



# Priorities for peri-urban recreation ecology research, policy, and practice in a transforming world

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## Abstract

**Context** Peri-urban landscapes are increasingly expected to support both outdoor recreation and biodiversity conservation. Different trade-offs and potential synergies between these two objectives call for a clear, interdisciplinary, and comprehensive framework for the design, management, and stewardship of

such landscapes to better support outdoor recreation and biodiversity conservation.

**Objectives** The aim of this work was to explore the most important interdisciplinary priorities for advancing peri-urban recreation ecology research in relation to policy and practice, and provide a basis for investigating the interrelations among these priorities to assess compatibility and coherence.

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**Methods** We designed and ran a session about the future of peri-urban recreation ecology, held in September 2024, at the 12th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas. In the session, we explored the most important limitations and opportunities in this field and identified ten priorities for the future. After the session, we continued the discussions virtually, from September 2024 to June 2025 and complemented them with a review of the recent literature.

**Results and Conclusion** We propose ten priorities for the future: (1) conceptualizing a social-ecological system approach, (2) developing a comprehensive, interdisciplinary framework, (3) enhancing participatory and data-driven knowledge, (4) developing indicators, metrics and models, (5) measuring the impacts of urban-nature proximity, (6) developing site-specific land-use strategies, (7) understanding the impacts of social media, (8) building capacity for unforeseen changes, (9) improving sustainable multifunctionality, and (10) supporting environmental justice.

**Keywords** Peri-urban landscapes · Peri-urban recreation ecology · Urbanization · Biodiversity · Outdoor recreation

## Introduction

Recreation ecology is the study of the impacts of outdoor recreation activities on nature, including water, soil, fauna, and flora (Cole 2021). This discipline has evolved to incorporate new activities, locations, technologies, challenges, and multidisciplinary approaches (Cole 2021; Miller et al. 2022a; Snow et al. 2025). Consequently, the concept is becoming more complex, multi-dimensional, and interactive (Pickering et al. 2022). Challenges, including human population growth and socio-economic shifts (Frolking et al. 2024; Chen et al. 2025), biodiversity loss and widespread land-cover change (IPBES 2019), and the impacts of climate change (Miller et al. 2022b), are among the most important factors influencing the future of the recreation-conservation nexus. Reflecting these challenges, the central question is determining how, where, and to what extent outdoor recreation and biodiversity conservation can overlap and interact. With urban densification, urban residents

increasingly use green and blue spaces in and near cities for outdoor recreation (Lehto et al. 2022). In this context, outdoor recreation competes for available land with other human activities, including housing and infrastructure development. Moreover, in some regions (e.g., Copenhagen), peri-urban afforestation, and nature managed for outdoor recreation have increased side by side with urbanization at the expense of agricultural lands (Caspersen et al. 2006). Land-cover conversions, together with subtler shifts in the use of land, create new and complex peri-urban landscapes. If recreation ecology is to inform how peri-urban landscapes are planned, used and managed, in support of both outdoor recreation and biodiversity conservation, interdisciplinary, comprehensive and coherent frameworks should be developed compatible with key priorities for the future.

In previous review studies, researchers have argued for novel and more appropriate model-based approaches for the analysis of recreational ecology impacts (Monz et al. 2013), highlighted research priorities and knowledge gaps in recreation ecology (Sumanapala & Wolf 2019), and advocated for ten factors influencing the environmental impacts of recreationists in protected areas (Pickering 2010). In a more recent work, Rastandeh et al. (2025), identified knowledge gaps and priorities for future research on the spatial dimension of recreation-conservation nexus in peri-urban landscapes. However, this Perspective moves beyond existing reviews and research agendas by providing novel insights from expert-elicited priorities for advancing peri-urban recreation ecology (PURE) research, policy, and practice. In this respect, it provides a cross-disciplinary basis for more holistic discussions about different, but interconnected, dimensions of recreation ecology with particular emphasis on “peri-urban” landscapes.

The insights were generated, mainly, through a session titled “Outdoor Recreation in a Transforming World: Top-10 Priorities for Future Sustainable Multifunctionality in Peri-urban Landscapes”, held at the 12th International Conference on Monitoring and Management of Visitors in Recreational and Protected Areas (MMV 2024). The topics for discussion were decided through an initial scoping review of the literature related to the field in the spring of 2024. Next, the panelists who co-authored this *Perspective*, were identified, selected, and invited to attend the session based on their previous publications. To

do this, a list of keywords was used to retrieve relevant peer-reviewed publications. These keywords included “outdoor recreation”, “recreation ecology”, “peri-urban”, “wildland-urban interface”, “peri-urban biodiversity”, “peri-urban wildlife”, and “peri-urban ecology”.

The geographical diversity of research projects undertaken by potential panelists was taken into particular consideration. In addition, diversity in the scope of research expertise and their conceptual and methodological approaches were important factors when selecting the final list of panelists. Invitations were sent to potential panelists via email. More detailed information, including the goal, objectives, and structure of the session, was shared with interested researchers who replied to the invitation. Ultimately, nine researchers from eight countries agreed to participate in the session, as a panelist, in-person or online. The panel represents a global-wide assemblage of researchers, from early-career to highly experienced, working on various dimensions of the topic in different geographical regions.

