frontiers | Frontiers in Sustainable Cities

TYPE Mini Review
PUBLISHED 25 March 2025
DOI 10.3389/frsc.2025.1562066

OPEN ACCESS

EDITED BY
Prashant Kumar,
University of Surrey, United Kingdom

REVIEWED BY
Tanya Mangion,
Norwegian University of Science and Technology, Norway
Lukas Beuster,
Delft University of Technology, Netherlands

*CORRESPONDENCE
Sara Lenzi
✉ sara.lenzi@deusto.es

RECEIVED 16 January 2025
ACCEPTED 06 March 2025
PUBLISHED 25 March 2025

CITATION
Lenzi S, Sádaba J and Retegi A (2025) Climate adaptation in urban space: the need for a transdisciplinary approach.
Front. Sustain. Cities 7:1562066.
doi: 10.3389/frsc.2025.1562066

Climate adaptation in urban space: the need for a transdisciplinary approach

Sara Lenzi[1,2]*, Juan Sádaba[3] and Aiur Retegi[1]

[1]Deusto Design Research Group, Faculty of Engineering, University of Deusto, Bilbao, Spain, [2]Ikerbasque Basque Foundation for Science, Bilbao, Spain, [3]Department of Architecture, University of the Basque Country, San Sebastián, Spain

Climate change demands innovative and holistic approaches to urban design that address both the tangible and intangible challenges posed by a rapidly evolving environment. This article explores the necessity of a transdisciplinary approach to climate adaptation in urban spaces, emphasizing the integration of architecture, social innovation, more-than-human design, and multisensory analysis. We examine the current approaches and controversies of architectural and urban solutions to climate adaptation. Drawing on the state-of-the-art from key fields, we discuss the potential of Nature-based Solutions, co-creation practices, and multimodal design to create adaptive urban spaces that address the physical, emotional, and social needs of human and more-than-human inhabitants. The article reviews emerging frameworks and case studies, including climate shelters, biodiversity-inclusive design, and the integration of soundscapes and smellscapes, to demonstrate the importance of considering diverse perspectives and stakeholders. By synthesizing these findings, we propose an integrated design framework for climate adaptation that moves beyond traditional architectural approaches by overlapping intangible layers of social awareness, ecological diversity, and cultural sensitivity.

KEYWORDS

climate adaptation, climate shelters, urban space and architecture, more-than human, multispecies, multisensory, soundscape

1 Introduction

One of the main challenges in city design lies in a misalignment between the rhythm to which urban space as an artificial human and more-than-human ecosystem evolves, and the often-abrupt transformative pace at which the socio-political, cultural, and emotional experiences of its inhabitants enfold. Urban planning regulations, which tend to operate in a top-down manner and require consensual approval through well-defined legal and political procedures, prevent a prompt response to the city's situation as a living evolving entity (Rius-Ulldemolins and Klein, 2020). The concept of resilience is, in some ways, contrary to the normative essence and inflexibility of urban planning (Yang et al., 2020). Today, this misalignment is worsened by the unprecedented and uncontrollable progression of climate change. Regulators, experts, and citizens are faced with the potentially catastrophic consequences of sudden climatic events which are pushing the boundaries of existing urban planning strategies and interventions in the city. New approaches are emerging that advocate for novel strategies to counteract the effect of climate change by pivoting how we look at the city space. These strategies include the design of permanent or temporary climate sheltering, multispecies integration, and multisensory perceptual awareness of the urban space. While some disciplines are already

structured to tackle the complexity of the city (e.g., architecture, urban design, social innovation), others (e.g., design research, soundscape studies) are pushing their boundaries or reframing priorities in the awareness that climate adaptation is key to the survival of human, and more-than-human, societies. But how can these emerging, domain-specific approaches contribute to defining a new transdisciplinary framework toward successful climate adaptation interventions in the urban space?

To answer this question, we explored emerging approaches to identify gaps and opportunities in current solutions. In Section 2, we report on the definitions and current controversies on climate change adaptation. In Section 3, we review emerging research in four key areas that are dealing with climate change and our response to it: architecture and urban design, social innovation, more-than-human design, and multisensory design. In Section 4, we highlight current gaps and potential future strategies to improve the functional and social adaptability of cities to the consequences of a changing climate.

2 Background: climate change and climate change adaptation

Although awareness of changing climate conditions already emerged in the 19th century, it was not until the late 20th century that the first World Climate Conference (1979) recognized the need for society to prepare for climate instability at large scale. At the time, however, mitigation, i.e., the possibility to slow the progress of climate change by reducing the anthropic impact on the environment, was the primary focus (World Meteorological Organization, 1979). The establishment of the Intergovernmental Panel on Climate Change (from now on, IPCC) in 1988 further highlighted the necessity of adaptation, with its early reports acknowledging that some impacts were unavoidable (IPCC, 1990). By 2007, the Fourth Assessment Report (AR4) of the IPCC formally defined adaptation as "adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderate harm or exploit beneficial opportunities" (IPCC, 2007). The 2015 Paris Agreement further solidified the importance of adaptation. Article 7 of the agreement emphasized strengthening adaptive capacities and building resilience worldwide, positioning adaptation as equal in importance to mitigation (UNFCCC, 2015). Fankhauser (2017) makes a clear distinction between mitigation, which aims at "the drastic reduction in greenhouse gas emissions" i.e., the phenomenon that causes climate change, and the need to face its consequences "through an equal emphasis on investment in climate resilience (adaptation)." The nomenclature around adaptation can be confusing. For greater clarity, the definition of key terms according to the Sixth IPCC Assessment Report (AR6) is provided in Table 1. We report only the definitions of the three main concepts of resilience, adaptation, and mitigation as they are relevant to the present study. For further details, the reader can refer to Annex: Glossary of the IPCC AR6 Synthesis Report (IPCC 2023 Annex I: Glossary, 2023).

In 2015, the United Nations' 2030 Agenda for Sustainable Development (United Nations, 2015) identifies two closely related sub-targets of the Sustainable Development Goal 11- Make cities and human settlements inclusive, safe, resilient and sustainable: Target 11.5, which aims to "Reduce the adverse effects of natural disasters," and Target 11.6 that aims to "Reduce the environmental impact of cities."

