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Nature futures for the urban century: Integrating multiple values into urban management

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ABSTRACT

There is an emerging consensus that the health of the planet depends on the coexistence between rapidly growing cities and the natural world. One strategy for guiding cities towards sustainability is to facilitate a planning process based on positive visions for urban systems among actors and stakeholders. This paper presents the Urban Nature Futures Framework (UNFF), a framework for scenario building for cities that is based on three *Nature Futures* perspectives: *Nature for Nature*, *Nature for Society*, and *Nature as Culture*. Our framework engages stakeholders with envisioning the three *Nature Futures* perspectives through four components using participatory methods and quantitative models: identification of the socio-ecological feedbacks in cities, assessment of indirect impacts of cities on biodiversity, development of multi-scale indicators, and development of scenarios. Stakeholders in cities may use this framework to explore different options for integrating nature in its various manifestations within urban areas and to assess how different community preferences result in various cityscapes and distribution of associated benefits from nature among urban dwellers across multiple scales.

Introduction

The urban century

The world is experiencing the fastest urban growth in history. An additional 2.5 billion people are expected to be living in cities by 2050, with the urban population growing by about 1.3 million every week (United Nations Department of Economic Social Affairs, 2019). It is predicted that urban areas will reach 1.7 million km^2 by 2050 (Zhou et al., 2019), with resulting loss of natural areas and nature's benefits

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occurring most rapidly in the middle- and low-income countries (McDonald et al., 2020). Historical analysis of trends, however, suggests that this future urban expansion could be substantially larger than those previous estimates (Liu et al., 2020), and will be highly dependent on how these urban areas grow (Güneralp et al., 2020). Besides the direct impact of urban growth, its indirect impacts are also mounting, extending across time and space at an unprecedented rate (Elmqvist et al., 2013; Seto and Pandey, 2019). Cities consume 75% of the world's resources (Lucertini and Musco, 2020) and account for more than 70% of the global CO_2 emissions (Seto et al., 2014), putting significant environmental pressure even on natural areas far from cities. For example, the supply of food consumed within urban areas can indirectly impact an area that is 36 times greater than the global urban area (McDonald et al., 2020). Therefore, contemporary urbanization presents immense challenges to achieving global sustainability, foremost among them, biodiversity conservation and human wellbeing (Grimm et al., 2008; Elmqvist et al., 2013; McDonald et al., 2018, 2020).

The Convention on Biological Diversity (CBD) is currently developing the post-2020 global biodiversity framework that will define new global biodiversity goals for the next decade. These goals are aligned with a shared vision of "humanity living in harmony with nature", to be achieved by 2050 (CDB, 2021). Complex challenges of urbanization are, therefore, a particular need to be acknowledged by the CBD (Puppim de Oliveira et al., 2011). The first draft of the Post-2020 Global Biodiversity Framework, which sets out 21 targets to bring about a transformation in society's relationship with nature, acknowledges the importance of increasing green urban spaces (Target 12), but has yet to fully recognize the role of cities in supporting the post-2020 biodiversity agenda (CDB, 2021). Achieving the goals of the CBD will require a political commitment that fully addresses the challenges of future urban growth and biodiversity conservation (McDonald et al., 2018, 2020).

While this rapidly urbanizing century present challenges (Seto et al., 2010), it also presents opportunities for decision-makers, planners, institutions, and urban dwellers, in particular, city managers and urban planners, to strategically think about design, planning and management of cities for alternative sustainable futures (Albrechts, 2010; Elmqvist et al., 2018; Pereira et al., 2018a; Girardet, 2020; Folke et al., 2021). There is a particular need for enhancing the governance capacity of cities through new thinking and approaches that recognize and consider multiple perspectives and values of nature (Güneralp et al., 2015; Chan et al., 2016; Leach et al., 2018; Hill et al., 2021) and embrace inclusive participation and equitable outcomes (Anguelovski et al., 2020; Langemeyer and Connolly, 2020).

Frameworks for planning around nature and urban growth

Numerous global efforts exist in setting priorities and actions to promote sustainability in urban development. Here we exemplify a non-comprehensive list of such efforts from around the world. Some of these efforts are centered more on human needs, including the United Nations Transforming Our World: The 2030 Agenda for Sustainable Development, in particular the Sustainable Development Goal 11 on inclusive, safe, resilient and sustainable cities (SDG 11; https://sustainabledevelopment.un.org/sdg11) and allied with that, the New Urban Agenda of United Nations (http://habitat3.org/the-new-urban-agenda), which provides recommendations for sustainable urbanization and incorporation of job creation, livelihood opportunities and improved quality of life in all urban development and policy strategies. Others provide metrics for the conservation of nature near cities, such as the City Biodiversity Index (Kohsaka et al., 2013). In addition, there are examples of networks of cities and community initiatives that build connections across levels of governments, sectors, and stakeholders and among cities in support of sustainable urban development across the world (e.g., C40 Cities, ICLEI–Local Governments for Sustainability and CitiesWithNature). While central to promoting urban sustainability, these efforts rarely recognize the multidimensionality of human relationship with nature (Kohler et al., 2019; Hill et al., 2021). This relationship is influenced by aspects of urban lifestyle, the heterogeneity of cities in terms of the diversity of their communities, histories, governance regimes, environmental settings, and urban forms (Berg and Sigona, 2013; Seto and Pandey, 2019; Güneralp et al., 2020; Bruyns et al., 2020), all of which collectively create barriers and opportunities to govern local biodiversity and ecosystem services within cities (Wilkinson et al., 2013; Shih et al., 2020).