During the session, the panelists explored and discussed PURE as an entry point for re-examining and potentially repositioning the field of recreation ecology and the management of peri-urban landscapes. The session addressed limitations, challenges, and opportunities for research, policy, and practice framed by PURE, identifying the most important/pressing priorities. After the session, we continued expanding the discussions virtually, from September 2024 to June 2025. Here, we summarize these ongoing discussions encapsulating the most important dimensions of PURE.

## Peri-urban landscapes

We use the phrase “peri-urban landscape” to describe the complex characteristics of PURE, as a social-ecological system, referring to the mosaic of agricultural, rural and (semi-) natural lands in urban regions (Simon 2008; Duraiappah et al., 2012; Nilsson et al. 2013; La Rosa et al. 2018). It can cover different forms of spatial land-use arrangements between built-up, rural, and (semi-) natural areas, with a more detailed description available in Rastandeh et al. (2025). In some regions, it includes the wildland-urban interface (WUI), where built-up

surfaces intermingle with vegetation (Radeloff et al. 2005; Gonzalez & Ghermandi 2024). However, we do not necessarily consider peri-urban landscapes and the WUI identical. One important reason for differentiating between these two spatial concepts relates to the different contexts in which they were defined. For decades, the spatial extent of the WUI has been defined in relation to fire dynamics and the impacts of wildfire on residential areas adjacent to flammable vegetation (Radeloff et al. 2005; Schug et al. 2023). Accordingly, less attention was given to human-wildlife interactions and nature-based recreational activities in the WUI (Kil et al. 2014; Kellner et al. 2017; Jenerette et al. 2022). In contrast, peri-urban landscapes often refer to the administrative borders of cities, as areas adjacent to, or surrounding, metropolitan areas, or between urban and rural landscapes (Buxton 2022). While both outdoor recreation and biodiversity conservation are fundamentally important functions in peri-urban landscapes, the focus of previous research has been more on either outdoor recreation or biodiversity conservation. Consequently, the complexity and dynamics of the recreation-conservation nexus in peri-urban landscapes have not been fully explored (Rastandeh et al. 2025).

Intense human activities and land-use changes in peri-urban landscapes severely undermine the ecological integrity of lands and waters (Tavares et al. 2012; Czekajlo et al. 2021; Arif et al. 2023; Galeana-Pizáña et al. 2024). Due to their potential capacity for providing opportunities for a diversity of human activities (e.g., suburban housing development, agriculture, energy production, outdoor recreation, and biodiversity conservation), peri-urban landscapes can act as multifunctional zones (e.g., areas where these human activities can co-occur), if designed and managed properly (Rastandeh et al. 2025). In this respect, peri-urban landscapes are becoming major hubs for human-nature interactions, with a multitude of challenges and opportunities for outdoor recreation and biodiversity conservation (Rossi et al. 2015; Cerveny et al. 2022; Farias-Torbidoni et al. 2023). A network of diverse green and blue spaces in peri-urban landscapes can provide a robust foundation for biodiversity conservation (Snep et al. 2006; Rastandeh et al. 2018; Magle et al. 2019; Rastandeh & Jarchow 2023; Roth et al. 2024; Gelmi-Candusso et al. 2025). At the same time, these landscapes have the capacity to be used for a broad range of land- and water-based

recreational activities (Komossa et al. 2019; Djahangard et al. 2024; Junker-Köhler et al. 2025). These two functions are highly interrelated; and sometimes, they are contradictory, with ensuing potential conflict of interests among recreationists, local people, and wildlife (Rastandeh et al. 2025). In other situations, synergies between outdoor recreation and biodiversity conservation can provide co-benefits for humans and wildlife in peri-urban landscapes (Terraube et al. 2017; König et al. 2020; Sonawane et al. 2021; Carter & Linnell 2023; Roth et al. 2024). One example of mutually reinforcing outdoor recreation and biodiversity conservation can be found in Zealandia, a strategic wildlife sanctuary situated in peri-urban landscapes of Wellington, New Zealand, where sustainable land-use multifunctionality has been implemented on the ground (Rastandeh et al. 2018).

### PURE as a social-ecological system

We describe PURE as a complex and constantly evolving social-ecological system, where abiotic, biotic, and cultural resources interact over space and time. During the conference session, we characterized this social-ecological system using four mega-scale stressors (i.e., climate change, urbanization, food-energy production, pandemics), and sub-stressors associated with them (e.g., invasive species, habitat fragmentation, zoonotic diseases, and a high degree of land-use change). Then, we linked these stressors to four major societal factors (i.e., education, environmental justice, social media, and traditions/values), and three dimensions related to data (methods and tools, databases and protocols, and technologies; Fig. 1).

We propose that the science of PURE can be developed based on in-depth examination of interactions among these elements. Here, we discuss how stressors, society, and data may influence the future of PURE research, policy, and practice. We also discuss how interdisciplinary inquiries at the nexus of stressors, data, and society may pave the way toward a better understanding of PURE through knowledge co-production. We suggest that an improved understanding of the interactions and feedback among stressors, society, and data may support evidence-based decision making on the future of peri-urban landscapes. As discussed in the session, we highlight

four different land-use strategies that are needed for the future of PURE (i.e., adaptation, mitigation, resilience, and sustainability). We argued that depending on the context, these strategies can become complementary, neutral, or contradictory.

