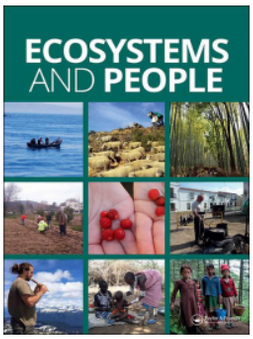

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REVIEW

Urban oases: the social-ecological importance of small urban green spaces

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ABSTRACT

Global challenges around biodiversity loss, climate change, and public health are heightening the importance of urban green spaces for supporting ecosystem services and human wellbeing. Trees, parks and forests integrated across cityscapes are proposed strategies to combat climate change and promote human health for current and future cities. This is true for small urban green spaces, perhaps just $\leq$ 1 ha in size. Depending on their structure and size, these spaces can provide structural vegetation complexity, promote species diversity, regulate temperatures and offer human thermal comfort. These spaces also provide recreation opportunity, nature experience, sense of belonging, and restoration to people. As cities densify, it is crucial to understand where these dimensions intersect in theory and practice to design and manage small green spaces in particular, as these systems may be easier than large green spaces to implement in urban planning. In this paper, we narratively review known biophysical and ecological properties of green spaces that support biodiversity, promote temperature regulation and climate resilience, and may ultimately benefit residents' health through different use activities and multisensory experiences that promote restoration and wellbeing. Furthermore, we review how stakeholder engagement and participatory processes can guide equitable green space provision and design, and we use case studies and our own research as examples. In doing so, this paper aims to further the understanding of the social-ecological importance of small urban green spaces and calls for inter- and transdisciplinary research that generates insight to design, manage and protect these places in a changing climate.

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Introduction

The growth and densification of cities drive massive changes to the biophysical environment and urban life (Kleerekoper et al. 2012; Habeeb et al. 2015). As cities densify and urban green spaces are lost, heat intensifies (Kaye et al. 2006), biodiversity generally declines (McKinney and Lockwood 1999; Hahs et al. 2009), and air quality decreases (Haase et al. 2018), all of which harms human health and wellbeing (WHO 2016). Cities will be particularly affected by the impacts of climate change due to longer periods of heat, drought and heavy precipitation (Mansur et al. 2016; Hobbie and Grimm 2020; Perera et al. 2020). In addition, cities face public health challenges related to increasing anonymization and social isolation that contribute to rising rates of mental illness and reduced psychological and social wellbeing of residents (Lai et al. 2021; Astell-Burt et al. 2022). With ongoing global rural exodus, these effects will likely impact more people in the future than today. Thus, global urbanization and climate change presents new challenges to governing urban ecosystems and urban landscapes that are simultaneously climate resilient, biodiverse and supportive of human wellbeing (Hunt and Watkiss 2011; Ossola and Lin 2021).

Urban green spaces including, among others, urban parks and forests (Beatley 2017; Andersson et al. 2019), will continue to gain social-ecological importance for combating climate change and creating health-promoting strategies for current and future cities (Flies et al. 2017) – for example via thermal cooling and the opportunity to spend time in and experience a (semi-)natural green environment (Hartig et al. 2014; van den Bosch and Sang 2017; Africa et al. 2019; Hobbie and Grimm 2020). Depending on their vegetation structure and size, urban green spaces can contribute to temperature regulation (Kong et al. 2014; Aram et al. 2019) and thermal comfort (Aram et al. 2019). Furthermore, the ecological significance of urban green spaces is linked to biodiversity via species diversity, structural complexity of the vegetation and the conservation of rare species (Threlfall et al. 2017). Their social significance has been linked to recreation opportunity, nature experience, senses of place and belonging and overall

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wellbeing (Shanahan et al. 2015). The health promoting potential of urban green spaces is not limited to the experience of visual aesthetics, but extends to auditory, olfactory, and haptic stimuli (Franco et al. 2017; Marselle et al. 2021). However, urban green spaces can also have negative implications for public health if, for example they are comprised of allergy promoting species or diverge from people's preferences for aesthetic or social reasons, leading to non-use or discomfort (Ferrini et al. 2017). City planners thus need to balance potential ecosystem services and disservices of urban green spaces (Blanco et al. 2019; Baumeister et al. 2022). As residents perceive disservices and value services differently, navigating such trade-offs is highly complex and requires direct engagement with communities (Drillet et al. 2020).

