



Nature-based solutions for changing urban landscapes: Lessons from Australia

1. Introduction

Nature-based solutions represent a unifying umbrella concept that brings together research and practice about systemic living solutions and innovations that aim to address various socio-ecological challenges. Nature-based solutions are inspired by nature, use nature, support and be supported by nature, while simultaneously provide multiple social, cultural, economic and ecological benefits (Frantzeskaki et al., 2019; United Nations Environment Programme 2021). The term and associated research stem from and bring together empirical evidence from green infrastructure, ecosystem-based adaptation, ecosystem services and water sensitive urban design to showcase under one concept the compelling advantages these solutions can bring in battling various urban challenges (European Commission, 2021). The proliferating research on nature-based solutions advances a new narrative and conceptual understanding of how these systemic approaches can deliver multiple benefits across ecological, economic, social and governance/planning dimensions. The global communities of climate science, sustainability science and environmental science, policy and planning science have made their case on the importance of nature-based solutions by anchoring them to global agendas such as the UN Habitat III, IPCC Cities and Climate Change, UN COP20 in New York and UN Economic and Financial Committee. To enrich theoretical understanding and transform knowledge into action, there is a continuing need to advance the science and application of nature-based solutions as integrative solutions to deal with climate change and a variety of social-ecological challenges (Lin et al., 2021).

The COVID-19 pandemic simply amplified and heightened the message that researchers of nature in cities have been arguing for many years: urban nature is an important infrastructure for climate resilience, for improving urban environmental conditions, and for contributing to public health and wellbeing of urban citizens (McDonald et al., 2018; Oke et al., 2021). Recent research further substantiates this argument by noting the importance of nature-based solutions as systemic interventions for the urban built environment and as integral part of the strategies needed to quickly prepare and adapt cities for the intensifying climate change pressures (Lin et al., 2021; Roggema et al., 2021). To this respect, Australia has been experiencing increasing frequency and severity of climate change impacts, particularly heatwaves, bushfires and droughts (Boer et al., 2020). Its cities and towns face unprecedented climate challenges which beg for long-term, innovative, and sustainable strategies able to cope with a hotter and drier urban world (Ossola and Lin, 2021).

With this motivation, we have elicited a suite of contributions in this special issue on the emerging science of nature-based solutions in

Australia by highlighting two focal areas that Australian research communities from sustainability science, environmental science, policy, and urban planning can uniquely contribute due to the geographic, ecological, and socio-economic particularities of the continent. The first focal area is about responding to climate change. Australian cities are hot-spots for threatened biodiversity, yet Australia's urban habitats are also degraded by invasive species, and as climate change impacts shift urban environments, questions of how to plan ecological restoration and conservation arise (Ives et al., 2016; Threlfall et al., 2019). The second one is about urbanisation processes and their relationships with nature-based solutions. Specifically, we focus on Australia as this country has seen an unprecedented economic and social growth in the last few decades that has led to one of the highest urbanisation rates in the world (~95% of population is urban). Despite being one of the most recently colonised continents, Australia brings together a complex social milieu that spans from its ancient rich Aboriginal custodianship to the hyper-diverse cultural landscape of modern society.

In this regard, evidence on the benefits of nature-based solutions across urban landscapes in such a rapidly evolving society, as well as under new environmental and climatic pressures, can well serve as useful lessons to further research and inform nature-based solutions application across the world's cities, especially those in fast-changing climates, urban fabrics and demographics.

2. Research foci for nature-based solutions in Australia

2.1. Climate change and the nature of and nature in nature-based solutions in cities

The first focal area that Australian research can provide knowledge and direction for advancing the science of nature-based solutions is on researching on the type of nature underlying urban solutions. Recent research on nature-based solutions points to the importance of urban biodiversity conservation as well as to the importance of understanding 'which nature' will likely withstand extreme climate change in a warming planet (Ossola and Lin, 2021). With its unique ecosystems and ecological knowledge on which species and ecological features are fit for the harsh Australian climate, Australian researchers can contribute with critical knowledge on how to best ecologically design, implement and maintain nature-based solutions to sustain their potential in delivering multiple benefits (Burley et al., 2019; Kirk et al., 2021).