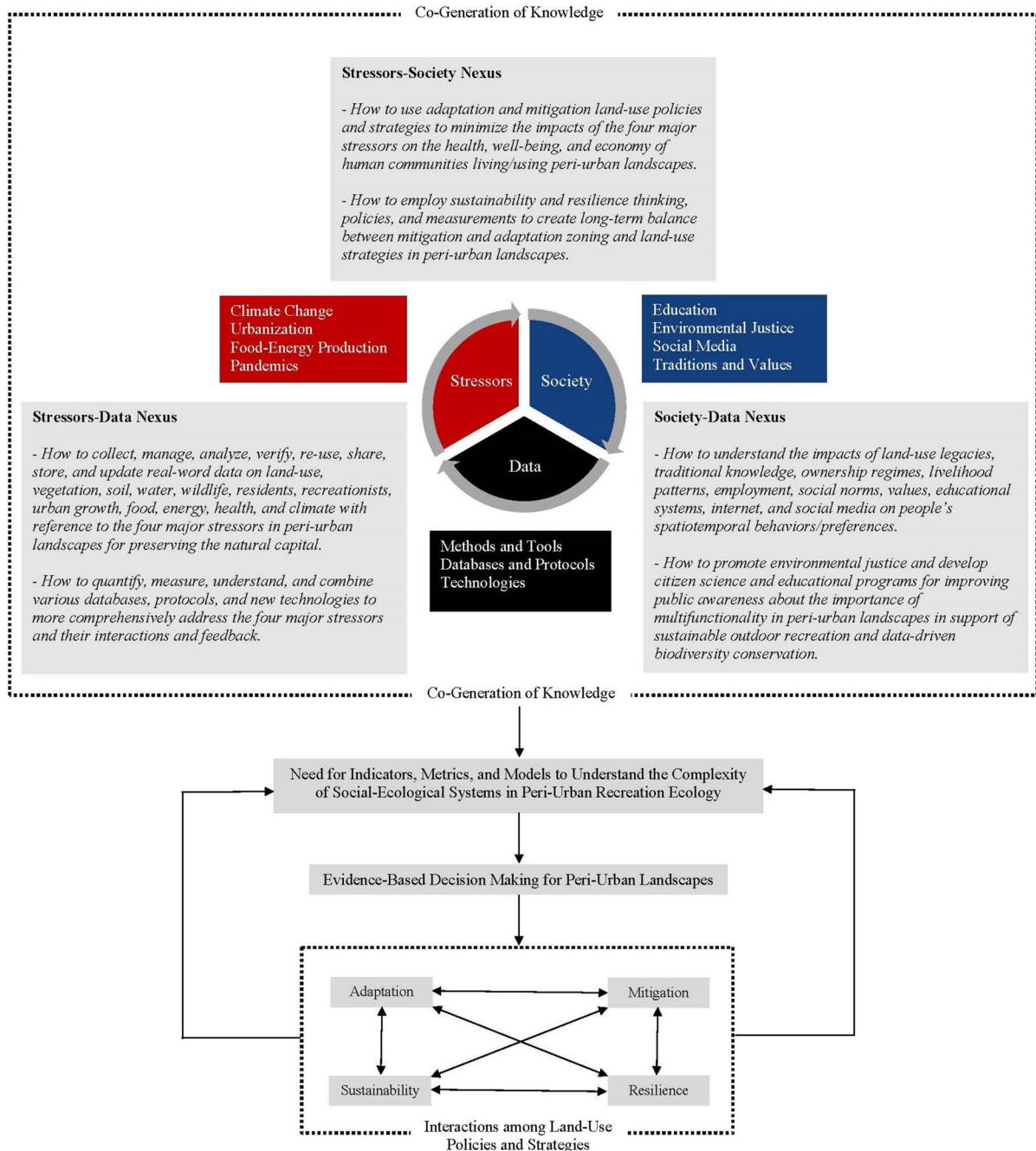
The overarching goal of the panel discussion was to find a middle-ground for transition from human-wildlife conflict to human-wildlife coexistence in peri-urban landscapes. We emphasized that such solutions must be climate-adapted, ecologically feasible, and socially acceptable to support outdoor recreation and biodiversity conservation in peri-urban landscapes. We also underscored the importance of a framework to integrate research, policy, and practice.

### Stressors

Urbanization, food production, energy extraction, and climate change are examples of mega-scale stressors, interacting in different ways, and generating sub-system complexities, consequently (Fig. 2). Such sub-system complexities influence recreationists and wildlife in peri-urban landscapes. In most cases, urbanization and climate change determine “where” and “when” recreational activities could occur. Food production and energy extraction significantly limit recreational opportunities at the local scale. In addition to these structural and long-term stressors, shock events like pandemics can result in shifts in behaviors, policies, and planning priorities (Piquer-Rodríguez et al. 2023), by affecting, for example, the frequency and density of use in peri-urban landscapes during and after such unforeseen crises.

