

Charting the course for the next decade of sustainability research and innovation

G. B. Sioen^{1,2} , S. McGreevy^{3,4} , J. Ungvari^{5,6}, F. Attig-Bahar^{7,8,9} and S. Juhola^{10,11} 

Editorial

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Corresponding author:

G. B. Sioen;
Email: giles.sioen@futureearth.org

¹Future Earth Global Secretariat, Tsukuba, Japan; ²Sustainable Society Design Center, Graduate School of Frontier Sciences, The University of Tokyo, Tokyo, Japan; ³Department of Governance and Technology for Sustainability, University of Twente, Enschede, The Netherlands; ⁴Systems of Sustainable Consumption and Production Knowledge-Action Network, Kyoto, Japan; ⁵Future Earth Global Secretariat, New York, NY, USA; ⁶Institute for a Sustainable Earth, George Mason University, Fairfax, VA, USA; ⁷Tunisia Polytechnic School, University of Carthage, Tunis, Tunisia; ⁸Institute of Social and Economic Research, Rhodes University, Grahamstown, South Africa; ⁹Future Earth Water–Energy–Food Nexus Knowledge-Action Network, Hainan, China; ¹⁰Ecosystems and Environment Research Program, University of Helsinki, Helsinki, Finland and ¹¹Risk Knowledge-Action Network, Hamburg, Germany

Abstract

Non-technical summary. The Anthropocene era demands urgent societal changes as we exceed planetary limits. Addressing key sustainability and governance challenges requires inter- and transdisciplinary approaches. Future Earth, a global initiative, brings together leading scholars to advance sustainability science by connecting natural and social sciences and humanities with policymaking. This Special Collection emerged from a 2021 call by Future Earth. Featuring 12 manuscripts, it explores themes like cutting-edge sustainability knowledge, interdisciplinary methods, cultural and developmental issues, and strategies for sustainable transformations. This collection offers a forward-looking view on critical research to guide policy and funding for a sustainable world.

Technical summary. The Anthropocene era necessitates urgent societal changes as we surpass planetary boundaries. Addressing the pressing questions of biogeochemical monitoring, feedback mechanisms, and effective governance systems requires interdisciplinary approaches. Future Earth, a global initiative formed by consolidating networks from major research programs, has been pivotal in advancing sustainability science through such approaches. By bridging natural and social sciences and humanities for enhancing the science–policy interface, Future Earth fosters research and innovation essential for global sustainability transformations. This Special Collection, ‘Charting the Course for the Next Decade of Sustainability Research and Innovation,’ arose from a 2021 call by Future Earth. The Special Collection highlights key scientific questions and future research directions. Contributions span themes such as state-of-the-art sustainability knowledge, transdisciplinary methods, cultural and developmental tensions, multi-actor process efficacy, and integrated knowledge for sustainable transformations. With manuscripts sourced from Future Earth’s Global Research Networks and other aligned organizations, this issue underscores a forward-looking perspective on critical interdisciplinary and transdisciplinary research needed to support high-level policy and funding directions, ultimately aiming to inform societal decisions for a sustainable and equitable world. We conclude that addressing the sustainability crisis requires a diverse and multi-faceted approach that draws upon the best knowledge of humankind.

Social media summary. Explore urgent societal changes and sustainability science with Future Earth’s Collection on sustainability research.

1. The Anthropocene calls for unprecedented collaboration

The age of the Anthropocene had led us to surpass planetary and social boundaries and place societies in a position where urgent changes are required (Rockström et al., 2023). Scientific concerns range from developing improved monitoring of biogeochemical cycles and their feedback across biophysical systems to ways of connecting them to modeling and data analysis. Pressing questions also center around different governance systems and their effectiveness, legitimacy, and justice in the light of necessary societal transformations (Gupta et al., 2021; Scoones et al., 2020). Increasingly, efforts are pointing toward a need to move away from building theory around the planetary crisis to applied action orientation that contributes to theory-building but does not make that its main or singular aim (Williams & Whiteman, 2021). Yet, many of today’s organizations remain disciplinary and sector focused (Harris et al., 2024), hampering transformations for sustainable resilient development (IPCC WGII Ch. 18, 2023) as well as research that cuts across these boundaries. Increasingly researchers are calling for connecting the biophysical and the socio-cultural with interdisciplinary and transdisciplinary approaches (Lawrence et al., 2022).

