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What's ahead: navigating the future of environmental science in and around cities in post-pandemic times

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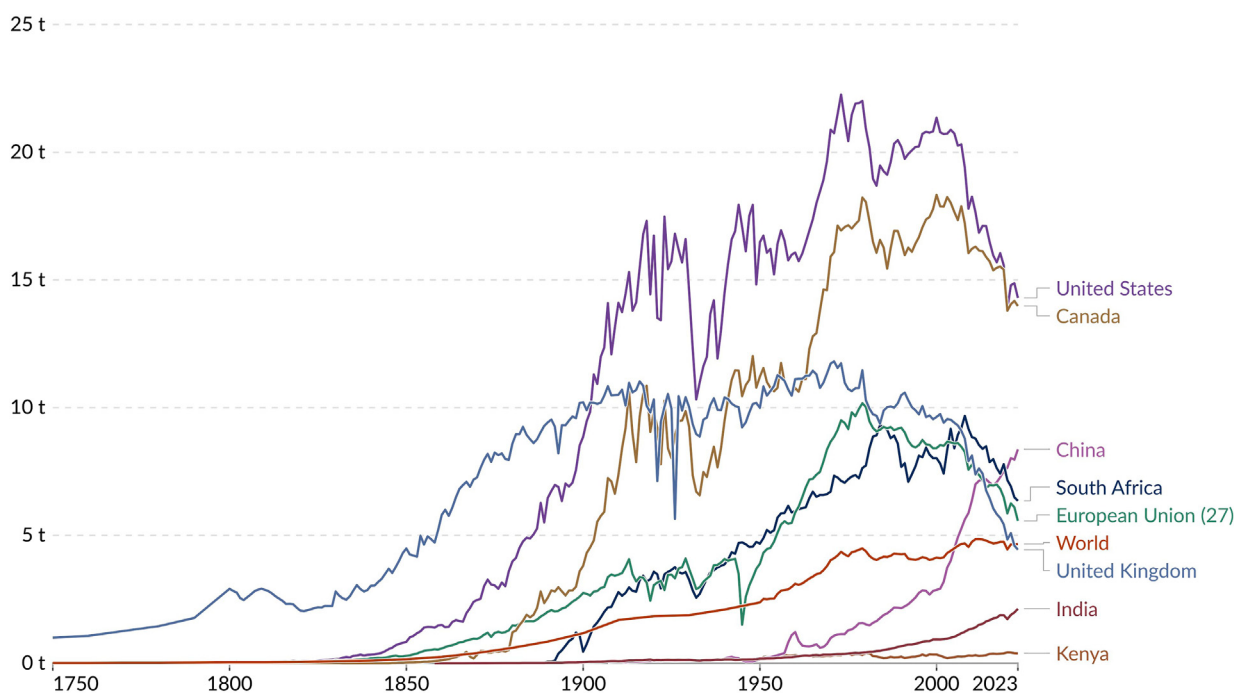
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It is evident that the planet is experiencing a series of ecological crises, manifesting in the form of temperature rise, ocean warming, biodiversity loss and natural disasters. This phenomenon has been further emphasised by the World Meteorological Organization's designation of 2024 as a 'year of extremes' having a direct impact on many people and societies globally. Therefore, it has perhaps never been more topical to quote Shakespeare's Hamlet: "The world is out of joint.". This sentiment captures the uncertainty surrounding the ability to meet the established targets of the Paris Agreement, namely, the 1.5- and 2-degree limits on global warming (Figure 1). In particular, the ongoing loss of biodiversity has significant ramifications for the resilience of our ecosystems, including urban ones, which are vital for responding to and recovering from disturbances associated with global warming (Andersson et al., 2022; Kowarik et al., 2025).