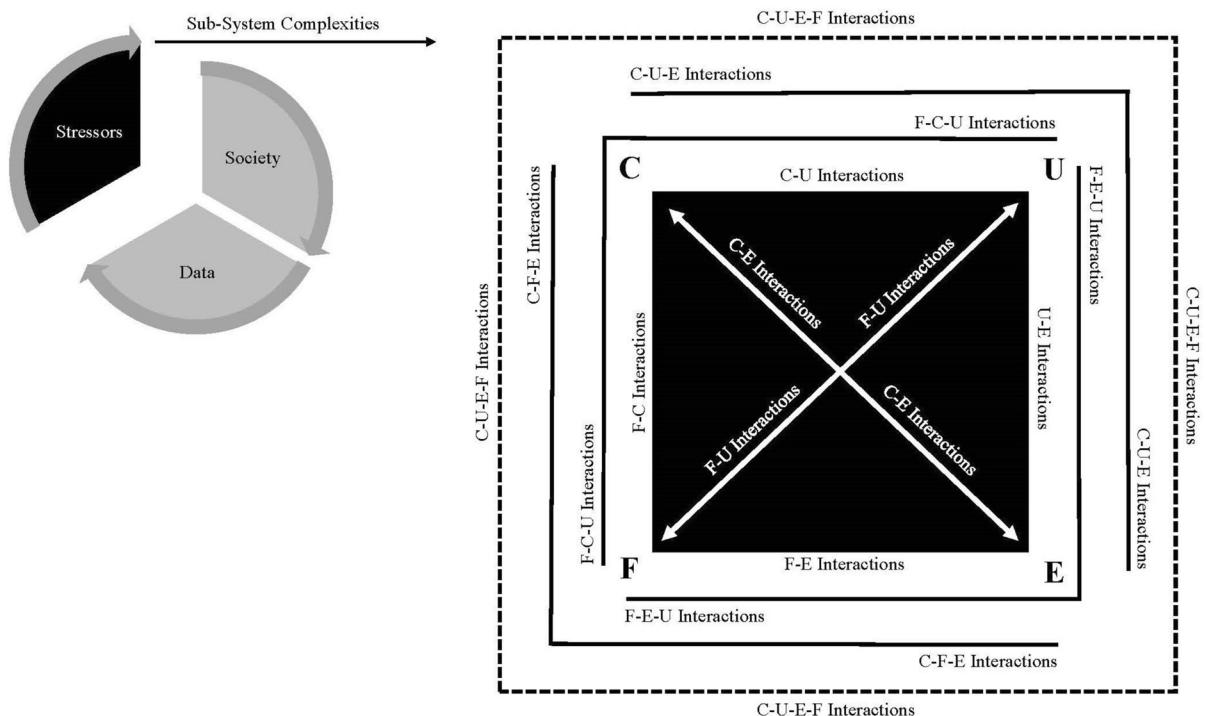
### Climate change

The impacts of climate change on biodiversity are evident, worldwide (IPBES 2019; WWF 2022). In addition, the basic questions of “where to go”, “when to go”, and “what to do” for outdoor recreation are often affected by weather (Askew & Bowker 2018; Willwerth et al. 2023; Wilkins & Horne 2024). As a result, climate change will alter outdoor recreation, with consequences for biodiversity, recreational facilities/infrastructure, recreationists, and local people whose livelihoods depend on outdoor recreation (Monz et al. 2021; Chapungu et al. 2024; McCreary et al. 2024). For example, seasonal changes in temperature and precipitation



**Fig. 1** Interactions among stressors, society, and data, including examples of multidisciplinary issues for scientific investigation leading to knowledge co-generation, the development and use of indicators, metrics, and models for supporting evidence-based decision making on peri-urban landscapes, and four major land-use strategies in the face of climate change and human activities (i.e., adaptation, mitigation, sustainability, and resilience) for addressing the complexity of PURE as a social-ecological system. In practice, synergies, trade-offs, challenges, and opportunities arising from the applications of these four strategies can provide real-world feedback for improving indicators, metrics, and models that can help to more deeply understand the complexity of social-ecological systems in peri-urban landscapes

ity, and resilience) for addressing the complexity of PURE as a social-ecological system. In practice, synergies, trade-offs, challenges, and opportunities arising from the applications of these four strategies can provide real-world feedback for improving indicators, metrics, and models that can help to more deeply understand the complexity of social-ecological systems in peri-urban landscapes



**Fig. 2** Potential interactions between and among mega-scale stressors in peri-urban landscapes: climate change (C), urbanization (U), food production (F), and energy extraction (E). The

impacts of future pandemics may make these interactions more complex and unpredictable

influence summer and winter outdoor activities, including thermal comfort (Miller et al. 2022b). Sea level rise and storms affect coastal recreational zones (Miller et al. 2024). Floods restrict access to recreational sites (Nhamo et al. 2021). Warmer conditions affect the timing, duration, and extent of snow cover directly affecting snow-based tourism (Steiger et al. 2024). Fires affect landscapes, facilities, safety, and biodiversity altering outdoor recreation patterns (Otrachshenko & Nunes 2022; Chapungu et al. 2024). Accordingly, climate change influences how recreationists decide “where to go”, “when to go”, and “what to do”.

#### Urbanization

More than 57% of the world’s population live in cities (World Bank 2025). As urbanization expands, the need for access to green and blue spaces in peri-urban landscapes becomes increasingly important

(Schetke et al. 2016; Huang et al. 2022; Shan & He 2025). Factors like distance from home to green/blue spaces, travel options/costs from city to peri-urban landscape, access to facilities for vulnerable groups, and socio-economic status affect how people use peri-urban landscapes for outdoor recreation (Rossi et al. 2015; Dahlberg et al. 2022; Lehto et al. 2022). The development of transportation networks in peri-urban landscapes, including roads and railways, can become a major threat to biodiversity through increasing the risk of wildlife-vehicle collision, environmental pollutions, and habitat fragmentation (Zuberogoitia et al. 2014; Chaves et al. 2022; Roth et al. 2024).

