CHAPTER 9

Systems Approaches to City Research and Innovation: Biodiversity, Culture, and Geography

Niki Frantzeskaki, Judy Bush, Perrine Hamel, Melissa Pineda-Pinto, Timon McPhearson, Dave Kendal, Marcus J. Collier, and Johanna Granados Alcala

9.1 Introduction

Cities are complex social—ecological—technological systems (SETS). A SETS framing highlights the interactions and interrelations in cities between people, biodiversity and ecosystems, and the built form and its

N. Frantzeskaki (✉)
Utrecht University, Utrecht, The Netherlands
e-mail: n.frantzeskaki@uu.nl

J. Bush
Faculty of Architecture Building and Planning, University of Melbourne, Melbourne, Australia
e-mail: judy.bush@unimelb.edu.au

C. Oke et al. (eds.), *A Global Research and Action Agenda on Cities and Climate Change Science*,
https://doi.org/10.1007/978-981-95-6517-7_9

tools and urban infrastructures (McPhearson et al., 2022). This systems approach emphasizes understanding the dynamic interactions and feedback mechanisms among these domains, recognizing that the whole is greater than the sum of its parts, and that changes in one sphere inevitably lead to emergent properties and cascading effects across the entire system (Chester et al., 2023). Its primary purpose is to move beyond sectoral analyses to inform integrated decision-making, ensuring that interventions promote resilience and sustainability without causing unintended negative consequences to the system's overall function and service provision. However, cities are often not evaluated, planned, or governed as

P. Hamel
Asian School of the Environment, Nanyang Technological University, Singapore, Singapore
e-mail: perrine.hamel@ntu.edu.sg

M. Pineda-Pinto
Melbourne Centre for Cities, Faculty of Architecture Building and Planning, The University of Melbourne, Melbourne, Australia
e-mail: melissa.pinedapinto@unimelb.edu.au

T. McPhearson
Urban Systems Lab, New York University, New York, NY, USA

Cary Institute of Ecosystem Studies, Milllbrook, NY, USA

Beijer Institute of Ecological Economics at the Swedish Royal Academy of Sciences, Stockholm, Sweden

T. McPhearson
e-mail: timon.mcphearson@nyu.edu

D. Kendal
Future in Nature, Melbourne, Australia
e-mail: dave@futurenature.au

M. J. Collier
Trinity College Dublin, University College Dublin, Dublin, Ireland
e-mail: marcus.collier@tcd.ie

J. Granados Alcala
Global Covenant of Mayors, Brussels, Belgium
e-mail: jgranadosalcala@gcomprojectsupport.org

such. This results in cities being imagined and conceived in less interconnected ways that overlook or ignore complexity, with fragmented governance systems and planning processes that produce undesired trade-offs, and that fail to consider cross-sector and cross-scale impacts. These underlie the knowledge gaps presented in the GRAA 2024 report. These knowledge gaps span local contextualization and institutional fitness of climate and biodiversity plans, issues of regional connectedness, and design, testing, and evidence-based planning for tailored urban solutions.

At the same time, to address these knowledge gaps, a growing number of urbanists conceptualize cities and urbanized regions as tightly intertwined and complex SETS (McPhearson et al., 2021, 2022, 2023; Chester et al., 2023; McPhearson et al., 2022). The SETS conceptual framework applied to urban systems suggests increased attention to the dynamic interactions between the social-economic, ecological, and technological-infrastructural domains of cities that drive patterns and processes affecting daily life and shape urban futures. A systems approach, whether applied through the SETS framework or others (Zhou et al., 2021), is critical to reveal new opportunities for innovation at the intersection of systems that are normally governed, planned, and managed in isolation.

Taking a systems approach to understanding urban patterns and urban change, as well as to designing urban plans and solutions, requires a focus on complexity. Complexity exists in both the diversity of urban system elements (land uses, governance, communities, biodiversity, health, education, and transport) and in their interactions (or nexus between elements): the interrelations of people, infrastructure, nature/ecosystems, and time in cities. Recent work on systemic approaches (including the IPBES Nexus Assessment 2025, discussed in O'Brien et al., 2025) puts an emphasis on understanding the interrelations between systems of provision and services. A nexus understanding and conceptualization, particularly within the SETS context, that focuses on how these individual system elements interact, interrelate, and affect each other may progress urban system thinking toward innovative conceptualizations and solutions. A nexus approach can potentially inform systemic understandings of city functions and urban change, as well as drive policy development and practice that recognizes these interrelations and interactions, which are inherent in cities.