Concurrently, and which only appears to be independent at first glance, since the 2010s, there has been in addition an observable rise in autocratic politics and a partial rejection of democracy as a societal model, owing to the evident distrust many people have in its ability to address the global challenges reported above. Only 45% of the world's population lives in a democracy, with 39% under authoritarian rule, and 15% in hybrid regimes that combine electoral democracy with authoritarian tendencies (Economist Intelligence Unit, 2025). The coronavirus pandemic has reinforced and accelerated these prevailing trends (Haase, 2021; Otto and Haase, 2021). Chief amongst these is the erosion of trust amongst younger generations in state support and social promises for the future, a phenomenon that is particularly evident in Western democracies.

What does this have to do with the most urgent question in the research field of social-ecological urban systems, and why does it need to be answered immediately? Because this question must be something like this: How do we address the global risks outlined above? How do we get a sustainable and socially balanced transformation off the ground that is geared towards the 1.5-degree target, that allows for the co-existence of humans and nature and thus the survival of all species, and that fairly distributes the benefits and burdens for us humans, to address the global risks outlined above, in particular the most vulnerable among us? What is more, because cities and their urban social-ecological systems are not the only answer, but a decisive one!

Why? Cities are the places where meanwhile most of the global population resides. It is anticipated that they will continue to experience growth in terms of both population and importance in the future: Mid-2024 approximately 4.8 of the more than eight billion people worldwide lived in towns or cities. This represents almost 60% of the global population. By 2030, this figure is set to reach 60% (Democracy Index, 2024). Urban areas are the locations of over 60% of all universities, functioning as pivotal centres of innovation and international



Data source: Global Carbon Budget (2024); Population based on various sources (2024)
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1. Fossil emissions: Fossil emissions measure the quantity of carbon dioxide (CO₂) emitted from the burning of fossil fuels, and directly from industrial processes such as cement and steel production. Fossil CO₂ includes emissions from coal, oil, gas, flaring, cement, steel, and other industrial processes. Fossil emissions do not include land use change, deforestation, soils, or vegetation.

FIGURE 1
Per capita CO₂ emissions as carbon dioxide (CO₂) emissions from fossil fuels and industry. Land-use change is not included (Ritchie, H. et al., 2023; our world in data).

