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EDITORIAL

# Earth's buried wealth: uncovering global soil biodiversity

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## Abstract

Soils harbor more than half the biodiversity of our planet, yet they are underappreciated and often unprotected. Among the initiatives promoting the sustainable use and conservation of soil biodiversity is the International Network on Soil Biodiversity (NETSOB - https://www.fao.org/global-soil-partnership/netsob/en/), a Technical Network of the Global Soil Partnership (GSP) within the Food and Agriculture Organization of the United Nations (FAO) that promotes the sustainable use and conservation of soil biodiversity. NETSOB, together with its chairs and members, initiated this special issue named "Highlights from the International Network on Soil Biodiversity" that covers advancements in soil biodiversity research, and provides insights into its ecological, economic, and policy dimensions. The articles included in this special issue cover topics such as the current knowledge of soil biodiversity worldwide, bibliometric analyses on ecosystem services provided by soil biodiversity, as well as on the state of global micro-, meso- macro- and megafauna biodiversity, the potential threats to soil biodiversity, and information on the establishment of the Global Soil Biodiversity Observatory (GLOSOB), an initiative established to assess and monitor soil biodiversity, and forecast changes in soil biodiversity worldwide. The articles in this special issue highlight the knowledge gaps in soil biodiversity, including the connections between specific components of soil biodiversity and parameters such as threats, ecosystem services and soil degradation, and value and limitations of using soil respiration and soil organic carbon as a proxy to infer soil biodiversity. We suggest that recognizing and preserving soil biodiversity is a matter of safeguarding our own future and the health of our planet.

Soils are increasingly recognised as key ecosystems harboring more than half the biodiversity of our planet (Anthony et al. 2023). Hereby, soils are looked upon as living, breathing ecosystems teeming with life. From microscopic bacteria to earthworms and fungi, soil biodiversity is the foundation upon which terrestrial life depends (Wall et al. 2012). Examining global soil biodiversity is not just a scientific endeavor; it is central to secure a wide variety of essential ecosystem services such as food production, water purification, soil remediation and climate regulation, all of which are vital for sustaining human well-being (Adhikari & Hartemink 2016; Mujtar et al. 2019; Eisenhauer et al. 2024; Eugenio et al. 2024). Yet, soils remain underappreciated and often unprotected (Guerra et al. 2022).


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Among the initiatives promoting the sustainable use and conservation of soil biodiversity is the recently established International Network on Soil Biodiversity (NETSOB - https://www.fao.org/global-soil-partnership/netsob/en/), a Technical Network of the Global Soil Partnership (GSP) within the Food and Agriculture Organization of the United Nations (FAO) that promotes the sustainable use and conservation of soil biodiversity. The GSP includes several Technical Networks, which are specialized working groups that focus on specific aspects of soil management, conservation, and health. These networks consist of experts, institutions, and stakeholders from around the world, collaborating to address challenges and share knowledge related to soils. Specifically, NETSOB coordinates global activities to monitor, assess, and conserve soil biodiversity, bringing together over 1,100 members from 140 countries. This network collaborates with initiatives like the Global Soil Biodiversity Initiative (GSBI - https://www.globalsoilbiodiversity.org/) and the Soil Biodiversity Observation Network (Soil BON - https://geobon.org/bons/thematic-bon/soil-bon/) to provide guidance on integrating soil biodiversity into national policies and action plans. The GSP, launched by the FAO in 2012, enhances awareness and advocacy for sustainable soil management through projects such as the State of Knowledge of Soil Biodiversity (FAO et al. 2020), but also through partnerships such as the Global Soil Biodiversity Atlas (Orgiazzi et al. 2016), and the Global Symposium on Soil Biodiversity (https://www.fao.org/about/meetings/soil-biodiversity-symposium/en/). These efforts have sparked a groundswell of interest and concern for the protection of soil biodiversity, highlighting the critical role of soil organisms in ecosystem health, climate resilience, and food security. Despite this growing recognition, there remains an urgent need for comprehensive policies and actions to address the gaps in soil biodiversity protection, underscoring the importance of continued global collaboration and commitment. Therefore, FAO was invited during the fifteenth meeting of the Conference of the Parties (COP 15) held in Montreal in December 2022 to establish a Global Soil Biodiversity Observatory (GLOSOB), an initiative building on existing local, national, and international soil biodiversity initiatives and actions, that should guide countries in establishing coordinated soil biodiversity monitoring plans (Parnell et al. 2025b).

To provide a knowledge foundation for the establishment of GLOSOB, NETSOB together with its chairs and members initiated this special issue named “Highlights from the International Network on Soil Biodiversity” that covers pivotal advancements in soil biodiversity research, and provides insights into its ecological, economic, and policy dimensions. Specifically, this special issue includes:

1. Notes on knowledge of soil biodiversity worldwide (Brown et al. 2025a)
2. Bibliometric analyses on soil microbial diversity and on ecosystem services provided by soil biodiversity (da Conceição Jesus et al. this issue, Parron et al. this issue)
3. Updates on the state of global micro-, meso- macro- and megafauna biodiversity (Correia et al. this issue, Niva et al. this issue)
4. Potential threats to soil biodiversity (Lindo et al. this issue)
5. Information on GLOSOB (Brown et al. 2025b, Parnell et al. 2025a).

