green infrastructure, housing, gentrification, and displacement. Findings led to an "Anti-Displacement Toolkit" aimed at identifying strategies for investing in urban greening without driving displacement (Klein et al. 2020). However, the toolkit—a series of potential policy solutions—was not immediately adopted by stakeholders to solve a policy solution. Instead, released in 2020, this toolkit was quickly overshadowed by the COVID-19 pandemic. However, once out into the world, the toolkit spread among a network of academics, activists, policymakers, and practitioners through the team's network of relationships, rippling out into unexpected policy spaces. Interest in the toolkit was spurred, in part, by changing political conditions in the wake of the uprising for racial justice following the murder of George Floyd by police in Minneapolis, which led to new openness among local politicians to adopting justice-oriented policies. During this "window of opportunity," planners developing local climate resilience planning integrated insights from the Toolkit to incorporate housing justice frameworks into their plans. From this example, we see the ways in which being open to ambiguity in problem-definition leads to new research questions that can result in unexpected research products that, during "windows of opportunity" allow research insights to be integrated into unexpected policy contexts.

8. Tenet 5. Modest imaginaries for equitable green infrastructure solutions

Finally, we advocate for a "modest imaginary" (Lawhon et al., 2022) to be held by scholars examining green infrastructure, equity and justice in cities. The goals outlined above—situating research in ecosystems of power, building on transdisciplinarity, knowledge brokering, and embracing ambiguity—can be achieved, we argue, through the notion of a "modest imaginary." Whereas urban planning and infrastructure has often mobilized plans with a degree of grandiosity, some working in the field of urban greening have more recently proposed that a turn away from grandiose plans toward a more modest imaginary invites a more open-minded approach to infrastructure planning that engages critically with multiple possible solutions and integrates a range of perspectives.

While the authors who coined the phrase outline the concept related to their research on sanitation practices in Kampala, Uganda, their analysis and conclusions offer broad insights applicable to urban greening research in both the Global North and South. Lawhon et al., (2022) call for a critical appraisal of technocratic infrastructure solutions and, instead, an open-minded approach to a diversity of infrastructural solutions. They argue that no single design will work for all situations, and while not all existing solutions should be tossed aside, they need to be engaged critically, and modestly, allowing for consideration of novel and different options. In particular, Lawhon et al. question the assumption that infrastructure approaches developed in the Global North are appropriate solutions in all contexts. Rather, a "modest imaginary" embraces diverse worldviews and "the multiple imaginaries informing ongoing and future practices" (ibid: 15). The authors also critique the broader consumption-driven economies that have been facilitated by technocratic approaches to infrastructure; as such, their call for modesty refers to modesty in resource consumption as well. In other words, a "modest imaginary" involves avoiding assumptions about what might be the "correct" solutions to infrastructure challenges, engaging wider and more diverse stakeholders, and prioritizing solutions that are more modest in their resource demands.

The "modest imaginary" framework shares some similarities with recent calls among urban greening scholars to embrace a "just green enough" approach (e.g., Wolch et al. 2014). In conceptualizing "just green enough," authors Curran and Hamilton (2012) argued that by centering the needs and priorities of current residents over investments in flashier, developer-oriented greening projects, urban greening initiatives might provide benefits for longtime residents. The "just green enough" approach, like the "modest imaginaries" approach, is critical of grandiose infrastructure investments, emphasizes a shift away from the demands of capital in the real estate market, and calls for a plurality of voices and worldviews in shaping urban greening projects.

In Minneapolis, Minnesota (USA), one community is calling for a more modest imaginary in a park planning process to ensure that they are able to play a role in shaping outcomes. Whereas the park planning agency proposed an ambitious redesign of a 48-acre former industrial site along the Mississippi River that included an amphitheater and significant bike and recreational infrastructure, the community consultation process revealed a preference for a "slow" approach to park planning that allowed the community to provide feedback throughout the development process rather than express all their preferences in the initial planning stage (Ramer et al. *in review*). This push to slow down the park planning process and allow residents to continually shape the design contrasts with the Promethean drive of some urban planning and has resonances with the call for a modest imaginary as articulated by Lawhon et al. (2023).

Embodying a 'modest imaginary' allows for a reorientation from a developmentalist ideal of what just futures *ought* to resemble - often driven by the goals of individual or groups of researchers - to acknowledging *already existing* infrastructures from which just futures may emerge (Lawhon et al., 2018, Lawhon et al., 2023). In making these practices visible, scholars may play a key role in fostering more just research processes and outcomes.

9. Conclusion: green Infrastructure for equitable futures

While the uptake of urban green infrastructure represents a promising development in urban sustainability and development practices, it cannot be assumed that these projects will benefit all residents or promote urban equity. Indeed, the history of urban development and infrastructure projects shows that there is a tendency for such projects to consolidate benefits for powerful groups, often at the expense of the vulnerable or marginalized. This tendency has resulted in uneven and unjust urban landscapes in which contemporary green infrastructure projects must play out. Traditional research approaches and practices will need to be critically evaluated and reworked in order to address this ecosystem of power and historical context. Turning to other disciplines can spur new insights; urban studies, for example, provides green infrastructure researchers insight into how to think about the relationship between equity and urbanization, questions of scale, and the need for historically attuned and locally situated research. Likewise, sustained reflection and iteration on green infrastructure research and practice in a range of places and contexts challenge us to further develop and assess the way we do justice- and equity-oriented green infrastructure research that meets our shared goal of a more just, equitable, and sustainable future.

CRediT authorship contribution statement

Austin Gage Matheney: Writing – original draft, Conceptualization. **Seema Mundoli:** Writing – review & editing, Writing – original draft, Conceptualization. **Sumetee Pahwa Gajjar:** Conceptualization. **Anne Guerry:** Writing – review & editing, Conceptualization. **Pippin Anderson:** Writing – review & editing, Conceptualization. **Adriana Castillo-Castillo:** Writing – review & editing, Writing – original draft. **Linjun Xie:** Writing – review & editing, Writing – original draft, Conceptualization. **Nontsikelelo Mogosetsi-Gabriel:** Conceptualization. **Maike Hammann:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Liz Llewellyn:** Writing – review & editing, Conceptualization. **Rebecca Walker:** Writing – review & editing, Writing – original draft, Conceptualization. **Olumuyiwa Bayode Adegun:** Writing – review & editing, Writing – original draft, Conceptualization. **Kate Derickson:** Writing – review & editing, Writing – original draft, Funding acquisition, Conceptualization. **Bonnie Keeler:** Conceptualization. **Nadia Sitas:** Writing – review & editing, Writing – original draft, Conceptualization.

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