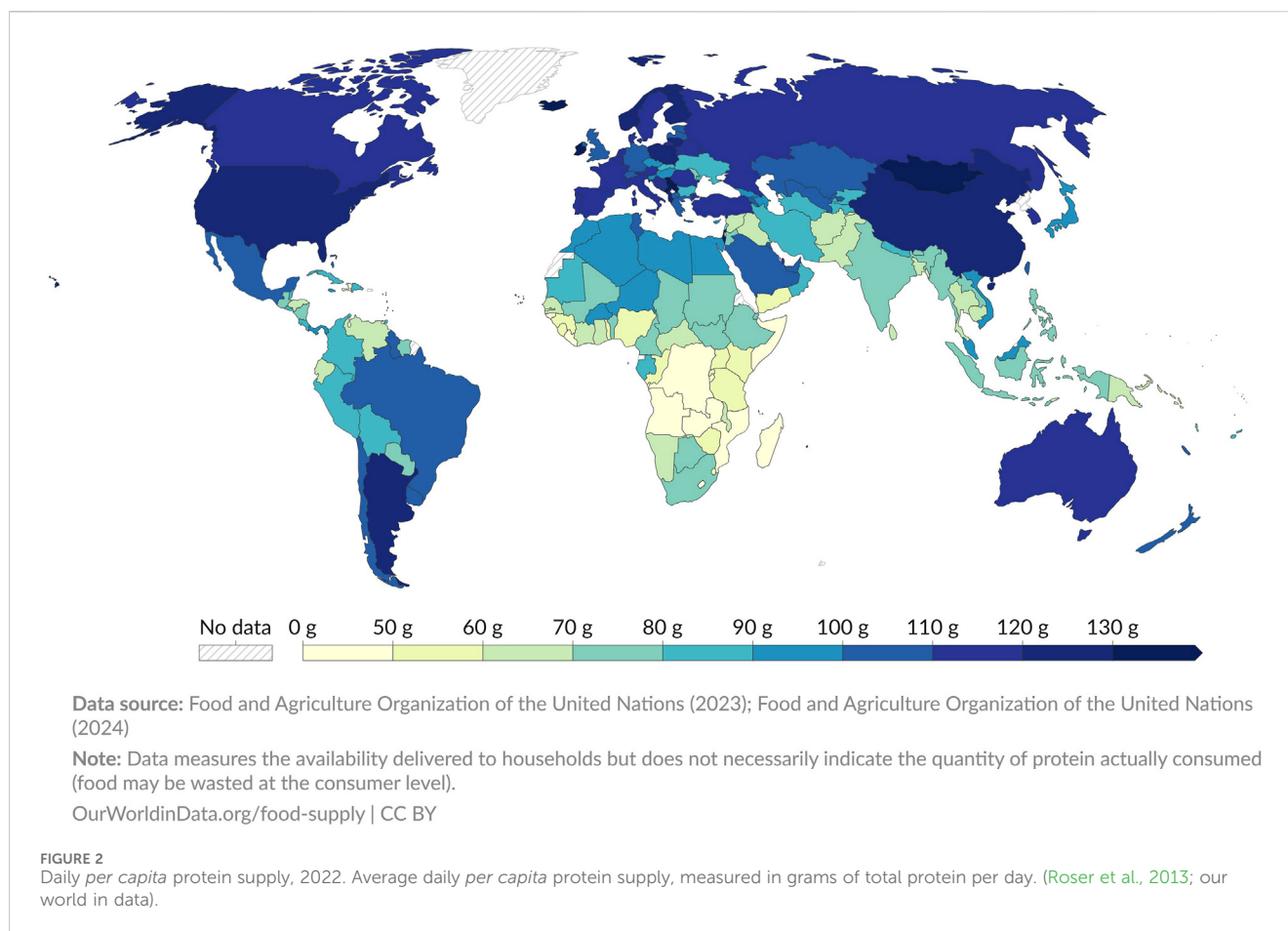
intellectual thought. Urban areas are further characterised by the proximity of humans to nature, as well as a high density of built, technological, social, economic, and green-blue matter and processes (Elmqvist et al., 2021). These characteristics are associated with a high level of complexity, termed the ‘urban metabolism’, and the potential for high resilience, attributed to high diversity and proximity to resources.

However, both density and proximity can also be problematic in terms of spillovers and vector jumps when not fully understood or ignored, as evidenced by the emergence of pathogens such as the SARS-CoV-2-II virus in 2020, the Zika virus in Brazil in 2016, and more recently monkeypox and Ebola, as well as a measles outbreak in the USA in 2025 (Haase, 2021). Furthermore, it is imperative to consider larger spatial contexts and to conduct research in these contexts to really capture the most urgent questions to be solved for urban systems. To illustrate this with a prominent example, the dramatic retreat of inland glaciers since 2000, which may be geographically distant from most cities, is particularly relevant given the imminent approach of tipping points in water supply to urban catchments that depend directly on meltwater, rivers and inland reservoirs.

At the same time, the complex social-ecological system of the city addresses numerous challenges and contentious scenarios daily.

These include mutations and adaptation in the natural part of the system, as well as a transient equilibrium of human-related interests. However, the societal part of the system also features a continually expanding array of conflict resolution methodologies. In essence, cities function as substantial living laboratories, tasked with grappling with predicaments such as climate change and biodiversity loss, which they contribute to, in addition to mitigation and adaptation. It is imperative to harness these attributes when contemplating a global transition towards enhanced sustainability and the attainment of the 1.5-degree target (Andersson et al., 2022).