2.1 Climate adaptation: context and definitions

As shown in Table 1, the IPCC distinguishes adaptation as it refers to human or natural systems. In natural systems, adaptation is "the process of adjustment to actual or expected climate." Human intervention may facilitate such an adjustment in natural systems. In human systems, the process of adjustment has the specific goal of "moderating harm or exploiting beneficial opportunities" (IPCC 2018 Annex I: Glossary, 2018). However, counteracting the harmful, dramatic effects of climate change, and taking advantage of beneficial (economical, political, social) opportunities can be very different goals with potentially colliding interests, strategies, processes, and outcomes. In this sense, climate change adaptation largely remains an ambiguous concept, and the results of climate adaptation efforts are, to date, unclear if not explicitly contested (Olazabal et al., 2024). Maladaptation, i.e., the failure of adaptation strategies to the point that efforts made to prevent the effects of climate change end up making people and places even more vulnerable to such effects, is a concrete risk (Schipper, 2020; Dilling et al., 2019).

The urban space is a complex system where natural and human environments coevolve by blurring their borders and create hybrid environments with multilayered relations (Latour and Weibel, 2005; Haraway, 2016; Sennett, 2018; Koolhaas et al., 2020). While the IPCC does not provide a separate, specific definition for urban adaptation, it extensively discusses adaptation strategies within urban contexts. The IPCC's Sixth Assessment Report includes the chapter "Cities, Settlements, and Key Infrastructure," which examines the unique challenges and adaptation needs of urban areas (Lwasa et al., 2022). The report highlights the need to:

- Develop urban green (e.g., parks, green roofs) and blue (water bodies) solutions to reduce urban heat islands and manage stormwater.
- Implement climate-resilient infrastructure that can endure climate-related stresses.

TABLE 1 Definitions of key concepts used in the climate change discourse and relevant to the present study, according to the glossary of the AR6 Synthesis Report of the International Panel on Climate Change.

Adaptation	The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In natural systems, human intervention may facilitate adjustment to expected climate and its effects.
Mitigation	A human intervention to reduce the sources or enhance the sinks of greenhouse gases.
Resilience	The capacity of social, economic, and environmental systems to cope with a hazardous event or trend or disturbance, responding or reorganizing in ways that maintain their essential function, identity, and structure, while also maintaining the capacity for adaptation, learning, and transformation.

- Promote sustainable transportation (e.g., electric vehicles and public transit).
- Enhance urban planning by incorporating climate-aware land-use planning and preventing development in high-risk areas.

However, the Report does not provide clear guidelines for how such generic goals might be achieved, and with which priority. The adaptation of the urban space to climate change has direct implications on human organized life as it entails an urgent need to provide shelter and mitigate risk in the context of sudden extreme events (Sádaba et al., 2024). Adaptation also has indirect implications as it involves a longer-term re-thinking of urban life and the development of new tools for city design. To be successful, such tools should consider both the tangible and intangible elements of organized life to support the psychological and social wellbeing of the city's inhabitants while ensuring the physical survival of life against adverse climatic events. As we will further discuss, these tangible and intangible layers encompass perceptual aspects, such as the design of the sensorial environment (e.g., sound and smell), the development of a holistic and more-than-human ethological and ecological sensitivity, and the adaptation of technological innovation through co-creation and bottom-up methods.

The goal of this article is to review current approaches, debates, and proposed solutions to the adaptation of urban space design to climate change from a multidisciplinary perspective. Such a perspective reflects the background and research interests of the authors which range from architecture and urban design, social innovation, Science and Technology Studies (STS), soundscape studies, and design research. We also believe it provides a much-needed perspective that, in times of crisis, takes into account not only the material and functional (*tangible*) characteristics of the city, but also its social, cultural, and psychological (*intangible*) needs.

3 Current approaches

We reviewed current approaches to urban space in the face of climate change and climate adaptation from a multidisciplinary perspective. We adopted a narrative literature review approach (Baumeister and Leary, 1997). We started from recent relevant (e.g., presented at the main conferences or published in the main venues for each community) contributions that sparked debate on climate adaptation strategies in our respective fields. We then proceeded by snowballing the results to obtain an overview of the most recent debates and controversies in the respective fields on the topic under study. Finally, we expanded the research to include representative work beyond scientific publications (e.g., design interventions, patented solutions).

3.1 Architecture and urban planning

Architecture and urban design are key to climate change adaptation as they shape the physical basis onto which human activities occur in the city. As stated in the Introduction, the pace at which urban regulations are set, and the immediate need of the city and its inhabitants are not always well matched (Semeraro et al., 2020). The very materiality of the city prevents swift adaptations to climate changes (United Nations Environment Programme, 2022). Cities have historically been designed for a specific climate: adaptation strategies to changes in the local climatic conditions will require a radical rethinking of how cities are designed and planned (Atanacković Jeličić et al., 2021; Silva, 2016). On a large scale, adaptation will involve higher level strategies which entail the construction of critical infrastructure (e.g., to mitigate the impact of sea level rise) and even the displacement of entire populations (Hauer et al., 2020). In this review, we limit our focus to the potential of design actions implemented on the smaller scale of the interactions between residents (both human and non-human) and the city.

A growing strategy that is receiving increasing attention is the design and implementation of Nature-based Solutions (NbS), defined by the European Commission as "Solutions that are inspired and supported by nature, which are cost-effective, simultaneously provide environmental, social and economic benefits and help build resilience. Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions" (European Commission: Directorate-General for Research Innovation, 2022). Despite the EU's definition, in their current state NbS tend to prioritize short-term goals (e.g., protecting people from sun exposure) instead of implementing long-term strategies toward long-term solutions (such as, for instance, the adaptation of the entire urban pavement to increase water absorption). Additionally, with their focus on "emergency design" NbS tend to overlook the social dimension, e.g., the long-term social benefit of the communities where they are implemented (Goodwin et al., 2024). Other emerging strategies currently under evaluation in a number of different cities around the world include, among other attempts, stormwater management systems (Pandis Iveroth et al., 2013), climate responsive materials and strategies (Rubio-Bellido et al., 2015), low-carbon transportation solutions (Jia et al., 2024), and metabolic urban design approaches (Verma et al., 2020).

