

Mainstream Nature-Based Solutions for Urban Climate Resilience

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Global urbanization over the last century has concentrated people, infrastructure, and economic activity in cities, pushing them to the front lines of damaging impacts of climate change and other social and economic shocks, including COVID-19. Extreme natural disasters in the last 3 years, such as Typhoon Mangkhut (in 2018) in the Philippines, Hurricane Maria (in 2017) and Florence (in 2018) in the United States, the reoccurring extreme floods in Jakarta, and droughts and fires in California and several regions in Australia (in 2020), are expected to become regular occurrences as climate change accelerates. Cities are already vulnerable to such extremes and may become the most severely threatened global locations, given the projections of continued urban expansion that further concentrates people in high-density locations, including in low-elevation coastal zones. With US\$90 trillion expected to be invested in infrastructure (IDB 2017), these new buildings, roads, rail lines, electrical grids, and other critical infrastructure may also be at risk from climate-driven extreme events. The current and future urban risks represent a pressing need for putting the same level of global political will and economic investment in climate adaptation as there is in climate mitigation. The current levels of adaptation are not enough, despite leadership and increasing resilience and adaptation investments in both Global South and North cities. Cities need new innovative strategies to build their capacities to adapt to a future that is increasingly uncertain (Chester et al. 2020).

The rise of urban nature-based solutions

A rapidly expanding number of cities are exploring nature-based solutions (NBS) to urban challenges arising from the interactions between climate change and the legacies of urban development that increase inequality, concentrate air pollution, and exacerbate other environmental hazards (Frantzeskaki et al. 2019). NBS is a unifying umbrella concept that stems from and brings together research on green infrastructure, ecosystem-based adaptation, urban ecosystem services, and water sensitive urban design to showcase under one term the compelling advantages these strategies bring in providing multifunctional solutions to pressing urban challenges (European Commission 2021). It is remarkable that global urban development still largely relies on a twentieth century model that largely paves over urban ecological infrastructure (Chan et al. 2018), creating urban heat islands and surface flood risk, among other social and environmental ills. But the incorporation of NBS is beginning to take off. For example, the installation of rain gardens as NBS in Malmö, Sweden, have been upscaled to become the primary urban drainage infrastructure, whereas green walls are designed to locally filter air pollution in Mexico City, Mexico, and the Sponge Cities program in China is a signature project of NBS for flood protection and climate resilience. The aim of such initiatives is to promote public health, enhance livability, and restore natural hydrologic and ecological

processes and biodiversity, which can provide an important source of climate adaptation for cities (Mastrángelo et al. 2019, Dasgupta 2021).

Mainstreaming NBS

NBS are gaining prominence in climate change and biodiversity agendas and targets globally as a way of investing in urban nature as a source of solutions for multiple urban challenges (Frantzeskaki et al. 2019, European Commission 2021). In the last few years, the global research communities of sustainability science, urban science, and climate science, jointly with policymakers and practitioners (e.g., IUCN, ICLEI), have expanded the case for NBS by anchoring them into global agendas and through policy-science dialogues. Examples of these activities include the UN Habitat III New Urban Agenda in 2016, the Intergovernmental Panel for Climate Change's Cities and Climate Change Charter in 2018, the UN COP20 in New York in 2019, the NBS COP25 event in 2019, which launched the NBS for Climate Manifesto focusing on NBS for finance and green jobs, the UN Environment Programme (UNEP 2021) report on the viability of NBS for climate adaptation, and the Dasgupta Review (Dasgupta 2021), which provides the business case for investing in NBS for resilience and the recent IPBES reports for promoting NBS governance (Mastrángelo et al. 2019). In May 2021, the Italian government put on the agenda for G20 that a postpandemic recovery should take up NBS in its core.

Investments in NBS implementation, as well as research, are scaling up quickly as well. Since the introduction of NBS in 2015 in the European Union agenda, research investment alone in Europe has been ambitious amounting to nearly €160 million in 2020 (Faivre et al. 2017). The research investment drives collaborations and the scaling of NBS research through strategic partnerships globally, including with Brazil and China. NBS are being mainstreamed through the adoption and investment by many cities in urban resilience knowledge and in advancing urban planning portfolios through knowledge exchange as part of global networks such as the Global Resilience Network, Cities with Nature (www.citieswithnature.org), and the NATURA global network of networks (natura-net.org).

Three knowledge frontiers

The scaling of nature-based solutions requires filling knowledge gaps with continuous research and examination of NBS sustainability to accelerate positive urban transformations at the scale and pace required in a post-COVID and high climate change world. If we are to expand and sustain these emergent NBS mainstreaming pathways are strategic actions to deliver on the SDGs both locally and globally, then it is critical for research to progress across three knowledge frontiers: to strengthen the global evidence of the efficacy of nature-based solutions, to bridge disciplinary silos for scalable nature-based solutions, and to ensure coproduction of nature-based solutions for more just urban futures.