There has also been a long progression of numerous intellectual frameworks that seek to incorporate natural features into urban planning and design, at least since the Garden City Movement at the end of the 19th Century (Howard, 1902). Among the most well-known is the Design with Nature idea of Ian McGarg, which argued that information on the environment and ecology should be overlaid with social and economic data as essential part of urban design, bringing one of the first multidisciplinary approaches aimed to reconcile people with nature (McGarg, 1969). Later, the New Urbanism movement sought to build at a human scale, with walkable, transit-oriented development that often included abundant street trees and small parks (Duany et al., 2000). In a similar vein, the biophilic design begins from the hypothesis that humans have an innate connection with and need for interaction with nature and seeks to integrate nature into buildings and the urban fabric (Kellert et al., 2011). There are now several initiatives dedicated to creating biophilic cities, seeking to incorporate biophilic practices into urban planning in a way that meets the pressing needs of cities in the 21st century (McDonald and Beatley, 2020; Catalano et al., 2021).

More recently, several frameworks have been proposed to prescribe certain policy and implementation directions for cities to contribute to global sustainability (e.g., Childers et al., 2014; Elmqvist et al., 2019). These frameworks engendered a surge in studies that applied visioning approaches to support nature-based planning for urban areas (McPhearson et al., 2017; Lembi et al., 2020; Iwaniec et al., 2020). Visioning itself has a long history in urban planning (Shipley and Newkirk, 1999; Shipley et al., 2004; Robinson, 2008; Kwartler and Longo, 2008; John et al., 2015). Visioning has typically been used for strategic planning for cities (Bruns and Schmidt, 1997; Fabos, 2004; Neuvonen and Ache, 2017) where nature is considered, if at all, for its perceived benefits to urban residents (but see Gobster 2001 for a notable exception).

While visioning has typically been used for high-level, strategic planning purposes, scenario analysis may be used to explore key uncertainties, the consequences of specific policy options, and pathways of actions towards envisioned future outcomes (Ferrier et al., 2016; Lundquist et al., 2017; Pereira et al., 2019; Elsawah et al., 2020). For example, scenario analysis is employed in many urban land change models to better understand future urban growth under multiple socio-economic and biophysical factors at various spatiotemporal scales and geographic contexts (see Kim et al., 2020 for examples). Such scenario-based approaches, however, fail to acknowledge nature as a component of urban environments that shapes the configuration of cities and, therefore, as integral to sustainable urbanization. When approaches are nature-focused, such as targeting conservation actions or the development of green spaces in urban areas, they are often limited in terms of including differences in preferences and values of nature (Andersson et al., 2014; Elmqvist et al., 2018), which may constrain urban environmental management practices and hamper community engagement for the co-production and co-management of urban nature (Zafra-Calvo et al., 2020; Taylor et al., 2021).

Equity and inclusivity in planning around nature and urban growth

A key part of improving planning for urban futures is acknowledging and accounting for equity in urban governance (Leach et al., 2018; Langemeyer and Connolly, 2020). This is particularly important in envisioning inclusive urban nature futures as nature is currently inequitably distributed in most urban areas (e.g., Keeler et al., 2019;

McDonald et al., 2015). Many urban scholars critically pointed out that urban greening agendas and urban planning most often fail to adequately address social equity issues (Ernstson, 2013; Anguelovski et al., 2018, 2020; Calderón-Argelich et al., 2021), creating new forms of inequities and environmental injustices within the city (Wolch et al., 2014; Haase et al., 2017; Amorim Maia et al., 2020). This means that envisioning possible urban nature futures necessarily involves confronting historical and contemporary inequities with respect to income, race, and ethnicity (Anguelovski et al., 2020).

We argue that visioning and scenario analysis of possible urban futures need to explicitly acknowledge the role of nature in shaping sustainable futures. This acknowledgment includes two aspects. First, properly accounting for any indirect impacts urban areas may have on distant ecosystems. Second, consideration of diverse values and perspectives in relation to nature need in the urban planning process (see Chan et al., 2016 and Hill et al., 2021 for discussion about pluralistic values and perspectives). Accordingly, we emphasize that the whole process to create these visions and scenarios should be co-developed in conjunction with a diverse group of stakeholders in the city, allowing for multiple voices and their collective imaginations to influence the final outcome (Davidoff, 2015; Pereira et al., 2020; Elsawah et al., 2020). Recent literature highlights that imaginative process approaches provide opportunities to explore more diverse and participatory scenarios (Bennett et al., 2016; Pereira et al., 2019), and more effectively embrace and address social equity (Leach et al., 2018; Langemeyer and Connolly, 2020). Such an imaginative approach for urban nature futures could unleash transformative power of values to inspire collective action and shape more inclusive urbanization (Pereira et al., 2018a).

The Intergovernmental Platform on Biodiversity and Ecosystem Services (IPBES) focuses on the links between nature and people and supports wider research and knowledge-policy communities, facilitating and inciting other studies to contribute to an inclusive and participatory co-construction process towards sustainability (Díaz et al., 2015). Building upon the assessment report of IPBES (see Ferrier et al., 2016 for details), the Expert Group on Scenarios and Models of IPBES (https://ipbes.net/scenarios-models), launched the development of a new generation of multi-scale and cross-sectoral future scenarios with positive perspectives where people and nature prosper together (Rosa et al., 2017). These perspectives generated the Nature Futures Framework (NFF) (Lundquist et al., 2017; Pereira et al., 2020), which represents a diversity of worldviews on nature, including pluralistic values and culture (Pascual et al., 2017; Hill et al., 2021). To operationalize the NFF, the expert group and a new taskforce of IPBES are developing methodological approaches to engage a wide range of stakeholders and knowledge systems in the design and implementation of place-specific planning and management for biodiversity conservation and sustainable development through the use of the narratives, models, and indicators (Kim et al., in preparation). They also call for research to contribute to further developments of the NFF (Pereira et al., 2020).