The growing demand for climate regulation, biodiversity conservation, recreation, nature experience and wellbeing in cities worldwide can be partly achieved through a network of connected, multifunctional and biodiverse small urban green spaces (Hansen and Pauleit 2014). Currently, there is no consensus on the definition of small urban green spaces, and specifically what spatial scale defines a 'small' space. Studies on urban public green space concepts such as 'pocket parks' (Peschardt et al. 2012) and 'pocket green spaces' (Wu et al. 2021) have defined small green spaces as those ≤1 ha to those ≤2 ha in size in urban and suburban areas (Currie 2017; Amaya-Espinel et al. 2019; Wu et al. 2021). We perceive these small spaces to play a critical role in our growing, increasingly warmer cities; many small green spaces, compared to just one large green space, may be key for nearby restoration and social interaction (Nordh and Østby 2013), but also critical as promoters of biodiversity and microclimatic cooling that amplifies at the landscape scale (Chang and Li 2014; Rosso et al. 2022). Although small in size, these spaces can have high resident visitation rates (Peschardt et al. 2012), cooling effects (Lin et al. 2018) and act as stepping stones for people and mobile organisms (Delgado-Capel and Cariñanos 2020) (Figure 1). Small urban green spaces can be effectively, collaboratively and equitably integrated into the urban landscape (Rosso et al. 2022) to promote 'land sharing' (i.e. an integrative land-use approach with many distributed and multifunctional green spaces) rather than 'land sparing' (i.e. a segregated land-use approach with few and large green spaces that maximize one function) (Uchida et al. 2020) to optimize benefits for all residents. Most people often live in dense areas where large green spaces are not necessarily well spatially distributed to have equal access to all residents (Kabisch and Haase 2014; Haase et al. 2017). Thus, small urban green spaces could promote benefits to those residents who suffer disproportionately from environmental

Figure 1. Urban green spaces are important for: climate change mitigation through shading and vegetation structural complexity (a: Hans-Fischer-Straße Park in Munich, Germany); biodiversity of plants and animals, arthropods and birds (b: spider web in field in Taxispark in Munich, Germany); and human health and wellbeing through stress release and restoration (c: woman sitting under the shade of a tree in Charleston, USA), and through and recreation and socializing (d: group meeting for Tai Chi exercises in a park in Taipei, Taiwan). Photo credits: Sophie Arzberger (a), Vera Knill (b), and Monika Egerer (c, b).

degradation, nature disconnection and structural barriers to both experiencing nearby green spaces and active participation in green space governance.

Surprisingly, a strong base of inclusive and equitable inter- and transdisciplinary perspectives and validated practical tools to explore the functions of small urban green spaces are still missing in urban ecosystem research, urban green space planning and public health governance. Thus, we still lack diverse and collaborative approaches to enhance the functions of small urban green spaces. We argue that a nuanced understanding of synergies between biodiversity conservation and climate change adaptation goals with the social functions and meanings attached to small urban green spaces can support a more vertically and horizontally integrated public green space and health governance of cities.

