Towards multifunctionality: adaptation beyond the nature–society dichotomy

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BACKGROUND PAPER
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Abstract

The framing of nature as separate from culture impacts our notion of landscapes and the functions, infrastructures and activities deemed appropriate within these, where natural landscapes are associated with nature conservation, and the built environment with human activity. In this paper, we propose bridging this nature–society dichotomy through a multifunctional perspective as a way to adopt a more systemic view of space in relation to landscape traits as well as material artefacts. We argue that multifunctionality is not only fundamental for adaptation, but a way to reconcile questions of social equity with biodiversity and environmental goals. We build on global experiences with nature-based solutions to identify three major roadblocks hindering current adaptation approaches and outline four leverage realms for moving towards multifunctionality.

Key messages

- Define who multifunctionality is for, including understanding the mechanisms for change, the interventions that will lead to collective gains and the identification of the societies and nature that will benefit and those that will not across spatial and temporal scales.

- Design for multifunctionality, by planning for multiple benefits from the beginning, assessing interoperability of interventions and ensuring a sense of place is incorporated in design practices.

- Monitor multifunctionality across scales, including long-term and at a landscape level, to assess effectiveness and performance of interventions, and monitor the provision of landscape services.

- Govern for multifunctionality, which means governing for connectivity, compatibility and a just adaptation.

Introduction

> *Man is both creature and moulder of his environment, which gives him physical sustenance and affords him the opportunity for intellectual, moral, social and spiritual growth. In the long and tortuous evolution of the human race on this planet a stage has been reached when, through the rapid acceleration of science and technology, man has acquired the power to transform his environment in countless ways and on an unprecedented scale. Both aspects of man's environment, the natural and the man-made, are essential to his well-being and to the enjoyment of basic human rights – even the right to life itself*
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> (United Nations, 1972).

In 1972, at the first global conference on the environment, there was a realization that nature and society are inextricably intertwined, yet too often considered separate, or even opposing, targets. Fifty years later, nature continues to be considered alongside the economy, rather than fully recognizing its role in underpinning our economic systems and well-being (Dasgupta, 2021).

The framing of nature as separate from culture impacts our notion of landscapes and the functions, infrastructures and activities deemed appropriate within these, where natural landscapes are associated with nature conservation, and the built environment with human activity. It has also impacted our monitoring systems which are largely framed around indicators and decisions that focus predominantly on either ecosystems or humans, and that overlook their interdependence (Caillon et al., 2017). Meanwhile, we remain a long way from achieving our global targets for biodiversity conservation and human well-being (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services, 2019). Bridging the nature–society dichotomy becomes increasingly urgent as it becomes progressively less likely that societies will be able to otherwise mitigate and adapt to changes brought about by biodiversity loss and climate change, and costlier to do so.

In this paper, we propose approaching adaptation through a multifunctional perspective as a way to adopt a more systemic view of space and recognizing that landscapes entail both natural and human traits. The recognition of landscapes as a result of the action and interaction of natural and/or human factors (2000 European Landscape Convention) provides a bridge to the traditional nature–society dichotomy. Multifunctional approaches are in this context increasingly relevant for optimizing multiple ecosystem services and increasing well-being (Bruley et al., 2021; Fagerholm et al., 2020). Indeed, multifunctionality is recognized as a condition for sustainability (de Groot, 2006; Selman, 2009), particularly in light of climate change (Lovell & Taylor, 2013). However, the operationalization of multifunctional principles for landscapes is lagging and there remain important roadblocks.

We build on global experiences with solutions inspired on, mimicking or based on nature, so-called nature-based solutions (NbS). While the extent to which NbS are 'natural' differs widely, most established solutions are rather local in nature, and not all of these are multifunctional, they nevertheless provide important learning insights that can inform the debate on multifunctionality (Dorst et al., 2019; Moosavi et al., 2021).

In the following pages, we first present the challenge addressed in this paper. We connect it to the growing body of literature around NbS. Building on this literature, we identify three roadblocks that shed light on aspects that have hindered the delivery of benefits and co-benefits to society and nature. Based on these insights we present an outlook highlighting a shift towards more hybrid solutions. The assumption is that greater system diversity combining natural and cultural structures could lead to more effective use of space and deliver benefits for both nature and society. But governance, financial and monitoring processes are currently lacking to ensure adoption and scaling up. Lastly, we present our proposal for action that contains four leverage realms needed for triggering a system shift away from single-purpose solutions towards multifunctional ones that reconcile the nature–society divide.

The challenge

There is a tendency to invest in sustainability interventions that are easy but have limited potential for transformational change (Meadows, 1999; Wilson et al., 2020). As a result, much of what might be labelled as sustainable fails to address the root causes of unsustainability and is therefore unlikely to substantially alter our current development trajectories (Abson et al., 2017). In response, there is increasing emphasis in research and policy on the underpinning role of natural systems, including biodiversity, for human well-being, and of the need to work with nature's frames (Woroniecki et al., 2020) to support societal well-being (Dasgupta, 2021; Nesshöver et al., 2017). Despite this recognition, the dominant approach for managing systems continues to be linear (in time and space) (Birney, 2021) and fails to incorporate dynamism and change, which are fundamental for ecosystem resilience, thereby failing to truly adopt a systems approach to wicked problems (Meadows & Wright, 2008).

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Nature as a response

Strengthening the relationship to nature is today acknowledged as a key to transformation (Raymond et al., 2017). In line with this, NbS are increasingly advocated in research agendas (e.g. European Environment Agency, 2021), conservation efforts (e.g. by the International Union for the Conservation of Nature), by international organizations (United Nations Environment Programme, 2021) and government policies (Department for Environment, Food & Rural Affairs, 2018; Naturvårdsverket, 2021).

NbS are seen as a toolbox of interventions that can contribute to multiple policy goals and offer opportunities for more coherent policy towards a sustainable future (Frantzeskaki et al., 2019). Embedded in the concept of NbS is the expectation that these types of interventions can generate benefits, for example to reduce risk from hazards, as well as generate co-benefits, for example to improve recreation spaces, carbon storage, reduce urban heat, benefit biodiversity and contribute to mental health and well-being in urban areas (Arkema et al., 2017; Braubach et al., 2017; Callaghan et al., 2021; Kondo et al., 2018; Ruckelshaus et al., 2020; Seddon et al., 2019; Silver et al., 2019; Uebel et al., 2021; Xie & Bulkeley, 2020; Yang et al., 2018). Additionally, NbS are expected to reconcile the dichotomy between economic growth and socio-environmental concerns, thus offering a transition path towards a sustainable economy (Maes & Jacobs, 2015). For instance, in Europe, the European Commission expects NbS to facilitate a transition towards a more resource efficient and competitive economy, to foster economic growth and to create new jobs (Nesshöver et al., 2017).

Despite these attempts to move away from engineered (technological or 'grey') solutions (Dasgupta, 2021; Morris et al., 2018), in practice, they remain the default. The

NbS concept represents a change in discourses framing our relationship with nature and environmental change, for example the making room for the river approach, working with water rather than against water, minimizing and mediating peak flows instead of resisting or preventing floods, or mitigating impacts to societies instead of defending through hard structures (Bark et al., 2021). But there are limitations to the implementation of NbS. We discuss these below and then provide an outlook for nature and society in the context of adaptation for development.

1. Lack of awareness of knowledge–power relations can exacerbate inequities

Conceptually, NbS remain apolitical and presented by policymakers and practitioners as a technocratic discourse without much reflection on power relations produced or reproduced through NbS (Cousins, 2021). The extent to which NbS can achieve the diversity and multiplicity of goals, however, is largely dependent on social practices that determine the use, production and distribution of ecosystems and access or exposure to their services and disservices. Thus, NbS need to be better situated into broader questions of power relations, social change and vulnerabilities. Practically, ecological interventions through NbS need to be better paired with diverse socio-economic goals and planning processes if they are to bring benefits to the areas and spaces where they are needed the most (Curran & Hamilton, 2020).

Beyond the benefits that NbS approaches might bring about, there has been little attention to questioning the power–knowledge relationships mobilized and reinforced through the integration of nature into society and the built environment. The recognition that nature–society interventions will not automatically be equally beneficial for all people across geographies, timescales and social groups is seldom made explicit or explored in depth (Barquet et al., 2021; Kotsila et al., 2021). As a result, little is known about how benefits are delivered to more economically marginalized communities or whether adaptation interventions are indeed targeting those that need them the most (Bisaro & Hinkel, 2016; Lehmann et al., 2018). This reflects the lack of stakeholder-informed approaches to systematically identify ecosystem service trade-offs, synergies and 'hotspots' associated with green solutions (Cousins, 2021; Meerow & Newell, 2017).