We propose nexus thinking as a way to innovate across scales (addressing regional connectivity) and across sectors (to tailor solutions

that are cross-sectoral and inclusive) to address the polycrisis: the interlinked, compounding threats posed by biodiversity loss, climate change, inequity and injustice. Innovation refers to policy, planning, and governance actions that are novel in their context and push forward for a systemic and cross-sectoral (hence nexus) thinking and doing, for more climate-resilient and nature-positive urban futures. Drawing from the knowledge gaps identified in the 2024 GRAA (Irvin et al., 2024), we summarize key gaps and recent advances in research and practice to address these gaps, with a focus on three themes: biodiversity, culture, and geography (other chapters in this book explore complementary themes).

9.2 Challenges and Opportunities

For cities innovating through greater engagement with nature, we need to consider the following nexus challenges and opportunities:

9.2.1 Biodiversity

The biodiversity knowledge gaps identified in the latest Innovate4Cities initiative report (Irvin et al., 2024) relate to the key challenge of policy "dis-integration": how to integrate biodiversity conservation and restoration into urban planning and development. Ecological degradation is driven by multiple human-induced impacts. The compounded factors of climate change, invasive species, habitat fragmentation, and pollution are exacerbating rapid biodiversity loss, with cities as fundamental drivers of these patterns through urban development, resource consumption, and greenhouse gas emissions (IPBES, 2019; Parmesan et al., 2022; Pörtner et al., 2021). Urban areas, including the species, community relationships, and larger social and infrastructure contexts in which urban nature exists, are facing multiple threats from human-mediated disturbances (McPhearson et al., 2023). This ecological degradation is exacerbated by environmental stressors and the changes in land-use patterns that come with urban development.

Urban nature provides a wide range of ecological, social, and economic benefits. Ecologically, green and blue infrastructure improves air and water quality, mitigates urban heat-island effects, and supports pollination and biodiversity corridors. Small patches of vegetation in cities create a network that serves as a critical habitat for birds, insects, and small mammals (Elmqvist et al., 2013). Socially, urban green spaces

contribute to public health by encouraging physical activity and reducing stress (Tzoulas et al., 2007). Well-planned and located nature-based solutions and green spaces that mitigate urban heat can contribute to cities' capacity to support vulnerable communities who have less access to cooler, high-quality housing (Bush, 2025). They also foster attachment and promote social interaction. Urban biodiversity reflects and reinforces First Peoples' holistic approaches to sustainability, custodianship, and resource management (Cumpston, 2020). Urban nature has cultural and spiritual dimensions, which contribute to building and maintaining a local identity. Economically, proximity to green areas increases property values and reduces energy costs by providing shade and cooling. Green urban areas host agricultural projects that are vital in some communities for food security, community engagement, and empowerment.

Irvin et al. (2024) highlight the importance of vibrant and active cities, advocating for governance models that integrate multiple decision-making levels and actors, where communities are active contributors, ensuring that community values are represented in urban planning efforts. Urban-biodiversity strategies must thus be tailored to local environmental, social, and economic contexts. Place-based responses should incorporate local knowledge, past and present culture, art, and heritage to address the community's needs.

Aligning and localizing multi-level governance are key to addressing policy dis-integration. First, there is a misalignment of regulatory governance at local, national, and global levels for biodiversity, making urban goals for biodiversity neither systematically prioritized nor addressed across different urban sectoral policies and plans. This cross-scale misalignment is a multi-level governance challenge: cities are sites in which multi-level governance must work to align local and national priorities such as climate change (Bergman et al., 2025) and biodiversity. Second, there is a need for coordination of actors at different levels of governance for the integration and localization of biodiversity in policies and plans, as well as recognizing and addressing in policy plans the connected needs between biodiversity, climate change, and resilience (McPhearson et al., 2025).

To effectively address these challenges, there is an urgent need for strategies that integrate biodiversity conservation into urban planning and development, and that address the critical nexus between biodiversity and culture. In multi-level governance contexts, this requires and is enabled by bi-directional flows of information from national to local and also

from cities to national and global levels. Such strategies should focus on protecting vegetation, enhancing green spaces, and implementing policies that strike a balance between development and environmental preservation, and that bring diverse knowledge and cultural values directly into biodiversity and ecological planning and governance. Traditional approaches to governance have tended to ignore many other ways of learning, knowing, and doing, and struggle to connect to local and regional cultural practices (Gazing Wolf et al., 2024; Orlove et al., 2023). Indigenous, local, and Traditional knowledge systems contain vast amounts of critical information that needs to be seen, heard, and used to work with other tools and strategies from Western science (Bartlett et al., 2012; Nelson & Shilling, 2018). Deep, local, and cultural relationships with urban ecosystems developed over generations and embedded within Indigenous knowledge systems need to be more actively integrated into approaches to urban development to build cities that enhance, rather than threaten, biodiversity (Cumpston et al., 2022).