In this paper, we narratively review, situate and elevate the central work on the social-ecological importance of small urban green spaces – what we consider 'urban oases'. We advocate for the disproportionate value of such small spaces through accumulation effects at the landscape scale, based on evidence from related contexts (e.g. conservation biology). Our focus lies specifically on how small urban green spaces can: (1) act as habitats for biodiversity by providing food and shelter across the urban landscape; (2) improve temperature regulation through shade provisioning or evaporative cooling; (3) promote human wellbeing as nearby places for people to experience nature, socially interact, mentally restore and be physically active; and (4) facilitate community engagement in equitable green space design and provision. In doing so, we highlight current and missing knowledge to appeal for future spatially integrated research that investigates the effects of small urban green spaces on the biophysical and social environment in terms of urban climate, biodiversity, human health and wellbeing. In addition, in using an example from our own research in Munich, we call for transdisciplinary research that can identify how the social and ecological structures, functions, and thus significance of small urban green spaces relates to these factors so that impetus can be given to the protection of existing and the creation of new oases for urban human dwellers and other species.

Small urban green spaces are important for biodiversity and conservation

Conservation initiatives have historically neglected the value of small habitat patches in landscapes for biodiversity conservation, despite their disproportionately high value for species conservation compared to large patches of equal area (Riva and Fahrig 2022). Single large or several small (SLOSS) comparisons show that overall, adding several small patches to a landscape can promote biodiversity through species accumulation effects, more so than protecting a single habitat of equal area (Riva and Fahrig 2023). In cities, the SLOSS 'dilemma' has similarly divided views on best practices in conservation initiatives (Lin and Fuller 2013; Soga et al. 2014; Collas et al. 2017). Large, relatively intact or semi-natural urban green spaces are important for maintaining populations of plants and insects (e.g. Soga et al. 2014; Plancheulo t al. 2019). However, small urban green spaces distributed across the urban landscape can also support both managed and spontaneous taxonomic and functional diversity of plants and animals through the provisioning of e.g. flowering trees and shrubs for food (Hausmann et al. 2016), and native vegetation for shelter (Chace and Walsh 2006).

Urban SLOSS research shows that the ability of small urban green spaces to support biodiversity likely depends on the habitat characteristics of the space itself, as well as the level of urbanization surrounding the space. The diversity of plant species, as well as the structural complexity (or 'habitat heterogeneity', e.g. canopy cover, tree height, layers of vegetation) of the green space, determine the diversity of animals (Threlfall et al. 2017; Kaushik et al. 2022). For example, within small urban green spaces, bird species richness is positively affected by higher vegetation cover and the abundance of old and coniferous trees, and by deadwood (Fernández-Juricic and Jokimäki 2001; Sandström et al. 2006; Husté et al. 2016; La Sorte et al. 2020). Increases in understory vegetation volume within small green spaces promotes bats, native birds, beetles, and other arthropods, and more native vegetation overall positively associates with all native taxa (Threlfall et al. 2017).

Often urban green spaces are highly diverse because they are horticulturally maintained and have been stocked with diverse plant species to make green spaces attractive to the public; thus, species with different origins have long been cultivated within them (Kowarik 2023). This patch-level species diversity can thereby accumulate across the landscape. From a landscape perspective, small urban green spaces are proposed stepping stones across a city landscape particularly for arthropods (Vergnes et al. 2012). LaPoint et al. (2015) suggest that small urban green space connectivity may be an important determining factor for realizing species conservation. This means that 'several small' may only work for biodiversity conservation if small urban green spaces are not isolated, but rather well integrated and connected within a network of small green spaces (Soga et al. 2014).

Thus, to conserve urban biodiversity, small green spaces must be abundant, connected, mature, well

vegetated, and rich in trees and shrubs. Yet open questions remain as to what drives the value of small urban green spaces for biodiversity conservation. For example, plant nativeness may or may not support more bird species in small urban green spaces (Threlfall et al. 2017). New studies are needed that focus specifically on small urban green spaces and their contribution to gamma biodiversity through alpha biodiversity. Few studies specifically consider urban green space size or assess multiple characteristics of small urban green spaces (e.g. tree age, native vegetation or understory structure) to inform biodiversity conservation management. This leaves open questions such as: Is there a minimum threshold of small urban green spaces in terms of number of green spaces and size of green spaces to support diverse species across a landscape? What is the added benefit of adding or restoring even small spaces in addition to existing urban green space? Which characteristics such as connectivity, structural complexity, floral diversity or water bodies can be considered in the design and management of new or restored urban green spaces (Nielsen et al. 2014)? In addition, studies are needed with broader taxonomic representation within small urban green spaces across diverse geographic regions to understand patterns of biodiversity (Rega-Brodsky et al. 2022). Lastly, we are still missing evidence-based practical management recommendations and interventions that balance human needs with the needs of other species within small green spaces (Aronson et al. 2017). This is because often research from the social perspective (e.g. assessing people's perceptions of biodiversity within space) do not quantify or assess biodiversity within the space to make a link between the two (Lai et al. 2019). Shared terminology as well as indicators are yet to be established for these types of studies (Houlden et al. 2021).