Dominant models for urban expansion may not secure “public” spaces for outdoor recreation around cities (Engström & Qvistrom 2022). They typically allocate open landscapes surrounding cities to build new residential properties in response to increasing urban populations. This can be associated with the expansion of transport networks to facilitate access. In addition, land and real estate markets in peri-urban

landscapes, including land speculation, play an important role in reducing the availability of land for both outdoor recreation and biodiversity conservation. Combined with climate change, such models of urban growth can give rise to drastic changes to remnant habitats in peri-urban landscapes through structural (e.g., land-cover change, habitat degradation and fragmentation) and non-structural alterations (e.g., environmental pollutions, weeds and feral animals), which can be detrimental to biodiversity and ecosystem processes (Shannon et al. 2017; Almenar et al. 2019; Dertien et al. 2021). Biodiversity loss, in turn, can then undermine the quality of outdoor recreation (Steinhäußer et al. 2015).

#### *Food-energy production*

Through time, land around cities has been, and still is, commonly dedicated to food production and/or energy extraction in support of urban residents (Bailoni et al. 2012; Opitz et al. 2016; Colucci et al. 2017; Patel et al. 2019; Drescher et al. 2021). With urban development and climate change, agriculture is among the most important drivers of widespread land-cover change, including in peri-urban landscapes (Winkler et al. 2021; Boakes et al. 2024). In this context, the use of natural resources in peri-urban landscapes for localizing food and energy production competes with other human activities, including outdoor recreation, with far-reaching consequences for biodiversity (Fischer et al. 2008; Ives & Kendal 2013; Barral & Guillet 2023; Pereira et al. 2024). Large-scale mono-functional extraction of energy, food, and raw material adversely affects outdoor recreation, as it limits access and can diminish the sensory experiences desired by many outdoor recreationists (Hahn et al. 2017). It also affects biodiversity conservation by fragmenting habitat and reducing ecological resilience (Eggers et al. 2018; Pohjanmies et al. 2021). Reaching balance between food production and energy extraction in peri-urban landscapes can provide more room for potential synergies between outdoor recreation and biodiversity conservation, where increased biodiversity affords increased recreational qualities, as well (Gunnarsson et al. 2017; Terraube et al. 2017; Marselle et al. 2021).

#### *Pandemics*

Lockdowns during the COVID-19 pandemic were associated with major changes to how green and blue spaces were used for outdoor recreation, especially in peri-urban and urban-proximate areas (Beckmann-Wübbelt et al. 2021; Smith et al. 2023). Depending on place and time, there were patterns of increased use resulting in harm to wildlife and habitats (Damnjanović 2021; Wójcicki et al. 2023), or decreased use, or change in the types of use and visitors (Smith et al. 2023). Thus, proactive planning is needed to deal with future pandemics that includes factoring in effects on outdoor recreation and biodiversity conservation (Geneletti et al. 2022). This includes resilience thinking, adaptation and mitigation strategies, and sustainable approaches in relation to local, regional, and national goals and circumstances (Elmqvist et al. 2019; Uchiyama & Kohsaka 2020, 2022; Fagerholm et al. 2022). However, the integration of such land-use strategies, including preparedness for pandemics, can be challenging owing to the diversity of goals, interests, management regimes, land ownership types, and power dynamics (Rastan-deh et al. 2025).

#### *Society*

We discussed the dual role of society for PURE, including factors such as education, environmental justice, social media, and traditions and values. The interactions within and among these factors determine how human dimensions in the recreation-conservation nexus in peri-urban landscapes could be addressed.

#### *Education*

There is a growing body of knowledge regarding recreation ecology in protected areas (e.g., national parks, nature reserves; Miller et al. 2022a). The questions of how to perform effective environmental education for visitors and local people (Fox & Thomas 2023; Zhang et al. 2023), partially in effort to support the goal of strengthening recreationists' pro-environmental behaviors and sense of environmental responsibility or stewardship (Jeanson et al. 2021; Choi & Kim 2024), are among the most frequent topics in research. Compared to remote national parks,

peri-urban landscapes are much easier for more people to access (Lehto et al. 2022). As a result, education on pro-environmental behaviors and broad/inclusive reconnection to nature can become even more important (MMV 2024). However, in peri-urban landscapes, these issues remain understudied. Education and outreach programs provide opportunities to involve local communities in recreational activities in peri-urban protected areas, including through public–private partnerships (i.e., partnerships between management agencies and partner organizations; Cerveny et al. 2020).

#### *Environmental justice*

Environmental justice dimensions of PURE are essential to ensure that access to peri-urban landscapes for outdoor recreation is just, safe, and affordable (Kato-Huerta & Geneletti 2023). In this respect, safety for all, accessibility, and affordability are three major topics of interest. Achieving environmental justice requires education, ethics codes, regulation, laws, and socially-acceptable zoning that support underrepresented and vulnerable social/ethnic groups. In many countries, for example, homelessness in public lands and protected areas around cities is a challenging issue with widespread implications for social-ecological sustainability and the resilience of peri-urban landscapes (Derrien et al. 2023; Pitas et al. 2024; Land & Derrien 2025). Despite its growing complexity, this issue is rarely a priority, in research, policy and practice.