9.2.2 Culture

The culture knowledge gaps identified in the Innovate4Cities initiative report (Irvin et al., 2024) highlight a key challenge in integrating cultural and historical considerations into urban development and climate action. This includes the need for better coordination in urban planning to equitably preserve cultural heritage, effectively incorporating community perspectives into heritage management, and understanding the impact of urbanization on cultural sites. Furthermore, there is a significant gap in fully integrating culture, art, heritage, and history into participatory planning processes for climate change solutions, which, if integrated, will ensure the inclusion of marginalized communities and recognize past injustices, and apply cultural insights for effective, place-based climate responses, including the incorporation of oral histories (Crowley et al., 2022).

Climate change is raising awareness of the dynamic and diverse nature of culture and heritage. Rather than automatic preservation of historical norms and baselines, processes that recognize that heritage and culture must be allowed to change are being adopted. A key mechanism used to put this understanding into practice is through community engagement (Waterton, 2015). Rather than assigning cultural value or historic importance a priori, or assuming power through expertise and scientific

understanding, community engagement allows multiple ways of understanding cultural value and prioritizing heritage to be revealed. This can aid the legitimacy of cultural and heritage processes. Key advances include theorizing community in ways that allow complex and fluid community identities, and recognizing the importance of benefits to participants in community-engagement processes. Genuine community engagement with diverse communities promises more human-centered outcomes, rather than technocratic outcomes (Gulsrud et al., 2018). These processes are being used to acknowledge and weave Traditional Knowledge systems and worldviews into decision-making and to support self-determination in settler-colonial societies such as Australia, New Zealand, and Canada (Bartlett et al., 2012; Waterton, 2015).

Progress toward addressing this gap from a justice perspective has seen some promising shifts. For example, the climate and multispecies justice frameworks demonstrate a crucial pivot toward integrating justice considerations into climate change discourse and action, moving beyond purely technical solutions to embrace socio-cultural, ethical, and historical dimensions. Climate justice, in particular when taking an intersectional perspective, empowers us to recognize and confront the interconnected social and environmental injustices that create urban vulnerabilities (Amorim-Maia et al., 2022). This, in turn, fosters the development of more practical and integrated strategies for equitable urban adaptation and transformation (Mikaelsson & Lager, 2024). Progress in the field of multispecies justice—which extends justice beyond human concerns to encompass non-human entities and entire ecological systems—involves the conceptualization and emergence of practices that foster respectful relationships with all life on Earth, drawing significantly from Indigenous philosophies and Local Knowledge, challenging anthropocentric approaches to governance and development (Celermajer et al., 2021). Efforts are being made to transform political, social, cultural, legal, and economic systems to be more responsive to the needs and rights of human and more-than-human beings. For example, the Nature Futures Framework is gaining traction as a way to explore and clarify the multiple dimensions of nature-related values—including those connected to more-than-human beings—in urban contexts (Mansur et al., 2022). It provides a useful basis for dialogue on how people perceive and engage with nature and culture in cities.

To integrate cultural considerations into urban development and climate action effectively, breaking down isolation and horizontal-vertical

jurisdictional barriers and challenging existing power structures requires a multi-faceted approach involving governance innovations, collaborative mechanisms, and a re-evaluation of how culture is valued and integrated. Ways to do this include mainstreaming the process of embedding climate-resilience considerations across different policy domains and governance levels (Adams et al., 2023). Such systemic integration could, in principle, create avenues for considering diverse cultural values and practices if the mainstreaming process itself is designed to be culturally sensitive and inclusive.

9.2.3 Geography

The geography knowledge gaps identified in the Innovate4Cities initiative report (Irvin et al., 2024) relate to our understanding of local geographical contexts for developing climate-responsive and nature-positive policies. Geography, the biophysical context, and the relationships between people, their environments, and their more-than-human neighbors are a foundational element in understanding the unique set of challenges and opportunities that each city faces (Castree et al., 2025). Geography, frequently referred to as local context, distinguishes one city from another (Irvin et al., 2024). Each city's geography has defined the city's form and development: circling mountains constrain urban expansion; rivers bring movement, transport, and flooding; climate, rainfall patterns, and landforms combine with evolving social dynamics and characteristics to shape how cities develop and function. While there is increasing research seeking to analyze and understand the "science of cities" (McPhearson et al., 2016) and develop informed approaches to urban sustainability and climate change (Frantzeskaki et al., 2021), key challenges remain in "localizing" this knowledge (Irvin et al., 2024): while facing similar challenges, cities are unique and responses must be adapted to local social-ecological-technological contexts. Although knowledge can be exchanged, it must always be contextualized. Further, there are substantial gaps in the global coverage of research findings, with less research focused on Global South cities (Chu et al., 2015) and smaller, regional urban settlements (Kendal et al., 2020).