The NFF does not address the specificities of the urban context, a critical gap considering the increasingly important role urban areas can play towards global sustainability (Acuto et al., 2018; Elmqvist et al., 2019). Thus, here, we expand upon and adapt the NFF to the urban context to create the Urban Nature Futures Framework (UNFF). Our framework allows for the creation of multiple positive visions for nature in cities, enabling decision-makers, planners, institutions, and urban dwellers to explore multiple transformative pathways for sustainable cities. We start by developing three archetypal positive Nature Futures visions for urban systems that also incorporates equity as an essential aspect in the development of the UNFF. Next, we introduce the four components for operationalizing the UNFF in a city: (1) identifying and leveraging socio-ecological feedbacks, (2) assessing indirect impacts of cities, (3) multiscale monitoring of nature in cities and indirect impacts of cities on nature, and (4) developing participatory scenarios for planning and policy. The rapid contemporary urbanization presents an imperative for cities to support biodiversity conservation and shape more sustainable trajectories. Now is the time for the application of new approaches beyond the business-as-usual (McDonald et al., 2018), such as the UNFF, which can guide transformative action towards more inclusive, greener, and sustainable urban futures.

Overview of the urban nature futures framework

Conceptualizing the urban nature futures framework

The NFF maps people's preferences for the future of nature into three main axes of values: eco-centric intrinsic values; utilitarian values (direct and indirect uses); and relational values (including cultural values) (Pereira et al., 2020). While most people recognize all three types of values, contrasting perspectives can be identified at the corners of a ternary plot where one value type dominates each corner (Fig. 1): (i) *Nature for Nature* (eco-centric intrinsic values of nature dominate) where nature has value in and of itself without direct human benefits and the preservation of nature's functions is of primary importance; (ii) *Nature for Society* (utilitarian values dominate) is a perspective leading to a set of multiple uses of nature for the benefit of people (Pascual et al., 2017); (iii) *Nature as Culture* (relational values dominate) is a perspective, often expressed in local knowledge systems where nature is shaped by culture and vice versa and where people's identity is associated with nature (Chan et al., 2012, 2016).

In reality, these three perspectives never exist in complete isolation from each other. As such, urban places in the future, as they are today, will reflect varying combinations of all three perspectives (Kim et al., in preparation). Indeed, different stakeholders and other social actors in the same city may have very different opinions about the importance of nature in urban (McDonald, 2015), or about which of these three perspectives should be the most important when envisioning the future. In this regard, it is important to recognize from the outset that achieving positive urban futures will likely require fundamental alteration of prevailing power relations (divisions of power among groups of people) (Bennett et al., 2016). Achieving this is a huge challenge and, at the very least, will require the development of strategies to proactively address power imbalances through the creation of safe enough spaces of engagement, dialogs, giving voice and empowering poorer and less powerful actors throughout the visioning process (for examples see Pereira et al., 2018b; Drimie et al., 2018; Marshall et al., 2018).

Here we illustrate urban futures at these three extremes to emphasize both the contrasts among them and the wide range of scenario space they encompass.

Visions of the urban nature futures

We developed three contrasting visions for the future of nature in cities, one for each individual nature futures perspective (Fig. 2). These future visions for cities were developed in workshop discussions by the co-authors. Each vision has the predominance of one of the values described above. All three visions describe a progressively more positive and diverse, future where our relationship with nature is valued more in the cities than it is now. The figures are illustrative and intend to be inspirational to show what kind of visions can be developed from the UNFF.

In the *Nature for Nature future* (Fig. 2a), there is more space for natural areas and biodiversity, enabling ecological processes to operate with little to no human intervention. Here, cities are designed to accommodate dynamic natural processes, such as animal dispersal and floodplain connectivity. Urban development is compact with extensively consolidated greenspaces to better protect and safeguard sensitive and endemic species. Natural habitats are protected and there is space for urban forests and wild parks, which are restored and sustained with native species, increasing ecological connectivity. Rivers and lakes are clean, wastewater treatment is effective, and water pollution is prevented from any and all sources. People and policymakers recognize

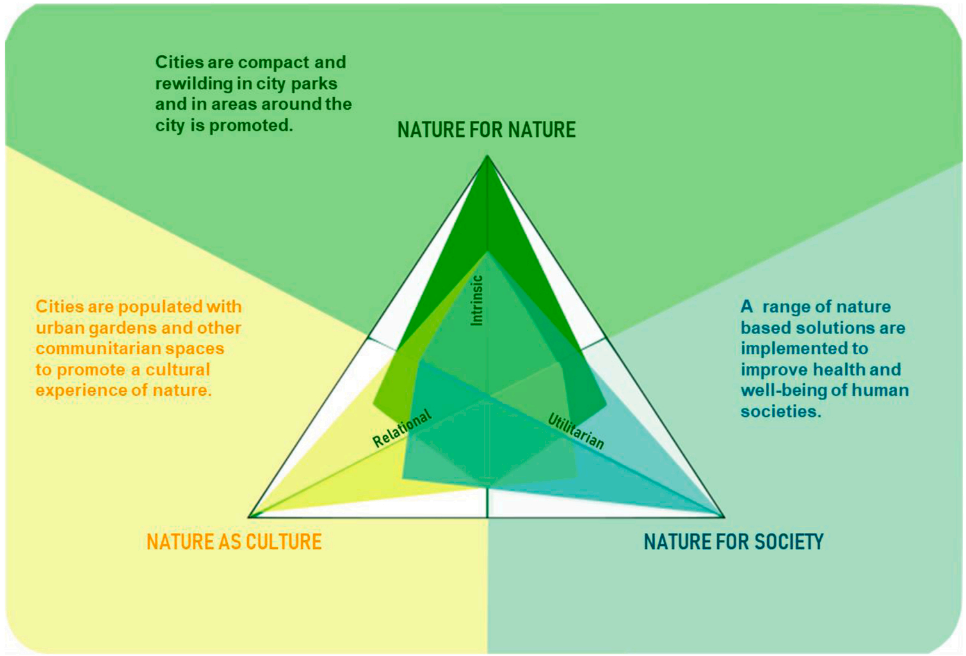

Fig. 1. The preference space of the Urban Nature Futures framework.