Small urban green spaces can mitigate urban heat and climate change impacts

Air and surface temperatures in cities and urban landscapes are generally higher compared to the rural surroundings (Oke et al. 1989), also known as the urban heat island effect. The magnitude of urban heat island depends on the large-scale climatic conditions and local-scale urban morphology (Manoli et al. 2019), and is expected to intensify as a consequence of global warming and urban densification (Sachindra et al. 2016; Huang et al. 2019). A commonly proposed strategy for urban climate change mitigation is increasing vegetation cover (Mackey et al. 2012; Gago et al. 2013).

Green space connectivity and urban canopy cover plays a key role for urban biodiversity conservation, and also for the neighborhood-scale microclimate. Similar to the SLOSS idea around biodiversity conservation, groups of smaller urban green spaces, including public parks, roadside greenery and residential lawns can collectively have a large combined impact on the thermal regime of a city, though these compounding cooling effects are underexplored (Park et al. 2017; Aram et al. 2019). Especially residential yards can play a significant role for urban heat mitigation because a high proportion of urban green is often located on privately owned land (Ossola et al. 2018). A canopy cover of more than 40% within the built environment can maximize the vegetation cooling effect (Ziter et al. 2019; Rahman et al. 2022). For larger parks ≥10 ha, the cooling effect can disperse several hundred meters into the surroundings, while for smaller parks ≤2 ha in size, the cooling distance rarely exceeds 100 m (Jaganmohan et al. 2016; Aram et al. 2019). Gallay et al. (2023) argue that the magnitude of the cooling effect on the surroundings largely depends on the presence of trees within the green space. The vegetation structure can – to some extent – surpass the influence of greenspace size (Gallay et al. 2023). Thus, well-distributed and well-structured small urban green spaces are most beneficial for the thermal regime on neighborhood-scale and potentially more important for urban heat mitigation than individual large parks.

In addition to having a good network of homogeneously distributed urban green, it is therefore necessary to understand how small green spaces can be designed and managed to achieve the maximum possible cooling effect. The cooling potential of a green space depends on its design and shape (Jaganmohan et al. 2016), on the structural composition of the vegetation (Cohen et al. 2012; Kraemer and Kabisch 2022) and the tree's species-specific cooling capacity (Rahman et al. 2017, 2020). The vegetation cover in urban green spaces is often spatially very heterogeneous causing spatial differences in the cooling effect. Kraemer and Kabisch (2022) reported temperature differences of up to 2°C for shaded vs. non-shaded parts of an urban green space with a limited cooling effect for non- shaded areas of green spaces during summer heat conditions. However, the open space prevents heat retention during the night and allows air flow into the neighborhood surroundings (Zardo et al. 2017). Kraemer and Kabisch (2022) thus advocate for the 'savannah approach' associated with the 'Savannah Hypothesis' (Batterbury and Bebbington 1999), which proposes that structurally diverse parks with a combination of mature trees and open grasslands can optimize microclimatic regulation effects. Chang and Li (2014) suggest that green spaces should be designed with more than 30% tree and shrub cover, and less than 50% impervious surface (Chang and Li 2014). Yet, it is largely unknown how the green space size influences the cooling efficiency of different park

designs. Understanding the size-dependent differences is crucial for making reasonable planning recommendations for future urban green space management to be most beneficial on a neighborhood-level where small green spaces can be best implemented for social and planning purposes. Furthermore, it is important to consider that designing parks explicitly for cooling and regulation services (e.g. prioritizing increased tree cover) may both reduce other benefits, for example cultural services derived from open space for recreation, and also synergize with other benefits, such as creating habitat for some wildlife.