There is growing research that emphasizes geography and local context in the elaboration of barriers and facilitators to address the polycrisis. An example is research for sustainability and climate change focused

on the relationship between urban form and carbon emissions (Hurlimann et al., 2025), which points to the contributions achievable through transit-oriented design and active transport. Integrating nature-based solutions into urban areas can improve sustainable urban form and function: tree-lined streets encourage active transport and heat mitigation (Tang & Bush, 2025), sustainable drainage infrastructures contribute to stormwater management (Bush et al., 2023), and nature-based solutions and ecosystem-based adaptation can contribute to reducing the risk from disasters, including flooding and drought (Frantzeskaki & McPhearson, 2022), although there continue to be knowledge gaps in how local context influences implementation and ongoing maintenance.

While cities are sharing information on planning and implementing nature-based solutions via platforms such as CitiesWithNature (https://citieswithnature.org/), and through city-based processes such as the Berlin Urban Nature Pact (https://citieswithnature.org/berlin-urban-nature-pact/), there are continuing research efforts, yet also knowledge gaps, related to developing business cases and funding mechanisms for diverse local contexts (Collier et al., 2023). Urban intermediaries, including city-networks, using tools such as digital platforms, enable knowledge-sharing and open training that supports cities to learn from and adapt actions tested in other cities facing similar challenges.

Localizing urban research and ensuring the inclusion of diverse voices from biophysical and social sciences (Castree et al., 2014), First Peoples and local communities (Cumpston et al., 2022), and diverse urban contexts (West et al., 2024) is essential. Localizing urban knowledge and urban research and understanding how the surrounding regional contexts influence cities are pivotal to responding to urban complexity and to better understanding the urban nexuses for co-designing climate solutions. Co-design is an integrative participatory decision-making process that seeks to ensure inclusive engagement and integration of diverse views (O'Donnell et al., 2025). Examples include foregrounding Traditional Owners' aspirations by reintegrating fire into urban landscapes for ecosystem management and reconnecting wetlands to floodplains and seasonal flows (Cumpston et al., 2022). Further, local responses to climate change need to account for climate impacts in more just and inclusive responses that more effectively take account of capacity disparities, climate injustice/justice, and vulnerabilities. City planners, practitioners,

and decision-makers need locally relevant research and insights, necessitating the collection and analysis of appropriate and meaningful indicators and data sets that span social and ecological factors (for example, Fanning & Raworth, 2025). There are opportunities for community science to contribute to this work, and in doing so to provide opportunities for broader participation and engagement (Tengö et al., 2021). Furthermore, initiatives such as "extreme community science" can help vulnerable communities achieve effective outcomes by improving data accessibility, fostering knowledge co-production, and building community capacity (English et al., 2018).

9.3 What Do We Need to Innovate With Nature in Cities?

In response to these challenges and to the identified knowledge and practice gaps, we take a systems approach through a nexus conceptualization and propose four ways forward. First, the adoption of integrated frameworks is critical so as to identify leverage points in the nexus of biodiversity—culture—geography/locality to move from problem identification to scaling innovative solutions. We propose to employ integrated frameworks to elucidate and map the complexity of the nexus in cities. Importantly, employing integrated frameworks is not intended to remove complexity but rather to provide tools to help navigate this complexity. Frameworks such as SETS, adaptive pathways, or the Nature Futures Framework (Pereira et al., 2020) show how to systematically map existing innovations, identify progressive pathways for action, and serve as organizing frameworks for transdisciplinary co-production of urban innovative solutions. Integrative frameworks can also aid urban researchers, planners, and practitioners to understand and embrace complexities as well as to identify synergies and trade-offs across the nexus to co-develop more-effective urban plans for innovating with nature in cities.

Second, innovative approaches to cities with nature, in the nexus of biodiversity—culture—geography, requires innovation in the concepts used to guide urban policy and planning. We thus propose that we need to progress narrative shifts toward more plural and decolonial understandings of innovations and the process (of what constitutes and what entails) innovating in cities with nature. Such plurality of understandings will allow for respect and acknowledgment of Traditional Owners' aspirations and custodianship of lands and waters. It will also open spaces

for local communities (including vulnerable, marginalized groups from an intersectional justice perspective), and set up a platform for dialogue between knowledge holders. As language can connect and divide in urban visions, plurality, and inclusivity in terms may be a way to also pluralize innovations with nature in cities.

Third, we propose to integrate biodiversity, cultural, and geographical considerations into urban development, planning and governance for dealing with the polycrisis. By integrating "culture" and "nature" (human and more-than-human) in policy and planning for the polycrisis, we can both acknowledge cities as complex SETS, as well as explicitly and intentionally consider the policy interactions across policy domains, and the governance interactions across governance levels and between governance and policy actors. Furthermore, while colonial processes of urbanization have contributed to dispossession and habitat destruction, transformative approaches to planning and governance that embed cultural considerations and Local and Traditional Knowledges may more effectively challenge business-as-usual power imbalances and economic processes to progress action for the polycrisis (Frantzeskaki et al., 2024).