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Future Earth focuses on opportunities, as well as tensions for research and changemaking. The exploration in this Special Collection included developing cross-cutting, interdisciplinary questions regarding new methods of data collection and analysis critical to understanding socio-economic and environmental dynamics and interactions. Future Earth convenes researchers, scientists, and scholars from all parts of the world, across different societal and academic sectors, and across the natural and social sciences and humanities. This allows the organization to represent the broad voice of researchers and innovators around the world. The organization is a consolidation of the former renown International Geosphere–Biosphere Programme (IGBP), International Human Dimensions Programme (IHDP), *Diversitas* (a program that focused on biodiversity science for human well-being), and a partnership initiative called The Earth System Science Partnership (ESSP), which included among those listed above the World Climate Research Programme (WCRP). Future Earth has been facilitating and bridging disciplinary knowledge across the topic-based networks of these former organizations (Global Research Projects) and newly developed networks by Future Earth (Knowledge-Action Networks) since 2015, when it formally established its secretariat. These networks have since 2022 collectively been called Global Research Networks (Figure 1) and consist of diverse groups of researchers, innovators, and other stakeholders.

From its inception, Future Earth has sought to advance and answer basic scientific questions regarding global environmental change. It has championed the convergence of natural and social sciences with the humanities and is committed to fortifying the nexus between science and policy via transdisciplinary methodologies (Smith *et al.*, 2018). Future Earth benefits from its global distribution and diversity, allowing integrated advancements beyond institutional- and country-specific priorities (e.g. see expert report that informs Horizon Europe's funding priorities (DG RTD European Commission, 2024)), with members in its expansive networks actively working on critical issues within the domain of sustainability science. This involves discerning the imminent global changes and exploring how societies can respond effectively.

In its present form, with a governance structure and an agenda co-designed by its wide network of researchers and innovators, Future Earth is well positioned to tackle interdisciplinary and transdisciplinary questions thanks to its design as 'a global initiative focused on advancing sustainability science'. Future Earth envisions 'a sustainable and equitable world for all, where societal decisions are informed by openly accessible and shared knowledge' with a mission to 'advance research in support of transformations to global sustainability'. The integrated scientific advances by Future Earth are in a crucial position to support high level policy fora and processes. Reflecting its magnitude, the Future Earth community collectively generated 1229 publications during the fiscal year 2022 (April 2022–March 2023). This comprehensive output encompasses peer-reviewed articles, non-peer-reviewed works, conference proceedings, books, among others, all contributing to the organization's unified vision and mission (Future Earth, 2023).

Future Earth also makes the whole greater than the sum of its parts. One example of an integrated science–policy initiative is the annual 10 New Insights in Climate Science report. Together with The Earth League and WCRP, the 10 most important new findings from science of the year have been identified through a consultation with the research community. Then, a diverse and expert

editorial board helps to cluster and distill the 10 most important scientific advancements. We invite authors from key studies to write a synthesis review on each insight. First, this work is peer-reviewed and published in a journal (see Bustamante *et al.*, 2023). Next, a science–policy report (see Future Earth *et al.*, 2023) is derived from it with accessible figures, language, and illustrative case studies. The report also contains implications relevant for negotiators at the United Nations Framework Convention on Climate Change Conference of the Parties (UNFCCC COP) to work with. The report is launched and shared to directly inform the decision makers of the latest relevant science.

2. Charting the course

Several contributions in the Special Collection expand the frontiers of scientific understanding and point toward the directions we aim to pursue tomorrow. These efforts have the potential to propel novel scientific advancements in sustainability science and influence the trajectory of funding allocations and policy-making. Overall, the Special Collection gathers manuscripts on state-of-the-art knowledge and a forward-looking view on the most pressing interdisciplinary and transdisciplinary sustainability research questions for the next decade. A description of how the Special Collection was designed and the themes solicited can be found in Supplementary material S2: Democratic Development of the Special Collection.