Fig. 2. Visual representations of the visions for each of the three *Urban Nature Futures*.

rivers as living systems, especially in the management and restoration of freshwater biodiversity and riparian buffer zones. Rewilding is promoted as a management strategy in large portions of the city parks, where soft management practices are implemented leading to an increase in the complexity of understory vegetation. Ecological corridors connect urban green areas to wider landscapes. Urban dwellers value nature intrinsically and experience wildlife through various activities such as bird watching and walks in the woods. There is education on biodiversity conservation, which in turn contributes to ecosystem protection and restoration. Housing and city infrastructure are designed to function with nature and people are better adapted to deal with environmental externalities such as floods.

In the *Nature for Society future* (Fig. 2b), there is a deployment of nature-based solutions (NBS), for example, enhancing the use of green and blue infrastructure such as constructed wetlands and urban tree planting. These nature-based solutions are designed solely to provide a range of ecosystem services, including clean air and water as well as providing new habitats for promoting biodiversity. Coastal and riparian zones are protected as natural defenses against floods in cities. People have more access to pocket parks and urban green areas, including increased access to a network of green corridors for walking, biking, and riding on the trails. City parks and landscapes are managed to promote good mental and physical health conditions for urban dwellers. There are incentives for recreational activities in open spaces and local capacity building for nature conservancy and implementation of risk reduction infrastructure. There are environmental education programs where people learn the value of nature for human well-being. There are community initiatives on climate mitigation, tree sponsorship, sorting of domestic waste for recycling, and cleaning of rivers. Urban gardens are regarded as part of a set of solutions to minimize agricultural footprint, which also contribute to other ecosystem services such as local climate regulation. In all these respects, there is emphasis on equitable distribution of these benefits across various communities in the city. There are economic incentives for the households, such as lower taxes for greener properties and energy-efficient homes. A circular economy is promoted, with more investments in renewable energy, and compact urban development that enhances transport efficiency and promotes integrated mixed-use environments with walkable neighborhoods.

In the *Nature as Culture future* (Fig. 2c), people have opportunities to enjoy nature as culture in a multitude of ways, actively engaging with nature in activities contributing to social cohesion, sense of place, cultural identity, and stewardship of nature, through which people actively take care of the environment. Important historical sites, such as botanical gardens, urban parks, and sacred sites, that represent the city's relationship with nature, are protected and well-managed. The protection of culturally important species is prioritized in city parks regardless of their origin. Urban parks and landscapes reflect cultural norms and the historical context that define the relationship of people with nature in different parts of the city. Spaces for nature and people are created for the emergence of new cultural expressions. For instance, artistic installments are integrated throughout the city, depicting the historical and cultural relationship of people and nature. People engage in community gardening as a cultural practice, promoting social cohesion and identity. Community gardens contribute not only to local food production but also to the diversity of various crops reflecting the cultural backgrounds of the gardeners as well as to their physical and mental health (Horst et al., 2017). Urban dwellers often visit nearby farms and cultural landscapes, participate in farming and cultural activities. There is consumer preference for farmers' market products. People value varieties of heirloom crops and natural products. There is learning through generations, creating opportunities to perpetuate socio-ecological memories and create new ones. Thus, education programs promote the benefits of cultural interactions with nature; the local history and traditional knowledge on nature are maintained through generations, contributing positively to human-nature relationships and to a sustainable future.

Addressing equity in the development of visions and scenarios of urban nature futures

We recognize that there are many challenges related to social equity and justice entrenched with the planning of nature in cities that are well discussed in the literature (Ernstson, 2013; Wolch et al., 2014; Haase et al., 2017; Anguelovski et al., 2018, 2020; Calderón-Argelich et al., 2021). For example, Anguelovski et al. (2020) raise critical reflections within urban greening practices and equity implications that should be carefully understood to advance justice outcomes in urban greening approaches. We highlight possibilities to better incorporate equity in the creation of visions and scenarios of possible urban futures and minimize inequitable outcomes. In this respect, three interconnected dimensions of equity need to be considered: recognitional, procedural and distributional equity (Leach et al., 2018; Langemeyer and Connolly, 2020, and Seigerman et al., in preparation).

Recognitional equity refers to the acknowledgment and respect we must give to people with different life experiences, social and cultural values, and the needs and preferences of different social groups. The articulation of plural values of nature is the core of the UNFF (see Section 2.1). Procedural equity entails the inclusive and meaningful incorporation of multiple voices into the decision-making process. Ensuring inclusive and effective participation requires equitable opportunities for community engagement (Elsawah et al., 2020), for instance, with participatory planning processes taking place at different times and within different locations that are easily accessible by urban residents. Other efforts include opportunities for effective communication, which should also be available to those who speak other languages, invitation of trusted leaders to participate and provide a sense of comfort to others of the community (see Ganthier et al., 2020 and Seigerman et al., in preparation for more practical examples). It is evident that recognitional and procedural equity are interlinked, and the process of developing UNFF visions and scenarios should aim to incorporate diverse values and interests from all groups but also acknowledge and balance power relations in the building process of visions and scenarios (Leach et al., 2018; Langemeyer and Connolly, 2020; Elsawah et al., 2020).