Recent research proposed the design and implementation of "climate shelters" i.e., public spaces that provide thermal comfort to the most vulnerable inhabitants during periods of extreme temperatures (López Plazas et al., 2023; Steer et al., 2017). In cities such as Barcelona and Bilbao, climate shelters have been officially adopted by local governors in an effort to actively protect people from increasing heat or sudden adverse meteorological events (e.g., heavy rain). In both cases, dedicated websites and other digital material (e.g., downloadable maps) inform citizens and visitors on the location of shelters across the city, both indoors and outdoors (Barcelona, 2025; Bilbao, 2025). At this stage, climate shelters are usually shadowed fresh spaces within urban parks or public buildings with free access and accessible during the hottest months of the year (Adams et al., 2023). The goal of leveraging natural elements already present in the city (such as public parks or gardens) resonates with the nature-based approach of NbS and indicates a trend in rethinking the city space as an integration of natural and artificial. While a promising strategy, critiques point to the potential inequalities in the distribution and accessibility

of such shelters when it comes to disadvantaged neighborhoods (Amorim-Maia et al., 2023). An increasing issue of social justice in the response of cities to climate adaptation is emerging (for a recent review of the topic see Walker et al., 2024). It is also worth noticing that while specific criteria to design climate shelters are being defined in a more structured way (Amorim-Maia, 2023), there is still largely a lack of real-world solutions that can be efficiently implemented and adapted to the city space (Sádaba et al., 2024).

3.2 Social innovation

While climate change is a global issue, climatic components, potential risks, and the vulnerability of local populations vary significantly across different geographical areas. Not taking into account this diversity is one of the most widely recognized reasons for unsuccessful climate adaptation strategies (Brousseau et al., 2024; Olazabal et al., 2024). Interventions driven by actors alien to the local context may fail to understand or account for specific factors, particularly where interventions are highly technocratic in nature (Nightingale et al., 2019). A recent literature review (Eriksen et al., 2021) includes examples of adaptation interventions that reinforced existing power systems in developing countries in Asia and Africa by involving only the local elites in the design process, thus reinforcing the stigmatization of disadvantaged and vulnerable communities whose habits are often blamed for climate instability (Thomas and Warner, 2019). Other examples point out that technological solutions (such as digital platforms) implemented by local governments in Latin America to access housing support after climate disasters, are inaccessible to the most vulnerable social groups as they require digital literacy and access to Internet connection (Camargo and Ojeda, 2017). Such interventions may undermine local adaptation responses that are more environmentally, financially, and politically sustainable (Eriksen et al., 2021). Local ownership of adaptation actions and genuine local participation in adaptation design and implementation are critical to avoid such pitfalls (Soanes et al., 2021). In order to tackle these issues, researchers are proposing specific frameworks to engage policy makers in devising strategies for transformative adaptation as well as collaborative approaches that foster communication and collaboration between communities at the frontline of climate change and governing bodies (Comelli et al., 2024; Gordon et al., 2022). Examples of design strategies that aim at grounding climate adaptation interventions within and in collaboration with the local communities which are directly affected by it are on the rise (Carrasco and Soto, 2020). Initiatives such as the Imagine Adaptation (2024)) aim to "to revisit the concept of adaptation success and go beyond technical framings to consider equity, justice, and maladaptive issues by pioneering new ways to evaluate adaptation and contributing to discussion on how local progress can inform global goals." (Ibid.)

3.3 Multispecies and more-than human

In recent design research, a shift is occurring from a human-centered approach to a more-than-human focus that should encompass all design endeavors (i.e., products, services, and systems) and support the transition toward a more inclusive, sustainable and just world especially in the context of the crisis engendered by climate change (Cameron, 2023; Giaccardi and Redström, 2020). Examples of such shift include the definition of frameworks that address the "shared fragility" between humans and more-than-humans to inform policy-making (Turhan et al., 2024); educational strategies to increase awareness of climate change and multispecies coexistence (Saari, 2020; Andrzejewski et al., 2009); interdisciplinary design practices that aim at "defining novel design methods especially in practical applications where policymakers, communities, businesses, and new forms of organization are engaging with challenges we face—often situated and local, but interdependent within complex systems of society and the environment" (Coops et al., 2024). Inevitably, more-than-human design also demands that the proposed methods and solutions take into account the characteristics and needs of other species, and the consequences that human-made designs have on the broader ecosystem. Pschetz et al. (2024) claim that non-human species have been forced to adapt their communication strategies to the pace of the urbanized and industrialized world. Entangled agencies of human and non-human actors in the city space are investigated at different scales to "de-center human actions" (Ruiz Arana, 2024).

On the other hand, ongoing research within social and natural sciences, such as the Multispecies Climate Change Education project, addresses how "multispecies perspectives could be better integrated into different facets of environmental education, including in disaster risk reduction" (CLAN—Human Animal Studies, 2025). Liminal Becomings (Policarpo, 2024) aims at reframing human-animal relations in natural disasters and "exploring the relational continuum between human and non-human animals in the experience of survival that follows disasters" (Ibid). Albeit sparse, the movement to reframe research on climate adaptation through the lenses of more-than–human values seems to transcend disciplinary borders. While architecture and urban design are more and more focusing on solutions that encourage a deeper relationship between human residents of the city and plants (for instance through NbS and climate shelters, see Section 3.1), and social sciences are looking at climate justice as a growing concern (see Section 3.2), design researchers and scientists are proposing new frameworks and educational protocols that consider the wellbeing of all living species in the face of climate change.

3.4 Multisensory

There is increasing evidence that anthropogenic activity affects how animals perceive their environment, with profound ecological consequences (Munoz and Blumstein, 2012). For both animals and humans, environmental perception is inevitably multisensory. Sound, light, and smell stimuli all contribute to define the relationship of the city with its inhabitants (Lindborg et al., 2024; Xiao et al., 2021) and represent a key source of information to navigate the city's tangible and intangible (e.g., cultural, and social) space (Parker et al., 2023). *Sound*scapes and *smell*scapes are part of the intangible heritage of a place, and an expression of the cultural, social, and individual characteristics of its inhabitants, both human and non-human (Schafer, 1977; Parker et al., 2023).