The contributions highlight the expertise within Future Earth, covering natural and social systems and the interactions between them (Supplementary material S3: Who contributed?). They also take a critical look at the methodologies and practices of sustainability science. Based on the contributions, we identify four themes in this Special Collection. First, the Evolutionary and Ecological Processes theme brings together papers that focus on the dynamics of change within natural systems, stressing the need to further understand feedback between biogeophysical systems. Second, the Governance and Policy theme highlights the challenges embedded in social systems when identifying solutions for a more sustainable future. The third theme Land Use and Climate Change illustrates the linkages between the natural and social systems, demonstrating the need to bridge across sciences to gain a comprehensive and an integrated understanding of systems interactions. The fourth theme, Interdisciplinary and Transdisciplinary Research, discusses the need to critically reflect on the challenges of engaging in new ways of doing science and the ways it may contribute to advancing sustainability.

2.1 Evolutionary and ecological processes

The work highlighted here discusses the importance of understanding evolutionary changes, in particular for adaptation to environmental change. Vázquez-Domínguez *et al.* (2024) describe examples of contemporary, rapid evolutionary changes of concern for sustainability. They also consider how urban development accelerates evolutionary processes such as altered phenotypic and physiological changes and the spread of infectious and zoonotic diseases. The authors concluded with a need for stronger collaboration between evolutionary biologists and the sustainability community (e.g. in the context of health). Edwards *et al.* (2024) bring forward research priorities for sustainable rice systems by 2050. They conduct a horizon beyond the conventional disciplinary focus of food production, incorporating preservation