Finally, distributional equity concerns the fair allocation of benefits and burdens among different groups within the city, including current and future generations. Given the focus on societal benefits, Nature for Society futures are well positioned to incorporate distributional equity aspects into scenario building. The literature on ecosystem services increasingly focuses on such aspects (Haase et al., 2017; Yi et al., 2019; Wolff, 2021), illustrating how our understanding of existing inequalities through ecosystem services assessments can help refine policies to reduce inequity (Nyelele and Kroll, 2020; Nghiem et al., 2021). For example, increased access to green developments in the city can be targeted to reduce well-being inequalities of low socioeconomic status neighborhoods (Liotta et al., 2020). While Nature for Nature futures focus on enhancing natural process rather than human well-being, consideration of distributional equity may involve the inclusion of protective measures to prevent green gentrification and displacement of marginalized and vulnerable communities (Anguelovski et al., 2020). Nature as Culture futures may incorporate distributional equity by considering the distribution of benefits associated with relational values: in the examples given in Section 2, this means ensuring that the range of nature manifestations (artistic installations, community gardens, etc.) meets the cultural needs and expectations from diverse groups, including most disadvantaged ones (Borelli et al., 2021).

Applying the urban nature futures framework in practice

There are four key components to the process of visioning urban nature futures: identifying socio-ecological feedbacks, assessing indirect impacts, establishing monitoring framework, and developing scenarios. The application of this framework requires decision processes to be participatory and inclusive by integrating equity aspects (Section 2.3) from the onset into the development of the urban nature futures. Incorporation of recognition, procedural, and distributive aspects of equity should be weaved through the identification of decision levers and indirect impacts of urban pressures, developing and tracking progress towards goals using indicators, and formulation of positive scenarios into the future using qualitative and quantitative evidence, data, and models (Akçakaya et al., 2016; Rosa et al., 2017, Kim et al., in preparation). In the sections below, we elaborate on the four components and their potential implementation within the UNFF.

Identifying and leveraging socio-ecological feedbacks

We often perceive natural landscapes as a culmination of dynamic interactions between human and non-human elements that have been coevolving over millennia. Understanding the feedback mechanisms among policy interventions, biodiversity, and ecosystem services helps to build desirable urban futures (Elmqvist et al., 2013; Bierbaum et al., 2018). Systems analysis approaches can inform formulation of effective policies by identifying important feedback dynamics in the socio-ecological system and leverage points that influence those dynamics (Güneralp and Seto, 2008; Ford, 2009; Raymond et al., 2017). Management decisions by individuals and institutions can thus reinforce those feedbacks that promote desirable changes in the socio-ecological system, producing a virtuous cycle (Tidball et al., 2018). Systems approaches, in turn, can facilitate visioning exercises and the development of transformative pathways scenarios (Wiek and Iwaniec, 2014). Visions, therefore, may be developed strategically, to target specific feedbacks for policy intervention.

Here, we provide two simplified examples of how feedback thinking can inform urban design and planning in relation to human-nature interactions in cities. Such feedback thinking and planning can be stimulated by urban planners and city managers, or by residents and activists themselves. The futures that are envisioned need not be entirely enacted by those in charge. For instance, urban gardens (Fig. 3a), which, besides reducing the ecological footprint of cities, can provide many socio-ecological benefits (Egerer et al., 2020) are an important community-driven initiative within the urban nature futures framework. Increasing areas for urban gardening can contribute to the revitalization of abandoned or underutilized urban land, creating more habitat for biodiversity, supporting climate and air regulation, and also providing recreation and food self-provisioning. The benefits for human health and well-being may attract more gardeners and families and increase socio-cultural movements of urban dwellers engaged in community garden culture, which in turn can foster social cohesion and support both the reconnection of people to nature and to local and traditional food production. Such initiatives improve socio-ecological dynamics, which may mobilize collective agency and influence the development of further positive actions towards more sustainable futures (Bennett et al., 2016; Pereira et al., 2018a). Panel 1 illustrates an example of socio-ecological benefits of urban gardening in New York City.

Another example is the development of bike paths (Fig. 3b), which creates green corridors, enhancing biodiversity, and producing ecosystem services that benefit human well-being. The consequences for human well-being, established by the net benefits for human health across a range of social, physical, and mental outcomes, enhance over time the number of bike users (Macmillan and Woodcock, 2017). As bike paths grow in popularity, their users organize and influence public opinion on bike use, which in turn, increases the demand for bike paths. To accommodate varying preferences of increasing number of bike users, various bike path designs can be utilized to maximize their appeal encouraging an even wider swath of the residents to adopt bike use. While the development of bike paths to some extent develops from the need by residents, urban planners and city managers need to be involved in the process to appropriately plan for these areas, highlighting the need for many actors in the feedback-thinking cycle.