Of all senses, the perception of the acoustic environment is the most studied, with the beneficial effects on communities' health and wellbeing and the restorative power of sound already well-documented (Levenhagen et al., 2021). In the context of climate change and adaptation, which is the object of this review, we turned to recent research in environmental sound studies where a progressive, ongoing shift is occurring from a traditional perspective in which bioacoustics (i.e., the study of animal sounds within an ecosystem, see Sueur and Farina, 2015) and soundscape studies (i.e., the acoustic environment as perceived by humans in context, see ISO 12913-1, 2014) are strictly independent disciplines, to a unified *ecoacoustic* perspective (Farina, 2018) where humans and other species interact through and by sound, and with the environment. On the basis that the acoustic environment is a precious source of information "about the whole landscape, its physical, environmental and cultural make-up, and that of its communities" (Ruiz Arana, 2024; p. 2,749), ecoacoustics can become a driver in environmental planning and management in the light of climate adaptation (Farina et al., 2024). In the context of urban green areas (a key element of both NbS and climate shelters), research shows how monitoring the quality of the urban soundscape enables the assessment of the city's broader ecosystem (Tabassum, 2024). This, conversely, informs and supports adaptive planning and management strategies that can maintain or enhance biodiversity (Zhao et al., 2022; Ng et al., 2018). Additionally, auditory factors—however intangible—have the strongest influence on perceived thermal comfort in public spaces (Nitidara et al., 2022). An increased soundscape quality would then improve climate adaptation, especially in the context of so-called heat islands (see Section 2).

As for the sense of smell, a recent review study (Xiao et al., 2021) shows how, increasingly, researchers advocate for the incorporation of trees, verdant spaces, parks, waterways, ponds, and fountains within urban design frameworks (Henshaw, 2014) on the basis that the olfactory experience associated with nature mitigates the perceived annoyance of traffic-related pollution and noise pollution. While current studies do not explicitly address the potential role of smell in climate adaptation, we believe that this renewed interest in a multisensory approach to the design of the urban environment is promising and could support an integrated design framework for climate adaptation design strategies.

4 Discussion

In this short review, we explored current debates and approaches to the adaptation of the urban space to climate change. Figure 1 recaps on our findings. While the fields of architecture and urban design are exploring novel strategies for climate adaptation (e.g., NbS, climate shelters), such solutions only respond to the tangible needs of the city (e.g., providing refuge to human residents during heatwaves). The risk of overlooking the much needed social, cultural, and emotional aspects that shape the urban space is starting to be acknowledged by the research community which points at misadaptation as a concrete risk, with issues of climate justice being more and more discussed. Other fields, such as more-than-human design and multispecies and multisensory studies, are tackling both tangible and intangible characteristics of climate change (e.g., the viewpoint of non-human species) moving toward a perspective that transcendent the boundary of disciplinary approaches (such as in ecoacoustics) and sensory perception (by including soundscapes and smellscapes in urban design strategies). By taking into account human relationship with other living beings, multispecies adaptation, and a multi-modal view of the city space, they are advocating for integrated solutions to climate adaptation.

Such integrated solutions should move beyond (see Figure 2) the foundational architectural and urban layer to define strategies—with appropriate tools and methods—that can incorporate social innovation practices (e.g., co-creation, participatory processes) with multisensory analysis of the urban space (e.g., soundscape and smellscape studies), more-than-human (e.g., speculative design, design for transition, inclusive design) and multispecies design (e.g., biodiversity and ecology studies) to involve all stakeholders in the multi-layered process of adapting the city space to climate change.

Three recent projects exemplify the potential of an integrated approach. The *T-Factor* project (Arniani and Martelloni, 2024) introduced temporary interventions to enhance climate resilience on the island of Zorrotzaurre (Bilbao, Spain), which is undergoing a radical long-term process of urban redevelopment. In the short term, the space offers opportunities for creative exploration. Three projects connected educational institutions on the island with local industries through a co-creative process that also involved the island's residents. The first project, *Chimenea Verde* (green chimney), is a sculptural installation inspired by Bilbao's industrial heritage. Filled with resilient plants, it serves as a green meeting point for residents within the concrete-dominated island. Built with local craftwork studio Petit Muller, it highlights how the engagement of residents in the definition of Nature-based Solutions increases the chances of acceptance and social justice. The *Besteak Project* demonstrates the value of including animals and plants in the design of public space interventions. What began as hacking traffic signs for bird nesting evolved into a community initiative developing upcycled urban furniture for stray cats (Abad Aguirre and Abad Aguirre, 2023).

Urban Oasis, a project developed by two of the co-authors (Sádaba et al., 2025), is an industrial design patent for adapting urban social spaces to climate change. Based on a Nature-based Solution—the *rain garden*—it enhances the natural water cycle and reduces flood risk within the city while providing shelter for humans and other species during heat waves. Speakers, sensors, and data connection are hosted in the functional branches-like aerial elements and can be used to design interventions that integrate sound and smell to increase restorative refuge during climate emergencies. A demo of the project, currently in progress, can be found at https://vimeo.com/1013052973.

In this review, we highlight emerging discussions in different research fields, from architecture and urban design to social innovation interventions and multispecies and multisensory studies, against the backdrop of the growing need for climate adaptation in urban space. However, still sparse, these discussions highlight the potential of cross-pollination between all the disciplines explored in this review. A new, transdisciplinary approach that takes into account both the tangible and the intangible needs of the city is required to improve the impact of