This pathway of research arose during the 'Millennium Drought' that impacted much of southern Australia between the 1990s and 2010s, underpinning a focus on drought impacts and urban water management linked to biodiversity and ecosystem health and function (Coutts et al.,

2013). This area of research has expanded and further gathered pace after the extreme bushfires in 2019 (Australian Academy of Science, 2021; Norman et al., 2021) under the urgency to swiftly improve canopy cover for climate change adaptation (Ossola et al., 2021a, 2021b), deal with heat and drought stress (Kendal et al., 2017; Alexandra and Norman, 2020), as well as establish a roadmap for implementing Australia's Strategy for Nature at the continental scale (Parris et al., 2020).

Contributions to this focal area advance evidence on the understanding of nature-based solutions to urban climate change mitigation and adaptation, by reporting and analysing tailored solutions for warming and drying urban landscapes, and for nature-based solutions that become urban-rural landscape tele-connectors.

Moosavi et al. (2021) survey how the term of nature-based solutions has been used and employed in Australia to address water-related challenges by using a literature review and content analysis of publications since 2012. Their review is complemented by interviews with water professionals in Australia that highlight their perspectives, expectations, and knowledge of both the terminology and underlying concept of 'nature-based solutions'. Their research points to the importance of vegetation as a foundational component of nature-based solutions (p.4), and the implementation challenges associated with multifunctionality and co-benefits of water-related nature-based solutions (p.6).

Further investigating how plants and nature can be creatively used in the built environment, Williams et al. (2021) review the state of Australian research on green roofs over the past 10 years, since the publication of landmark green roof research for the Australian context in 2010 (Williams et al., 2010). This paper updates these green roof research findings, discussing specifically the adaptations needed for fitting them to the Australian harsh climatic conditions and unique ecological context. In their research paper, they highlight the importance of plant physiological knowledge, technical and ecological designs for building climate-ready green roofs while ensuring their sustainability; a lesson that could be translated to many other urban contexts worldwide.

Moving to the other side of the water availability spectrum, Tabasum et al. (2021) present a financial assessment estimating the damage of tree canopy cover due to heatwaves and drought with the aim to inform better decisions in the ways that trees are selected, planted, and maintained. Extreme weather events and climate change can cause millions of dollars in damage to Australia's green assets, calling for solutions that are not only sustainable but also *climate ready*. Their contribution connects knowledge of the ecology of trees – in our dimension of the nature of nature-based solutions – with urban planning decisions and governance processes. Importantly, their analysis notes the importance that “*species selection shifts away from aesthetic appeal and towards climate suitability of species*”.

2.2. Urbanisation with nature-based solutions

Australia is experiencing unprecedented pressures of climate extremes, including droughts, heatwaves, and floods. The climate pressures in Australia require climate-smart solutions that can integrate with digitally enabled urban innovations, especially in the context of smart cities research, digital twins, and the political agenda of City Deals as strategic investments in urban infrastructure projects. In this context of climate-proofing Australian cities, research on nature-based solutions can showcase pioneering concepts, hybrid solutions or integrative designs between nature-based solutions and grey infrastructure, smart cities technologies, renewable energy in cities especially given the global high urbanisation rate. All these conflating, and at times conflicting, agendas pose new questions on how urbanisation and nature-based solutions can play out in shaping urban present and future in Australian cities (Sharifi et al., 2021). This provides the basis for the second focal area covered in this special issue: urbanisation with nature-based solutions (and not against nature or in competition with

nature).