Lastly, current approaches to nature are built on the assumption that there is a consensual understanding about nature, and that such understanding is static across time. However, interactions and experiences of nature change over time and can differ greatly from place to place. For instance, the idea of nature as a contributor to well-being or recreation can be irrelevant in contexts where ecosystem services are fundamental for survival (Wessels et al., 2021). In other places, nature might be tightly associated with criminality or violence, as forests and jungles have provided hideout opportunities for insurgent groups and criminal networks (Barquet, 2015; Olaniyan, 2018). In urban areas, the design of vegetated areas can influence perceptions of danger and tranquillity (Herzog & Chernick, 2000). More fundamentally, there continues to be a perception of grey infrastructure as superior and more effective than NbS (Mulligan et al., 2020). Incorporating perceptions of nature into decision-making is important so that adaptation measures do not end up exacerbating inequalities or lead to maladaptation (Schipper, 2020). To date, however, there is a lack of understanding of perceptions of nature in non-Western urban contexts and a lack of comparative studies across geographies and landscapes (Bark et al., 2021).

2. Lack of deeper understanding of the co-benefits and costs

Because NbS are living solutions in dynamic contexts, standardizing measurements is a challenge. At the same time, the lack of data on, for example, life cycle costs of NbS, currently hinders their implementation. Therefore, some degree of standardization of costs and quantification of benefits would be necessary for cities to even be able to consider NbS. Also, comparative studies contrasting costs and benefits of NbS against other engineered (grey) approaches could contribute to clarifying their multiple benefits. Future projects should evaluate habitats created or restored for cost-effectiveness in comparison to artificial structures under the same environmental conditions (Morris et al., 2018).

When it comes to synergies between NbS and climate change, there are studies reporting on greenhouse gas mitigation outcomes (Burden et al., 2019; Ward et al., 2016). However, we know that ecosystems such as wetland grasslands are important for carbon storage and might be more reliable carbon sinks than forests in regions facing droughts and risks of wildfire. Thus, it is likely that there are unrecognized synergies between mitigation and adaptation from interventions in, for example, wetland ecosystems, and their capacity to store water, reduce greenhouse gas emissions and promote biodiversity and ecological processes, which require further investigation. Future studies should focus on studying the mitigation and adaptation outcomes simultaneously in order to assess the extent to which NbS can maximize synergies.

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When it comes to ecosystems and biodiversity, future research could better highlight the specific mechanisms and conditions that allow for improving or repairing ecosystems. For example, a well-known case is the Rhine River Delta in the Netherlands, where 15 years of river restoration for mitigation of fluvial flood has also proven successful for enhancing biodiversity (Straatsma et al., 2017). However, the benefits were primarily for fast-spreading species at the expense of other species. This indicates that NbS alone are not always enough for full ecosystem recovery or to increase species richness.

Although research connecting NbS to health and well-being is the aspect of social sustainability best represented in the literature, the explicit connections between NbS and health planning remain underdeveloped (Kabisch et al., 2017). For example, although NbS have shown to be beneficial for reducing heatwaves in urban environments (Augusto et al., 2020), the specific links through which NbS could impact public health remain largely unexplored. Original research as well as reviews are needed to assess the regulating services that NbS might have on air pollution reduction and related morbidity, asthma and other respiratory diseases, and on storm water management, including infections due to poor filtering of drinking water (van den Bosch & Ode Sang, 2017).

The global spate of Covid-19-related lockdowns from 2020 spurred research into the mental and physical health benefits of urban green space. Renaturing, rewilding and greening urban areas are expected to play an essential role in improving citizens' quality of life (Davies et al., 2021). Indeed, during the Covid-19 pandemic, restrictions on movement made stark the individual welfare benefits of 'green spaces' and, crucially, their inequitable distribution (Burnett et al., 2021; Slater et al., 2020; Soga et al., 2021; Ugolini et al., 2020). This recognition of the restorative potential of green space for mental well-being – and of the biodiversity within it (Uebel et al., 2021) – may increase the appeal and acceptability of nature-based, rather than engineered, solutions, particularly in urban areas (Honey-Rosés et al., 2020; Ugolini et al., 2020). If cross-sectional correlations with health and well-being are confirmed with further longitudinal studies on primary care patients, then the public health policy imperative will be strengthened, too, and we would expect increased integration of nature-based structures within urban planning (Callaghan et al., 2021).

Regarding trade-offs between NbS and other goals, there is a need to assess not only the services provided by NbS but also potential future limitations and uncertainty that could constitute costs or risks in the future (Roman et al., 2021). Ecosystem disservices are the 'ecosystem generated functions, processes and attributes that result in perceived or actual negative impacts on human wellbeing' (Shackleton et al., 2016, p. 590). Climate change, in particular, can alter ecosystems and their services, and may reduce the performance of green solutions that rely on them. Socio-economic changes can also alter the functioning of NbS. These changes may undermine the integrity of ecosystems and affect the capacity of NbS to deliver the expected outcomes. Despite this, most frameworks treat NbS as static and unaffected by changing future conditions (Calliari et al., 2019).

3. Challenges of financing and governance

When it comes to financing NbS, public actors have been the main source of investment to date (Chausson et al., 2020) though this might not be the best way of financing NbS in many of the urban contexts where most land is privately owned. While the literature acknowledges the need for diversifying funding sources, there are at least two challenges for this: the first is the need to ensure that private investments also yield public benefits (for instance for flood protection); and the second is to attract private actors who are willing to invest despite the fact that return on investments is typically higher risk and longer term than for other types of infrastructure. Moreover, the very fact that silos must be bridged with novel mechanisms, and/or that more complex governance structures may be needed, can work against the development of innovative business models (McQuaid, 2019).

Rich people in both developed and developing countries need to change consumption patterns towards less resource-intensive and carbon-intensive lifestyles, while basic needs are currently not met for many poor people

A key knowledge need is to develop business models and partnerships that ensure the economic sustainability of NbS, accounting for life cycle costs and benefits. In practice, this means expanding the value proposition of business models to include social and environmental values and will require formalization of efforts to broaden the consideration of beneficiaries and partners. A requirement for early consideration of the broad governance model and development of the necessary governance structures emerges from these needs (McQuaid, 2019).

While some types of NBS, such as green roofs, have been able to allow for private value capture attracting in this way private or blended capital, NbS delivering public goods have to rely on different financing strategies and instruments (Uzsoki et al., 2021). Blended capital or blended finance involves the use of, for example, public and philanthropic funds to change the risk/return profile of projects, thereby encouraging private investment (Earth Security, 2021). Uzsoski and colleagues (2021) list relevant sources for financing NbS: sustainable linked loans, resilience bonds, concessional loans, government subsidies and tax breaks, savings-based financing, tax-increment financing, stormwater credit trading systems, crowdfunding strategies, project bundling, climate and sustainability funds, or environmental impact bonds. However, any of these financial strategies need to fulfil certain criteria, including the identification of ecosystem services, the beneficiaries of these services, the relationship between the beneficiaries and the services, and a biophysical and financial valuation of the benefits associated with the services. But there is no standardized way of measuring ecosystem services, which increases the difficulty of fulfilling these criteria (Uzsoki et al., 2021).

There are scalar issues posed by the very nature of NbS that translate into implementation challenges (Cousins, 2021). While the promises of multiple benefits might be attractive for tapping into different global discourses of sustainability, adaptation or green recovery, from a planning approach, it also means that there is a shared responsibility and a requirement for the coordination and cooperation across administrative levels, governmental structures and jurisdictional boundaries. Research to date has not properly explored how scalar issues impose challenges on NbS planning. Understanding their governance and how benefits accrue at different spatial scales is fundamental (Demuzere et al., 2014; Pataki et al., 2011). There remain several knowledge gaps pertaining to processes that decide how ecosystem services are provisioned, governed and distributed across the urban landscape (Brink et al., 2018; Haase, 2017).

To make NbS politically feasible, their management needs to be embedded into existing regulations. At the same time, there is a need to review existing national legislation which might either favour grey infrastructure over NbS, or not regulate at all, and in that case, there will be an institutional void hindering their implementation.

Outlook

There are clear indications of increased interest in research and policy for bridging the divide between nature and society, for example through NbS. However due to a range of structural limitations discussed in the previous section (see also Dorst et al., 2022), coupled with the need to make more effective use of space and existing grey structures, there is a need for more explicitly hybrid solutions combining green or blue infrastructures with existing or new grey ones – rather than purely nature-based. Hybrid solutions combine 'the conservation and/or restoration of ecosystems with the selective use of conventional engineering approaches to provide people with solutions that deliver climate change resilience and adaptation benefits' (Thiele et al., 2020, p. 32).