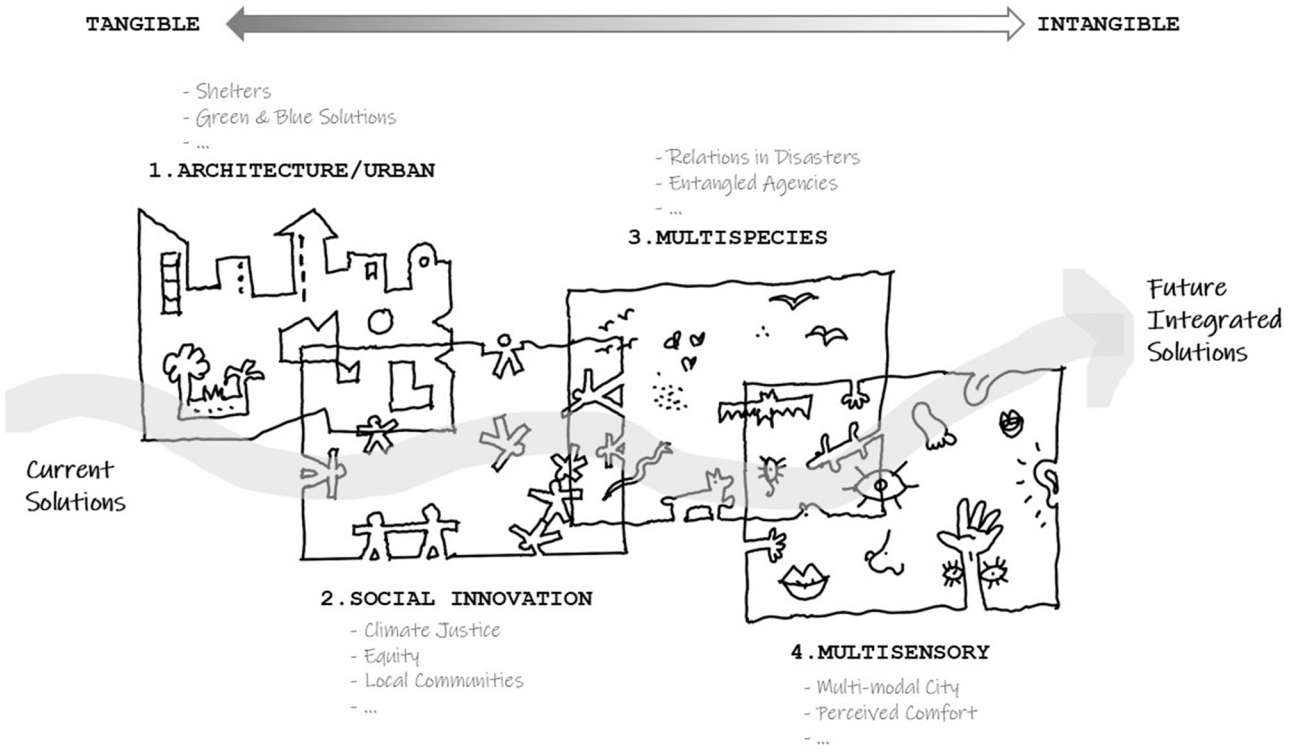

FIGURE 1
Architecture and urban design provide solutions to the tangible needs of the city. Social innovation, more-than-human design, and multi-sensory studies tackle adaptation within a continuum between tangible and intangible.

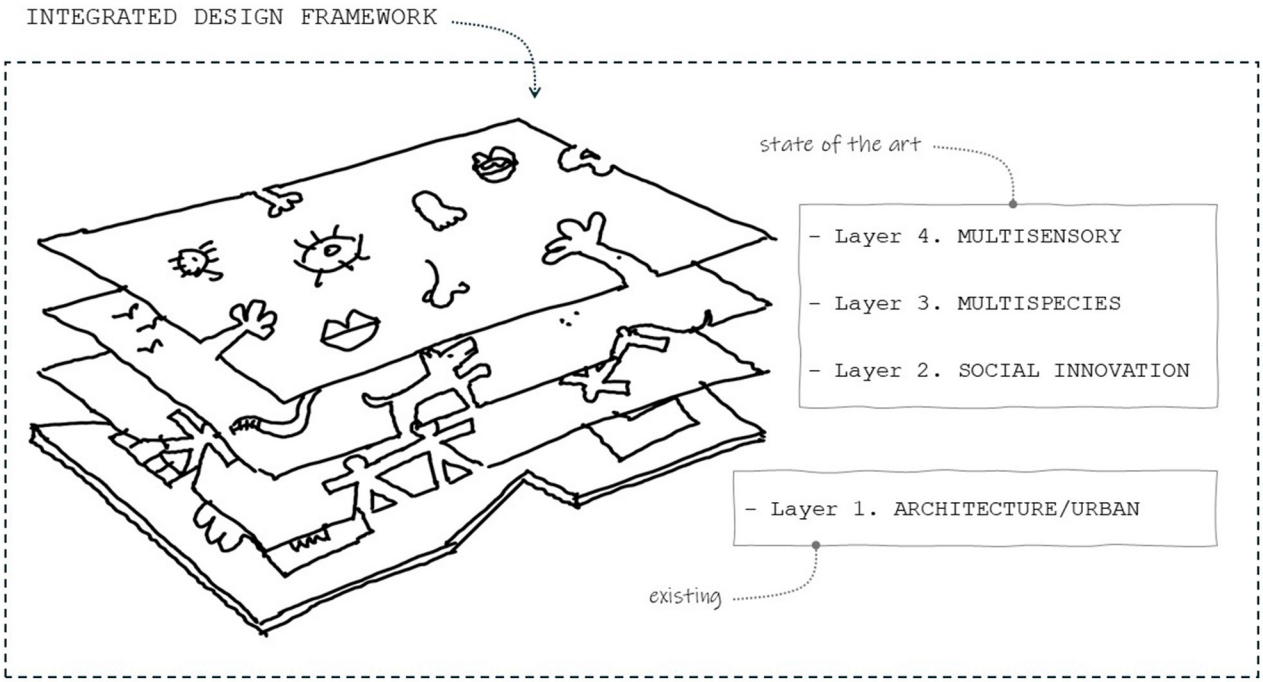

FIGURE 2
Integrated design framework. Integrated future solutions are multi-layered i.e., they combine architecture and urban design with social innovation, multisensory analysis, more-than-human and multispecies design.

such converging research and empower the momentum to support a more effective and just climate adaptation.

Author contributions

SL: Conceptualization, Writing – original draft, Writing – review & editing. JS: Investigation, Methodology, Writing – original draft, Writing – review & editing. AR: Writing – review & editing, Investigation.

Funding

The author(s) declare that financial support was received for the research and/or publication of this article. SL's work is partially funded by the Marie Skłodowska-Curie Cofund Programme of the European Commission (H2020-MSCA-COFUND-2020-101034228-WOLFRAM2). The publication of this research was funded by the EKOPOL research group under the project "Iraunkortasunerako bideak - Ecosocial Transition for Sustainability" (IT1567-22).

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The author(s) declare that no Generative AI was used in the creation of this manuscript.