It is imperative that future research on socio-ecological systems in urban areas increasingly focuses on the systematic analysis of the emergence, progression, and resolution of complex problems along the lines of human-nature interaction, explicitly combining qualitative and quantitative approaches in a triangular fashion. The system responses are just as complex as the systems themselves; if we want to understand how transformation “happens”, we must research responses from all angles (McPhearson et al., 2025, in press). This necessitates the utilisation of contemporary satellite-based remote sensing and earth observation techniques, the exploration of niches for urban flora and fauna species in the field, and the comprehension of the diversity of urban living situations experienced by city dwellers and



how these are linked to local and global economic and financial cycles (Wellmann et al., 2023).

What future challenges are anticipated in the coming decade, and how can the scientific community prepare to tackle them collectively—see from an urban systems' angle? Urban areas are set to encounter a plethora of challenges in the present and the future, including climate change, biodiversity loss, long-term sustainability, public health and equity, congestion and pollution, structural racism and civic engagement, and, in an ideal scenario, the enhancement of democracy. In order to address these challenges, it is imperative that future cities adopt a collaborative approach with their residents to identify and implement effective solutions. This collaborative effort is crucial to ensure the continuity and inclusivity of urban development (Buijs et al., 2024).

To connect directly here, what innovative strategies, collaborations, or technologies can be leveraged to address these burning questions and future challenges? It is essential that experience and knowledge from different sources are systematically analysed and brought together. This requires a broader positioning and the facilitation of a discourse on facts and data that is both broad and open. Recent decades have seen an increase in societal disparities (Haase, 2024), particularly following the dissolution of the socialist system in 1990 and the rise of neoliberalism in the 1990s. This phenomenon is not merely a consequence of policy; rather, it is a fundamental societal issue that has come to the fore. Existing and emerging societal gaps and

drawbacks have the potential to hinder progress in addressing the aforementioned challenges.

In the domain of social-ecological urban research, there has been an excessive reliance on planners and environmental experts in public administrations and large NGOs as the predominant recipients or consumers of research outcomes. This practice has led to a situation where diverse urban society is underrepresented as the primary target audience. However, the increasing digitalisation of life offers significant opportunities to directly involve diverse urban society in research and in communication of outcomes. Through the co-creation of data, supported by Smartphone-based apps using the power of AI, for example, there is an opportunity to reaffirm both interest and faith in science and to prevent systemic knowledge on global change, climate hazards, and biodiversity loss from being confined to the ivory tower of science.

In its own interest, environmental and sustainability science should, especially in times of regression of the democratic and liberal social model, examine the reasons for the global rise of this autocratic, nationalist movement and the mistrust in climate, health and biodiversity research and the rise of green bashing. Moreover, social-ecological system's research of the 21st century should address issues of water supply, food (exemplified in Figure 2; Roser et al., 2013) and energy security and concerns about the cost of living in a more direct manner.

Furthermore, there is a necessity to explore how the values and objectives of global environmental governance can resonate with

those who hold deep scepticism towards the prevailing international order. Urban social-environmental governance of the 21st century must reduce shortsightedness, cumbersome procedures, or the influence of interest groups and, at the same time, exploiting their inherent advantages (Haase, 2024). Examples of such advantages might include, as discussed above, the free flow of information, participation, or accountability (Buijs et al., 2024). As previously referenced, the climate and biodiversity tipping points should be incorporated into the objectives of local and supra-regional policies, analogous to the SDGs. This would serve to more explicitly direct long-term framework laws, and focus deliberative mini-publics or hybrid mosaic governance (Buijs et al., 2024).

Finally, while not a counter-thesis to the aforementioned points, it is submitted that this perspective opens up a second, complementary line of thought. In accordance with Boone et al. (2014), the concept of “the city” may not be interpreted simply as a conventional spatial delineation. Rather, it is the urban lifestyle, termed “urban-ness” by Boone et al.—defined by the physical and functional characteristics that support and facilitate urban-like livelihoods, life styles, connectivity, and places—that necessitates transformation and should, as a filter and enabler, be positioned at the core of the systematic, systemic, and integrative analysis of frontiers researchers on social-ecological urban systems.

Author contributions

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