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RECEIVED 22 October 2025

ACCEPTED 03 November 2025

PUBLISHED 27 November 2025

CITATION

Siegert M (2025) Editorial: What's ahead:
navigating the future of environmental science.
Front. Environ. Sci. 13:1730170.
doi: 10.3389/fenvs.2025.1730170

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Editorial: What's ahead: navigating the future of environmental science

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KEYWORDS

climate change, biodiversity, natural environment, pollutants, cities

Editorial on the Research Topic

[What's ahead: navigating the future of environmental science](#)

The 21st century is a period of critical and substantial change for humanity, and unlike any other. At its beginning, the seriousness and consequences of continued fossil-fuel burning, and wilful destruction of the natural environment, to planetary heating and biodiversity loss was clear and unequivocal. A quarter of a century on, while awareness of the issue has been strengthened by science, and while technological, social and financial progress on some solutions has been made, the world is now 1.3 °C warmer than in pre-industrial times. The 2015 Paris Climate Agreement aimed “to limit global warming to well below 2 °C, preferably to 1.5 °C”. In 2024, with an atmospheric CO₂ concentration of 423 ppm (in 2000 it was around 368 ppm), the annual temperature of our planet was measured at 1.55 °C, the first year to break the 1.5 °C mark, with the multi-annual global temperature set to surpass 1.5 °C within the coming decade unless greenhouse gas emissions are rapidly reduced ([Bevacqua et al., 2025](#)). Similarly, biodiversity loss and ocean health have plummeted in the last 50 years, due to mismanagement of land, over-fishing and the introduction of pollutants, and with the average size of wildlife populations dropping by 73%.

Regarding human existence and its future within a self-contained ‘human world’, as most people do, is a tragic mistake. Everything humanity requires to survive comes from the ‘natural world’, and by ignoring this, or taking it for granted, we damage our future prosperity and development ([Siegert, 2016](#)).

Our drive to “net-zero” greenhouse gas emissions is essential for our future, and this must be accompanied by the sustainable, non-destructive, and targeted extraction of resources, alongside increased recycling and repair, and decreased disposal of, and disregard for, waste. The 21st Century is a pivotal time for humanity. Will we continue on our present pathway or shall we transition, as science demands, to a sustainable future where humanity integrates harmoniously with nature?

In this Research Topic, we address this question by examining the future of a variety of themes and sectors within environmental science, to understand the damage that is now sadly unavoidable and what can be preserved and protected in the coming decades of this century.

Our cities, which now house around 60% of the global population, are essential as instruments of positive change, as they offer resource and service efficiencies to large populations. However, they also can lead to separation between our awareness of, and appreciation for, the natural world. As [Haase](#) points out, population density presents

problems unique to cities in terms of pathogens as was so brutally exposed during the COVID pandemic of 2020–22. The future of cities is an important environmental issue. Careful building design, co-creation of green spaces with residents' needs, installation of utilities and services built for the future as well as for existing requirements, reductions in traffic, air pollution and waste, will be the hallmarks for success and wellbeing. The transformation can be driven, according to Haase through application of the “polluter pays” principle, which would firstly offer finances for necessary change and secondly lead to financial incentives for best practice. Several cities have started to adopt such practice, albeit written and explained publicly in other ways, to restrict congestion, to encourage shared heat and power systems, and to create shaded, water-retaining green shared spaces.

To understand how to solve the climate and biodiversity crises, and to prepare for the changes necessary, we require information to guide prioritisation and urgency. For this, environmental informatics and remote sensing is key (Kokhanovsky). While spaceborne and airborne remote sensing, with appropriate ground truthing and coupling with numerical models, has allowed unprecedented knowledge of environmental concerns and impacts, greater details are needed in key regions and across timescales. Kokhanovsky (2025) explains how a variety of next-generation satellites, operating within specific parts of the e/m spectrum, will ensure greater knowledge of environment change and the reasons behind it. For example, one of the most complex low-Earth orbit satellite systems is due for launch in 2025, enabling global coverage for climate monitoring and prediction until mid-century. Similarly, Biomass—an EU satellite working with a radar at UHF (~400 MHz), launched on 29 April 2025, aims to measure the carbon content of the world's forests for the first time. These and other satellite systems will mean a huge increase in data, needing rapid processing and analysis. The rise of machine learning and AI has been a crucial element in transferring satellite information into environmental knowledge and, hence, environmental informatics is likely to dominate scientific discovery in coming decades over spatial and temporal scales that have been challenging to deal with previously.