Strengthen the evidence base

Despite significant investments in nature-based solutions and a proliferation of research, there are major interlinked knowledge gaps that still need to be explored. First, we must discover evidence for where nature-based solutions are most effective. Currently, there is no systematized and comprehensive database of how NBS initiatives are conceived and governed, for what challenges, and in what

contexts they are implemented. The recent publication of the European Commission's *Evaluating the Impact of Nature-Based Solutions* (European Commission 2021) is a bold attempt to respond to the need for a synthesis especially on evaluating NBS; however, it remains geographically bounded to the European context. How could and should NBS be mainstreamed in different city contexts? We need a global roadmap for NBS that synthesizes knowledge and advances a global policy agenda with regional specificity and sharing of local successes and challenges to fully mainstream NBS for building urban resilience to climate impacts in cities that also safeguards local biodiversity.

Second, the lack of understanding of the governance of implementing novel solutions for ecosystem restoration is one of the key knowledge gaps for achieving the UN Sustainable Development Goals (SDGs). There is need for understanding how, through new governance approaches of NBS (Chan et al. 2018, Frantzeskaki et al. 2019, European Commission 2021), green jobs and enterprises can be stimulated and generated (Frantzeskaki et al. 2019), creating a pathway for transformation (Faivre et al. 2017). Finally, examining the unintended social and ecological impacts of NBS investments means taking a systemic view that considers such climate resilience interventions to address social and environmental justices (Tozer et al. 2021).

Bridge disciplinary silos for improving design

Nature-based solutions cannot deliver multiple benefits if they are detached or disconnected from the complexity of the existing urban infrastructure fabric. In compact cities such as New York, London, Shanghai, and Rotterdam, scaling nature-based solutions at city scale means finding ways to connect and design them to work jointly with existing infrastructures (Chan et al. 2018, Frantzeskaki et al. 2019). Hybrid systems such as green roofs on buildings that are integrated

into the building's design to provide cooling, to reduce energy use, and to absorb stormwater are important to invest in but can also go further to be combined with solar panels for local energy production and runoff systems. Such designs require multiple types of expertise and coordination. To expand the evidence base for how to build and sustain new NBS innovations and deliver the needed benefits will require bringing multiple forms of knowledge and expertise together (Frantzeskaki et al. 2019, Chester et al. 2020). A way forward is to employ design approaches that are synthetic and systemic at their core, which means NBS in planning, policy, and implementation needs to be done across policy and science disciplinary silos incorporating knowledge from ecologists, engineers, landscape planners, social scientists, and economists.

Coproduce and share knowledge globally

The functioning and delivery of multiple benefits of NBS rely on the social-ecological-technological systems context they operate within, therefore depending not only on infrastructure, technology, and healthy ecosystems but also on the visions, acceptance, and stewardship of people and social institutions. It is therefore critical to consider the social processes that are a fundamental component of decision-making to shape NBS plans and investments (IDB 2017, Frantzeskaki et al. 2019, Dasgupta 2021). NBS initiatives may implicitly or explicitly differentially address deeper roots of environmental, social, and racial privilege (Tozer et al. 2021). Generating meaningful and diverse values and ways of relating to nature require NBS to be coproduced as a strategy for climate resilience.

Cities are already beginning to adopt coproduction to design, plan, and govern NBS locally (Chan et al. 2018, Frantzeskaki et al. 2019). These local efforts as critical but need to be brought to global scale policy processes in an open and engaging way to democratize NBS knowledge and

set relevant policy agendas. Bringing global networks of local and regional networks together, such as through the model developed by the US National Science Foundation's Accelerating Research through International Network-to-Network Collaborations program provides an example for sharing best practices for design and planning as well as lessons learned from cities already experimenting and improving coproduction of NBS governance. This knowledge frontier is key to standardize the diverse knowledge of NBS and strengthen knowledge translation with more rigorous examination of emerging NBS types and designs.

Conclusions

NBS are not silver bullet solutions. They are a critical tool in the toolkit of climate adaptation and resilience and can serve as platforms for collaborative efforts across sectors. Therefore, mainstreaming NBS could have enormous benefit beyond climate change adaptation in ways that have the potential to meet multiple SDGs. Investing in nature in cities is an instrumental and essential component of resilience solutions to insure our cities, infrastructures, and societies against future shocks and pressures. NBS needs to be a key component of recommendations in the next Intergovernmental Panel

on Climate Change report for climate adaptation in cities and to formulate pathways for nature-positive futures that can be taken up in national and local level agendas where climate resilience planning is rapidly taking place. It is clear now more than ever that nature-based solutions and further adaptation of nature-based approaches for urban resilience and sustainability are paramount for accelerating urban transitions to more resilient and healthy cities.

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