Another important dimension of environmental justice is the extent to which Indigenous Peoples are involved in landscape design, management, and stewardship (Lane 2006; McGregor et al. 2020; McLeod et al. 2024). Thus, understanding Indigenous Knowledge and hearing the voices of Indigenous Peoples, as key stakeholders, are core to environmental justice in PURE. Indigenous Knowledge can play an outsized role in supporting biodiversity in lands and waters controlled, or historically used, by Indigenous Peoples (Rastandeh and Jarchow 2022; Cooper et al. 2023). Many urban regions are home to a diverse range of human populations, including Indigenous Peoples, with diverse values, needs, demands. Furthermore, greater populations in urban regions may mean higher visitor pressures on peri-urban landscapes, with high risks of

user conflicts and crowding issues relating to distributional justice and interactional justice issues (Rigolon et al. 2022). In particular, in landscapes historically valued by Indigenous Peoples, site-specific, inclusive land-use strategies informed by Indigenous Knowledge should be incorporated into PURE.

#### *Social media*

With social media dominating communications globally, it affects how, when and why people use peri-urban landscapes for outdoor recreation (Toivonen et al. 2019; Teles da Mota & Pickering 2020; Lingua et al. 2023). Popular digital platforms often promote outdoor recreation, but can harm biodiversity and lead to conflict with other activities and stakeholders (Arndt 2023; Davis et al. 2024). For example, untrained influencers have contributed to overtourism by encouraging people to visit areas in unsustainable ways (Solanky & Gupta 2021). There are countless examples of images and videos of visitors on social media whose behaviors damage the environment, as well as inaccurate information about nature (e.g., species, ecosystems, climate, etc.), regions, and cultures (Mangachena et al. 2022). In addition, some social media and sports apps show unofficial trails resulting in unsustainable use of green and blue spaces in peri-urban landscapes (Mendes et al. 2023; Smith & Pickering 2025).

Social media can be used to promote environmental awareness about peri-urban landscapes. Examples demonstrate how social media increases environmental awareness among local communities and those engaged in outdoor recreation. An in-depth understanding of positive and negative impacts of social media on outdoor recreation and biodiversity conservation is therefore important, but lags behind the dominance of social media in people's lives and as a key source of information shaping where, when and why they engage in outdoor recreation.

#### *Traditions and values*

Land-use legacies, land ownership regimes, livelihoods, employment, and social norms shape people's traditions and values for landscapes (Rastandeh et al. 2021). They have important roles in characterizing

land-use patterns, as well as the acceptability of different activities, including outdoor recreation (Brown et al. 2020). Traditions linked to the use of land and water relate to historical preferences and/or Indigenous Knowledge (Bruchac 2014; Radcliffe & Parissi 2024). Furthermore, such differences in underpinning values can influence perceptions of elements of landscapes (Kohsaka & Flitner 2004; Kohsaka & Handoh 2006; Kovács et al. 2022). If integrated with policy and practice, this kind of knowledge can support equity, as well (Santafe-Troncoso & Tanguila-Andy 2024). In multicultural contexts, conflicts between perceptions of acceptable human activities can increase in tandem with the multitude of values (Flemsæter et al. 2015). Therefore, dialogues about values and traditions need to be open and inclusive to support environmental justice. In this respect, developing an understanding of the role of traditions and values in the design, management and stewardship of peri-urban landscapes should become an essential dimension of PURE.

## Data

In an era of smart phones, big data, artificial intelligence (AI), large language models (LLM), and advanced digital technologies, accurately collecting, visualizing, and analyzing data may be pivotal for generating knowledge in PURE. Without data-driven, evidence-based decision making, there can be limited support for policy and practice. In this context, insufficient data and methods to analyze and present data are among major challenges. We discussed this issue in relation to methods and tools, databases and protocols, and technologies.

### Methods and tools

Understanding when, how, where and why people use peri-urban landscapes for outdoor recreation, how wildlife uses and relies on these landscapes (i.e., the spatial ecology of wildlife), and human–environment dynamics in relation to climate, land-use, water, and other environmental factors, requires efficient, reliable tools and methods to collect and analyze data (Rastandeh et al. 2025). New sources of data include publicly available user-created content such as that available on citizen science platforms, sports/fitness apps and social media. There are large publicly

available citizen science databases that contain information about wildlife, as well as where people go and when and their interests in biodiversity (Cheung et al. 2022). These include billions of records covering millions of species provided by hundreds of thousands of people on platforms such as iNaturalist and eBird. They have been used in research to understand, map, and analyze the spatial distribution of biodiversity across different spatial scales, including in peri-urban landscapes (Rutter et al. 2021). However, for reliable e-data collection by citizens, the state of democracy, as well as the freedom of expression are essential.

Another source of user-created data is volunteered geographic information from fitness apps that can provide insights into outdoor recreation use of peri-urban landscapes (Norman & Pickering, 2019; Mendes et al. 2023; Smith et al. 2023). This includes data from platforms such as Strava, Alltrails, Trailforks, Wikiloc and MapMyFitness, with millions of people posting billions of routes for hiking, running and riding (Norman & Pickering, 2019; Nogueira Mendes et al. 2023; Costa et al. 2024). Such data can be used to assess temporal and spatial use of landscapes, including for specific activities (Mendes et al. 2023; Smith et al. 2023; Venter et al. 2023). Finally, social media has become a major source of data about outdoor recreation, including in peri-urban landscapes (Teles da Mota & Pickering 2020). This includes analyzing location, text, and image data (Wartmann et al. 2021), as well as understanding visitor preferences for locations and wildlife (Ghermandi 2022). Processing such data has become much faster and easier with the emergence of deep learning models for text and image recognition (Gosal et al. 2019; Winder et al. 2022).