One clear example of humanity's misuse of the natural world is within the quality of soil. While essential for growing our food, there is a “mixed matrix” of human-caused problems such as heavy metals, pesticides, “forever chemicals” (such as per- and polyfluoroalkyl substances, PFAS) and microplastics (among others), that have led to widespread contamination of soil and the food grown from it. Chen et al. describe how advances in soil science can be used in future to remediate and protect soil quality. For example, novel biological agents are being developed to degrade persistent contaminants (Książek-Trela et al., 2025). Alongside such advances, policy and regulatory modification is necessary, making the role of national governance important, guided by international agreements such as the Stockholm Convention on forever chemicals, and essential to building positive change.

Ogunseitan also discusses pollutants but on systems other than those involving soil; including freshwater, air and the ocean. Again, forever chemicals have emerged as a huge issue in environmental toxicology, that is especially concerning with respect to the “natural planetary boundaries” of human development (Richardson et al., 2023), with evidence that we have already transgressed the safe operating zone for chemical pollution (Persson et al., 2022). The

solution lies in the integration of science with political decision making and governance. Here, there are reasons to be both optimistic and concerned. As Zhao et al. (2025) point out, now is the time for greater stringency on protecting the natural world from toxins, but at the same time the recent reduction in funding to the US Environmental Protection Agency (EPA), and the deregulation of US environmental rules, testifies to a moment when science is being wilfully ignored by some powerful decision makers (Tollefson, 2025).

The environmental benefits of strong planning, governance and science-led decision making are becoming clear, however. Waring points to the rise of “regenerative agriculture,” or agroecological farming, as an example of how local decisions on small holding farms (which produce over a third of the world's food, Lowder et al., 2021), through the better timing of specific crop planting and harvesting dependent on local conditions, reduction of pesticides and the creation of natural woodland areas (agroforestry), support both organic crop yields and biodiversity. The combination of ecological advice and farming practice is an exciting one for larger scale adoption, to maximise food production during times of extreme climate and weather conditions. While such adoption by large corporations is in early stages, in Europe at least it is interesting to note that most farmers are appreciative of, and motivated by, the desire to restore the natural world alongside farming practice (Markiewicz-Keszycka et al., 2025).

Moving to freshwater systems – the life and wellbeing of all lifeforms on Earth – climate change and poor human decisions have led to their neglect and underappreciation by governments and agencies. A good example is from the UK, where sewage discharge directly into rivers is at an all-time high due to extreme rain events and illegal actions (Ford et al., 2025). Arthington point to the application of firm governance solutions to freshwater systems such as the Emergency Recovery Plan (ERP) to tackle freshwater biodiversity loss (Tickner et al., 2020), and which has widespread support from freshwater scientists. However, some caution is needed, especially in the application of governance measures to areas and regions that are presently poorly understood in terms of the system specifics that drive ecological processes. That said, with climate change providing less to, and the growth in human population requiring more from, already pressured freshwater systems a level of ‘rethinking’ is required. An example lies in social-ecological resilience and ‘rehabilitation’ to restore natural freshwater systems and make them better able to resist the pressures being observed and measured. “Nature-based solutions” (such as the restoration of wetlands) is a good example, and when coupled as part of “integrated” water resources management, such an approach is promising for addressing the trade-offs between human and ecological water requirements.

It is clear that local solutions play an important role, when multiplied, in solving global environmental challenges. At the global scale, we should be aware that the integration of physical, biological and chemical systems dictates how the natural environment responds when stressed by humans. This biogeochemical integration has become a key component of environmental science (Slaveyko). As we look ahead, fossil fuel burning and the climate heating that results – if left unsolved – will play an increasing driver of biogeochemical changes. Within the nine Earth system processes with “safe operating spaces” Rockström et al. (2023), biogeochemical flows of nitrogen, phosphorus and carbon

have emerged as being severely stressed (Richardson et al., 2023). While we have discovered and understood a lot about biogeochemical flows and processes, much remains to be known, especially for allowing better integration with numerical modelling to guide predictions and, from that, policy advice. Here, the use of AI is an emerging field in biogeochemistry, especially in consideration of how forever chemicals and plastics are transferred across natural domains.

In summary, 21st century environmental science is at the forefront of the climate and biodiversity crises. Pressure on natural systems is evident from increasing temperature and extreme weather events, as well as from politically/financially-motivated reductions in environmental protection, and through counter narratives to climate change action from some political fields. That said, among the areas and systems covered in this Research Topic, a number of returning themes have emerged that offer promising advances. The first is in new technology to better measure and understand natural systems, such as from bespoke satellites and by the increasing need for data assessment via AI. Another is the growing support for climate action and protection of our natural world among practitioners such as farmers and the general public. We neglect and misuse the natural environment at our peril. Failure to act now will make it increasingly difficult to solve in years to come; hence this has become a major intergenerational issue, with the voice of the young and consideration of the future necessarily becoming more important in decision making.

Author contributions

MS: Writing – original draft, Writing – review and editing.

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Funding

The author declares that no financial support was received for the research and/or publication of this article.

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

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