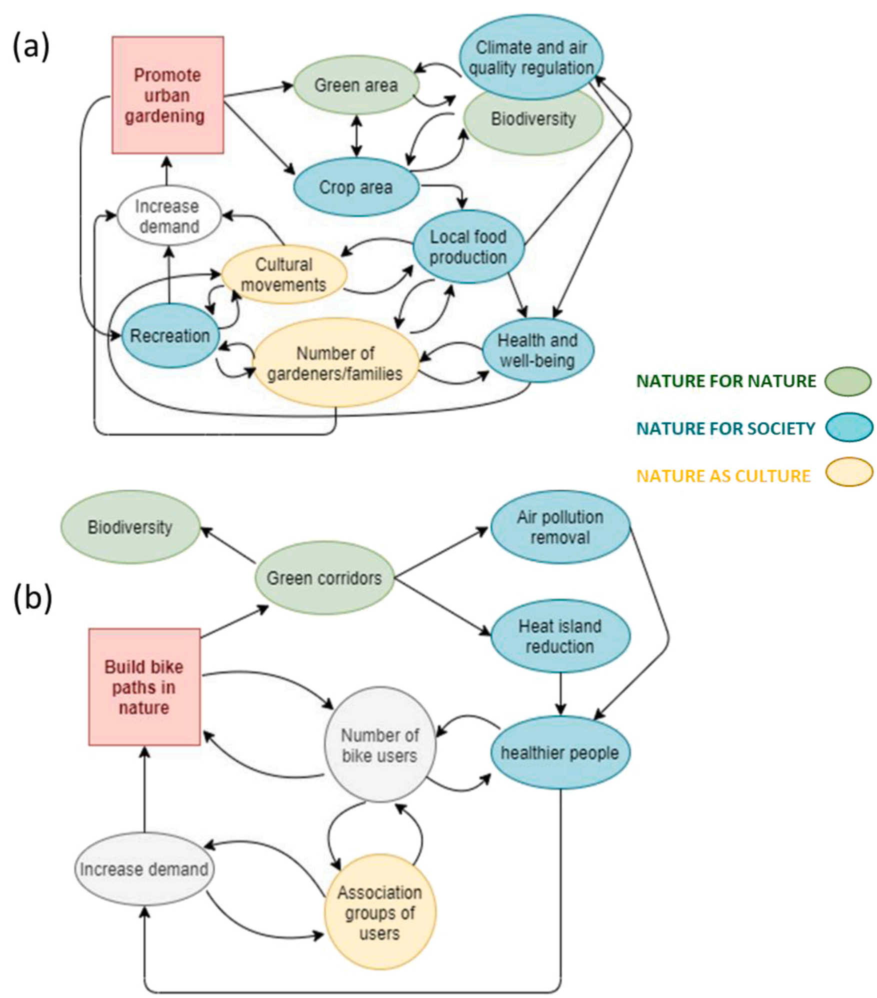

Fig. 3. Examples of socio-ecological feedback loops put in motion through specific policy interventions: a. Socio-ecological feedbacks involving urban gardening. b. Socio-ecological feedbacks involving bike ridership in nature. The different colors illustrate the connections and feedbacks between interventions and Nature Values, based on different Nature Perspectives: Nature as Culture, Nature for Society, Nature for Nature.

Panel 1. Socio-ecological benefits of urban community gardening in New York City

Community gardening in New York City (NYC), United States, highlights the ability of local residents and activists to enact the urban futures framework, and build a bottom-up approach to a more sustainable city living. NYC is one of the most densely populated cities in the world. Community gardening is very popular throughout NYC, with at least 500 community gardens throughout the city (Gittleman et al., 2010). Initiatives such as GrowNYC (https://www.grownyc.org/) have been developed with more than 125 new gardens, at a rate of about 10 new gardens per year, and engage with 3 million residents a year. The majority of gardens begin as vacant lots and are developed through initiatives with local residents (Egerer et al., 2020). While 80% of these gardens grow food, they also contribute to many spheres of the local community, raising awareness on conservation and creating cultural value. Community gardens host many social, educational, and cultural events, including neighborhood and church gatherings, holiday parties, school events, voter registration drives, and health fairs. Such events help to promote social cohesion, for instance in the Latino community of NYC, where gardens are used to educate youth about the value of farming and the Latino culture (Saldivar-Tanaka and Krasny, 2004). Positive benefits for conservation are amplified through community gardening, with many gardens promoting green infrastructure throughout the city more broadly, having zero waste programs, recycling programs, and composting programs. For example, 66% of gardens in NYC practice composting (Gittleman et al., 2010). Community gardens provide many educational benefits, as for example, 43% of community gardens in NYC partner with at least one school (Gittleman et al., 2010). Such positive flow on effects is noted by most NYC residents through tendencies towards decreased litter and increased community pride. As a result of participation in community gardens, 20% of members also engaged in political activism to support the gardens (Saldivar-Tanaka and Krasny, 2004). The spatial dynamics of community gardens throughout NYC can result in a more biophysically and socially connected city (Egerer et al., 2020), but the level of socio-ecological connectivity is heterogeneous, highlighting the ability to strategically plan the placement of future community gardens throughout NYC. This vision highlights the many different nature values associated with the community gardens in NYC, and is meant to be a dynamic and evolving guide for further developments in the area.

Assessing and mitigating indirect impacts from urban activities

Cities are essential nodes within larger, globally interconnected supply-chain networks; however, consumption and production are often spatially disconnected and city consumers are often not aware of the impacts they are having beyond the immediate surroundings of their cities (Deutsch et al., 2013; Marques et al., 2017). Moreover, despite being recognized by the research community (Shih et al., 2020), practitioners and professionals, in general, are not fully aware of the importance of mitigating the impacts of urban development on biodiversity and ecosystem services (Ahmed and Puppim de Oliveira, 2017). These poorly recognized linkages between urban areas and their hinterlands span from perceptions of urbanites about places they may have never or rarely been (typically quantified through willingness to pay, for ecosystem services in distant locations) to physical movement of materials (e.g., mining of raw materials to construct the built environment), people (migration, tourism and lifestyle mobility), and financial resources (e.g., remittances between urban and nonurban places) (Güneralp et al., 2013).

To ensure transformation towards urban sustainability and associated positive nature futures within cities, the indirect impacts of cities on distal places – including those on biodiversity and ecosystems of these places – should be explicitly acknowledged and integrated in their strategic urban policy and planning. These indirect impacts often result from the increasing consumption of a wide variety of resources (food, materials, energy, and water) that are supplied from ever-increasing hinterlands of urban areas (Bellezoni et al., 2021). The various consequences of this rising consumption for biodiversity in distal places should be better understood (Liu et al., 2003; Güneralp et al., 2013; McDonald et al., 2020). It is, however, important to acknowledge the varying levels of consumption among urban residents in developing policy options that target reducing the resulting indirect impacts. Therefore, both the scale and distributional aspects of indirect impacts of rising urban consumption should be explicitly included and accounted for in scenario and model development (Section 3.4).

