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Editorial

Urban Ecosystem Services: Agroecology, Green Spaces, and Environmental Quality for Sustainable Futures

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1. Introduction

The cycle of population growth, rural-to-urban migration, and subsequent urban overbuilding poses a significant threat to both human health and the health of urban ecosystems [1–3]. This vicious cycle results in detrimental consequences, such as increased urban temperatures (forming urban heat islands); air, soil, and water pollution; and habitat destruction, with subsequent negative effects on biodiversity [4,5]. Furthermore, the rise in extreme temperature events due to climate change, along with the related mortality and hospitalization cases [6,7], necessitates a shift in how we think about urban planning, especially in terms of achieving the Sustainable Development Goals (SDGs) and the objectives of the Global Biodiversity Framework (GBF) [8].

Addressing these challenges requires a transition towards more sustainable and ecologically based urban planning strategies [9,10]. One promising approach is the application of the ecosystem service (ES) concept in urban planning and design, which holds significant potential for improving environmental and human health outcomes in the built environment [11]. Therefore, in order to advance human well-being and sustainable development, urban ecosystems must be managed sustainably to ensure their conservation and sustainable use [12]. Although the demand for ESs like food and clean water is increasing, human activity is simultaneously reducing the ability of many ecosystems to fulfill these needs [12].

In addition, despite the benefits of ESs, challenges to their implementation in local city planning still exist [11]. To address these challenges, a key priority is the creation of accessible green spaces that provide crucial ESs. This ensures that all residents, especially children [13–15], have access to nature, enhancing their overall quality of life [16,17] and contributing to a more equitable and sustainable urban environment. Therefore, continued research into the benefits of ESs is essential. This provides policymakers and local governments with the necessary evidence-based guidance for incorporating these services into city planning. Thus, this editorial highlights the key findings from the fifth Special Issue (SI) on urban ESs, with the aim to inform and support policymakers and local government decision-making

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Received: 20 January 2025
Accepted: 21 January 2025
Published: 30 January 2025

Citation: Russo, A.; Cirella, G.T. Urban Ecosystem Services: Agroecology, Green Spaces, and Environmental Quality for Sustainable Futures. *Land* **2025**, *14*, 288. https://doi.org/10.3390/land14020288

2. SI Contributions

This SI on ESs demonstrates the development of research in this field after the previous four SIs [18]. This fifth edition includes 12 contributions, encompassing a wide range of topics, ranging from the microscopic realm of lichens to the vital role of urban trees. For instance, Nam et al. (2024) (Contribution 12) focused on optimizing street tree selection to maximize ecological benefits and enhance urban green space management. Their research encompassed 221.9 km of streets and 19,717 trees in Uijeongbu City, South Korea, classifying them into 12 street types based on characteristics such as road width, aspect ratio, land use, and the presence of power lines. By matching tree species to specific street types, this study identified the traits and functions most suitable for each environment. For example, narrow streets with power lines, the second most common street type, offered limited species options, highlighting the need for greater diversity. With dominant species representing an average of 44% across all street types, the importance of introducing a wider variety of species becomes even more apparent. Ultimately, the findings demonstrated that trees better suited to their environment provided superior ESs compared to less suitable ones, supporting policies that promote tree diversity to enhance urban resilience and ecological functionality.

Building on the theme of urban ecosystems, Wei et al. (2024) (Contribution 11) evaluated the synergies between objective and subjective assessments of urban park ESs in Shanghai's Century Park. Their study focused on buffer gradients, or spatial zones surrounding parks, to analyze how different perspectives influence the understanding of ecosystem benefits. The authors compared objective measurements, such as ecological metrics, with subjective evaluations collected from park users. The results indicated that objective and subjective assessments often aligned; however, discrepancies emerged in certain buffer zones due to user perceptions or environmental variations. This research underscores the value of integrating both evaluation methods to improve urban park design and management, ultimately leading to enhanced ecosystem service delivery and greater user satisfaction.

Shifting the focus to smaller urban green spaces, Ćwik, Wójcik, and Przydział (2024) (Contribution 10) assessed the conservation and recreational potential of small forest enclaves in Rzeszów, a city in Southern Poland characterized by limited forest cover (2.8%) and a dysfunctional natural system. Using the ES and ecosystem disservice framework, the authors analyzed 14 indicators across three of the city's five larger forest patches. Their findings revealed a mismatch between current management practices and the actual conservation potential of these areas. Specifically, two enclaves demonstrated significant, previously overlooked conservation value, while one site exhibited the highest recreational potential. This study emphasizes the need for more informed policies to optimize the use and protection of urban forest patches for both nature conservation and recreation.