Fourth, instead of only using monitoring and evaluation to learn from what has been done, we propose to emphasize opportunities for applying lessons to develop innovative planning and development, taking an adaptive, forward-looking approach. In this way, learning across diverse urban contexts will serve two innovative pathways: to localize urban research and practice (policy and planning) and to avoid imagination lock-ins (associated with business-as-usual approaches). To support local monitoring and evaluation efforts, as well as connect these to global reporting processes, careful selection of indicators is required. It can be challenging to identify appropriate indicator sets that can effectively represent the complexity of ecosystem structure and function, within the broader urban fabric, and allow time and place comparisons. For such learning-forward practices to take off, strengthening dialogues and collaborations between researchers, practitioners, and communities is foundational. Collaborative learning processes that integrate citizen-science efforts with structured data collection, as well as diverse knowledge systems, can contribute to the fundamental processes of recognition, participation, co-learning, and co-management.

Acknowledgements The authors acknowledge Chiara Morfeo, of C40 Cities, for her contributions to the development of this chapter.

Competing Interests

The authors have no conflicts of interest to declare.

References

Adams, C., Frantzeskaki, N., & Moglia, M. (2023). Mainstreaming nature-based solutions in cities: A systematic literature review and a proposal for facilitating urban transitions. *Land Use Policy, 130*, Article 106661. https://doi.org/10.1016/j.landusepol.2023.106661

Amorim-Maia, A. T., Anguelovski, I., Chu, E., & Connolly, J. (2022). Intersectional climate justice: A conceptual pathway for bridging adaptation planning, transformative action, and social equity. *Urban Climate*, *41*, 101053. https://doi.org/10.1016/j.uclim.2021.101053

Bartlett, C., Marshall, M., & Marshall, A. (2012). Two-eyed seeing and other lessons learned within a co-learning journey of bringing together indigenous and mainstream knowledges and ways of knowing. *Journal of Environmental Studies and Sciences, 2*(4), 331–340. https://doi.org/10.1007/s13412-012-0086-8

Bergman, J., Buylova, A., Jacksson, J., Nasiritousi, N., Sanderink, L., & Tobin, P. (2025). The multilevel governance of polarised climate politics: How a pioneer city navigates a dynamic political context. *Environmental Politics*. https://doi.org/10.1080/09644016.2025.2533605

Bush, J. (2025). Planning nature-based solutions for cooling Australian cities. In P. B. Cobbinah & M. Addaney (Eds.), *Handbook on planning and climate change adaptation* (pp. 229–246). Edward Elgar Publishing. https://doi.org/10.4337/9781803926926

Bush, J., Frantzeskaki, N., Ossola, A., & Pineda-Pinto, M. (2023). Priorities for mainstreaming urban nature-based solutions in Australian cities. *Nature-Based Solutions, 100065*. https://doi.org/10.1016/j.nbsj.2023.100065

Castree, N., Adams, W. M., Barry, J., Brockington, D., Büscher, B., Corbera, E., Demeritt, D., Duffy, R., Felt, U., Neves, K., Newell, P., Pellizzoni, L., Rigby, K., Robbins, P., Robin, L., Rose, D. B., Ross, A., Schlosberg, D., Sörlin, S., & Wynne, B. (2014). Changing the intellectual climate. *Nature Climate Change, 4*(9), 763–768. https://doi.org/10.1038/nclimate2339

Castree, N., Barnes, T., & Salmond, J. (Eds.). (2025). *Making geography matter: The past and present of a changing discipline*. Routledge.

Celermajer, D., Schlosberg, D., Rickards, L., Stewart-Harawira, M., Thaler, M., Tschakert, P., Verlie, B., & Winter, C. (2021). Multispecies justice: Theories, challenges, and a research agenda for environmental politics. *Environmental Politics, 30*(1–2), 119–140. https://doi.org/10.1080/09644016.2020.1827608

Chester, M. V., Miller, T. R., Muñoz-Erickson, T. A., Helmrich, A. M., Iwaniec, D. M., McPhearson, T., Cook, E. M., Grimm, N. B., & Markolf, S. A. (2023). Sensemaking for entangled urban social, ecological, and technological systems in the Anthropocene. *Npj Urban Sustainability, 3*(1), Article 1. https://doi.org/10.1038/s42949-023-00120-1

Chu, E., Anguelovski, I., & Carmin, J. (2015). Inclusive approaches to urban climate adaptation planning and implementation in the Global South. *Climate Policy, 16*(3), 372–392. https://doi.org/10.1080/14693062.2015.1019822

