

GLOSOB: The Global Soil Biodiversity Observatory

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1. Background

Our well-being and the livelihood of all human societies are tightly connected with soil biodiversity and the ecosystem services it provides (Akhikari & Hartemink 2016). The fundamental role of soils in global biogeochemical cycles, the functioning of terrestrial ecosystems for food, fuel, and fiber production, the filtration, degradation and immobilization of contaminants, and in climate change adaptation and mitigation all underpin the importance of promoting conservation, restoration, and sustainable activities around this precious resource (Figure 1).

Despite substantial advances in the knowledge of soil biodiversity and its functions, only around one percent of soil organisms have been characterized so far. Soil biodiversity loss is one of the greatest threats in many regions of the world and is likely underestimated due to the lack of data (FAO 2020). Data on soil biodiversity and its status at local, national, continental and global levels is therefore key to understanding the impact of human activities on ecosystem functions and services and to inform protection and restoration actions and policies.

Although protection of aboveground biodiversity has been promoted for decades, little attention has been given to belowground biodiversity. A few regional and national initiatives specifically address soil biodiversity, while

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others evaluate indirect links to soil biota (Brown et al. this issue). However, those assessments target different soil taxa and often use different metrics (Brown et al. this issue). Harmonized measurements of soil biodiversity need to be a priority for soil surveys and any soil sampling and mapping efforts to better understand and value soil biodiversity's contribution to soil health. Furthermore, considering its importance to ecosystem service provisioning, monitoring soil biodiversity is a critical component for quantifying land use sustainability and to the long-term maintenance of global soil health (Guerra et al., 2021). Therefore, standardized guidelines and protocols for assessing soil biodiversity need to be developed and included in soil survey description manuals, as well as in long-term monitoring programs of soil/environmental quality and the provisioning of ecosystem services from soils (Parnell et al. this issue).

2. Call for a Global Soil Biodiversity Observatory

As part of the post-2020 Plan of Action of the International Initiative for the Conservation and Sustainable Use of Soil Biodiversity (CBD 2020), adopted at the 2022 Conference of the Parties to the United Nations Convention on

Biological Diversity (CBD COP15), the Food and Agriculture Organization of the United Nations (FAO) was mandated to implement a global soil biodiversity and ecosystem function monitoring framework. This initiative aligns with past and recent efforts of the FAO's Global Soil Partnership (GSP) and its recently created International Network on Soil Biodiversity (NETSOB), as well as those from other international initiatives such as the Global Soil Biodiversity Initiative (GSBI) and the global Soil Biodiversity Observation Network (SoilBON). Through these initiatives, participating countries are therefore encouraged to improve their knowledge of soil biodiversity and implement sound policies and actions to prioritize soil biodiversity in National Reports and National Biodiversity Strategies and Action Plans (NBSAPs).

The Global Soil Biodiversity Observatory (GLOSOB) aims to be the global source of standardized reference data and information on soil biodiversity. The goal is to guide evidence-based decision-making and be the key provider of technical knowledge for measuring, mapping, and monitoring soil biodiversity in a harmonized way. The outcome will be to provide insight for soil biodiversity conservation and restoration practices for sustainable agriculture. GLOSOB priorities are to:

- a) improve knowledge on soil biodiversity;
- b) address soil biodiversity information gaps; and