For all three examples of user-created content, there are important limitations, including who uses each platforms and why, changes in the platforms, including the availability of data, how representative may be the data, and privacy and ethical considerations (Teles da Mota & Pickering 2020; Venter et al. 2023). These sources of data can facilitate multi-level participatory/knowledge co-production, inclusive approaches to reach a broad variety of urban and peri-urban societies. Such tools and methods can be used for building, co-creating, co-developing, and maintaining reliable and useful databases for PURE research, policy, and practice. Such tools and methods have the potential to shorten the feedback between

peri-urban landscapes and stakeholders, which can improve the adaptive capacity in planning and management in this rapidly changing context.

#### Databases and protocols

It is important to integrate different types of data when building robust, permanent databases for policy makers and practitioners. Such databases can be an integral part of evidence-based decision support systems, for a broad range of stakeholders using peri-urban landscapes. As decisions on outdoor recreation and biodiversity conservation are made by various organizations, with different, if not contradictory, goals, new monitoring mechanisms are also required to measure the effectiveness of using such databases. These monitoring mechanisms should be capable of providing a common platform to ensure that accurate decisions are made collectively by organizations of diverse interests and goals. Owing to the proximity of peri-urban landscapes to cities (i.e., the major hubs of socio-economic activities), these databases should be co-designed and jointly owned in ways that they are accepted by a wider part of urban and peri-urban societies and can be updated in accordance with uncertainties associated with rapid socio-economic and land-use changes at local, regional, and national scales.

In addition, as data on PURE may involve human and animal subjects, specific protocols are needed to facilitate the process of data collection, management, and storage with attention to ethical, societal, and regulatory requirements (Sandbrook et al. 2021). In some organizations, countries, and regions, there exist protocols that apply to such data (e.g., the General Data Protection Regulation – GDPR – across the European Union); however, both multi-organizational and/or international research collaborations may still face some barriers in data collection and processing, as organizations and countries follow different organizational/national policies and protocols for Human Subject Research (HSR).

#### Technologies

Technology is changing rapidly, including in relation to PURE. This includes how to measure, monitor, and assess visitors' behaviors in peri-urban landscapes. The spatial and temporal behaviors of visitors, as well as the values they hold for these areas can be mapped and modelled using more innovative forms of Public Participatory GIS (Sieber 2006), Social Values for Ecosystem Services (Sherrouse et al. 2011), and Landscape Values Mapping (Biedenweg et al. 2019; Rastandeh et al. 2021), harnessing different types of user-created content. Global Positioning Systems (GPS) devices, and publicly available location data can also be used to improve our overall understanding of how recreationists may use green and blue spaces in peri-urban landscapes (Smith et al. 2021; Wessstrom et al. 2021; Wilkins et al. 2021). Technologies such as remote sensing, on ground passive and active sensors, AI-assisted tools, and machine learning algorithms, including deep learning methods are all being increasingly used in research (Silvestro et al. 2022; Bibri et al. 2024; Zhang et al. 2025), and in relation to PURE, in particular (Sun & Shao 2020; Lingua et al. 2023). Examples include the use of camera traps in Morrisville, North Carolina (Miller et al. 2017), the Stone Mountain State Park, North Carolina (Miller et al. 2020), Bavaria, Germany (Mitterwallner et al. 2024), photograph analysis based on social media content in Finland (Väistänen et al. 2021), and mobile-phone data-driven analysis for measuring environmental equity among recreationists in peri-urban landscapes of Tokyo, Japan (Guan & Zhou 2024). In this respect, human dimensions of PURE can be linked to data, as well as the tools and methods needed for understanding the interactions and feedback between outdoor recreation and biodiversity conservation in relation to the abiotic, biotic, and cultural components of peri-urban landscapes. Technologies should be strategically used to inform the future directions of research, policy, and practice in PURE.

#### Future directions

Rastandeh et al. (2025) discussed the recreation-conservation nexus in peri-urban landscapes and

suggested three priorities for further research on the “spatial” dimensions of human-wildlife interactions in relation to social and ecological dynamics in peri-urban landscapes. In this *Perspective*, we extended this discussion by conceptualizing PURE, as a social-ecological system and identifying future research, policy, and practice priorities. The issues discussed above reflect the multidimensionality and multifunctionality of peri-urban landscapes. The knowledge we cogenerated over one year of in-person and online discussions can be used to inform the future of PURE. This work was an effort to gather a diverse range of experts in the field from different regions corresponding the multidimensionality of topics in PURE. However, reflecting the importance and diversity of PURE, our discussions in this *Perspective* should be considered as the “tip of the iceberg”. Here, we highlight ten priorities for PURE research, policy, and practice. If properly aligned with the Sustainable Development Goals (SDGs), they can function as a starting point for deeper and more widespread dialogues. Therefore, the potential link between the priorities we identified and the SDGs may be considered as a platform for further research in the future.

#### Conceptualizing a social-ecological system approach

There is a pressing need for an inclusive, spatially-explicit definition of peri-urban landscapes to more clearly characterize its specific social-ecological dynamics. The concept of PURE needs to be framed as a complex social-ecological system. Thus, conceptual frameworks that align with traditions in peri-urban planning are needed to be used in both detailed city planning and regional spatial planning outside cities. One fundamental question to be addressed within such frameworks is how abiotic, biotic, and cultural elements interact over space and time on a gradient from a city center to wildlands, and how those interactions affect the recreation-conservation nexus across various scales in such a complex, diverse, and contrasting gradient.