Publisher's note

References

Abad Aguirre, J., and Abad Aguirre, I. (2023). "Besteak," in: *15th International Conference of the European Academy of Design* (São Paulo: Blucher), 259–260. doi: 10.5151/ead2023-1BIL-04Poster-04-Abad

Adams, Q. H., Chan, E. M., Spangler, K. R., Weinberger, K. R., Lane, K. J., Errett, N. A., et al. (2023). Examining the optimal placement of cooling centers to serve populations at high risk of extreme heat exposure in 81 US cities. *Public Health Rep.* 138, 955–962. doi: 10.1177/00333549221148174

Amorim-Maia, A. T. (2023). *Creating Inclusive and Effective Climate Shelters*. Policy Brief. BCNUEJ. Available online at: https://tinyurl.com/3hzevenh (accessed January 16, 2025).

Amorim-Maia, A. T., Anguelovski, I., Connolly, J., and Chu, E. (2023). Seeking refuge? The potential of urban climate shelters to address intersecting vulnerabilities. *Landsc. Urban Plan.* 238:104836. doi: 10.1016/j.landurbplan.2023.104836

Andrzejewski, J., Pedersen, H., and Wicklund, F. (2009). "Interspecies education for humans, animals, and the earth," in *Social Justice, Peace, and Environmental Education* (New York: Routledge), 148–166. doi: 10.4324/9780203879429-16

Arniani, M., and Martelloni, L. (2024). *From Within: Temporary Use for Collective Change*. T-Factor Horizon 2020 Project. Available online at: https://tinyurl.com/2da5c357 (accessed January 16, 2025).

Atanacković Jeličić, J., Rapaić, M., Kapetina, M., Medić, S., and Ecet, D. (2021). Urban planning method for fostering social sustainability: can bottom-up and top-down meet? *Results Eng.* 12:100284. doi: 10.1016/j.rineng.2021.100284

Barcelona. (2025). *Climate Shelters Network*. Available online at: https://tinyurl.com/mr38kj5s (accessed February 15, 2025).

Baumeister, R. F., and Leary, M. R. (1997). Writing narrative literature reviews. *Rev. General Psychol.* 1, 311–320. doi: 10.1037/1089-2680.1.3.311

Bilbao. (2025). *Red de Refugios Climáticos*. Available online at: https://tinyurl.com/4sy4bafp (accessed January 9, 2025).

Brousseau, J. J., Stern, M. J., Pownall, M., and Hansen, L. J. (2024). Understanding how justice is considered in climate adaptation approaches: a qualitative review of climate adaptation plans. *Local Environ.* 29, 1644–1663. doi: 10.1080/13549839.2024.2386964

Camargo, A., and Ojeda, D. (2017). Ambivalent desires: state formation and dispossession in the face of climate crisis. *Polit. Geogr.* 60, 57–65. doi: 10.1016/j.polgeo.2017.04.003

Cameron, F. R. (2023). From sustainable development to sustaining practices for human, more-than and other-than human worlds. *Mus. Int.* 75, 214–221. doi: 10.1080/13500775.2023.2348883

Carrasco, G., and Soto, W. (2020). "Social innovation labs for climate action: south to south collaboration to tackle climate change," in *Proceedings of Pivot 2020: Designing a World of Many Centers-DRS Pluriversal Design SIG Conference, 4 June 2020, held online*, eds. R. Leitão, L. Noel, and L. Murphy. doi: 10.21606/pluriversal.2020.204

CLAN—Human Animal Studies. (2025). *Multispecies Climate Change Education*. Available online at: https://tinyurl.com/5cjb673t (accessed January 11, 2025).

Comelli, T., Pelling, M., Hope, M., Ensor, J., Filippi, M. E., Menteşe, E. Y., et al. (2024). Normative future visioning: a critical pedagogy for transformative adaptation. *Buildings Cities* 5, 83–100. doi: 10.5334/bc.385

Coops, F., Lockton, D., Gaziulusoy, I., Tonkinwise, C., Boehnert, J., Ortega Pallanez, M., et al. (2024). *Designing (for) Transitions and Transformations: Imagination, Climate Futures, and Everyday Lives,* eds. C. Gray, E. Ciliotta Chehade, P. Hekkert, L. Forlano, P. Ciuccarelli, and P. Lloyd (DRS2024: Boston, USA), 23–28. doi: 10.21606/drs.2024.167

Dilling, L., Prakash, A., Zommers, Z., Ahmas, F., Singh, N., de Wit, S., et al. (2019). Is adaptation success a flawed concept? *Nat. Clim. Change* 9, 572–574. doi: 10.1038/s41558-019-0539-0

Eriksen, S., Schipper, E. L., Scoville-Simonds, M., Vincent, K., Adam, H. N., Brooks, N., et al. (2021). Adaptation interventions and their effect on vulnerability in developing countries: Help, hindrance or irrelevance? *World Dev.* 141:105383. doi: 10.1016/j.worlddev.2020.105383

European Commission: Directorate-General for Research and Innovation. (2022). *The Vital Role of Nature-Based Solutions in a Nature Positive Economy*. Publications Office of the European Union. Available online at: https://data.europa.eu/doi/10.2777/307761 (accessed February 15, 2025).

Fankhauser, S. (2017). Adaptation to climate change. *Annu. Rev. Resour. Econ.* 9, 209–230. doi: 10.1146/annurev-resource-100516-033554

Farina, A. (2018). Perspectives in ecoacoustics: a contribution to defining a discipline. *J. Ecoacoust.* 2:10. doi: 10.22261/jea.trzd5i

Farina, A., Krause, B., and Mullet, T. C. (2024). An exploration of ecoacoustics and its applications in conservation ecology. *BioSystems* 245:105296. doi: 10.1016/j.biosystems.2024.105296

Giaccardi, E., and Redström, J. (2020). Technology and more-than-human design. *Des. Issues.* 36, 33–44. doi: 10.1162/desi_a_00612

Goodwin, S., Olazabal, M., Castro, A. J., and Pascual, U. (2024). Measuring the contribution of nature-based solutions beyond climate adaptation in cities. *Glob. Environ. Change.* 89:102939. doi: 10.1016/j.gloenvcha.2024.102939

Gordon, E., Lim, Y., Paradis, J., Guarna, T., Degetau, G., and Vijaykumar, M. (2022). *Deep Listening: A Framework for Collaborative Climate Adaptation,* eds. D. Lockton, S. Lenzi, P. Hekkert, A. Oak, J. Sádaba, and P. Lloyd (DRS2022: Bilbao, Spain). doi: 10.21606/drs.2022.802

Haraway, D. (2016). *Staying with the Trouble: Making Kin in the Chthulucene*. Durham, NC: Duke University Press. doi: 10.2307/j.ctv11cw25q

Hauer, M. E., Fussell, E., Mueller, V., Burkett, M., Call, M., Abel, K., et al. (2020). Sea-level rise and human migration. *Nat. Rev. Earth Environ.* 1, 28–39. doi: 10.1038/s43017-019-0002-9

Henshaw, V. (2014). *Urban Smellscapes: Understanding and Designing City Smell Environments*. New York, NY: Routledge. doi: 10.4324/9780203072776

Imagine Adaptation. (2024). Available online at: https://imagineadapt.bc3research.org/ (accessed January 9, 2025).