The use of hybrid solutions in urban areas is expected to increase, for example to improve protection in the face of extreme floods, or improve water provision and treatment in areas with high population densities, or to mitigate the impacts of extreme weather events on critical infrastructures (Sarabi et al., 2019). A major

Green, grey and hybrid solutions

Green infrastructure refers to the development of natural and semi-natural terrestrial areas that contribute to addressing societal needs, from recreational areas to areas designed for biodiversity protection. Often justified on the basis of a narrower range of benefits, they are nonetheless expected to deliver a wide range of co-benefits. Blue infrastructure is similar, but refers to those interventions specifically designed to solve challenges and opportunities around water, for example flood mitigation or rainwater harvesting. Blue infrastructure is regularly included within classifications of green infrastructure.

Hybrid (or green-blue-grey) infrastructure are those interventions that combine elements of traditional infrastructure with green or blue. They are particularly prevalent in urban areas where green solutions will be integrated with existing and new engineered solutions and their use can help build incremental and inclusive upgrading of infrastructural systems, particularly in underserved communities (Mulligan et al., 2020).

driver behind the shift from purely green or blue to green-blue-grey is the flexibility that hybrid solutions have in contrast to solely nature-based. As hybrid solutions can be more easily adapted to existing built infrastructure, they can also be less land demanding, which can avoid land-use conflicts and reduce opportunity costs, thereby outperforming NbS in purely economic terms (but subject to the difficulties of assessing value in economic terms). Thus, rather than purely green, blue or grey, we should expect to see a spectrum of solutions where different combinations can be matched to the political, social, cultural, economic and natural systems at a site.

Hybrid solutions can also be connected to more diverse sources of funding by increasing the number of benefits derived from a project and beyond adaptation, to provide mitigation services and extend the lifetime of ageing infrastructures. For example, they can be purposed for infrastructure improvements, such as with the provision of wastewater services (Chen et al., 2021; Wang et al., 2018); industrial by-products, like steel slag, can be reused to create habitats (Kuwae & Crooks, 2021); or hybrid infrastructures could be designed to help minimize, compensate or avoid damage from infrastructure expansion to ecosystems and the environment (Larsen et al., 2018). Offshore, the use of multi-service platforms will be increasingly needed for co-locating marine activities while decreasing capital and operating costs (Abhinav et al., 2020) .

Multilateral development banks (MDBs) are playing a key role in delivering the substantial investment needs of developing countries, for example in the field of sustainable infrastructure (Thiele et al., 2020). The Sustainable Development Goals provide the overall framework in which MDB investment in sustainable infrastructure is taking place. More recently, MDBs agreed to step up their efforts to foster 'nature-positive' investments (Bennett, 2021). However, MDBs alone will not be able to provide all the financing necessary, given that their operational models primarily focus on providing sovereign finance and the needs of developing countries. Thus, other sources of private investment, for example through public–private partnerships or blended finance, are still needed. MDBs will play a role for de-risking investments or creating new markets and demonstrating the potential for new investments.

However, delivering investments for hybrid solutions will depend greatly on the enabling framework that is created by national, regional and municipal governments. For example, public policies need to be better aligned to climate resilience requirements, data policies and cost assessments need to cover the entire life cycle, and long-term investors need to make climate resilience a precondition for investment (Thiele et al., 2020).

To enable hybridity, planning and governance need to become more multifunctional and less siloed. Current institutional structures generally do not deal well with interventions that cut across sectors and generate multiple benefits. Instead, questions of ownership (who is responsible?), budget lines (who pays?) and attribution (who owns the results?) become problematic and end up hindering engagement (Fiertz & Barquet, 2022).

Proposal for action: From single to multifunctional use of space

> *What is needed is an enthusiastic but calm state of mind and intense but orderly work. For the purpose of attaining freedom in the world of nature, man must use knowledge to build, in collaboration with nature, a better environment*
>
> (United Nations, 1972, p. 19)

Back in 1972, there was an attempt to make sense of complexity by calling for ‘intense but orderly work’. Fifty years later, we have come to appreciate the importance of systems thinking to make sense of why things are the way they are and to reflect on possible solutions to very complex problems. Our proposal for action builds on this thinking. We present a simple suggestion: to shift from single-purpose thinking to multi-use acting.

Multifunctionality can be understood as ‘the simultaneous provision of multiple functions’ (Byrnes et al., 2014). Multifunctionality is a concept often used in the context of ecosystems, their performance and services (Manning et al., 2018). However, we propose expanding the concept to also encompass the artefacts and practices produced by societies such as materials, technologies, structures and cultures (Bomberg et al., 2017; Jerome et al., 2019). Such understanding highlights the dialectic of nature and society (Fuchs, 2006; Marx & Engels, 1975) and connects structure and function in a delimited geographical space (Belmeziti et al., 2018).

We identify four leverage realms (Meadows, 1999) to move beyond the nature–society dichotomy and address key roadblocks for multifunctional planning (summarized in Figure 1). For each leverage realm, we present challenges and provide recommendations.

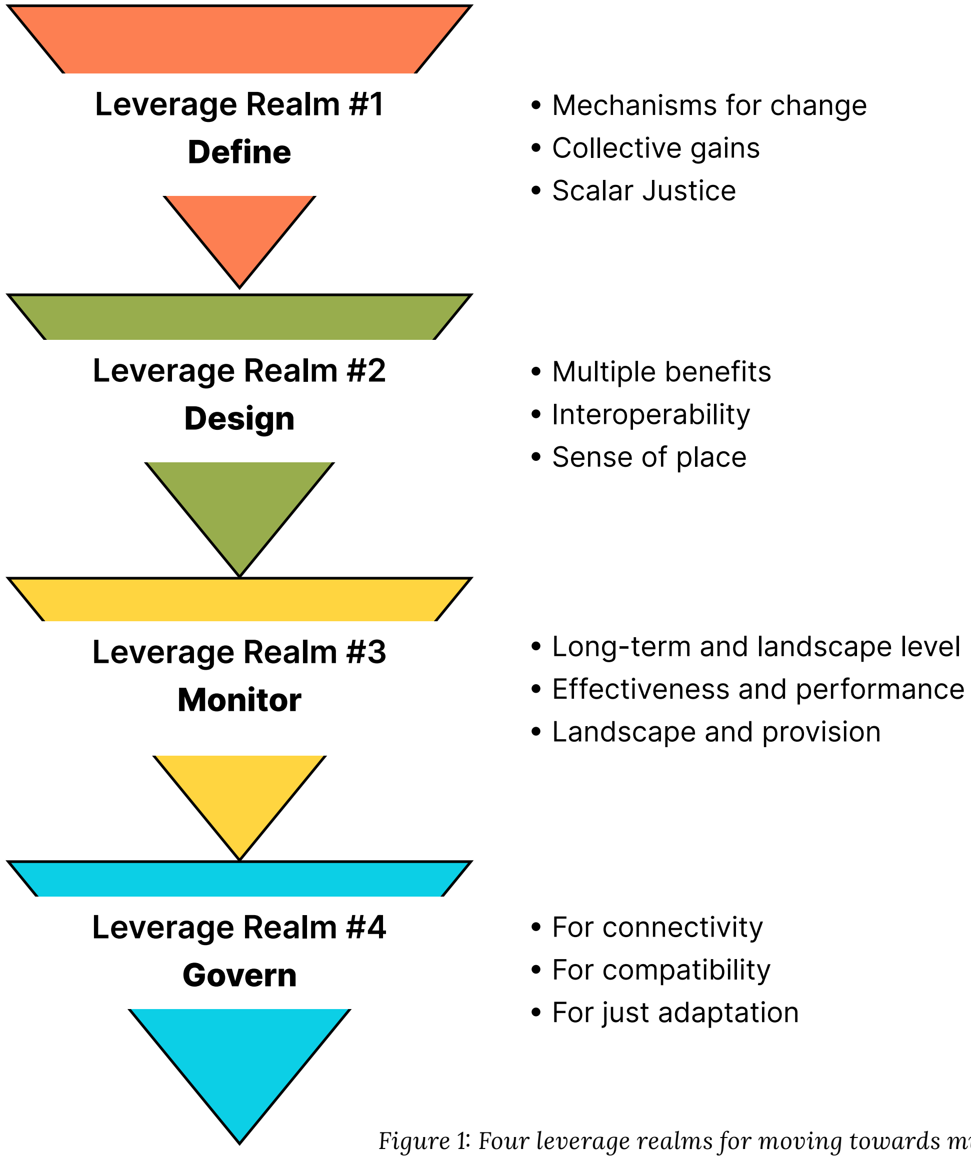

Figure 1: Four leverage realms for moving towards multifunctionality

Leverage realm #1 Define who multifunctionality is for

Explicitly defining who might gain from multifunctionality will also reveal those who will not. As well as identifying the human beneficiaries of the 'solution', there is a need to identify nature-related risks and opportunities emerging from society's dependencies on nature. These may include financial loss resulting from negative impacts on nature, and the costs stemming from the loss of certain species, genetic variety and/or key ecosystem services. Beyond loss, transitioning to more nature-positive practices may generate transition costs that should be planned for and mitigated (Taskforce on Nature-Related Financial Disclosures, 2021). More fundamentally, it is also worth considering what nature will gain – or lose – from different options. This includes understanding specifically what species or ecosystems are targeted, as well as the context in which the solutions are being delivered. Is this about ecosystem connectivity and function, or conservation of species? What species, ecosystems or ecological functions are likely to be gained?