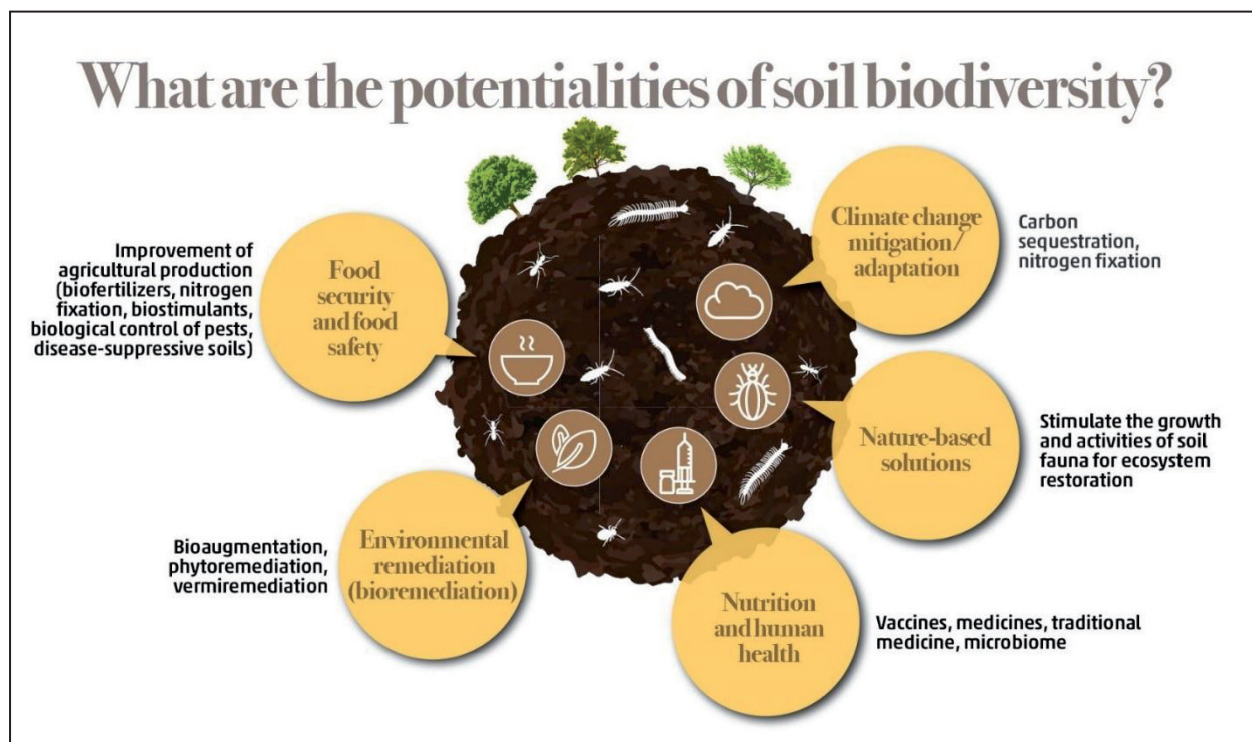


Figure 1. The role of soil biodiversity in providing ecosystem services and mitigating the impact of human activities. Figure by Matteo Salas.

- c) develop/strengthen national capacities to monitor, protect and sustainably manage soil biodiversity. GLOSOB includes monitoring soil biodiversity on managed lands and natural ecosystems.

GLOSOB intends to coordinate with and complement existing local, national, and international soil biodiversity initiatives where possible. This includes GSBI, SoilBON, The Global Initiative of Crop Microbiome and Sustainable Agriculture, and other similar networks and initiatives. The GLOSOB follows a country-driven approach that is adapted to country capabilities through a tiered approach.

GLOSOB will be developed in four phases, an implementation phase, a planning phase, an execution phase, and a maintenance phase (Figure 2).

- 1) The first phase is the implementation of GLOSOB *per se*, following a three-tiered voluntary participation, involving various levels of assessment of essential biological variables (EBVs; Guerra et al. 2020). The specific variables measured at each tier, harmonized methods, and how they are collected are determined in the implementation phase, with the assistance of the NETSOB steering group.
- 2) The second phase will be the planning of the observatory for each country. This will involve countries, communities, and indigenous people

determining participation tier, allocating resources, signing agreements, assessing training and/or capacity building needs, and establishing sampling strategies. Where requested, GSP technical networks, or partners can help build capacity in planning steps.

- 3) The third phase will be the execution phase where sample collection according to the national sampling strategy and biodiversity measurements at the appropriate tier will commence. Capacity building on interpreting soil biodiversity measurements will be implemented.
- 4) The fourth phase will be the maintenance phase. Data will be compiled, analyzed, and interpreted for reports and for guiding policy. Capacity to advance to the next tier will commence. Initiatives to conserve and protect soil biodiversity can be enacted.