Expanding the scope beyond traditional urban green spaces, Morris et al. (2024) (Contribution 9) explored integrating agroecology into urban planning to maximize ESs in peri-urban areas, addressing the challenges posed by urban sprawl. Unlike traditional urban agriculture, which focuses primarily on food security, this approach prioritizes regulating ESs crucial to urban systems. Using a GIS-based model called ESMAX, the authors identified spatial configurations of agroecological farm systems (AFSs) that optimize the provision of three key regulating ESs and their multifunctional performance. Applying their methodology to a 200-hectare peri-urban development, where 1-hectare and 4-hectare AFS parcels were interspersed with residential areas, they found that evenly distributed AFS parcels provided the highest multifunctionality across ESs. This research demonstrates how spatially explicit agroecology can reconcile urban expansion with the ecological goals of a "Good Anthropocene", advocating for a hybrid approach to rural and urban systems in the context of global dedensification trends.

Further highlighting the importance of considering human well-being in ecosystem management, Janeczko et al. (2024) (Contribution 8) examined the psychological restoration benefits of various forest management practices in a suburban forest near Otwock, Poland, within the Warsaw metropolitan area. Comparing the effects of exposure to mature forest stands, second-growth forests, and clear-cutting areas on 55 university students, they assessed mood, vitality, and restorative experiences using psychological questionnaires. The results showed that mature forest stands provided the most significant psychological benefits, including improved mood, reduced tension, and increased vitality. While second-growth forests provided some restorative benefits, they were less pronounced. In contrast, exposure to clear-cutting areas negatively affected mood, increasing tension and depression while reducing vigor. These findings highlight that clear-cutting not only diminishes the health and well-being benefits of forests but also negatively affects urban visitors seeking recreational and restorative experiences. This study highlights the importance of forest management practices that prioritize the maintenance of natural or near-natural landscapes to maximize human health and well-being in urban and suburban areas.

Focusing on broader ecological trends, Long, Bai, and Zheng (2024) (Contribution 7) evaluated the ecological environment quality of Changle District, Fuzhou, China, from 2000 to 2020, using the Remote Sensing Ecological Index (RSEI) method. Examining the spatiotemporal dynamics of ecological changes and identifying key driving forces, they found that the RSEI score improved from 0.6333 in 2000 to 0.6625 in 2022, indicating an overall improvement in ecological conditions, particularly in the southern and southwestern areas. However, localized degradation was observed in the northwest and eastern regions due to industrial emissions, transportation activities, and land use changes, such as the expansion of construction land. Using the GeoSOS-FLUS model, they predicted that without significant improvements, urbanization will intensify, increasing built-up areas to 32.93% by 2030, primarily at the expense of grasslands. This research emphasizes the need for targeted strategies, such as reducing industrial and traffic emissions, optimizing land use, and promoting ecological sustainability.

Similarly, Yang and Li (2024) (Contribution 6) explored strategies to improve urban ecological welfare performance (EWP) in the Yangtze River Economic Belt, a key region for China's sustainable development. Developing a quantitative framework linking the welfare of urban residents with ecological resource consumption, they used the spatiotemporal Logarithmic Mean Divisia Index (ST-LMDI) model to assess EWP across 108 prefecture-level cities from 2006 to 2022. Their analysis revealed a "W"-shaped trajectory in EWP during this period, with marked spatial disparities, particularly demonstrating superior performance in downstream coastal areas like the Yangtze River Delta. This was attributed to advanced social and economic structures and public fiscal investments. Identifying six factors influencing EWP—social benefit, economic benefit, population dispersion, urban population density, urbanization scale, and ecological sustainability—they found that economic benefits and urbanization scale were the primary drivers of improved EWP, while population dispersion served as a significant inhibitor. This study highlights the dynamic interplay between economic growth, ecological preservation, and public welfare, offering valuable insights for local governments to craft tailored policies that balance development with sustainability.