There are three recently spotted trends worth highlighting here. The first two trends are presented by Wilson et al. (2020) who find that, first, most behavioural adaptation – at the individual level – is short-term, small-scale in nature and incremental. Such adaptation relies on the costs and benefits aligning for the individual, including through market mechanisms, regulation, or awareness and participation. By contrast, transformational change, required to steer the system towards multifunctionality, is a process that may involve institutional reforms and cultural changes, and which generates long-term impacts. The second trend is that most empirical studies on climate adaptation focus on adaptation interventions with individual benefits. Less is known about those with collective benefits. The third trend is highlighted by Coggins and colleagues (2021) who found in their systematic review of the literature on adaptation that most studies have addressed equity and/or justice issues at a single scale (countries, subnational levels, cities, communities, households and individuals). Not only are multiscale approaches rare, also, much debate is taking place at the international level without connecting to national or local implementation. As a result, ideas of equity and justice are stronger in the discourse of climate adaptation but lack specific mechanisms for effective operationalization.

Why are these trends important to consider when defining multifunctionality?

First, we know very little about single-purposed adaptation interventions of a more transformative character, which means that finding lessons for implementing multifunctional transformative interventions could be a challenge. While existing interventions may unintentionally have achieved multifunctionality, in order to define new interventions, it is crucial to understand the mechanisms and conditions (e.g. ways of organizing, structures in place, changes required) which led to specific outcomes.

Second, ensuring that adaptation actions are steered towards collective gains is essentially a question of justice and equity. This is particularly important for how we think multifunctional interventions could lead to sustainable transformation. Are multifunctional interventions about numbers, meaning they should deliver to as many people as possible irrespective of how vulnerable these people are in the first place? Should multifunctional interventions be about purpose, meaning they should seek to deliver as many benefits as possible to specifically vulnerable populations? Or should they be about space, meaning that an intervention should maximize the services provided within a delimited area?

Lastly, scale is fundamental for multifunctionality, as interventions of this type demand a systemic approach that cuts across traditional jurisdictional lines and provides connectivity of nature and society. But budget lines remain constrained by our political systems founded on administrative boundaries. This is not only problematic for practically financing and governing multipurpose interventions, but could also create inequities and injustice at a more systemic level. The classic upstream-downstream challenge in river basins provides a good example where the beneficiary might not be the same as the payer. Alternatively, those required to act or pay (upstream) will not benefit to the same extent as those downstream. Multifunctional interventions would thus need to address scalar injustices by ensuring benefits throughout the system in order to create acceptance for the intervention in the first place.

Leverage realm #2 Design for multifunctionality

Combining technologies for delivering several critical services through a common physical structure is nothing new. Many of today's water infrastructures provide multiple services. For example, hydropower reservoirs are often designed and/or operated to provide services beyond electricity generation, such as water supply, flood and drought management or irrigation. Worldwide, there are over 8000 large, multipurpose water systems by design, plus a significant number of systems that operate as multipurpose although were designed for a single purpose (OECD Environment Directorate, 2017). There is thus an untapped opportunity to learn from these as well as other indigenous approaches before designing new multifunctional interventions (Sahle & Saito, 2021). More specifically, understanding how existing multifunctional practices are impacted by modern practices, user demands or global chains can inform new multifunctional landscape design and local policies, for example by locating important areas of landscape service provision. This can in turn contribute to preserving important ecosystems and functions, and enhancing landscape integrity, functionality and resilience (Marinelli et al., 2021).

The experience with NbS suggests that while there may be unintended positive outcomes or multiple benefits from their implementation, unless these are incorporated in the design of the intervention it will be difficult to manage and monitor their broader impacts, and hence it will be difficult to tell whether the intervention has indeed led to improvements (Fiertz & Barquet, 2022; Hanson et al., 2020). Although NbS are promoted for their multifunctionality, projects are typically site-based and target a particular benefit, thereby failing to incorporate landscape approaches and a suite of socio-economic and environmental benefits (Meerow & Newell, 2017). By contrast, designing for multifunctionality implies considering the range of benefits and trade-offs an intervention could have, at the design stage, and setting up the appropriate institutional mechanisms for their governance.

Multifunctionality demands networked designs to ensure that individual features form, and contribute to, an interconnected system at a landscape scale (Jerome et al., 2019). Interconnectedness is also reflected in the concept of 'interoperability' or the integration of components into a system of systems. Interoperability allows for the systemic consideration of multiple systems and their functions together. Increasing connectivity through multiple nodes can reduce critical points or vulnerabilities within single infrastructure systems. Considering interoperability in adaptation strategies also creates opportunities for different adaptation pathways at different timescales, for example by adjusting or enhancing certain functions depending on changing conditions (Vercruysse et al., 2019).

Designing for multifunctionality also implies understanding individual and collective drivers for change and identifying the social fabric required for sustainable change to occur. The individual and cultural immaterial aspects, such as values and sense of place, are increasingly recognized as fundamental for achieving just and sustainable planning practices (Grenni et al., 2020). A place-based approach requires deep understanding of the people–place relationships – including expectations concerning what the landscape should be like and what it should be used for – and a recognition of the uniqueness of places, in terms of local resources, assets, people's capacities, knowledge and preferences (Puren et al., 2018; Soini et al., 2012).

However, multifunctional design needs to address the inherent tension between the underlying mechanisms for creating a sense of place, such as place attachment and place identity (Tuan, 1977), and the mechanisms needed to create acceptance for systemic interventions, for instance at ecosystem or landscape scales where there might be no sense of identity or belonging of the societies impacted by the interventions. Additionally, transformation might require changes in the physical and built environment, in the norms and cultures defining societies, and in the functions attributed to landscapes, all of which shape our sense of place. In other words, multifunctional design will have to redefine people's sense of belonging in order to attain transformative change.

Leverage realm #3 Monitor multifunctionality across scales

Despite broad recognition of the importance of multifunctionality for sustainable landscapes, tools for assessing, planning and monitoring are yet to properly integrate multifunctional feedbacks across scales (Galler et al., 2015).

Measuring multifunctionality for nature and society is extremely challenging for various reasons.

Effects of interventions are usually not assessed over longer periods of time and across space (Galler et al., 2013; Manning et al., 2018), and there is little knowledge on the interlinkages between socio-economic developments, landscape patterns and multiple ecosystem service provision (Huber et al., 2020). This is especially the case for green interventions, which frequently require ongoing monitoring in contrast to grey infrastructure (Moosavi, 2017). Lack of long-term, landscape-level monitoring translates into a knowledge gap when it comes to the costs associated with monitoring, as well as poor evidence regarding what measures are most effective, whether implemented interventions have had long-term effects, or who or what has benefited from those effects (Havs och Vattenmyndigheten, 2021). As a result, potential trade-offs between multifunctionality (e.g. maximizing multiple benefits) and effectiveness (e.g. minimizing impacts) are not well understood (Mugume et al., 2017).

There is a need to simulate the effects of measures against a range of social, economic and environmental parameters, for example hydrological extremes, their resilience to environmental impacts (e.g. from hydropower), seasonal forecasts and climate projections, hotspots of taxonomic and phylogenetic (evolutionary) diversity, and indicator taxa of ecosystem condition, as well as their performance against the use of space for economic development.

Leverage realm #4 Govern for multifunctionality

Multifunctionality could enable a more just adaptation, but knowledge gaps about direct and indirect implications of land use on multifunctionality hamper implementation (Huber et al., 2020; Storbjörk & Hjerpe, 2021). As a result, discourse is simply not materializing at the speed necessary to prepare cities for the effects that are already impacting societies globally.

To accelerate implementation of multifunctional interventions, there are several gaps that need to be addressed. First, multifunctional governance needs to integrate the connectivity concept, a spatially explicit approach that incorporates neighbourhood effects (Peters & Herrick, 2004), and which calls for inclusive information on flows that connect across spatial units. To do this, there is a need to develop better models where connectivity becomes a major part of the formulation, and tools that allow us to measure what needs to be parameterized (van der Ploeg et al., 2018). These models should go beyond biophysical processes to incorporate management and mitigation strategies for sustainable land management, and connectivity in relation to socio-economic sustainability.