There are many ways that cities can minimize environmental pressures they place on other places while enhancing nature and human well-being (Woo et al., 2014). These may include, for example, innovating in the use of green and blue infrastructure (Macedo et al., 2021), supplying an increasing proportion of food to markets from urban and peri-urban producers, improving solid waste management through the re-use of by-products of natural resources (Paes et al., 2021), maximizing local renewable energy potential, reintroducing treated water to freshwater systems, conversion of food waste into organic fertilizer, and enhancing ecosystem-services infrastructure that supports local biodiversity (Lucertini and Musco, 2020). In particular, increases in energy and material use efficiencies combined with equitable and healthy high-density urban developments can substantially reduce energy consumption and greenhouse gas emissions (Weisz and Steinberger, 2010; Güneralp et al., 2017). This would require a higher land-use mix and connectivity, with higher residential and employment densities, accessibility, and more energy-efficient buildings and public transportation systems (Seto and Pandey, 2019). Cities may also adopt payment for ecosystem-services (PES), for instance, to protect their water supplies by paying to upstream landowners for good management practices (Salzman et al., 2018). Cities could also compensate producers for shifting to sustainable agriculture practices and organic farming; fiscal transfers between cities and other municipalities may also promote more responsible urbanization and more-effective conservation of biodiversity (McDonald et al., 2008). There is several useful information available that cities can use for practical application (e.g. the United Nations Food and Agriculture Organization provides a useful toolkit as a guidance on how to assess and build sustainable food systems, the C40 Cities initiative provide examples of tools applied in cities worldwide - https://www.c40.org/).

Notwithstanding these examples that illustrate how cities can mitigate indirect impacts, we acknowledge that there will necessarily be different levels of buy-in from a diversity of socioeconomic groups within cities. A challenge for cities and policy makers will be to ensure that the burden of mitigating indirect impacts is equitable among residents of that city, for example, by ensuring large companies placed within cities work proportionately to mitigate their level of indirect impacts. The incorporation of the participatory scenario approaches, such as the UNFF, can facilitate this process as it allows for the use of experimental strategies, test innovates understanding, and require constant and cross-sectoral communication among a diverse set of stakeholders (Elsawah et al., 2020), increasing the voice of various socioeconomic groups in decision-making (see Section 2). Ultimately though, the first step in this process will be to recognize, and quantify, the level of indirect impacts on distal places.

Establishing a multi-scale monitoring framework

Indicators are important tools for tracking progress and quantifying the success of policy implementation. However, measuring the impact of cities - specifically urban planning and management decisions - on biodiversity is challenging because it requires not only a shared understanding of what urban biodiversity or urban "nature" is, but also an identification of the indirect impacts of urban activities (Section 3.2) and recognition that different process play out at multiple time scales,

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which will vary depending on stakeholder decisions and pathways to achieve such urban futures (Elsawah et al., 2020). The myriad of indicators explains diversity of views that exist, each with its own understandings and definitions, including those used in the City Biodiversity Index (CBI, Chan et al., 2014), the Sustainable Development Goals (Target 11.7.1), the City Resilience Index (Indicator 7.3 and 8.1), the System of Environmental Economic Accounting (Wang et al., 2019) and other potential tools and indicators for urban sustainability (Science for Environment Policy, 2018). The current suite of indicators, however, has important gaps, especially those that are potentially relevant for *Nature as Culture* perspective. For example, take the CBI, a self-assessment tool that has been used by more than 30 cities around the world to monitor and evaluate their progress towards biodiversity protection (Kohsaka et al., 2013): The index captures several values associated with *Nature for Nature* perspective (those in the Native biodiversity group, i.e., connectivity measures, change in number of native species, proportion of protected natural areas) as well as several others associated with *Nature for Society* (Ecosystem services indicators, i.e. regulation of quantity of water, climate regulation, recreational and education services). However, comparatively fewer of its indicators are related to *Nature as Culture* (indicators from the governance and management group, i.e., participation and partnership, education and awareness only partially address this component of the UNFF). In addition, most of these existing tools rarely consider the interdependencies of cities around the globe, which make them unable to capture and monitor the indirect impacts of cities on nature at different spatial and temporal scales.

To fill these gaps, cities themselves will need to develop a set of indicators to monitor progress across different neighborhoods and communities within the city. This comprises a more locally inclusive set of indicators that fully captures the diversity of nature views, including the ones reflecting *Nature as Culture* futures, in addition to those indicators that track the tangible indirect impacts of urban activities beyond the immediate surroundings of the city (Section 3.2). For instance, the number of culturally important species, culturally important green spaces (i.e., historic and urban community gardens), or nature-themed events, could all be used to quantify a city's commitment to Nature's cultural values. Critical to this process is ensuring identification of indicators is as inclusive as possible to capture the cultural diversity among the many communities in cities; thus, city managers could promote the participation of a broad range of interested stakeholders, actor groups, governments, conservation agencies, research institutions, community organizations, and citizen scientists by ensuring that procedural equity is integrated into the development process (Section 2.3). In this respect, Urban Biodiversity Hub may serve as a model to build upon with examples of biodiversity monitoring in cities from around the world (https://www.ubhub.org/).

Developing scenarios to generate evidence for decision making and public awareness

Many positive policy-relevant scenarios and tools have been proposed to develop visions and scenarios integrating human-nature interaction in cities in different regions of the world (Table 1). These scenario-based approaches include developing conceptual models, positive visioning combined with qualitative assessments, and/or quantitative modeling. Each of these approaches can incorporate various participatory methods for stakeholder engagement. Some scenarios are centered on the benefits of NBS, quantifying and modeling values associated with *Nature for Society* (examples 1, 3, 4 and 5 in Table 1); others are centered in the intrinsic value of biodiversity, using indicators related to *Nature as Nature* (example 2). In some cases, aspects from three UNFF value perspectives are considered, although scenarios are narrowly targeted to specific policy interventions and do not provide guidelines for broader application (examples 6 and 7). These kinds of positive future scenarios are needed in many cities (McPhearson et al., 2017). However, those frameworks do not provide a comprehensive scenario approach that integrates different perspectives of nature in cities with explicit consideration to trade-offs and co-benefits among contrasting perspectives on nature, including intrinsic, utilitarian, and

Table 1
Examples of policy-relevant scenario approaches used for urban planning and management of nature. The table highlights the method used for scenarios exploration (participative methods with stakeholder engagement, future visions exercises, conceptual model, qualitative assessment, quantitative modeling and analysis of data), presents examples of indicators and metrics used to explore scenarios, and indicates which Nature value perspectives are emphasized, *Nature for Nature* (NN), *Nature for Society* (NS), *Nature as Culture* (NC).