A worldwide expert survey carried out in March 2022 reflects answers provided by over 2,000 people worldwide (Brown et al. 2025a). Questions cover a broad range of topics including measuring soil microbial and faunal communities, monitoring, ecosystem services and threats to soil biodiversity. The survey covers information on soil biodiversity from specialists to serve as a starting point for scientists and policymakers working on the conservation and sustainable management of soil biodiversity. The survey identifies three main challenges to strengthen soil biodiversity research: harmonising and building capacity on soil biodiversity measurements, increasing awareness of the importance of soil organisms and their ecosystem service delivery, and increasing policy support at national and international levels.

Major gaps in soil biodiversity knowledge have been identified at a global level using existing global datasets on soil biodiversity (Cameron et al. 2018), and four studies in this issue identify group-specific gaps using bibliometric analysis. da Conceição Jesus et al. (this issue) examine articles published between 2011 and 2022 about soil microorganisms and their processes. The authors conclude that groups other than bacteria and fungi, such as viruses, algae and lichens, are severely understudied. United States and China appear to be the leading nations studying soil microbial diversity and processes; not surprisingly, countries in Latin America, Africa and Asia are still underrepresented. Parron et al. (this issue) look at studies published in the last decade and show that the United States and China also lead studies on the economic valuation of soil ecosystem services. The ultimate gap identified lies on studies estimating all the services associated with soils at a global level, which turned out to be a single study with preliminary results published in 1997. The authors also outline potential economic tools and policies that can help promote sustainable management practices.

Regarding soil fauna, Correia et al. (this issue) and Niva et al. (this issue) describe the state of the art for micro-, meso, macro and megafauna in connection to their ecological niches, contribution to soil ecosystem functioning, and distribution patterns. Correia et al. (this issue) bring together literature published between January 2011 to February 2022 showing that most microfauna publications involved protists, despite the economical importance of nematodes both for agricultural and human and animal health matters, and that springtails are the most studied mesofauna group, even though mites are important pests and biological control agents. The African continent, the Middle East, Central and Southeast Asia, and much of Latin America and the Caribbean have little scientific output on micro- and mesofauna research, despite their expected rich soil biodiversity. The other end of the size-spectrum of soil biodiversity, i.e., the macro- and the megafauna, is investigated by Niva et al. (this issue) who looked at literature published in the last decade. They show that earthworms are the most studied macroinvertebrate group worldwide, particularly in bioindication studies, and that, among megafauna, rodents and reptiles are frequently studied because of their soil bioturbation activities. For these organisms, Niva et al. (this issue) highlight the outstanding lack of knowledge in the African continent, where for many countries no studies were found by their search in the last decade. For many taxa, particularly in the meso and macrofauna, taxonomy and capacity building for species identification were identified as a critical issue needing attention.

The identified knowledge gaps are especially alarming when we link them to the threats soil organisms face (Barreto & Lindo 2022), and to the benefits of soil biodiversity, both tangible (Sun et al. 2023) and cultural/spiritual (Motiejūnaitė et al. 2019). In this special issue, we describe threats impacting soil biodiversity and how they are connected (Lindo et al. this issue). Human activities such as deforestation, intensive agriculture, urbanization, and climate change form a network of threats, or a "threat-work" causing soil degradation at an alarming rate (Phillips et al. 2024; Lindo et al. this issue). Ultimately, the threats to soil biodiversity can be linked to changes in, and loss of, soil organic matter and its subsequent negative effects (Lindo et al. this issue).

A limited number of studies use advanced measurements and include multi-level connections between soil organisms that have improved our understanding of their potential global importance. However, the methodological approaches used in different studies prevent their consolidation into a global assessment. To ameliorate this, the GLOSOB was established to assess and monitor soil biodiversity, and forecast changes in soil biodiversity worldwide (Brown et al. 2025b; Parnell et al. 2025a,b). The immediate purpose is to detect degradation and implement practices to prevent further loss of biodiversity and ecosystem services (Brown et al. this issue). In this way, GLOSOB will examine the impacts of land use and management practices on soil biodiversity and provide decision makers with knowledge on policies to promote and protect soil biodiversity; GLOSOB aims to be the global source of standardized reference data and information on soil biodiversity.

Assessing and monitoring soil biodiversity is critical for understanding ecosystem health, resilience, and sustainability. Sustainable soil management practices are critical to protecting and preserving soil biodiversity. Practices such as crop rotation, organic farming, minimal tillage, and agroforestry promote soil health and preserve the diverse communities of soil organisms. Those practices result in enhanced soil structure, carbon sequestration, fertility, and resilience to erosion and degradation, ensuring its ability to support plant growth and ecosystem functioning. They also mitigate the negative impacts of intensive agriculture, such as soil compaction, nutrient depletion, and loss of biodiversity. By prioritizing sustainable soil management, we not only protect soil biodiversity but also enhance agricultural productivity, mitigate climate change, and safeguard the long-term sustainability of agrifood systems (Lindo et al. this issue). Ultimately, NETSOB promotes the sustainable use and conservation of soil biodiversity through three working groups focused on the measurement, assessment and monitoring of soil biodiversity (Working group 1), the sustainable use, management, and conservation of soil biodiversity (Working group 2), and on the economics and policies related to soil biodiversity (Working group 3).

The articles in this special issue highlight the work of the International Network on Soil Biodiversity, NETSOB. In the end, recognizing and preserving soil biodiversity is not just a matter of ecological conservation; it is a matter of safeguarding our own future and the health of our planet.

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