Second, a cross-scale landscape approach must assess how 'natural' interventions can be made compatible with patterns of mobility or economic activity while leaving room for more dynamic and uncertain processes like climate change. Furthermore, there is a need to develop, connect and validate mechanisms to optimize the allocation of resources, pinpointing where specific monitoring or management actions are likely to be most effective under current and future climate scenarios, biodiversity and socio-economic dynamics (Royal Botanic Gardens, Kew, 2021). This can provide an indication of the most suitable type of management in relation to biological values (such as highest species richness or carbon storage) or socio-economic function (such as recreational use). The assumption is that areas differ vastly according to the metric evaluated, and that while certain forms of management (e.g. protected areas) could also provide gains for socio-economic activities (e.g. fisheries), there are often considerable trade-offs – meaning that not all values may be maximizable at the same time (Antonelli et al., 2021).

Third, questions of ownership, finance and service provision are particularly unclear when considering the long-term life cycle of unconventional interventions – such as green, blue or hybrid – including their maintenance. Here, research highlights the potential of public–private partnerships as models for shared responsibility (Winslow, 2021). More generally, there is a need to assess the politics of multifunctional infrastructure performance and planning (Meerow, 2020) and review the approaches used to calculate benefits beyond costs and revenues, as these do not capture who pays the costs and who receives the benefits (Fiertz & Barquet, 2022). Yet most decision-making processes for adaptation rely on mainstream economic appraisals that build primarily on measuring net present value: the difference between the present value of cash inflows and the present value of cash outflows over a period of time. There are some well-recognized difficulties associated with this approach (Padilla, 2002), especially because property values are often used as a starting point to assess whether an intervention is worth the costs (Arkema et al., 2017). But not everyone owns property, and this is true for the most marginalized and vulnerable in society. Hence, property cannot be a precondition nor a metric for adaptation (sensu Harvey, 2003; Lefebvre, 1991). Without knowledge of the distribution of costs and benefits, multifunctional interventions could maintain or reinforce inequities if more marginalized groups shoulder a disproportionately greater burden.

Conclusions

This paper proposes a dialectic understanding of multifunctionality to bridge the nature–society dichotomy in current planning and adaptation practices.

Embedded in the concept of multifunctionality are principles of connectivity, dynamism and scale that align better with an ecosystem approach compared to current single-purposed interventions. Beyond ecosystem traits, a joint nature–society understanding to multifunctionality integrates artefacts and practices produced by societies with nature. This does not imply that all ecosystems should be permeated by social structures. Rather, it highlights the need that many places and societies face today: to reconcile questions of social equity with biodiversity and environmental goals.

We summarized the rich literature on NbS as it sheds light on the benefits and trade-offs from nature-inspired interventions, and can serve as a basis for moving towards more hybrid approaches that can deliver multiple functions. Based on these experiences we suggest four leverage realms for multifunctional interventions:

1. Define who multifunctionality is for, including understanding the mechanisms for change, the interventions that will lead to collective gains and the identification of the societies and nature that will benefit and those that will not across spatial and temporal scales.

2. Design for multifunctionality, by planning for multiple benefits from the beginning, assessing interoperability of interventions and ensuring a sense of place is incorporated in design practices.

3. Monitor multifunctionality across scales, including long-term and at a landscape level, to assess effectiveness and performance of interventions, and monitor the provision of landscape services.

4. Govern for multifunctionality, which means governing for connectivity, compatibility and a just adaptation.

References

Abhinav, K., Collu, M., Benjamins, S., Cai, H., Hughes, A., Jiang, B., Jude, S., Leithead, W., Lin, C., Liu, H., Recalde-Camacho, L., Serpetti, N., Sun, K., Wilson, B., Yue, H., & Zhou, B. (2020). Offshore multi -purpose platforms for a Blue Growth: A technological, environmental and socio-economic review. Science of the Total Environment, 734, Article 138256. https://doi.org/10.1016/j.scitotenv.2020.138256

Abson, D. J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., von Wehrden, H., Abernethy, P., Ives, C. D., Jager, N. W., & Lang, D. J. (2017). Leverage points for sustainability transformation. Ambio, 46(1), 30–39. https://doi.org/10.1007/s13280-016-0800-y

Antonelli, A., Goria, S., Sterner, T., & Silvestro, D. (2021). Optimising biodiversity protection through artificial intelligence. bioRxiv. https://doi.org/10.1101/2021.04.13.439752

Arkema, K. K., Griffin, R., Maldonado, S., Silver, J., Suckale, J., & Guerry, A. D. (2017). Linking social, ecological, and physical science to advance natural and nature-based protection for coastal communities: Advancing protection for coastal communities. Annals of the New York Academy of Sciences, 1399(1), 5–26. https://doi.org/10.1111/nyas.13322

Augusto, B., Roebeling, P., Rafael, S., Ferreira, J., Ascenso, A., & Bodilis, C. (2020). Short and medium- to long-term impacts of nature-based solutions on urban heat. Sustainable Cities and Society, 57, Article 102122. https://doi.org/10.1016/j.scs.2020.102122

Bark, R. H., Martin-Ortega, J., & Waylen, K. A. (2021). Stakeholders' views on natural flood management: Implications for the nature-based solutions paradigm shift? Environmental Science & Policy, 115, 91–98. https://doi.org/10.1016/j.envsci.2020.10.018

Barquet, K. (2015). 'Yes to Peace'? Environmental peacemaking and transboundary conservation in Central America. Geoforum, 63, 14–24. https://doi.org/10.1016/j.geoforum.2015.05.011

Barquet, K., Leander, E., Green, J., Tuhkanen, H., Omondi Odongo, V., Boyland, M., Fiertz, E. K., Escobar, M., Trujillo, M., & Osano, P. (2021). Spotlight on social equity, finance and scale: Promises and pitfalls of nature-based solutions. Stockholm Environment Institute. https://cdn.sei.org/wp-content/uploads/2021/09/spotlight-on-social-equity-finance-and-scale-nbs-2021.pdf

Belmeziti, A., Cherqui, F., & Kaufmann, B. (2018). Improving the multi-functionality of urban green spaces: Relations between components of green spaces and urban services. Sustainable Cities and Society, 43, 1–10. https://doi.org/10.1016/j.scs.2018.07.014

Bennett, V. (2021). Multilateral development banks to step up protection of nature. European Bank for Reconstruction and Development. https://www.ebrd.com/news/2021/multilateral-development-banks-to-step-up-protection-of-nature.html

Birney, A. (2021). How do we know where there is potential to intervene and leverage impact in a changing system? The practitioners perspective. Sustainability Science, 16(3), 749–765. https://doi.org/10.1007/s11625-021-00956-5

Bisaro, A., & Hinkel, J. (2016). Governance of social dilemmas in climate change adaptation. Nature Climate Change, 6(4), 354–359. https://doi.org/10.1038/nclimate2936

Bomberg, M., Furtak, M., & Yarbrough, D. (2017). Buildings with environmental quality management: Part 1: Designing multifunctional construction materials. Journal of Building Physics, 41(3), 193–208. https://doi.org/10.1177/1744259117711196

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Ward Thompson, C., & Martuzzi, M. (2017). Effects of urban green space on environmental health, equity and resilience. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.), Nature-based solutions to climate change adaptation in urban areas (pp. 187–205). Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5_11

Brink, E., Wamsler, C., Adolfsson, M., Axelsson, M., Beery, T., Björn, H., Bramryd, T., Ekelund, N., Jephson, T., Narvelo, W., Ness, B., Jönsson, K. I., Palo, T., Sjeldrup, M., Stålhammar, S., & Thiere, G. (2018). On the road to 'research municipalities': Analysing transdisciplinarity in municipal ecosystem services and adaptation planning. Sustainability Science, 13(3), 765–784. https://doi.org/10.1007/s11625-017-0499-0

Bruley, E., Locatelli, B., & Lavorel, S. (2021). Nature's contributions to people: Coproducing quality of life from multifunctional landscapes. Ecology and Society, 26(1), Article 12. https://doi.org/10.5751/ES-12031-260112

Burden, A., Garbutt, A., & Evans, C. D. (2019). Effect of restoration on saltmarsh carbon accumulation in Eastern England. Biology Letters, 15(1), 20180773. https://doi.org/10.1098/rsbl.2018.0773

Burnett, H., Olsen, J. R., Nicholls, N., & Mitchell, R. (2021). Change in time spent visiting and experiences of green space following restrictions on movement during the COVID-19 pandemic: A nationally representative cross-sectional study of UK adults. BMJ Open, 11(3), Article e044067. https://doi.org/10.1136/bmjopen-2020-044067

Byrnes, J. E. K., Gamfeldt, L., Isbell, F., Lefcheck, J. S., Griffin, J. N., Hector, A., Cardinale, B. J., Hooper, D. U., Dee, L. E., & Emmett Duffy, J. (2014). Investigating the relationship between biodiversity and ecosystem multifunctionality: Challenges and solutions. Methods in Ecology and Evolution, 5(2), 111–124. https://doi.org/10.1111/2041-210X.12143