	Name	Approach	Methods and model of scenarios exploration	Example of indicators and metrics	Nature preferences	Reference/source
1	Bay Area Green Print	A tool to plan for biodiversity and ecosystem service provision in San Francisco.	Stakeholder engagement, modeling and analysis	Habitat Connectivity, Water quantity, Food production, Recreation	NN NS	https://www.bayareagreenprint.org/
2	Biodiversity Sensitive Urban Design (BSUD)	A tool to incorporate ecological knowledge into urban planning, design, case studies in Melbourne.	Qualitative assessment, possible to incorporate quantitative modeling	Vegetation cover, proportions of native and non-native species	NN	Garrard et al. 2017
3	Sustainable Future Scenarios (SFS)	Scenarios to explore alternative futures for Phoenix Metropolitan area.	Visions, stakeholder engagement, qualitative assessment, modeling and analysis	Water use and availability, green infrastructure, heat	NS	Iwaniec et al. (2020) https://sustainability.asu.edu/future-scenarios/
4	Stakeholder- and policy-driven scenarios	Scenario approach for a sustainable and resilient future of Rotterdam city.	Stakeholder engagement, visions, modeling and analysis	Recreation, food production, carbon storage, solar energy production, soil sealing	NS	Larondelle et al. (2016)
5	Living Melbourne: our metropolitan urban forest	Strategic plan for a greener, more liveable Melbourne region.	Stakeholder engagement, visions, qualitative assessment, modeling and analysis	Habitat fragmentation, connectivity, water quality, water-sensitivity urban design.	NN NS	https://resilientmelbourne.com.au/living-melbourne/
6	Urban growth Atlantic forest	Positive future scenarios for the urban Atlantic forest, Brazil.	Visions, conceptual model	Species diversity, connectivity, green spaces per person, percentage of impervious surface	NN NS NC	Lembi et al. 2020
7	The Nature Outlook 2050	Pluralistic visions to improve green infrastructure in Flanders, Belgium.	Stakeholder engagement, visions, qualitative assessment, modeling and analysis	Species diversity, air and water quality, biomass, flood risk, carbon storage, food security, safety and social cohesion	NN NS NC	Michels et al. (2019) https://www.inbo.be/en/news/inbo-publication-nature-outlook-2050

relational values. The UNFF proposed here demands such a comprehensive and inclusive scenario development process through a closer examination of socio-ecological feedbacks and indirect impacts of cities on biodiversity.

Using the UNFF, these scenarios should reflect depictions of the main drivers influencing patterns of urban growth, such as urban population and economic growth, with one scenario on a business-as-usual (BAU) that describes the likely future form of cities if human society continues along its current trajectory. Scenarios then can envision pathways that favor (or disfavor) one or more of the nature futures perspectives with different mixes of policy and management options. These scenarios should integrate key socio-ecological feedbacks identified through participatory engagement and include key policy levers for mitigating both direct and indirect impacts (see Elsawah et al., 2020 for discussion on scenario development process). Once put in place, the policy and management interventions can be monitored using indicators throughout the implementation phase (see Kim et al. in preparation for indicators and modeling development process). For instance, there is typically a negative correlation between population density (important for getting the benefits of compact cities, such as lower transportation energy use and hence greenhouse gas emissions) and provision of nature in cities, such as urban tree canopy and open space provision (McDonald et al., 2021; Fuller and Gaston, 2009). However, with careful consideration to green space cover and configuration, a level of congruence between high population (or building) densities and green space accessibility can be achieved (Seto et al., 2014; Fan et al., 2019; Wolff and Haase, 2019). Understanding and quantifying these potential tradeoffs are important for urban planning and management decisions.

Conclusion

For the urban century to prosper, it will demand new approaches that bring back nature to the cities, recognizing the diverse values and views people have over nature. This implies a formulation of commitments and efforts with explicit attention to how cities can contribute to conservation. Recognizing the capacity of urban planning and management to support biodiversity conservation throughout all the post-2020 biodiversity targets would be a good start (CBD, 2021). For example, reducing pollution from urban sources by enhancing green and blue infrastructure in cities, integrating diverse biodiversity values into urban policy and planning, and ensuring that the indirect impacts from urban activities on biodiversity are monitored and mitigated, could potentially contribute to achieving these targets (Target 6, 11 and 14 respectively). This will also require technological advances that are aligned with policy solutions at multiple scales, cross-sectoral dialog and coordination among governments. Stakeholders in cities need frameworks and tools to incorporate nature in the envisioning and planning of the future of our cities in its various dimensions. In this regard, the UNFF is an important organizing framework that can effectively be used to co-design positive Nature Futures for cities, with the ultimate goal of charting a course to a greener, sustainable, and more equitable urban century.

CRediT authorship contribution statement

H.M.P. initiated the idea and conceptualization of this work. A.V.M., H.M.P. and R.I.M. organized the workshop and led this project. A.V.M. coordinated and wrote the manuscript with inputs from all authors and special contributions from R.I.M., B.G. and H.J.K. All co-authors were participants in the workshop and contributed to the conceptualization of this manuscript. R.I.M. and H.M.P. coordinated project administration and funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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