Zhang et al. (2024) (Contribution 5) investigated the eco-environmental effects of land use changes in Chongqing, a mountainous city, by applying the ecological–production–living spaces framework and machine learning models. Calculating the EQI for the city's central urban area from 2000 to 2020, they evaluated the impact of land use patterns on the environment. Their findings revealed that living spaces increased by 361.53 km^2, while production and ecological spaces decreased by 331.42 km^2 and 30.11 km^2, respectively. Consequently, the eco-environment quality declined steadily, with the EQI dropping from 0.3665 in 2000 to 0.3501 in 2020, reflecting an overall degradation in the region's ecological state. This study also identified the key factors influencing this decline, including pesticide use, grain production, and the economic output of the primary industry, using a random forest model. This research underscores the growing tension between economic development and ecological sustainability, advocating for integrated land use policies to balance these competing concerns.

Huang et al. (2024) (Contribution 4) explored the ecological security pattern (ESP) of the Beijing–Tianjin–Hebei (BTH) urban agglomeration from 2000 to 2030, focusing on balancing economic development and ecological protection. Using the GMOP and PLUS models to simulate future land use changes across three scenarios—natural development, ecological protection (EP), and economic development—and applying the MSPA model and circuit theory to identify ecological source areas and construct the ESP, they found that the proportion of ecological source areas increased from 22.24% in 2000 to 23.09% in 2020, with the EP scenario resulting in the highest proportion. They also observed an increase in the number of ecological corridors, with the EP scenario again showing more corridors. This study highlighted the influence of both socio-ecological drivers (e.g., elevation, slope, population) and ecological factors (e.g., temperature, NDVI, precipitation) on the ESP. These findings emphasize the importance of considering both types of drivers to improve and restore regional environments and enhance the overall ESP and landscape connectivity in the BTH region.

On a smaller scale, Moreno-Palacios et al. (2024) (Contribution 3) assessed corticolous lichen communities in urban and peri-urban areas of Ibagué, Colombia, focusing on their richness, composition, abundance, and correlation with atmospheric oxide concentrations. Examining 25 individuals from four abundant phorophyte (tree) species, they recorded 29 lichen taxa across 13 families and 17 genera. Their findings revealed higher lichen coverage and species richness in the urban area compared to the peri-urban area. Non-metric multidimensional scaling (NMDS) analysis further distinguished two distinct lichen communities between these areas, with compositional differences based on the phorophyte species. This study identified both exclusive and indicator taxa for each zone and established associations between environmental variables using a general linear model. Higher concentrations of atmospheric gases such as CO, SO_2, NO_2, and O_3 were detected in the urban area, with observed positive and negative correlations between these gases and specific lichen taxa. This research highlighted the varied responses of lichen communities in urban and peri-urban ecosystems to environmental factors, demonstrating significant or minimal changes in richness, coverage, and phorophyte association. This study concluded that the interaction of the lichen assemblage with atmospheric oxides helped identify patterns of species tolerance or sensitivity, making them valuable bioindicators.

Shifting to the intersection of urban design and climate change, Wai et al. (2024) (Contribution 2) conducted a simulation-based study to examine how parametric design can influence outdoor thermal comfort and mitigate urban overheating, particularly in the context of energy consumption and climate change. Recognizing the significant contribution of buildings to carbon emissions, especially through energy use for thermal comfort, and the increasing frequency and intensity of extreme heat events, this study highlighted the potential of parametric design as a flexible and sustainable approach to address these challenges by simulating various design scenarios. Using the Grasshopper program with the Ladybug plug-in within Rhinoceros 3D, the authors simulated outdoor thermal comfort scenarios in Melbourne, Australia, analyzing how different built environment scenarios impacted outdoor thermal comfort in specific climates. By comparing the thermal performance of various design scenarios, this study identified the key factors influencing thermal comfort, such as building height, orientation, and urban geometry. The findings underscored the role of parametric design in analyzing microclimate patterns and improving outdoor thermal comfort in existing urban environments. They provide valuable insights for stakeholders and builders to enhance urban planning and building design practices, contributing to a zero-emission future.