Caillon, S., Cullman, G., Verschuuren, B., & Sterling, E. J. (2017). Moving beyond the human/nature dichotomy through biocultural approaches: Including ecological well-being in resilience indicators. Ecology and Society, 22(4), Article 27. https://doi.org/10.5751/ES-09746-220427

Callaghan, A., McCombe, G., Harrold, A., McMeel, C., Mills, G., Moore-Cherry, N., & Cullen, W. (2021). The impact of green spaces on mental health in urban settings: A scoping review. Journal of Mental Health, 30(2), 179–193. https://doi.org/10.1080/09638237.2020.1755027

Calliari, E., Staccione, A., & Mysiak, J. (2019). An assessment framework for climate-proof nature-based solutions. Science of The Total Environment, 656, 691–700. https://doi.org/10.1016/j.scitotenv.2018.11.341

Chausson, A., Turner, B., Seddon, D., Chabaneix, N., Girardin, C. A. J., Kapos, V., Key, I., Roe, D., Smith, A., Woroniecki, S., & Seddon, N. (2020). Mapping the effectiveness of nature-based solutions for climate change adaptation. Global Change Biology, 26(11), 6134–6155. https://doi.org/10.1111/gcb.15310

Chen, W., Wang, W., Huang, G., Wang, Z., Lai, C., & Yang, Z. (2021). The capacity of grey infrastructure in urban flood management: A comprehensive analysis of grey infrastructure and the green-grey approach. International Journal of Disaster Risk Reduction, 54, Article 102045. https://doi.org/10.1016/j.ijdrr.2021.102045

Coggins, S., Berrang-Ford, L., Hyams, K., Satyal, P., Ford, J., Paavola, J., Arotoma-Rojas, I., & Harper, S. (2021). Empirical assessment of equity and justice in climate adaptation literature: A systematic map. Environmental Research Letters, 16(7), Article 073003. https://doi.org/10.1088/1748-9326/ac0663

Cousins, J. J. (2021). Justice in nature-based solutions: Research and pathways. Ecological Economics, 180, Article 106874. https://doi.org/10.1016/j.ecolecon.2020.106874

Curran, W., & Hamilton, T. (2020). Nature-based solutions in hiding: Goslings and greening in the still-industrial city. Socio-Ecological Practice Research, 2(4), 321–327. https://doi.org/10.1007/s42532-020-00064-1

Dasgupta, P. (2021). The economics of biodiversity: The Dasgupta review. HM Treasury. https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/962785/The_Economics_of_Biodiversity_The_Dasgupta_Review_Full_Report.pdf

Davies, C., Chen, W. Y., Sanesi, G., & Lafortezza, R. (2021). The European Union roadmap for implementing nature-based solutions: A review. Environmental Science & Policy, 121, 49–67. https://doi.org/10.1016/j.envsci.2021.03.018

de Groot, R. (2006). Function-analysis and valuation as a tool to assess land use conflicts in planning for sustainable, multi-functional landscapes. Landscape and Urban Planning, 75(3–4), 175–186. https://doi.org/10.1016/j.landurbplan.2005.02.016

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A. G., Mittal, N., Feliu, E., & Faehnle, M. (2014). Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. Journal of Environmental Management, 146, 107–115. https://doi.org/10.1016/j.jenvman.2014.07.025

Department for Environment, Food & Rural Affairs. (2018). A green future: Our 25 year plan to improve the environment. https://www.gov.uk/government/publications/25-year-environment-plan

Dorst, H., van der Jagt, A., Raven, R., & Runhaar, H. (2019). Urban greening through nature-based solutions: Key characteristics of an emerging concept. Sustainable Cities and Society, 49, Article 101620. https://doi.org/10.1016/j.scs.2019.101620

Dorst, H., van der Jagt, A., Toxopeus, H., Tozer, L., Raven, R., & Runhaar, H. (2022). What's behind the barriers? Uncovering structural conditions working against urban nature-based solutions. Landscape and Urban Planning, 220, Article 104335. https://doi.org/10.1016/j.landurbplan.2021.104335

Earth Security. (2021). The blended finance playbook for nature-based solutions. https://earthsecurity.org/report/the-blended-finance-playbook-for-nature-based-solutions/

European Environment Agency. (2021). Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction. Publications Office. https://data.europa.eu/doi/10.2800/919315

Fagerholm, N., Martín-López, B., Torralba, M., Oteros-Rozas, E., Lechner, A. M., Bieling, C., Stahl Olafsson, A., Albert, C., Raymond, C. M., Garcia-Martin, M., Gulsrud, N., & Plieninger, T. (2020). Perceived contributions of multifunctional landscapes to human well-being: Evidence from 13 European sites. People and Nature, 2(1), 217–234. https://doi.org/10.1002/pan3.10067

Fiertz, K., & Barquet, K. (2022). Nature-based solutions for coastal adaptation: Matching the evidence to a local case in southern Sweden [Manuscript submitted for publication].

Frantzeskaki, N., McPhearson, T., Collier, M. J., Kendal, D., Bulkeley, H., Dumitru, A., Walsh, C., Noble, K., van Wyk, E., Ordóñez, C., Oke, C., & Pintér, L. (2019). Nature-based solutions for urban climate change adaptation: Linking science, policy, and practice communities for evidence-based decision-making. BioScience, 69(6), 455–466. https://doi.org/10.1093/biosci/biz042

Fuchs, C. (2006). The dialectic of the nature-society-system. TripleC: Communication, Capitalism & Critique. Open Access Journal for a Global Sustainable Information Society, 4(1), 1–39. https://doi.org/10.31269/triplec.v4i1.24

Galler, C., von Haaren, C., & Albert, C. (2013). Planning multifunctional measures for efficient landscape management: Quantifying and comparing the added value of integrated and segregated management concepts. In B. Fu & K. B. Jones (Eds.), Landscape ecology for sustainable environment and culture (pp. 249–284). Springer Netherlands. https://doi.org/10.1007/978-94-007-6530-6_13

Galler, C., von Haaren, C., & Albert, C. (2015). Optimizing environmental measures for landscape multifunctionality: Effectiveness, efficiency and recommendations for agri-environmental programs. Journal of Environmental Management, 151, 243–257. https://doi.org/10.1016/j.jenvman.2014.12.011

Grenni, S., Soini, K., & Horlings, L. G. (2020). The inner dimension of sustainability transformation: How sense of place and values can support sustainable place-shaping. Sustainability Science, 15(2), 411–422. https://doi.org/10.1007/s11625-019-00743-3

Haase, A. (2017). The contribution of nature-based solutions to socially inclusive urban development: Some reflections from a social-environmental perspective. In N. Kabisch, H. Korn, J. Stadler, & A. Bonn (Eds.), Nature-based solutions to climate change adaptation in urban areas: Linkages between science, policy and practice (pp. 221–236). Springer International Publishing. https://doi.org/10.1007/978-3-319-56091-5_13

Hanson, H. I., Wickenberg, B., & Alkan Olsson, J. (2020). Working on the boundaries: How do science use and interpret the nature-based solution concept? Land Use Policy, 90, Article 104302. https://doi.org/10.1016/j.landusepol.2019.104302

Harvey, D. (2003). The right to the city. International Journal of Urban and Regional Research, 27(4), 939–941. https://doi.org/10.1111/j.0309-1317.2003.00492.x

Havs och Vattenmyndigheten. (2021). Havs-och vattenmyndighetens forsknings- och utvecklingsbehov 2021 [The Swedish Maritime Administration's research and development needs 2021] (Beslut DNR. 02584-2021). https://www.havochvatten.se/download/18.9d6062e17c13f61b9e65b4b/1632999011685/beslut-dnr%2002584-2021-havs-forsknings-och-utvecklingsbehov-perioden-2021-2023-1.pdf

Herzog, T. R., & Chernick, K. K. (2000). Tranquility and danger in urban and natural settings. Journal of Environmental Psychology, 20(1), 29–39. https://doi.org/10.1006/jevp.1999.0151

Honey-Rosés, J., Anguelovski, I., Chireh, V. K., Daher, C., van den Bosch, C. K., Litt, J. S., Mawani, V., McCall, M. K., Orellana, A., Oscilowicz, E., Sánchez, U., Senbel, M., Tan, X., Villagomez, E., Zapata, O., & Nieuwenhuijsen, M. J. (2020). The impact of COVID-19 on public space: An early review of the emerging questions – design, perceptions and inequities. Cities & Health. Advance online publication. https://doi.org/10.1080/23748834.2020.1780074

Huber, L., Schirpke, U., Marsoner, T., Tasser, E., & Leitinger, G. (2020). Does socioeconomic diversification enhance multifunctionality of mountain landscapes? Ecosystem Services, 44, Article 101122. https://doi.org/10.1016/j.ecoser.2020.101122

Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. (2019). Summary for policymakers of the global assessment report on biodiversity and ecosystem services (summary for policy makers). https://doi.org/10.5281/ZENODO.3553579

Jerome, G., Sinnett, D., Burgess, S., Calvert, T., & Mortlock, R. (2019). A framework for assessing the quality of green infrastructure in the built environment in the UK. Urban Forestry & Urban Greening, 40, 174–182. https://doi.org/10.1016/j.ufug.2019.04.001

Kabisch, N., van den Bosch, M., & Lafortezza, R. (2017). The health benefits of nature-based solutions to urbanization challenges for children and the elderly: A systematic review. Environmental Research, 159, 362–373. https://doi.org/10.1016/j.envres.2017.08.004

Kondo, M., Fluehr, J., McKeon, T., & Branas, C. (2018). Urban green space and its impact on human health. International Journal of Environmental Research and Public Health, 15(3), 445. https://doi.org/10.3390/ijerph15030445

Kotsila, P., Anguelovski, I., Baró, F., Langemeyer, J., Sekulova, F., & Connolly, J. J. T. (2021). Nature-based solutions as discursive tools and contested practices in urban nature's neoliberalisation processes. Environment and Planning E: Nature and Space, 4(2), 252–274. https://doi.org/10.1177/2514848620901437

Kuwae, T., & Crooks, S. (2021). Linking climate change mitigation and adaptation through coastal green–gray infrastructure: A perspective. Coastal Engineering Journal, 63(3), 188–199. https://doi.org/10.1080/21664250.2021.1935581

Larsen, S. V., Kørnøv, L., & Christensen, P. (2018). The mitigation hierarchy upside down: A study of nature protection measures in Danish infrastructure projects. Impact Assessment and Project Appraisal, 36(4), 287–293. https://doi.org/10.1080/14615517.2018.1443260

Lefebvre, H. (1991). The production of space. Blackwell.

Lehmann, I., Martin, A., & Fisher, J. A. (2018). Why should ecosystem services be governed to support poverty alleviation? Philosophical perspectives on positions in the empirical literature. Ecological Economics, 149, 265–273. https://doi.org/10.1016/j.ecolecon.2018.03.003

Lovell, S. T., & Taylor, J. R. (2013). Supplying urban ecosystem services through multifunctional green infrastructure in the United States. Landscape Ecology, 28(8), 1447–1463. https://doi.org/10.1007/s10980-013-9912-y

Maes, J., & Jacobs, S. (2015). Nature-based solutions for Europe's sustainable development. Conservation Letters, 10(1), 121–124. https://doi.org/10.1111/conl.12216

Manning, P., van der Plas, F., Soliveres, S., Allan, E., Maestre, F. T., Mace, G., Whittingham, M. J., & Fischer, M. (2018). Redefining ecosystem multifunctionality. Nature Ecology & Evolution, 2(3), 427–436. https://doi.org/10.1038/s41559-017-0461-7

Marinelli, M. V., Valente, D., Scavuzzo, C. M., & Petrosillo, I. (2021). Landscape service flow dynamics in the metropolitan area of Córdoba (Argentina). Journal of Environmental Management, 280, Article 111714. https://doi.org/10.1016/j.jenvman.2020.111714

Marx, K., & Engels, F. (1975). Collected works. International Publishers.

McQuaid, S. (2019). Nature-based solutions business model canvas guidebook. Connecting Nature. https://connectingnature.eu/sites/default/files/downloads/NBC-BMC-Booklet-Final-%28for-circulation%29.pdf

Meadows, D. (1999). Leverage points: Places to intervene in a system. The Sustainability Institute.

Meadows, D., & Wright, D. (2008). Thinking in systems: A primer. Chelsea Green Publishing.

Meerow, S. (2020). The politics of multifunctional green infrastructure planning in New York City. Cities, 100, Article 102621. https://doi.org/10.1016/j.cities.2020.102621

Meerow, S., & Newell, J. P. (2017). Spatial planning for multifunctional green infrastructure: Growing resilience in Detroit. Landscape and Urban Planning, 159, 62–75. https://doi.org/10.1016/j.landurbplan.2016.10.005

Moosavi, S. (2017). Ecological coastal protection: Pathways to living shorelines. Procedia Engineering, 196, 930–938. https://doi.org/10.1016/j.proeng.2017.08.027

Moosavi, S., Browne, G. R., & Bush, J. (2021). Perceptions of nature-based solutions for urban water challenges: Insights from Australian researchers and practitioners. Urban Forestry & Urban Greening, 57, Article 126937. https://doi.org/10.1016/j.ufug.2020.126937

Morris, R. L., Konlechner, T. M., Ghisalberti, M., & Swearer, S. E. (2018). From grey to green: Efficacy of eco-engineering solutions for nature-based coastal defence. Global Change Biology, 24(5), 1827–1842. https://doi.org/10.1111/gcb.14063

Mugume, S. N., Melville-Shreeve, P., Gomez, D., & Butler, D. (2017). Multifunctional urban flood resilience enhancement strategies. Proceedings of the Institution of Civil Engineers - Water Management, 170(3), 115–127. https://doi.org/10.1680/jwama.15.00078

Mulligan, J., Bukachi, V., Clause, J. C., Jewell, R., Kirimi, F., & Odbert, C. (2020). Hybrid infrastructures, hybrid governance: New evidence from Nairobi (Kenya) on green-blue-grey infrastructure in informal settlements. Anthropocene, 29, Article 100227. https://doi.org/10.1016/j.ancene.2019.100227

Naturvårdsverket. (2021). Naturbaserade lösningar—Ett verktyg för klimatanpassning och andra samhällsutmaningar [Nature-based solutions – a tool for climate adaptation and other societal challenges]. http://urn.kb.se/resolve?urn=urn:nbn:se:swedgeo:diva-947

Nesshöver, C., Assmuth, T., Irvine, K. N., Rusch, G. M., Waylen, K. A., Delbaere, B., Haase, D., Jones-Walters, L., Keune, H., Kovacs, E., Krauze, K., Külvik, M., Rey, F., van Dijk, J., Vistad, O. I., Wilkinson, M. E., & Wittmer, H. (2017). The science, policy and practice of nature-based solutions: An interdisciplinary perspective. Science of The Total Environment, 579, 1215–1227. https://doi.org/10.1016/j.scitotenv.2016.11.106

OECD Environment Directorate. (2017). Multi-purpose water infrastructure: Recommendations to maximise economic benefits. Organisation for Economic Co-operation and Development. https://www.oecd.org/env/outreach/MPWI_Perspectives_Final_WEB.pdf

Olaniyan, A. (2018). Foliage and violence: Interrogating forests as a security threat in Nigeria. African Security Review, 27(1), 88–107. https://doi.org/10.1080/10246029.2017.1369135

Padilla, E. (2002). Intergenerational equity and sustainability. Ecological Economics, 41(1), 69–83. https://doi.org/10.1016/S0921-8009(02)00026-5

Pataki, D. E., Carreiro, M. M., Cherrier, J., Grulke, N. E., Jennings, V., Pincetl, S., Pouyat, R. V., Whitlow, T. H., & Zipperer, W. C. (2011). Coupling biogeochemical cycles in urban environments: Ecosystem services, green solutions, and misconceptions. Frontiers in Ecology and the Environment, 9(1), 27–36. https://doi.org/10.1890/090220

Peters, D. P. C., & Herrick, J. E. (2004). Strategies for ecological extrapolation. Oikos, 106(3), 627–636. https://doi.org/10.1111/j.0030-1299.2004.12869.x

Puren, K., Roos, V., & Coetzee, H. (2018). Sense of place: Using people's experiences in relation to a rural landscape to inform spatial planning guidelines. International Planning Studies, 23(1), 16–36. https://doi.org/10.1080/13563475.2017.1329087

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., Geneletti, D., & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. Environmental Science & Policy, 77, 15–24. https://doi.org/10.1016/j.envsci.2017.07.008

Roman, L. A., Conway, T. M., Eisenman, T. S., Koeser, A. K., Ordóñez Barona, C., Locke, D. H., Jenerette, G. D., Östberg, J., & Vogt, J. (2021). Beyond 'trees are good': Disservices, management costs, and tradeoffs in urban forestry. Ambio, 50(3), 615–630. https://doi.org/10.1007/s13280-020-01396-8

Royal Botanic Gardens, Kew. (2021). Science strategy 2021–2025. https://doi.org/10.34885/rbgkewsciencestrategy2021

Ruckelshaus, M., Reguero, B. G., Arkema, K., Compeán, R. G., Weekes, K., Bailey, A., & Silver, J. (2020). Harnessing new data technologies for nature-based solutions in assessing and managing risk in coastal zones. International Journal of Disaster Risk Reduction, 51, Article 101795. https://doi.org/10.1016/j.ijdrr.2020.101795