The second focal area advances the knowledge gained from experimentation and piloting of nature-based solutions in Australian cities over the past decade, especially through the lens of green infrastructure, urban forestry, and water sensitive urban design. In Australia, cities are now pushing densification agendas and their implementation raises questions of how this will be realised in harmony with nature conservation or even restoration of urban ecosystems. With some bold strategies on urban nature such as the Urban Forest strategy of greater metropolitan Melbourne (Coenen et al., 2020) and the upcoming Greening Sydney Strategy (2021), Australian cities are governance spaces to watch and examine the institutional design and settings, the governance arrangements, and the ways they interface with urban design and urban planning for bringing nature-based solutions in the mix of urban development for denser and more resilient cities of the future. In this context, smaller scale initiatives – like the Community Greening program in Sydney – seek to redress long-lasting issues related to unequal access to greenspace while promoting meaningful place-making in social housing estates and disadvantaged communities (Truong et al., 2022).

The contributions to the special issue provide critical insights on the governance and planning successes as well as some key challenges of nature-based solutions in Australian cities. Across the contributions, a common message is that collaborative governance is a strong requirement for planning and governance of nature-based solutions in Australian cities (Malekpour et al., 2021; Frantzeskaki and Bush, 2021). There are different entry points, albeit interconnected, to ensure inclusive and collaborative governance of nature-based solutions in Australian cities: through carefully designed participation of practitioners (for including tacit and on-the-ground knowledge) in urban planning that can be guided via governance design frameworks (Malekpour et al., 2021), through rich in ecological/biodiversity knowledge urban design frameworks (Kirk et al., 2021) and through fit-in-context institutional design interventions such as ‘*ecologies of intermediaries*’ (Frantzeskaki and Bush, 2021).

Specifically, Malekpour et al. (2021) present a framework for designing collaborative governance arrangements based on longitudinal and in-depth engagement with urban practitioners across Australia. Amongst the enablers of collaborative governance, they (p.8) highlight experimentation and demonstration projects as well as the importance of enabling policy for innovative solutions.

Kirk et al. (2021) present an urban design framework that can inform urban planning towards integrating biodiversity in planning Australian cities: the Biodiversity Sensitive Urban Design framework. This approach presents a process on how to move from data collection to species-generated biodiversity actions together with participants in a real-life application in Fishermans Bend, Melbourne Australia. What Kirk et al. (2021) note is the importance of bringing together different forms of knowledge including Indigenous knowledge and culture through an envisioning engagement process (p.7).

Frantzeskaki and Bush (2021) analyse the way an ecosystem of intermediaries progressed the transformative agenda of the Urban Forest Strategy of metropolitan Melbourne as a form of collaborative institutional space. They showcase how important collaboration and relation-building and managing is for knowledge sharing, aggregation of knowledge and expertise to formulate and implement transformative agendas. By deepening the analysis of the institutional infrastructure behind the one-of-its-kind metropolitan nature-based solutions strategy in Melbourne, they provide a transitional thinking perspective in how policy and governance transitions need to be shaped and charted for more daring policy at local government level for progressing nature-based solutions in cities.

Kingsley et al. (2021) posit urban agriculture as a nature-based solution in Australia and in this way, argue for a civic governance dimension on how to govern urban resilience in Australian cities through nature-based solutions more deeply linked to food production,

community connection, and public health and wellbeing. By framing urban agriculture as a nature-based solution, this can represent a precious opportunity to educate people and communities on the delicate intricacies and connections between humans and nature, starting from the very produce we put in our mouths and the soil in urban farmers' hands. On a similar line, [Truong et al. \(2022\)](#) find that community gardens in social housing can increase 'place-making' in less advantaged communities and promote social equality; in the authors' words: *"landscaping and gardening efforts were helping to change stereotypes and prejudices that others in the larger community might have held towards them and the social housing estate"*.

3. Lessons for building an Australian nature-based solutions research community

Our special issue points to a nascent Australian research community for nature-based solutions research and practice. As the contributions of the special issue put forward, nature-based solutions is a bridging concept that has the potential to shift the focus from the 'problem' towards systemic thinking about solutions; further, these solutions specifically consider integrative solutions, including the imperative for inclusive governance ([Frantzeskaki et al. 2020](#); [Frantzeskaki and Bush 2021](#)). As many contributing authors noted, there is a need to deepen and contextualise the knowledge of nature-based solutions from the ecological, socio-cultural, technical, and political context of Australian cities. An overview of the case study grounds, and the types of nature-based solutions presented in the special issue as well as the areas of knowledge depths are presented in [Fig. 1](#).