Collier, M. J., Frantzeskaki, N., Connop, S., Dick, G., Dumitru, A., Dziubała, A., Fletcher, I., Georgiou, P., Hölscher, K., Kooijman, E., Lodder, M., Madajczyk, N., McQuaid, S., Nash, C., Osipiuk, A., Quartier, M., Reil, A., Rhodes, M.-L., Rizzi, D., & Xidous, D. (2023). An integrated process for planning, delivery, and stewardship of urban nature-based solutions: The Connecting Nature Framework. *Nature-Based Solutions, 3*, Article 100060. https://doi.org/10.1016/j.nbsj.2023.100060

Crowley, K., Jackson, R., O'Connell, S., Karunarthna, D., Anantasari, E., Retnowati, A., & Niemand, D. (2022). Cultural heritage and risk assessments: Gaps, challenges, and future research directions for the inclusion of heritage within climate change adaptation and disaster management. *Climate Resilience and Sustainability, 1*, Article e45. https://doi.org/10.1002/cli2.45

Cumpston, Z. (2020). Cities are country: Illuminating aboriginal perspectives of biodiversity in urban environments. Research synthesis. *Clean Air and Urban Landscapes Hub*. https://doi.org/10.5281/zenodo.4782538

Cumpston, Z., Fletcher, M.-S., & Head, L. (2022). *Plants: Past, present and future*. Thames and Hudson.

Elmqvist, T., Fragkias, M. (Ed.), Goodness, J. (Ed.), Güneralp, B., Marcotullio, P. J. (Ed.), McDonald, R. I. (Ed.), Parnell, S. (Ed.), Schewenius, M., Sendstad, M., Seto, K. C., & Wilkinson, C. (2013). *Urbanization, biodiversity and ecosystem services: Challenges and opportunities*. Springer Nature. https://doi.org/10.1007/978-94-007-7088-1

English, P. B., Richardson, M. J., & Garzón-Galvis, C. (2018). From crowdsourcing to extreme citizen science: Participatory research for environmental health. *Annual Review of Public Health, 39*(1), 335–350.

Fanning, A. L., & Raworth, K. (2025). Doughnut of social and planetary boundaries monitors a world out of balance. *Nature, 646*(8083), 47–56. https://doi.org/10.1038/s41586-025-09385-1

Frantzeskaki, N., & McPhearson, T. (2022). Mainstream nature-based solutions for urban climate resilience. *BioScience, 72*(2), 113–115. https://doi.org/10.1093/biosci/biab105

Frantzeskaki, N., Lambertucci, S., Carr, E., Dempsey, J., Karamidehkordi, E., Sengupta, A., Rojas Marchini, F., Vogel, C., Andriamahefazafy, M., Boonstra, W., Espinoza-Cisneros, E., Garcia, K., Morita, K., Nelson, V., Ojeda, D.,

Plieninger, T., Stirling, A., Tokunaga, K., Chen, R., … & Guibal, C. (2024). Overcoming the challenges of achieving transformative change towards a sustainable world. In K. O'Brien, L. Garibaldi, & A. Agrawal (Eds.), *Thematic assessment report on the underlying causes of biodiversity loss and the determinants of transformative change and options for achieving the 2050 Vision for Biodiversity of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services*. IPBES secretariat. https://doi.org/10.5281/zenodo.11382246

Frantzeskaki, N., McPhearson, T., & Kabisch, N. (2021). Urban sustainability science: Prospects for innovations through a system's perspective, relational and transformations' approaches. *Ambio, 1–9*. https://doi.org/10.1007/s13280-021-01521-1

Gazing Wolf, J., Ignace, D. D., David-Chavez, D. M., Jennings, L. L., Smiles, D., Blanchard, P., Simmons, E., Doan-Crider, D., Kills, R. P. S.-S., Montgomery, M., Nelson, M. K., Black Elk, L., Black Elk, L., Bridge, G., Chischilly, A. M., Deer, K., DeerinWater, K., Ecoffey, T., Vergun, J.,..., & Rattling Leaf, J. (2024). Centering indigenous knowledges in ecology and beyond. *Frontiers in Ecology and the Environment*, *22*(7), e2776. https://doi.org/10.1002/fee.2776

Gulsrud, N. M., Hertzog, K., & Shears, I. (2018). Innovative urban forestry governance in Melbourne? Investigating "green placemaking" as a nature-based solution. *Environmental Research*, *161*, 158–167. https://doi.org/10.1016/j.envres.2017.11.005