3. GLOSOB structure and governance

Given the global scope and the necessary coordination with governments and existing networks and initiatives, the following functions are proposed to manage and coordinate GLOSOB:

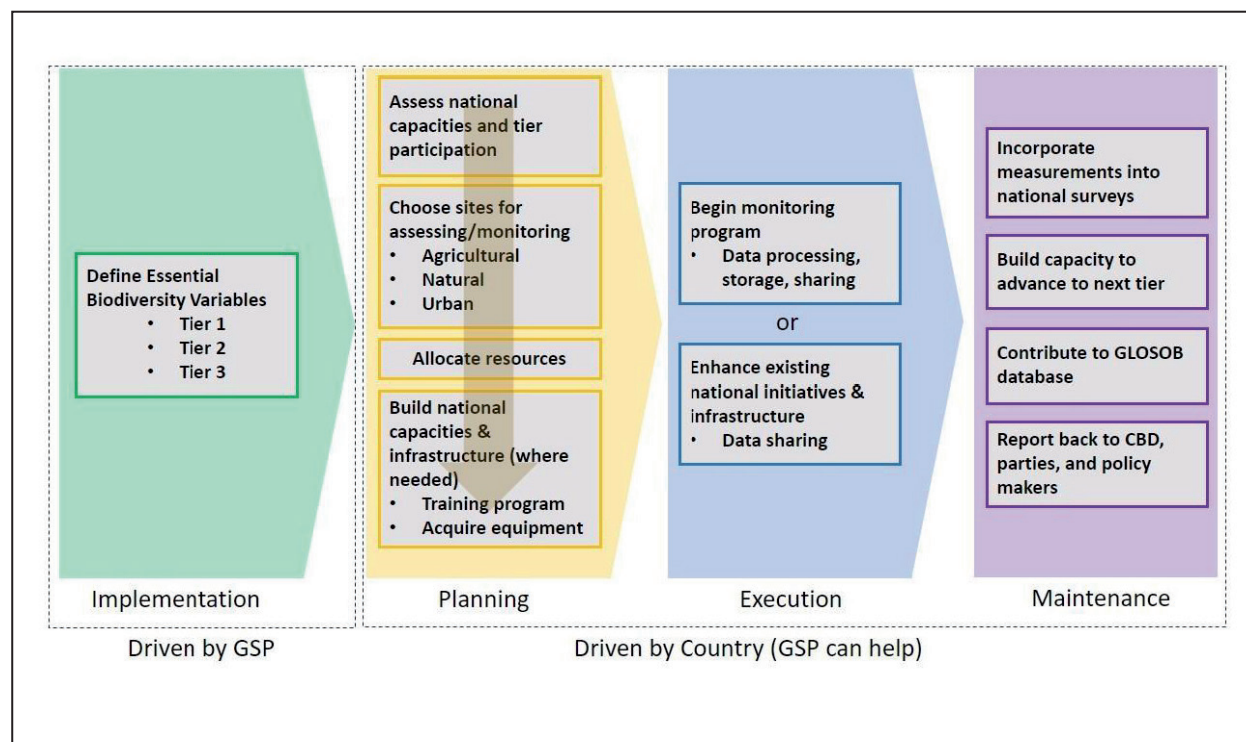


Figure 2. Plan of action for the Global Soil Biodiversity Observatory. Components of the four phases of the observatory (implementation, planning, execution, and maintenance) are outlined.

The initiation phase will be driven by the GSP. Tiers, essential biological variables and how measurements are collected for GLOSOB will be advised by the NETSOB steering group.

The planning, execution, and maintenance phases will be driven by individual countries. GSP technical networks are available to advise and help build capacity where needed. Where possible, these phases can be executed by existing initiatives.

GSP Secretariat will engage with country governments to determine their level of commitment. GSP programs and technical working groups will work at local levels to establish sites and collect soil biodiversity measurements.

4. What will GLOSOB evaluate and monitor?

Soil biodiversity (from microflora and microfauna to macrofauna) will be sampled, measured, and monitored using standardized methods (standard operating procedures, SOPs) defined by NETSOB and GLOSOLAN (Global Soil Laboratory Network), which complement the Essential Biological Variables (EBVs) established by other initiatives (Guerra et al. 2021, Table 1). Where standard methods are inappropriate or inadequate, additional soil samples will be examined at a standard central laboratory to provide comparison.