Specifically, we identify key areas of in-depth knowledge and areas for future exploration from the contributions to the special issue. Areas of depth of knowledge from Australian research on nature-based solutions include:

- i) Knowledge on water-sensitive urban design (WSUD) is extensive in Australia and as planning, decision making and management of WSUD belongs to the "broader family of NBS" as [Malekpour et al. \(2021\)](#) and [Moosavi et al. \(2021\)](#) state. This reflects Australia's exposure to environmental extremes, and its increasing expertise related to urban water management necessitated by facing incredible climatic (e.g., heatwaves, floods and droughts) and environmental challenges (e.g., poor soil quality and limited water).

- ii) Some of Australia's native biodiversity shows remarkable resilience, indeed in some cases outperforming introduced species. In many urban contexts ranging from streetscapes, green roofs and urban parks, species native to Australia and indigenous to a local area offer greater performance and higher resilience for coping with climate change, urbanisation and environmental challenges ([Kirk et al., 2021](#); [Tabassum et al., 2021](#); [Williams et al., 2021](#)). Australia is blessed with an amazing diversity of more than 20,000 vascular plants and hundreds of endemic animal species that often call our cities home. For example, Sydney hosts an astonishing 651 tree species, almost 14% of all the tree species planted in the world's cities ([Ossola et al., 2020](#)). It remains to be seen to what extent this incredible diversity can be further leveraged to create more climate resilient NBS. Australian cities often host rare and threatened species; urban areas and their city managers can aspire to ensure that Australia cities do not lead to further species extinctions or invasions, and that critical *urban habitat stepping-stones* can facilitate species movement under climate and environmental change.

Areas that research from the Australian research community are identified that require further development include:

- i) The first key area centres on how to extend the conceptualisation of nature-based solutions to better explain how the concept of nature-based solutions relates to, builds upon and extends other concepts such as green infrastructure, water sensitive urban design, biodiversity sensitive urban design, sustainable urban water drainage systems, and ecosystem-based adaptation. The contributions of [Moosavi et al. \(2021\)](#) point to this future research direction. Specifically, [Moosavi et al. \(2021\)](#) emphasise that for the progress of the research of nature-based solutions, a need for a shared language is paramount, proposing a diagrammatic representation of nature-based solutions as an umbrella concept aligning it to the relational representation of associative water management terms proposed by [Fletcher et al. \(2015\)](#).
- ii) The impact of nature-based solutions for well-being and public health needs to be further researched in Australian cities. [Williams et al. \(2021\)](#) point to this direction by noting that *"there is clearly scope for further research exploring the well-being benefits of a greater range of green roof vegetation, designs and experiences"* (p.6).