Small urban green spaces are resources to promote mental, social and physical human wellbeing

Next to their ecological importance, well distributed and accessible small urban green spaces can support various dimensions of human health, here defined as 'a state of physical, mental, and social wellbeing and not merely the absence of disease or infirmity' (Larson 1996). Benefits include therapeutic and preventative value in view of mental health disorders, sedentary lifestyles, lack of positive social relationships, endured distress (Lee et al. 2012; Chau et al. 2013; Valtorta et al. 2016; Erzen and Çikrikci 2018), as well as diseases such as Type II diabetes, stroke and coronary heart disease (Twohig-Bennett and Jones 2018). Visiting urban green space in general has been connected with decreased stress levels, increased cognitive capacity, improved restoration, and better overall subjective wellbeing (Hartig et al. 2003; Ojala et al. 2019; Reyes-Riveros et al. 2021; Liu et al. 2022). Experimental studies have found that stress recovery was higher in urban park and woodland treatments compared to an urban street treatment (Tyrväinen et al. 2014; Van den Berg et al. 2014). For example, after watching a stressful video, negative mood of participants first increased (from a mean value of 1.84 ± 0.47 points to 2.33 ± 0.79) but then decreased after exposure to an urban parkland video treatment (1.51 ± 0.52) (Van den Berg et al. 2014).

Small urban green spaces can promote healthy behaviors including physical activity and social interactions. Both are positively associated with the availability of nearby small urban green space that offers features and functions perceived as attractive (e.g. safety, multisensory aesthetics, thermal comfort) and accessible by people (Wang et al. 2022). A strong sense of community has been negatively associated with subjective distance and positively associated with subjective quality of small urban green spaces. Moreover, the positive relationship between physical activity and perceived neighborhood safety was mediated by social cohesion in a sample of Californian mothers (Jennings and Bamkole 2019; see also Yuma-Guerrero et al. 2017). Levels of psychological distress were lower in city landscapes with many small urban green spaces compared to landscapes with few large green spaces (Ha et al. 2022).

The availability of many small green spaces that are densely distributed across a city landscape, as well as a high diversity of urban green types, can increase people's levels of life satisfaction to contribute to overall wellbeing (Wu and Chen 2023). Long green space visits can lower rates of depression and more frequent visits can improve social cohesion (Shanahan et al. 2016; Jennings and Bamkole 2019). Arguably, long, and frequent visits are easier to integrate into daily life when e.g. small 'pocket parks' are located close to one's home; many evenly distributed small urban green spaces across neighborhoods and a city landscape could be more accessible (reachable) for more city residents compared to a few large urban green spaces in a city landscape, thereby improving equitable and just human wellbeing effects. Hence, many small urban green spaces located in proximity to people's homes can provide similar positive wellbeing outcomes as few larger urban green spaces (Allard-Poesi et al. 2022). Yet, the effects of small urban green space parameters, e.g. in terms of specific built or natural features, spatial arrangements and climatic conditions, and the pathways linking these relationships are still largely unknown.