Finally, Liu et al. (2024) (Contribution 1) examined the spatiotemporal dynamics of constructed wetland landscape patterns in Chengdu, China, focusing specifically on the Bailuwan Wetland Park. Aiming to understand how rapid urbanization impacts wetland ecosystems, particularly in inland megacities like Chengdu, the authors used satellite imagery from 2010 to 2021 to investigate changes in landscape patterns across various land use/land cover types and time frames. Their findings revealed that urbanization significantly affected several patch- and landscape-level characteristics, including class area, number of patches, patch density, and various indices such as landscape shape, fragmentation, and diversity. Over the decade studied, they observed an increase in the patch number and density, indicating greater complexity and fragmentation in the landscape. The overall landscape became more heterogeneous, while diversity decreased. Particularly, the conversion of 52 hectares of agricultural land to vegetation increased landscape complexity. This study also found a decrease in the area of lakes and rivers after the park's establishment, coupled with an increase in bare land. These findings highlight the substantial role of urbanization in altering wetland landscape patterns, leading to greater fragmentation and a potential loss of biodiversity. The authors emphasized the critical need to prioritize the restoration and protection of urban constructed wetlands to mitigate the negative effects of rapid urban development on these vital ecosystems.

3. Conclusions

This SI presents a diverse body of research on ESs, exploring topics ranging from lichen communities as bioindicators (Moreno-Palacios et al., 2024) (Contribution 3) to ecological security patterns in urban agglomerations (Huang et al., 2024) (Contribution 4). Studies examined urban green space management (Nam et al., 2024; Wei et al., 2024; Ćwik, Wójcik, & Przydział, 2024) (Contribution 12, 11, 10), the integration of agroecology in peri-urban areas (Morris et al., 2024) (Contribution 9), the psychological benefits of forests (Janeczko et al., 2024) (Contribution 8), and the impacts of urbanization on ecological quality and land use (Long, Bai, & Zheng, 2024; Zhang et al., 2024; Liu et al., 2024) (Contribution 7, 5, 1). This Special Issue also addressed ecological performance and human welfare (Yang & Li, 2024) (Contribution 6) and urban design for climate change mitigation (Wai et al., 2024) (Contribution 2).

The studies from this SI emphasize the importance of integrating ecological considerations into urban planning, particularly in regions experiencing rapid urbanization and environmental challenges. However, a deeper understanding is essential, especially in the Global South and tropical ecosystems in developing countries. These regions, often grappling with critical socio-economic pressures and climatic uncertainties, may perceive and manage ESs differently than regions with more resources and established systems [19]. Understanding how ESs are integrated into urban planning across diverse socio-ecological contexts is crucial for ensuring the sustainability of urban ecosystems in these vulnerable regions. This requires targeted research to identify barriers to implementation and foster interdisciplinary approaches that consider local realities [20].

ESs, the benefits people derive from natural systems, are a rapidly growing area of research with immense potential for sustainable natural resource management. However, it is essential to recognize the complexities inherent in the supply of these services [21]. Failing to account for the intricate feedback loops within and between natural and social systems could lead to misleading or ineffective policy recommendations [21]. A narrow academic approach that overlooks these complexities risks underestimating the uncertainty in how ecosystem services are delivered. On the other hand, explicitly acknowledging these complexities and uncertainties will allow for more reliable and informative models, which are essential in predicting the impacts of environmental change and guiding urban planning and policy decisions [21].

Future research must prioritize accurately quantifying and valuing ESs while addressing key gaps in knowledge. These gaps include advancing trade-off analyses from simple spatial correlations to exploring causal relationships between ESs and utilizing multi-criteria methods that consider both spatial and temporal changes [19]. Additionally, a broader scale of analysis, such as entire landscapes or river basins, is necessary to gain a more integrated understanding of ecosystem interactions and their role in urban planning [19]. The integration of diverse stakeholder preferences is also critical for promoting mutually beneficial outcomes in ecosystem management [19].

As technological advancements progress, exploring how artificial intelligence (AI) can support the monitoring, modeling, and decision-making processes related to ESs will be crucial [22]. AI can optimize data collection and analysis, providing valuable insights into the state and trends of ecosystem services. Moreover, effective governance mechanisms must be established to facilitate collaboration among stakeholders, support adaptive management, and ensure equitable policy outcomes, particularly in resource-constrained settings [20]. By addressing these multifaceted challenges, we can develop more robust strategies for managing urban ecosystems and ensuring the long-term sustainability of ecosystem services in urban areas.

Author Contributions: Writing—original draft preparation, A.R.; writing—review and editing, A.R. and G.T.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflicts of interest.

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