Sahle, M., & Saito, O. (2021). Mapping and characterizing the Jefoure roads that have cultural heritage values in the Gurage socio-ecological production landscape of Ethiopia. Landscape and Urban Planning, 210, Article 104078. https://doi.org/10.1016/j.landurbplan.2021.104078

Sarabi, S. E., Han, Q., Romme, A. G. L., de Vries, B., & Wendling, L. (2019). Key enablers of and barriers to the uptake and implementation of nature-based solutions in urban settings: A review. Resources, 8(3), 121. https://doi.org/10.3390/resources8030121

Schipper, E. L. F. (2020). Maladaptation: When adaptation to climate change goes very wrong. One Earth, 3(4), 409–414. https://doi.org/10.1016/j.oneear.2020.09.014

Seddon, N., Turner, B., Berry, P., Chausson, A., & Girardin, C. A. J. (2019). Grounding nature-based climate solutions in sound biodiversity science. Nature Climate Change, 9(2), 84–87. https://doi.org/10.1038/s41558-019-0405-0

Selman, P. (2009). Planning for landscape multifunctionality. Sustainability: Science, Practice and Policy, 5(2), 45–52. https://doi.org/10.1080/15487733.2009.11908035

Shackleton, C. M., Ruwanza, S., Sinasson Sanni, G. K., Bennett, S., De Lacy, P., Modipa, R., Mtati, N., Sachikonye, M., & Thondhlana, G. (2016). Unpacking Pandora's box: Understanding and categorising ecosystem disservices for environmental management and human wellbeing. Ecosystems, 19(4), 587–600. https://doi.org/10.1007/s10021-015-9952-z

Silver, J. M., Arkema, K. K., Griffin, R. M., Lashley, B., Lemay, M., Maldonado, S., Moultrie, S. H., Ruckelshaus, M., Schill, S., Thomas, A., Wyatt, K., & Verutes, G. (2019). Advancing coastal risk reduction science and implementation by accounting for climate, ecosystems, and people. Frontiers in Marine Science, 6, 556. https://doi.org/10.3389/fmars.2019.00556

Slater, S. J., Christiana, R. W., & Gustat, J. (2020). Recommendations for keeping parks and green space accessible for mental and physical health during COVID-19 and other pandemics. Preventing Chronic Disease, 17, Article 200204. https://doi.org/10.5888/pcd17.200204

Soga, M., Evans, M. J., Tsuchiya, K., & Fukano, Y. (2021). A room with a green view: The importance of nearby nature for mental health during the COVID-19 pandemic. Ecological Applications, 31(2), Article e2248. https://doi.org/10.1002/eap.2248

Soini, K., Vaarala, H., & Pouta, E. (2012). Residents' sense of place and landscape perceptions at the rural–urban interface. Landscape and Urban Planning, 104(1), 124–134. https://doi.org/10.1016/j.landurbplan.2011.10.002

Storbjörk, S., & Hjerpe, M. (2021). Climate-proofing coastal cities: What is needed to go from envisioning to enacting multifunctional solutions for waterfront climate adaptation? Ocean & Coastal Management, 210, Article 105732. https://doi.org/10.1016/j.ocecoaman.2021.105732

Straatsma, M. W., Bloecker, A. M., Lenders, H. J. R., Leuven, R. S. E. W., & Kleinhans, M. G. (2017). Biodiversity recovery following delta-wide measures for flood risk reduction. Science Advances, 3(11), Article e1602762. https://doi.org/10.1126/sciadv.1602762

Taskforce on Nature-Related Financial Disclosures. (2021). Proposed technical scope: recommendations for the TNFD. https://tnfd.global/wp-content/uploads/2021/07/TNFD-%E2%80%93-Technical-Scope-3.pdf

Thiele, T., Alleng, G., Biermann, A., Corwin, E., Crooks, S., Fieldhouse, P., Herr, D., Matthews, N., Roth, N., Shrivastava, A., von Unger, M., & Zeitlberger, J. (2020). Blue infrastructure finance: A new approach, integrating nature-based solutions for coastal resilience. International Union for Conservation of Nature. https://bluenaturalcapital.org/wp2018/wp-content/uploads/2020/03/Blue-Infrastructure-Finance.pdf

Tuan, Y.-F. (1977). Space and place: The perspective of experience (7th ed.). University of Minnesota Press.

Uebel, K., Marselle, M., Dean, A. J., Rhodes, J. R., & Bonn, A. (2021). Urban green space soundscapes and their perceived restorativeness. People and Nature, 3(3), 756–769. https://doi.org/10.1002/pan3.10215

Ugolini, F., Massetti, L., Calaza-Martínez, P., Cariñanos, P., Dobbs, C., Ostoić, S. K., Marin, A. M., Pearlmutter, D., Saaroni, H., & Šaulienė, I. (2020). Effects of the COVID-19 pandemic on the use and perceptions of urban green space: An international exploratory study. Urban Forestry & Urban Greening, 56, Article 126888.

United Nations. (1972). Declaration of the United Nations Conference on the Human Environment. https://documents-dds-ny.un.org/doc/UNDOC/GEN/NL7/300/05/IMG/NL730005.pdf?OpenElement

United Nations Environment Programme. (2021). State of finance for nature: Tripling investments in nature-based solutions by 2030. https://www.unep.org/resources/state-finance-nature

Uzsoki, D., Casier, L., & Wuennenberg, L. (2021). Financial instruments to create and maintain NBS. In E. Croci & B. Lucchitta (Eds.), Nature-based solutions for more sustainable cities: A framework approach for planning and evaluation (pp. 255–266). Emerald Publishing. https://doi.org/10.1108/978-1-80043-636-720211021

van den Bosch, M., & Ode Sang, Å. (2017). Urban natural environments as nature-based solutions for improved public health: A systematic review of reviews. Environmental Research, 158, 373–384. https://doi.org/10.1016/j.envres.2017.05.040

van der Ploeg, M. J., Baartman, J. E. M., & Robinson, D. A. (2018). Biophysical landscape interactions: Bridging disciplines and scale with connectivity. Land Degradation & Development, 29(4), 1167–1175. https://doi.org/10.1002/ldr.2820

Vercruysse, K., Dawson, D. A., & Wright, N. (2019). Interoperability: A conceptual framework to bridge the gap between multifunctional and multisystem urban flood management. Journal of Flood Risk Management, 12(S2), Article e12535. https://doi.org/10.1111/jfr3.12535

Wang, X., Daigger, G., Lee, D.-J., Liu, J., Ren, N.-Q., Qu, J., Liu, G., & Butler, D. (2018). Evolving wastewater infrastructure paradigm to enhance harmony with nature. Science Advances, 4(8), Article eaaq0210. https://doi.org/10.1126/sciadv.aaq0210

Ward, S. E., Smart, S. M., Quirk, H., Tallowin, J. R. B., Mortimer, S. R., Shiel, R. S., Wilby, A., & Bardgett, R. D. (2016). Legacy effects of grassland management on soil carbon to depth. Global Change Biology, 22(8), 2929–2938. https://doi.org/10.1111/gcb.13246

Wessels, N., Sitas, N., Esler, K. J., & O'Farrell, P. (2021). Understanding community perceptions of a natural open space system for urban conservation and stewardship in a metropolitan city in Africa. Environmental Conservation, 48(4), 244–254. https://doi.org/10.1017/S0376892921000345

Wilson, R. S., Herziger, A., Hamilton, M., & Brooks, J. S. (2020). From incremental to transformative adaptation in individual responses to climate-exacerbated hazards. Nature Climate Change, 10(3), 200–208. https://doi.org/10.1038/s41558-020-0691-6

Winslow, J. F. (2021). Multifunctional green infrastructure: Planning and design for long-term care. Socio-Ecological Practice Research, 3(3), 293–308. https://doi.org/10.1007/s42532-021-00088-1

Woroniecki, S., Wendo, H., Brink, E., Islar, M., Krause, T., Vargas, A.-M., & Mahmoud, Y. (2020). Nature unsettled: How knowledge and power shape 'nature-based' approaches to societal challenges. Global Environmental Change, 65, Article 102132. https://doi.org/10.1016/j.gloenvcha.2020.102132

Xie, L., & Bulkeley, H. (2020). Nature-based solutions for urban biodiversity governance. Environmental Science & Policy, 110, 77–87. https://doi.org/10.1016/j.envsci.2020.04.002

Yang, R., He, S., Hu, Q., Zhai, G., Yi, J., & Zhang, L. (2018). Comparative investigations on wettability of typical marine, continental, and transitional shales in the Middle Yangtze Platform (China). Energy & Fuels, 32(12), 12187–12197. https://doi.org/10.1021/acs.energyfuels.8b02805

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