How long and how often a person experiences a green space, what a person does there, how they experience it and how they feel there, may in part be determined by individual factors, but in part also by structural characteristics (e.g. tree density), biodiversity (e.g. perceived bird diversity) and microclimatic conditions within the space (Dallimer et al. 2014; Marselle et al. 2021). While much research on nature experience focuses on the visual sense, the capacity of a green space to promote wellbeing occurs through multisensory pathways (Houlden et al. 2021; Marselle et al. 2021). Natural sounds are increasingly recognized as relevant to experience comfort and restoration (Ode Sang et al. 2022). Multiple sensory impressions, their interaction and the related experiences of (dis)comfort can be pivotal to obtain health benefits and also influence visitation rates to public green spaces (Nitidara et al. 2022; Rosso et al. 2022). For example, while both natural sounds such as bird song (Hedblom et al. 2019; Buxton et al. 2021; Fisher et al. 2021), and pleasant smells from flowers (Hedblom et al. 2019), can lower stress levels, improve mood, and increase perceived restoration, thus more likely attracting regular visits, surrounding traffic noise, smell from waste and low shading capacity might be perceived as disturbances and repel people from using a space. Thus, investigating the relevance of perceived shelter or 'buffering' effects, provided by vegetation and causing an 'oasis effect',

might be of particular value to explore for small spaces where visitors are more directly exposed to adjacent gray structures. In this context, investigating perceived songbird diversity alongside measured songbird diversity could be a promising way to predict the health promoting potential of a small green space, as it has potential to indicate levels and forms of structural complexity, habitat quality, and a soundscape that is considered pleasant and attractive to people.

Mechanistic frameworks on why and how nature may support human health (e.g. Hartig et al. 2014; Frumkin et al. 2017; Bratman et al. 2019; Marselle et al. 2021) theoretically integrate relationships between experience and exposure of nature and human health, with some considering nature as a generic concept and others specifically considering urban green space types or biodiversity. These frameworks can streamline and guide transdisciplinary research in public health and urban planning to enhance the currently limited mechanistic understanding of individual pathways through which different forms of experience with and exposure to particular green space features and conditions (biodiversity, microclimate conditions) affect multiple aspects of human health. As demands rise for green spaces to become more multifunctional in the face of population growth, densification and climate change, such causal models must be tested and adapted at the community level to guide the design and distribution of many small mono- and multifunctional urban green spaces as part of larger green infrastructure.

While the above-introduced relations between urban green spaces and wellbeing are associated with human-nature interactions, they are also strongly related to the planned and spontaneous social encounters facilitated by green spaces (Holtan et al. 2014; Jennings and Bamkole 2019; Wang et al. 2022). Small urban green spaces that are perceived by people as available, accessible, and attractive can foster bonding processes, including processes of self-identity building and attachment to the natural and social environment in the neighborhood. These processes transform neutral spaces into meaningful places that serve emotional, health relevant functions for people (Chemero 2010; Stedman 2011; Menatti and Da Rocha 2016). These functions may be more or less strongly perceived as place dependent among people. Thus, the processes of attributing subjective relational and functional values, bonding experiences, and identification processes with a place must be understood to design or maintain small green spaces with attributes (e.g. size, shape, structures, location, climatic conditions) that are used and beneficial to residents' subjective wellbeing. We argue that a spatially integrated, interdisciplinary understanding of the context in which small urban green spaces are developed and managed is necessary to ensure their social-ecological fit in a neighborhood.

Small but powerful: transdisciplinary pathways forward to promote small urban green spaces for equitable health, biodiversity, and climate resilience