IPCC 2018 Annex I: Glossary. (2018). *Global Warming of 1.5°C. An IPCC Special Report on the impacts of global warming of 1.5°C above pre-industrial levels and related global greenhouse gas emission pathways, in the context of strengthening the global response to the threat of climate change, sustainable development, and efforts to eradicate poverty*, eds. V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P.R. Shukla, A. Pirani, et al. (Cambridge University Press, Cambridge, UK and New York, NY, USA) 541–562.

IPCC 2023 Annex I: Glossary. (2023). *Climate Change 2023: Synthesis Report. Contribution of Working Groups I, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. A. Reisinger, D. Cammarano, A. Fischlin, J. S. Fuglestvedt, G. Hansen, Y. Jung, et al. (IPCC, Geneva, Switzerland), 119–130. doi: 10.59327/IPCC/AR6-9789291691647.002

IPCC. (1990). *Climate Change: The 1990 and 1992 Assessments*. Available online at: https://tinyurl.com/bd3vc7z6 (accessed January16, 2025).

IPCC. (2007). *Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. R. K. Pachauri, and A. Reisinger (IPCC, Geneva, Switzerland), 104. Available online at: https://www.ipcc.ch/report/ar4/syr/ (accessed February 15, 2025).

ISO 12913-1. (2014). *Acoustics—Soundscape—Part 1: Definition and Conceptual Framework. Geneva: International Organization for Standardization*. Available online at: https://www.iso.org/standard/52161.html (accessed February 4, 2025).

Jia, Z., Yin, J., Cao, Z., Wei, N., Jiang, Z., Zhang, Y., et al. (2024). Large-scale deployment of intelligent transportation to help achieve low-carbon and clean sustainable transportation. *Sci. Total Environ.* 949:174724. doi: 10.1016/j.scitotenv.2024.174724

Koolhaas, R., Foster, N., and AMO. (2020). *Countryside, a Report*. Cologne: Taschen.

Latour, B., and Weibel, P. (eds). (2005). *Making Things Public: Atmospheres of Democracy*. Cambridge: MIT Press.

Levenhagen, M. J., Miller, Z. D., Petrelli, A. R., Ferguson, L. A., Shr, Y., Gomes, D. G. E., et al. (2021). Ecosystem services enhanced through soundscape management link people and wildlife. *People Nature* 3, 176–189. doi: 10.1002/pan3.10156

Lindborg, P., Aletta, F., Liew, K. M., Matsuda, Y., Xiao, J. L., Yue, R., et al. (2024). "Multimodal Hong Kong: understanding the intangible cultural heritage through sight, sound, and smell," in *Proceedings of the InterNoise Conference 2024* (Nantes), 713–724. doi: 10.3397/IN_2024_2638

López Plazas, F., Crespo Sánchez, E., Llorca Pérez, R., and Santacana Albanilla, E. (2023). Schools as climate shelters: design, implementation and monitoring methodology based on the Barcelona experience. *J. Clean. Prod.* 432:139588. doi: 10.1016/j.jclepro.2023.139588

Lwasa, S., Seto, K. C., Bai, X., Blanco, H., Gurney, K. R., Kilkiş, S., et al. (2022). *Urban systems and other settlements. In IPCC, 2022: Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, eds. P. R. Shukla, J. Skea, R. Slade, A. Al Khourdajie, R. van Diemen, D. McCollum, et al. (Cambridge University Press, Cambridge, UK and New York, NY, USA).

Munoz, N. E., and Blumstein, D. T. (2012). Multisensory perception in uncertain environments. *Behav. Ecol.* 23, 457–462. doi: 10.1093/beheco/arr220

Ng, M. L., Butler, N., and Woods, N. (2018). Soundscapes as a surrogate measure of vegetation condition for biodiversity values: a pilot study. *Ecol. Indic.* 93, 1070–1080. doi: 10.1016/j.ecolind.2018.06.003

Nightingale, A. J., Eriksen, S., Taylor, M., Forsyth, T., Pelling, M., Newsham, A., et al. (2019). Beyond technical fixes: climate solutions and the great derangement. *Clim. Dev.* 12, 343–352. doi: 10.1080/17565529.2019.1624495

Nitidara, N. P. A., Sarwono, J., Suprijanto, S., and Nugroho Soelami, F. X. (2022). The multisensory interaction between auditory, visual, and thermal to the overall comfort in public open space: a study in a tropical climate. *Sustain. Cities Soc.* 78:103622. doi: 10.1016/j.scs.2021.103622

Olazabal, M., Loroño-Leturiondo, M., Amorim-Maia, A. T., Lewis, W., and Urrutia, J. (2024). Integrating science and the arts to deglobalise climate change adaptation. *Nat. Commun.* 15:2971. doi: 10.1038/s41467-024-47400-7

Pandis Iveroth, S., Vernay, A.-L., Mulder, K. F., and Brandt, N. (2013). Implications of systems integration at the urban level: the case of Hammarby Sjöstad, Stockholm. *J. Clean. Prod.* 48, 220–231. doi: 10.1016/j.jclepro.2012.09.012

Parker, M., Spennemann, D. H. R., and Bond, J. (2023). Sensory perception in cultural studies—a review of sensorial and multisensorial heritage. *Sens. Soc.* 15, 1–31. doi: 10.1080/17458927.2023.2284532

Policarpo, V. (2024). *The ABIDE Project: Attuning to Animals and Multispecies Experiences of Disasters*. Available online at: https://tinyurl.com/3wmw7jr2 (accessed January 16, 2025).