Hurlimann, A., Moosavi, S., Warren-Myers, G., March, A., Bush, J., & Cutroni, L. (2025). Facilitating climate change action across built environment life stages—Perspectives from built environment professionals. *Cities, 165*, Article 106113. https://doi.org/10.1016/j.cities.2025.106113

IPBES. (2019). *Global assessment report on biodiversity and ecosystem services of the intergovernmental science-policy platform on biodiversity and ecosystem services*. IPBES secretariat. https://doi.org/10.5281/zenodo.4782538

Irvin, A., Oke, C., Khan, S., Jance IV, B., Ranalder, L., Barth, B., Deacon, A., Abusamra, R., Addison, A., Adebisi, J., Adsett, C., Ailio, E., Al Jadaa, D., Aslan, S., Assalini, S., Assarkhaniki, Z., Astolfo, J. P., Badino, M., Bai, X., …, & Williams, A. (2024). Next-generation city climate action: Findings from the 2024 Innovate4Cities conference and update to the global research and action agenda on cities and climate change science (GRAA). Global Covenant of Mayors for Climate and Energy, UN-Habitat & University of Melbourne. https://doi.org/10.26188/27147612

Kendal, D., Egerer, M., Byrne, J. A., Jones, P. J., Marsh, P., Threlfall, C. G., Allegretto, G., Kaplan, H., Nguyen, H. K. D., Pearson, S., Wright, A., & Flies, E. J. (2020). City-size bias in knowledge on the effects of urban nature

on people and biodiversity. *Environmental Research Letters, 15*(12), Article 124035. https://doi.org/10.1088/1748-9326/abc5e4

Mansur, A. V., McDonald, R. I., Güneralp, B., et al. (2022). Nature futures for the urban century: Integrating multiple values into urban management. *Environmental Science & Policy, 131*, 46–56. https://doi.org/10.1016/j.envsci.2022.01.013

McPhearson, T., Andersson, E., Grilo, F., Lopez, B., Zein, N., Grimm, N., Wellmann, T., Kendal, D., Haase, D., & Lausch, A. (2023). Urban ecological resilience: Ensuring urban ecosystems can provide nature-based solutions. In T. McPhearson, N. Kabisch, & Frantzeskaki, N. (Eds.), *Nature-based solutions for cities* (pp. 49–81), Edward Elgar Publishing. https://doi.org/10.5281/zenodo.4782538

McPhearson, T., Cook, E. M., Berbés-Blázquez, M., Cheng, C., Grimm, N. B., Andersson, E., Barbosa, O., Chandler, D. G., Chang, H., Chester, M. V., Childers, D. L., Elser, S. R., Frantzeskaki, N., Grabowski, Z., Groffman, P., Hale, R. L., Iwaniec, D. M., Kabisch, N., Kennedy, C., & Troxler, T. G. (2022). A social-ecological-technological systems framework for urban ecosystem services. *One Earth, 5*(5), 505–518. https://doi.org/10.1016/j.oneear.2022.04.007

McPhearson, T., Frantzeskaki, N., Ossola, A., Diep, L., Anderson, P. M. L., Blatch, T., Collier, M. J., Cook, E. M., Culwick Fatti, C., Grabowski, Z. J., Grimm, N. B., Haase, D., Herreros-Cantis, P., Kavonic, J., Lin, B. B., Lopez Meneses, D. H., Matsler, A. M., Moglia, M., Morató, J.,..., & Zhou, W. (2025). Global synthesis and regional insights for mainstreaming urban nature-based solutions. *Proceedings of the National Academy of Sciences*, *122*(29), e2315910121. https://doi.org/10.1073/pnas.2315910121

McPhearson, T., Kabisch, N., & Frantzeskaki, N. (2023). Towards mainstreaming nature-based solutions for achieving biodiverse, resilient, and inclusive cities. In *Nature-based solutions for Cities* (pp. 363–375). Edward Elgar Publishing.

McPhearson, T., Pickett, S. T. A., Grimm, N. B., Niemelä, J., Alberti, M., Elmqvist, T., Weber, C., Haase, D., Breuste, J., & Qureshi, S. (2016). Advancing urban ecology toward a science of cities. *BioScience, 66*(3), 198–212. https://doi.org/10.1093/biosci/biw002

McPhearson, T. E. et al. (Eds.) (2021). In *Resilient urban futures* (pp. 173–186). Springer International Publishing. https://doi.org/10.1007/978-3-030-63131-4_12

McPhearson, T. E. et al. (2022). A social-ecological-technological systems approach to urban ecosystem services. *One Earth, 5*(5), 505–518. https://doi.org/10.1016/j.oneear.2022.04,.007

Mikaelsson, M. A., & Lager, F. (2024), *Justice and equity in climate change adaptation: Overview of an emerging agenda*. Stockholm Environment Institute. https://doi.org/10.5281/zenodo.4782538

Nelson, M. K., & Shilling, D. (Eds.). (2018). *Traditional ecological knowledge: Learning from Indigenous practices for environmental sustainability*. Cambridge University Press.