Interdisciplinary analyses and inclusive engagement of diverse community representatives are needed for small urban green spaces to have the potential to effectively integrate into the neighborhood fabric as activating, recreational, nature-connected, and community-building places for diverse people over the long term and under changing conditions. A transdisciplinary research approach that engages neighborhood-level communities in the processes of analyzing, designing, and managing small urban green spaces can play a transformative role in the citywide promotion of human health, biodiversity, and climate resilience. Several examples exist of mixed-method approaches in community- or neighborhood-based small urban green space research. For example, in the 1960s USA, 'pocket parks' became places of community cohesion, biodiversity promotion and environmental restoration (Babalis 2020). In contemporary Krakow, Poland, the city administration has favored such 'pocket parks' as easy to integrate, small-scale solutions for biodiversity and human health (Labuz 2019). In Mediterranean cities, citizen science approaches, in which city residents contributed to data on invasive plant species within pocket parks, is used to maintain and monitor park conditions to reduce management costs and enhance the quality of nature experiences (Rosso et al. 2022). Structured and institutionalized community engagement in environmental monitoring can produce data on biophysical changes as well as offer social, mental, and physical health benefits for the citizen scientists themselves (Williams et al. 2015). A unique form of citizen science is a 'Citizen Observatory'– a long-term, community-based environmental monitoring and information system (see: https://www.weobserve.eu/about/wo/). Citizen Observatories integrate engagement 'levels' from working with people to sense environmental conditions (Haklay 2013) to participatory data analysis and their interpretation in dialogues around urban transformation among residents, researchers, practitioners, and policy makers. Citizen Observatories are thus a form of 'Living Labs' that aim to establish communication and ongoing exchange between different actors and create evidence for advocacy and place-based decision-making (Veeckman and Temmerman 2021). Three Belgian cities have implemented Citizen Observatories to collaboratively discuss air quality, noise pollution and heat stress (https://cordis.

europa.eu/article/id/413410-co-designing-citizen-participation-in-environmental-monitoring). The Swiss National Landscape Monitoring Program (LABES 2018–2020) also proposes to engage residents in the monitoring of landscape scale environmental changes as well as surveying their perception of changes and current use, satisfaction and wellbeing related to their neighborhood environment (Wartmann et al. 2021).

Building on such work, our research in Munich, Germany, tests the hypothesis that many, well-distributed and connected small urban green spaces have the potential to reconcile objectives around climate resilience, biodiversity promotion and preventative public health in cities. We ask: 1) How do different vegetation compositions and structures of urban green spaces affect their microclimatic aspects, and how does green space size influence in these relationships? 2) How do these biophysical characteristics of small urban green spaces relate to human use and related wellbeing benefits (e.g. restoration, nature connection)? 3) What do people need from small urban green spaces in the context of climate change and public health promotion, and what are recommendations for the equitable design and management of small urban green spaces?

We use a transdisciplinary approach, in which we integrate the lived experience of residents through citizen science and expert perspectives through Living Lab formats. We use qualitative and quantitative methods from forest sciences, climatology, ecology, environmental psychology and human geography. We believe that mixed-methods approaches are best fit to quantify relations between a set of green space characteristics (structural vegetation complexity, tree and bird diversity), microclimatic cooling effects and their relevance for human wellbeing (Figure 2). We present a brief summary of our transdisciplinary approach, some preliminary findings, and an outlook on how we aim to relate social and natural science perspectives to one another.

Our research focuses on 35 public urban green spaces divided into 61 plots that represent a gradient in vegetation structural complexity and green space size. Within these plots, we measure songbird diversity, microclimatic cooling effects and vegetation structure metrics as a baseline. These plot-based findings will be linked to a neighborhood analysis to not only identify how local cooling effects are influenced by the vegetation in the plots but also how the microclimatic cooling is linked to the spatial distribution of the green spaces and the overall 'greenness' of the neighborhood. We work with a mix of quantitative and qualitative empirical social research methods to assess the role of these green space characteristics for human restoration, nature connection, sensory comfort and preventive behaviors that predict people's wellbeing, relative to the assessed biophysical, ecological and climatic factors.