#### Developing a comprehensive, interdisciplinary framework

The design, management, and stewardship of peri-urban landscapes should be climate-adapted, ecologically feasible, and socially supported. To meet these three interconnected goals, the use of a comprehensive framework to articulate the complexity and dynamics of social-ecological systems is essential. Such a framework is not currently available in research nor policy and practice. In Fig. 1, we provided a preliminary version of such a framework; and the next step will be to examine how this framework can be contextualized to various settings. For this reason, one important dimension of future research, policy, and practice in PURE is to focus on a transition from concept to implementation using the suggested framework.

#### Enhancing participatory and data-driven knowledge

To support the multifunctionality of peri-urban landscapes for outdoor recreation and biodiversity conservation, future policies and practices should become more inclusive, data-driven, and evidence-based. Research on PURE can help; however, new tools, methods, and protocols are needed to build and maintain long-term databases for research; but with an even greater focus on the realities on the ground. Such research should be future-oriented, multidisciplinary, site-specific, time-sensitive, and focus on human dimensions, with particular emphasis on a high level of public participation and collaboration among organizations with diverse interests and goals.

#### Developing indicators, metrics and models

To make more informed decisions about peri-urban landscapes, more powerful, accurate indicators, metrics, and models are needed to understand the complexity of PURE. These tools must be “functional” and may be developed by researchers; however, they should also have the capacity to be used by practitioners and policy makers. Land-use issues linked to human-wildlife coexistence are complex and multidimensional, and influenced by spatial and temporal scales, diverse stakeholders, power dynamics, and mega-scale trends linked to climate change, urbanization, food production, energy extraction,

and potentially, future pandemics. In this context, the proper use of big data, cross-disciplinary databases, and emerging technologies is the key.

#### Measuring the impacts of urban-nature proximity

The proximity of peri-urban landscapes to dense human population centers can intensify the cumulative impacts of climate change and human activities on biodiversity, which in turn, increases the complexity of these socio-ecological systems when making decisions about outdoor recreation against biodiversity conservation. Further work is needed to understand how to monitor, measure, and support human-wildlife coexistence in these dynamic systems using appropriate tools, as well as the tradeoffs of weighing both challenges and benefits of outdoor recreation in (semi) natural areas in peri-urban landscapes.

#### Developing site-specific land-use strategies

The four categories of land-use strategies for supporting human-wildlife coexistence in peri-urban landscapes (i.e., adaptation, mitigation, resilience, and sustainability) should be employed with attention to the context (i.e., local challenges vs. local opportunities). For example, areas of interest for outdoor recreation and areas of ecological importance for biodiversity conservation often overlap, interact, and/or clash over space and time. These four land-use strategies should be employed to maximize synergies while minimizing conflicts between outdoor recreation and biodiversity conservation. At the same time, it is important to recognize that real-world applications of these strategies in peri-urban landscapes can be complementary, neutral, or contradictory depending on socio-economic, environmental, and climate conditions in each region.

#### Understanding the impacts of social media

Greater focus should be placed on effective methods and approaches through which the positive and negative impacts of social media on PURE become more predictable and manageable. Of major importance is also to examine how the content of social media is understood by recreationists of different age, cultural, or educational backgrounds in various regions.

#### Building capacity for unforeseen changes

Changes in outdoor recreation during the COVID-19 pandemic revealed that peri-urban landscapes are not ready for rapid changes associated with pandemic crises, and likely not other abrupt changes in the future. The feasibility of applying more resilient land-use strategies should be taken into consideration when preparing peri-urban landscapes for abrupt changes in both the number of recreationists and their spatio-temporal preferences for outdoor recreation activities in the face of future pandemics. Preparedness for managing overcrowding in peri-urban landscapes requires flexible, time-sensitive zoning strategies that provide secured spaces for wildlife in the face of such unforeseen situations.

#### Improving sustainable multifunctionality

Due to spatial proximity to cities, as the main source of consumption, peri-urban landscapes are cost-effective places for food and energy production. To minimize human-wildlife conflicts, the relationships between food-energy, biodiversity conservation and outdoor recreation should be evaluated using real-world data on human activities, wildlife, land-cover, climate, and environmental factors. By understanding human land-use preferences and species behaviors/movement patterns over space and time, relevant land-use strategies can be employed to minimize the impacts of human activities on biodiversity conservation while supporting sustainable multifunctionality. Applying wildlife-friendly strategies in agricultural lands (e.g., land-sharing) is an example of possible ways for meeting this goal.

#### Supporting environmental justice

Environmental justice, as a goal, should be incorporated into the design, management, and stewardship of peri-urban landscapes. To provide equal, safe, and inclusive access to land and water in peri-urban landscapes, more proactive, real-world, cross- and multidisciplinary collaborations among social and ecological scientists, practitioners, and policy makers are required. One way, among others, to support environmental justice in peri-urban landscapes is to include various stakeholders (e.g., public and private land-owners), in the process of all-encompassing decision

making for the future of these landscapes. This can be achieved by designing more collaborative, decentralized strategies for applying local nature-based solutions in response to real-world challenges perceived by stakeholders of different interests.

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## Declarations

**Conflict of interest** The authors declare no competing interests.

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