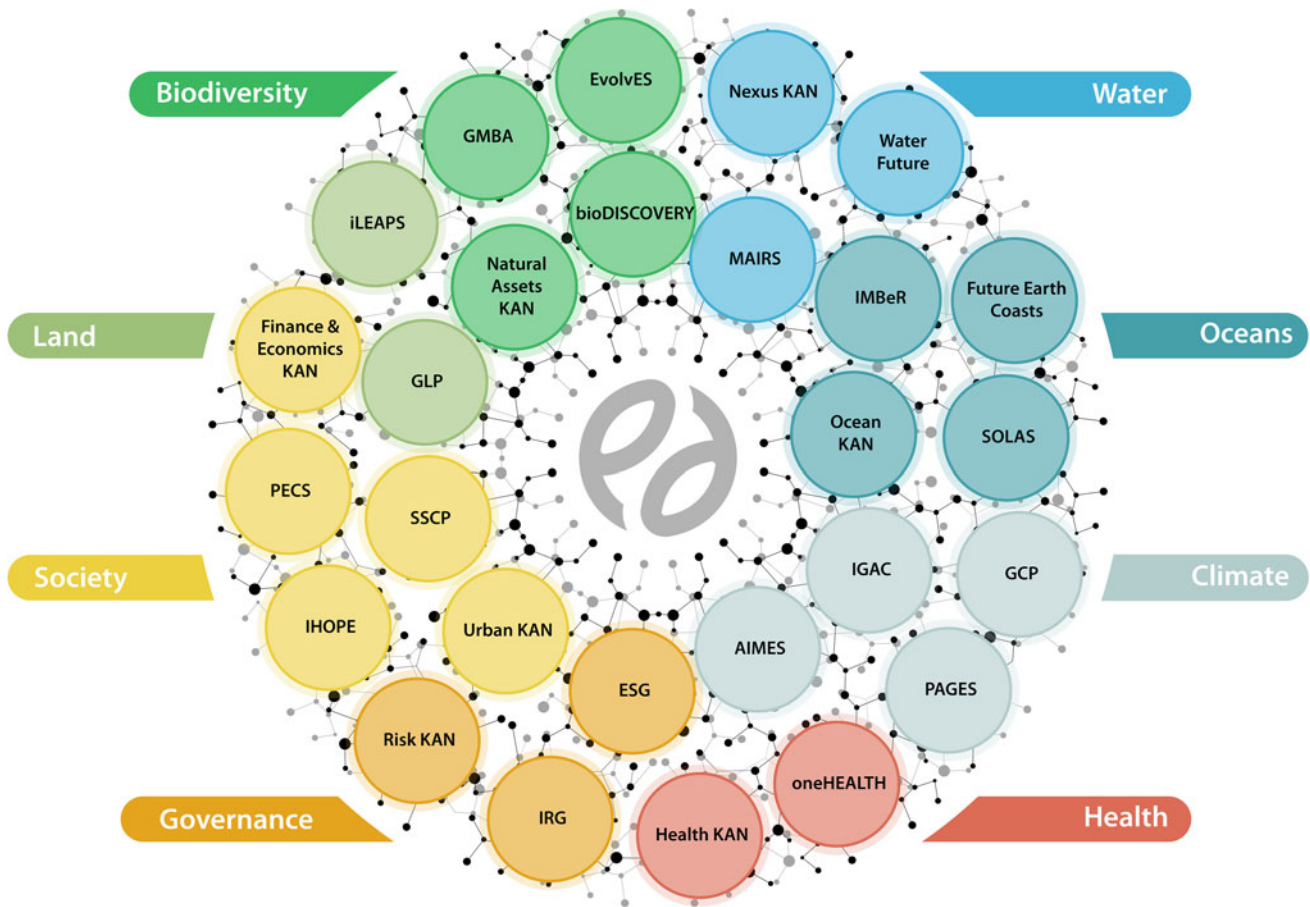


Figure 1. Illustration of Future Earth's Global Research Networks and a selection of diverse thematic areas they encompass (as of September 2024). Each Global Research Network (full names in Supplementary material Table S1) has its own governance and resources which they utilize to advance research and innovation on both their prioritized topics and a broader set of shared efforts within the Future Earth network. The Global Research Networks are interconnected with support by the Global Secretariat. Further purpose-driven connections are with regional committees, and national or local committees.

of natural capital and ensuring sustainable food security. Expanding the focus enables them to consider broader sustainability issues related to rice production now and into the future.

2.2 Governance and policy

Advocacy for policy shifts from climate science to action, emphasis on transdisciplinary research to tackle emerging challenges of climate issue and displacement, impact of sustainable development goals (SDGs) on governance, as well as recommending strategies for local SDG advancement through institutional support and community engagement are explored in this section.

Shrivastava et al. (2023) make several recommendations to move from climate science to climate action. These include encouragement for governments to improve taxation on goods and activities based on carbon emissions and handling excess deaths by carbon pollution as homicide. Shrivastava et al. (2023) further illustrate how climate violence of emerging 'new politics' and increased global population displacement will create greater challenges for people and suggest that the role for science is to embrace transdisciplinarity for research to effectively engage with this new emergence. Hickmann et al. (2024) illustrate five governance areas where some effects of the SDGs have been observable: (1) global governance, (2) national policy integration, (3) subnational initiatives, (4) private governance, and (5)

education and learning for sustainable development. However, Hickmann et al. (2024) question the effectiveness of goal setting and delve deeper to draw lessons and guide empirical research on the promises and pitfalls of accelerating SDG implementation. Further advancements to enable local SDG action emerged from the study by Ningrum et al. (2024). In the study, the authors recognize there are many contextual and capacity differences for advancing on the SDGs but overall recommend (1) institutional embeddedness, (2) support stakeholder coordination, and (3) support community engagement.

2.3 Land use and climate change

The intricate connections between climate change and human development are irrefutable. Contemplating strategies to pivot away from greenhouse gas emissions, particularly those stemming from human activities like land-use changes, is more crucial now than ever before.

Hayman et al. (2024) describe in their manuscript how afforestation, reforestation, or growing bioenergy crops (with carbon capture and storage) are important land-based strategies to achieve the goals of the Paris Climate Agreement and to enhance biodiversity. The effectiveness of these actions depends on terrestrial ecosystems and their role in controlling or moderating the exchange of water, heat, and chemical compounds between the

Table 1. Special Collection papers of charting the course, their observed emerging themes, and their emphasis on the central themes of the call

Emerging themes	Manuscript	State-of-the-art in sustainability science	Inter- and trans-disciplinary methods and science-policy interface	Diverse contexts and sustainability	Multi-actor processes and why they succeed or fail	Knowledge integration for sustainability transformations
Evolutionary and ecological processes	Vázquez-Domínguez <i>et al.</i>	x	x			
	Edwards <i>et al.</i>	x				x
Governance and policy	Shrivastava <i>et al.</i>	x	x	x		
	Hickman <i>et al.</i>	x			x	x
	Ningrum <i>et al.</i>			x	x	x
Land use and climate change	Hayman <i>et al.</i>	x				x
	Asokan <i>et al.</i>	x		x	x	
Inter- and transdisciplinary research	Schulte <i>et al.</i>	x	x			x
	Harris <i>et al.</i>	x	x			x
	Marciniak <i>et al.</i>		x		x	x
	Wardani <i>et al.</i>		x		x	
	Matias		x	x		

land surface and the atmosphere. Co-benefits are increasingly brought forward for the utilization of various practices. Asokan *et al.* (2024) argue for the need to utilize design approaches that incorporate community needs when implementing environmental infrastructure essential for sustainable development. Derived from a select number of case studies, the work provides learnings that could prevent NIMBY-syndrome and better serve local communities, thus accelerating adaptation and mitigation efforts.