Pschetz, L., Gebker, M., Wieland, S., and Bastian, M. (2024). *Designing Temporal Ecologies: Reframing Multispecies Temporalities Through Design*, eds. C. Gray, E. Ciliotta Chehade, P. Hekkert, L. Forlano, P. Ciuccarelli, P. Lloyd (DRS2024: Boston, USA), 23–28. doi: 10.21606/drs.2024.1068

Rius-Ulldemolins, J., and Klein, R., (2020). From top-down urban planning to culturally sensitive planning? Urban renewal and artistic activism in a neo-bohemian district in Barcelona. *J. Urban Aff.* 44, 524–544. doi: 10.1080/07352166.2020.1811114

Rubio-Bellido, C., Pulido-Arcas, J. A., and Cabeza-Lainez, J. M. (2015). Adaptation strategies and resilience to climate change of historic dwellings. *Sustainability* 7, 3695–3713. doi: 10.3390/su7043695

Ruiz Arana, U. (2024). "Multispecies soundscapes: a more-than-human approach," in *Proceedings of the InterNoise Conference 2024*. Nantes, France, 2743–2749. doi: 10.3397/IN_2024_3226

Saari, M. H. (2020). "Re-examining the human-nonhuman animal relationship through humane education," in *Research Handbook on Childhood Nature. Springer International Handbooks of Education*, eds. A. Cutter-Mackenzie-Knowles, K. Malone, and E. Barratt Hacking (Springer, Cham). doi: 10.1007/978-3-319-67286-1_69

Sádaba, J., Alonso, Y., Latasa, I., and Luzarraga, A. (2024). Towards resilient and inclusive cities: a framework for sustainable street-level urban design. *Urban Sci.* 8:264. doi: 10.3390/urbansci8040264

Sádaba, J., Luzarraga, A., and Lenzi, S. (2025). Designing for climate adaptation: a case study integrating nature-based solutions with urban infrastructure. *Urban Sci.* 9:74. doi: 10.3390/urbansci9030074

Schafer, R. M. (1977). *The Soundscape. The Tuning of the World*. New York, NY: Knopfs.

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

Semeraro, T., Nicola, Z., Lara, A., Sergi Cucinelli, F., and Aretano, R. (2020). A bottom-up and top-down participatory approach to planning and designing local urban development: evidence from an urban university center. *Land* 9:98. doi: 10.3390/land9040098

Sennett, R. (2018). *Building and Dwelling: Ethics for the City*. Farrar, Straus and Giroux.

Silva, P. (2016). Tactical urbanism: towards an evolutionary cities' approach? *Environ. Plan. B: Plan. Des.* 43, 1040–1051. doi: 10.1177/0265813516657340

Soanes, L. M., Pike, S., Armstrong, S., Creque, K., Norris-Gumbs, R., Zaluski, S., et al. (2021). Reducing the vulnerability of coastal communities in the Caribbean through sustainable mangrove management, *Ocean Coast. Manag.* 210:105702. doi: 10.1016/j.ocecoaman.2021.105702

Steer, K., Abebe, E., Almashor, M., Beloglazov, A., and Zhong, X. (2017). On the utility of shelters in wildfire evacuations. *Fire Saf. J.* 94, 22–32. doi: 10.1016/j.firesaf.2017.09.001

Sueur, J., and Farina, A. (2015). Ecoacoustics: the ecological investigation and interpretation of environmental sound. *Biosemiotics* 8, 493–502. doi: 10.1007/s12304-015-9248-x

Tabassum, M. (2024). Understanding urban green spaces through lenses of sensory experience: a case study of neighborhood parks in Dhaka city. *Sens. Soc.* 1, 1—33. doi: 10.1080/17458927.2024.2392960

Thomas, K. A., and Warner, B. P. (2019). Weaponizing vulnerability to climate change. *Glob. Environ. Change* 57:101928. doi: 10.1016/j.gloenvcha.2019.101928

Turhan, E., Aydin, C. I., Usta Baykal, N., and Bekar, I., (2024). "Integrating multispecies justice approach for climate risk management in forest areas of mediterranean Europe," in *Strengthening European Climate Policy*, eds. E. Galende Sánchez, A. H. Sorman, V. Cabello, S. Heidenreich, C. A. Klöckner (Palgrave Macmillan, Cham). doi: 10.1007/978-3-031-72055-0_11

UNFCCC. (2015). *Adoption of the Paris Agreement*. United Nations Framework Convention on Climate Change. Available online at: https://tinyurl.com/yc66wzb5 (accessed January 16, 2025).

United Nations Environment Programme. (2022). *Too Little, Too Slow: Climate Adaptation Failure Puts World at Risk. Adaptation Gap Report 2022*. Nairobi: United Nations Environment Programme. Available online at: https://www.unep.org/resources/adaptation-gap-report-2022 (accessed January 16, 2025).

United Nations. (2015). *Transforming Our World: The 2030 Agenda for Sustainable Development-A/RES/70/1*. Available online at: https://tinyurl.com/mr3ekmvm (accessed November 29, 2024).

Verma, P., Singh, P., Raghubanshi, A. S., and Singh, R. (2020). *Urban Ecology: Emerging Patterns and Social-ecological Systems*. Amsterdam: Elsevier.

Walker, S. E., Smith, E. A., Bennett, N., Bannister, E., Narayana, A., Nuckols, T., et al. (2024). Defining and conceptualizing equity and justice in climate adaptation. *Glob. Environ. Change* 87:102885. doi: 10.1016/j.gloenvcha.2024.102885

World Meteorological Organization. (1979). *Declaration of the World Climate Conference*. Available online at: https://tinyurl.com/42xtah3j (accessed January 16, 2025).

Xiao, J., Aletta, F., Radicchi, A., McLean, K., Shiner, L. E., and Verbeek, C. (2021). Recent advances in smellscape research for the built environment. *Front. Psychol.* 12, 1–7. doi: 10.3389/fpsyg.2021.700514

Yang, Q., Song, Y., and Cai, Y. (2020). Blending bottom-up and top-down urban village redevelopment modes: comparing multidimensional welfare changes of resettled households in Wuhan, China. *Sustainability* 12:7447. doi: 10.3390/su12187447

Zhao, Y., Sheppard, S., Sun, Z., Hao, Z., Jin, J., Bai, Z., et al. (2022). Soundscapes of urban parks: an innovative approach for ecosystem monitoring and adaptive management, Urban Forestry and Urban. *Greening* 71:127555. doi: 10.1016/j.ufug.2022.127555