O'Donnell, M., Collier, M., Pineda-Pinto, M., Cooper, C., Nulty, F., & Castañeda, N. R. (2025). Redefining co-design for social-ecological research and practice: A systematic literature review. *Environmental Science & Policy, 164*, Article 103998. https://doi.org/10.1016/j.envsci.2025.103998

O'Brien, K., Garibaldi, L. A., Agrawal, A., Bennett, E., Biggs, R., Calderón Contreras, R., Carr, E. R., Frantzeskaki, N., Gosnell, H., Gurung, J., Lambertucci, S. A., Leventon, J., Chuan, L., Reyes García, V., Shannon, L., Villasante, S., Wickson, F., Zinngrebe, Y., & Périanin, L. (2025). IPBES transformative change assessment: Summary for policymakers (10.2.0).

Orlove, B., Sherpa, P., Dawson, N., Adelekan, I., Alangui, W., Carmona, R., Coen, D., Nelson, M. K., Reyes-García, V., Rubis, J., Sanago, G., & Wilson, A. (2023). Placing diverse knowledge systems at the core of transformative climate research. *Ambio, 52*(9), 1431–1447. https://doi.org/10.1007/s13280-023-01857-w

Parmesan, C., Anshari, G., Buotte, P., Campbell, D., Castellanos, E., Cowie, A. et al. (2022). Nature-based solutions for climate change: Mitigation and adaptation. In H.-O. Pörtner, D. C. Roberts, M. Tignor, E. S. Poloczanska, K. Mintenbeck, A. Alegría et al. (Eds.), *Climate change 2022: Impacts, adaptation, and vulnerability. Contribution of working group II to the sixth assessment report of the Intergovernmental Panel on Climate Change* (pp. 303–309). Cambridge University Press.

Pereira, L. M., Davies, K. K., den Belder, E., Ferrier, S., Karlsson-Vinkhuyzen, S., Kim, H., Kuiper, J. J., Okayasu, S., Palomo, M. G., Pereira, H. M., Peterson, G., Sathyapalan, J., Schoolenberg, M., Alkemade, R., Carvalho Ribeiro, S., Greenaway, A., Hauck, J., King, N., Lazarova, T., & Lundquist, C. J. (2020). Developing multiscale and integrative nature–people scenarios using the nature futures framework. *People and Nature, 2*(4), 1172–1195. https://doi.org/10.1002/pan3.10146

Pörtner, H. O., Scholes, R. J., Agard, J., Archer, E., Arneth, A., Bai, X., Barnes, D., Burrows, M., Chan, L., Cheung, W. L., Diamond, S., Donatti, C., Duarte, C., Eisenhauer, N., Foden, W., Gasalla, M. A., Handa, C., Hickler, T., Hoegh-Guldberg, O.,..., & Ngo, H. T. (2021). *IPBES-IPCC co-sponsored workshop report on biodiversity and climate change*. IPCC, I. a. https://doi.org/10.5281/zenodo.4782538

Tang, C., & Bush, J. (2025). Cooler streets for a cycleable city: Assessing policy alignment. *Buildings and Cities, 6*(1), 1–13. https://doi.org/10.5334/bc.508

Tengö, M., Austin, B. J., Danielsen, F., & Fernández-Llamazares, A. (2021). Creating synergies between citizen science and Indigenous and local knowledge. *BioScience, 71*(5), 503–518. https://doi.org/10.1093/biosci/biab023

Tzoulas, K., Korpela, K., Venn, S., Yli-Pelkonen, V., Kaźmierczak, A., Niemela, J., & James, P. (2007). Promoting ecosystem and human health in urban areas using green infrastructure: A literature review. *Landscape and Urban Planning, 81*(3), 167–178. https://doi.org/10.1016/j.landurbplan.2007.02.001

Waterton, EE. (2015). Heritage and community engagement. In T. Ireland & J. Schofield (Eds.), *The ethics of cultural heritage* (pp. 53–67). Springer. https://doi.org/10.1007/978-1-4939-1649-8_4

West, S., Haider, L. J., Hertz, T., Mancilla Garcia, M., & Moore, M. L. (2024). Relational approaches to sustainability transformations: Walking together in a world of many worlds. *Ecosystems and People, 20*(1), Article 2370539. https://doi.org/10.1080/26395916.2024.2370539

Zhou, W., Pickett, S. T. A., & McPhearson, T. (2021). Conceptual frameworks facilitate integration for transdisciplinary urban science. *NPJ Urban Sustainability*,*1*(1), Article 1. https://doi.org/10.1038/s42949-020-00011-9