2.4 Interdisciplinary and transdisciplinary research

Many of our contributions call for interdisciplinary and transdisciplinary research to achieve better uptake of knowledge for transformations. The manuscripts touch upon some of the tensions that have been arising as institutions and incentives have not been able to keep up with this increasingly complex and inter-contextual knowledge. Schulte *et al.* (2024) called for incorporating social aspects in integrated assessment modeling, commonly used in climate and biophysical scenario making. Although this integration effort is already happening to some extent, there is no shared understanding of how to do this for different contexts and research questions. Schulte *et al.* (2024) concluded that increasing the connection between natural and social science communities and sharing goals around complementary efforts from the broader research community may advance integration. Harris *et al.* (2024) reviewed transdisciplinary literature and outlined tensions at each stage of the innovation/research process. They proposed several strategies for managing tension by recognizing the challenges, learning how to work with tensions, and building capabilities for future careers involving transdisciplinary research. The paper shows a key competence for transdisciplinary researchers' ability to develop complex collaborative relationships for sustainability drawing together different institutional logics, approaches, methods, goals, and values. Similar observations are made by the Future Earth Pathways Initiative in which Marciniak *et al.* (2024) describe a lack of skills and competencies, relatively unmaturing transformative methods and concepts, and

an institutional landscape still geared toward disciplinary and descriptive-analytical research which is hindering the sustainability science community. Wardani *et al.* (2024) illustrated a practice framework that focuses on the stakeholder collaboration process. The framework incorporates reflexivity and co-learning for all stakeholders of co-design processes. Works like this could inform process design by reflecting on stakeholder contributions, interactions, integration, and expected outcomes. Although each relevant manuscript highlights promising developments for conducting transdisciplinary sciences (Harris *et al.*, 2024; Marciniak *et al.*, 2024; Wardani *et al.*, 2024), Matias (2024) emphasizes the need for epistemic humility and authentic interest to learn from other actors such as Indigenous communities on the frontlines of human-wildlife interfaces and cites on the Health Knowledge-Action Network research agenda that promotes research approaches that are transdisciplinary, multi-scalar, inclusive, equitable, and broadly communicated (Ebi *et al.*, 2020).

3. Integrated summary

We summarize the papers featured in the Special Collection and how they address the Special Collection themes in Table 1. All papers cover more than two themes and many cover three, which points to the highly integrated nature and nuance needed by science to address sustainability challenges.

Considering that the manuscripts were challenged to be forward-looking in their approaches, identifying crucial research questions, across different societal and academic sectors, and across the natural, social, and human sciences, this Special Collection truly brings forward a unique view on research and innovation for global sustainability.

4. Insights to address the sustainability crisis

Addressing the sustainability crisis requires a diverse and multi-faceted approach that draws upon the best knowledge of humankind. Future Earth is well positioned to gather scientific insights

through both conventional scientific methods as well as the emerging interdisciplinary and transdisciplinary approaches that include strategies for co-designing pathways for sustainable and resilient development. This Special Collection not only captures the state-of-the-art in sustainability science but also charts a course for how better and more socially robust knowledge can emerge from diverse contexts and be acted upon effectively. Improving the governance of complex sustainable development and multi-stakeholder policymaking processes, successfully bridging the knowledge silos and barriers between science and society, better understanding evolutionary change and better managing transformational change, as well as reconsidering the ways technology, urban–rural space, and land use might be patterned to mitigate and adapt to climate breakdown are just some of the key messages of the Special Collection. Although this Special Collection does not encompass all the work being undertaken within Future Earth, we hope these insights contribute to shaping our collective response as an international scientific community and interconnected society for the coming decade, ensuring a sustainable future for our planet.

Supplementary material. The supplementary material for this article can be found at <https://doi.org/10.1017/sus.2024.41>.

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