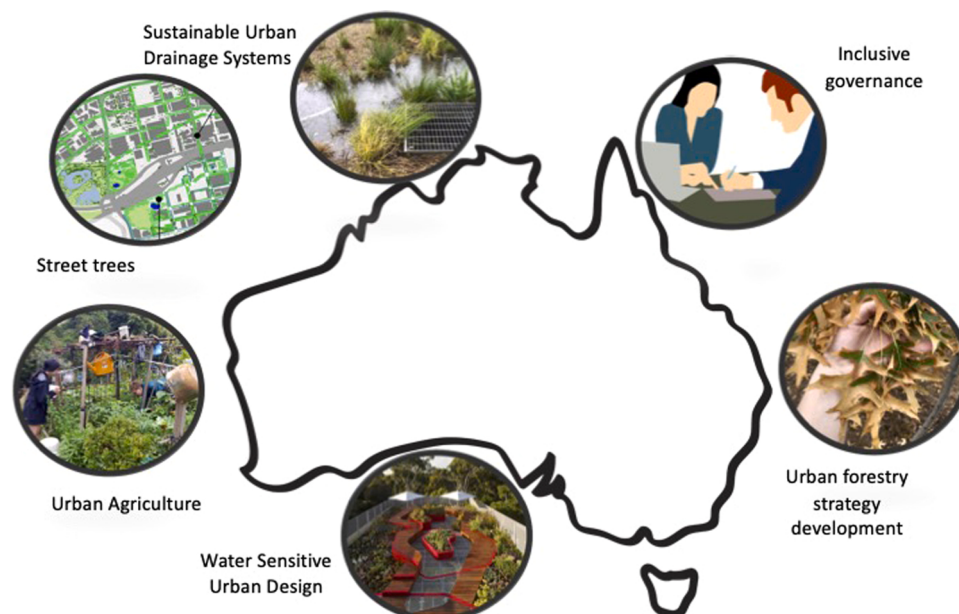


Fig. 1. Areas of knowledge depth on nature-based solutions implemented across Australian cities.

- iii) The ways that transdisciplinary research can be instrumental for understanding, unpacking, and directing designs of nature-based solutions for multifunctionality also needs more attention. Moo-savi et al. (2021) point to this future research direction by highlighting that “*nature-based solutions have the potential to bring together the expertise of often-segregated disciplinary territories and divided sectors, as well as local knowledge from stakeholders*” (p.10).
- iv) A promising area of research remains how different types of knowledge including Indigenous Knowledges and expertise can be appreciated and woven into the process of co-designing, co-implementing, and stewarding/co-managing urban nature in cities in Australia. Australian researchers have engaged with the question on how to appreciate, recognise and value Indigenous Knowledge and experience of land, place, and time. Future research on nature-based solutions in Australia is needed to learn from this experience to co-design with Indigenous Knowledge nature-based solutions, what are the practices and approaches that work and what are the implications for planning and governing nature-based solutions in cities. Indigenous Knowledge encapsulates ancient wisdom from the aboriginal cultural custodianship of country, and current knowledge about how to nurture and protect every-day nature, how to connect or reconnect nature with people and with harnessing the power of nature for protecting human liveability. In addition, it is important to pave the way for aboriginal-led research on nature-based solutions in Australian cities in the future (Cumpston, 2020).
- v) Nature-based solutions research in Australia could greatly benefit from studies investigating the interplay between nature and emerging technologies, such as robotics, big data, artificial intelligence, and virtual/augmented realities (Goddard et al., 2020). As Australian cities push for innovation to pave the way for urban planning and sustainability in the 21st century (e.g., digital twins), it remains to be seen how nature-based solutions could benefit from or be hindered by technological advances, most of which are only starting to emerge. Thus, research on nature-based solutions that acknowledges the dynamic and ever-changing nature of cities, in Australia and globally, is still scant and much needed (Ossola et al., 2021a, 2021b). We see our special issue as a first step towards a growing research community of nature-based solutions in Australia. Many of the contributors point to the need of a collaborative approach to science and more efforts towards building a community with shared language, stronger collaborative research ties and opportunities as well as cross-disciplinary opportunities for synthesis and future-looking research (Williams et al. 2021).

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Niki Frantzeskaki^{*1}

Department of Human Geography and Spatial Planning, Faculty of Geosciences, Utrecht University, The Netherlands

Alessandro Ossola²

Department of Plant Sciences, University of California, Davis, CA, USA
Department of Biological Sciences, Macquarie University, North Ryde, NSW, Australia

School of Ecosystem and Forest Science, The University of Melbourne, Burnley, VIC, Australia

E-mail addresses: aossola@ucdavis.edu, alessandro.ossola@mq.edu.au, alessandro.ossola@unimelb.edu.au.

Judy Bush³

Faculty of Architecture, Building and Planning, The University of Melbourne, Australia

E-mail address: judy.bush@unimelb.edu.au.

^{*} Corresponding author.

E-mail address: n.frantzeskaki@uu.nl (N. Frantzeskaki).

¹ ORCID: <https://orcid.org/0000-0002-6983-448X>

² ORCID: <https://orcid.org/0000-0002-0507-6026>

³ ORCID: <https://orcid.org/0000-0002-7847-6610>