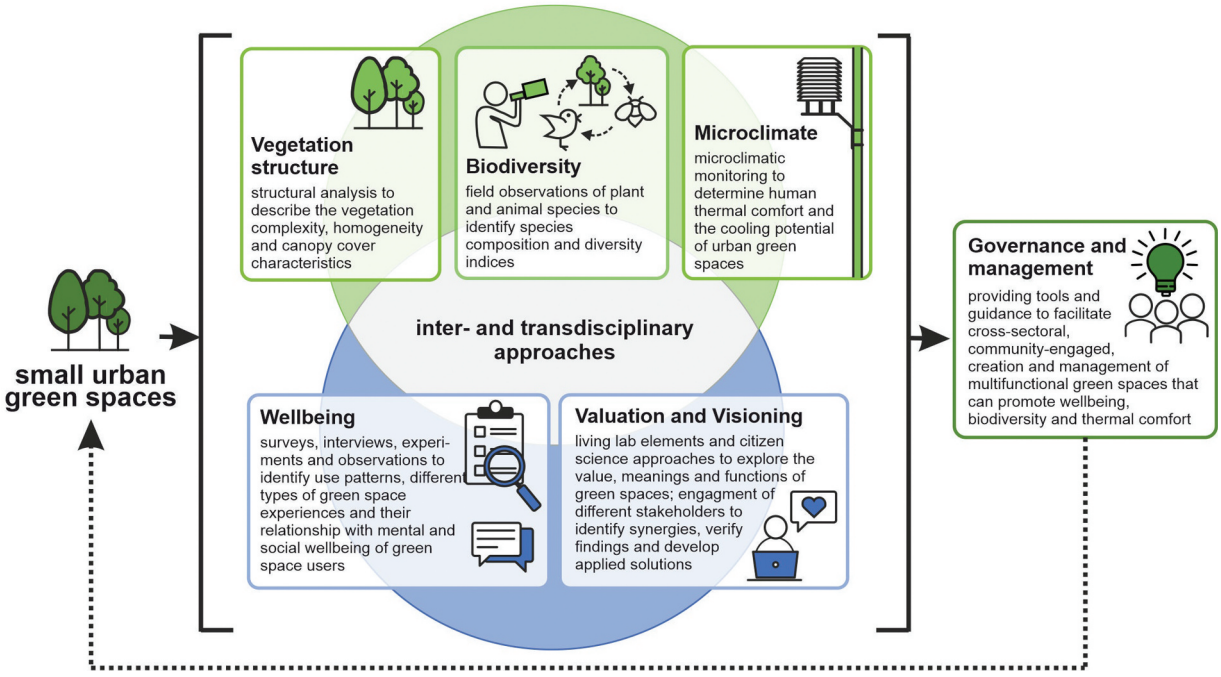

Figure 2. Small urban green spaces must be examined from diverse perspectives including from ecology and conservation, climatology, environmental psychology, public health and participatory research to in turn inform governance and management at the local neighborhood level and the city planning level. In our research in Munich, Germany, we use inter- and transdisciplinary approaches and illustrate how ways of combined data collection from natural and social sciences, enriched with participatory formats can provide guiding tools relevant to stakeholders across different sectors. Graphic by Sophie Arzberger.

We engage people throughout the research process using different 'levels' of citizen science (Haklay 2013) and participatory formats, such as online crowdsourcing of 'urban oases', thermal comfort walks, participatory mapping and visioning workshops. All of this data will be overlayed in an online map to provide a spatially explicit tool for actors in the public health department, planning department, and for the broader population. Our work will explore potentials for strengthening links between research, civil society, policy and practice for long-term collaboration at the neighborhood level to support an integrated and inclusive process for small urban green space design and health promotion.

Conclusion

We understand small urban green 'oases' in our cities and towns from transdisciplinary perspectives. Quality urban green is generally beneficial for cooling our neighborhoods, supporting biodiversity, and boosting our health and wellbeing. Yet, there are still several pathways mediating the role of urban green spaces under climate change and public health crises that remain relatively unclear in research and practice, particularly for small urban green spaces. Investigations must examine the relationships between small urban green space characteristics and structures to various diversity parameters, meteorological variables, and perceived psychological, social and physical effects on human wellbeing. As many cities are setting targets to green their cities under climate change and social change – e.g. achieve carbon neutrality, increase green infrastructure, promote urban rewilding – small urban green spaces can be critical nature-based solutions to achieve these goals and realize a healthy urban future. Inter- and transdisciplinary research that works with urban communities and across thematic silos are paramount to implement robust approaches that promote human wellbeing, biodiversity, climate protection and thus, the social-ecological resilience of cities.

Disclosure statement

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