Note: current soil biodiversity monitoring initiatives are encouraged to participate in GLOSOB to ensure complementarity and cooperation between efforts.

5. Participation in GLOSOB

There are three tiers of GLOSOB participation (Table 1). Participation tier should be determined at the country level in discussions between national experts and policy makers. Where requested, GSP secretariat and its technical networks can provide training and guidance on national capacities.

The goals of each tier are:

- 1) to provide a minimum number of EBVs necessary for a basic-level description of soil biodiversity and basic functions at a particular site. The maximum number of countries should be able to participate at the limited tier of GLOSOB and establish critical baseline data on soil biodiversity.
- 2) to facilitate and build capacity and encourage countries to engage further and advance to next tier. Upon joining GLOSOB, host countries should either

participate at tier 3 or commit resources/plans to build capacity to get to tier 3. GSP technical networks and partner organizations can help countries build local capacity. Tiers 1 and 2 should be viewed as transition stages.

GLOSOLAN and NETSOB are currently developing and standardizing several soil biodiversity-related methods and will disseminate SOPs, training, and quality assurance for soil biodiversity measurements when ready. Where possible, countries are encouraged to use GLOSOB (GLOSOLAN) standard SOPs. In cases where GLOSOB standards are inappropriate, additional samples will be sent to approved laboratories to provide transfer function data as explained by SoilBON (Guerra et al. 2021).

Locations for monitoring soil biodiversity will be determined by country or regional stakeholders. National sampling strategies can be provided through training GSP networks.

Each sampling location for monitoring sites for the GLOSOB should have the following minimum metadata: GPS coordinates, climate type, rainfall, temperature regimes, altitude, relief (slope/position), biome/ecoregion, main land use type (FAO classification), soil type (Order, preferably using WRB classification), records of past and current agricultural/forestry/pastoral management practices (if applicable), main native vegetation class, GSN maps, and land use history (preferably last 5 years, where applicable).

6. GLOSOB

The GLOSOB will adapt to in-country ability to measure the different EBVs at each tier level. Different soil biodiversity groups (from microbes to macrofauna) will be sampled, measured, and monitored using standardized methods, where possible.

Countries are expected to identify soil biodiversity locations for monitoring. Soil biodiversity measurements should also become a standard in the revised FAO Guidelines for soil description as part of national soil surveys. Furthermore, soil health and monitoring activities and assessments of agricultural sustainability should include soil biodiversity measurements.

In countries or regions where soil biodiversity observatories or initiatives are planned or ongoing, it is recommended that GLOSOB complement and reinforce these efforts (country-level resources are committed to these efforts to collect GLOSOB measurements or to collect measurements to allow comparison).

In summary, GLOSOB is to be implemented and operationalized as follows (see also Figure 2):

- Participation: Countries and institutions express their desire to become part of GLOSOB activities.
- Essential measurements: Sampling and monitoring methods and tools for EBVs as defined by NETSOB and GLOSOLAN.
- Tiered approach: national capacities are assessed within the country (GSP to assist where needed) to initiate and carry out soil biodiversity monitoring programs. Each country adopts a tier from the three tiers defined in GLOSOB based on the country's ability to include EBVs assessments. A national plan is developed to meet the EBVs for each tier and to upgrade tiers as resources are available and capabilities/capacities are developed.
- Country-driven approach: the generation of soil biodiversity data/information will be decentralized, and preferably funded by participating countries. In some cases, extra-national funds can be used to help countries participate in GLOSOB, but the tier, sampling strategy, and data are owned by the recipient country.

Table 1. Essential Biodiversity Variables and Measurements proposed in GLOSOB for each tier. Advancement in tier adds additional EBVs to the previous tier.

Tier	Bioindicators [#]	How to Measure it
1	Enzymatic activity	Acid Phosphatase, N-acetyl-B-glucosamine , xylosidase, cellobiohydrolase, B-glucosidase
	Aggregate Stability	Water stable soil aggregates
	Soil physical and chemical properties	Bulk density, pH, Visual Soil Assessment, soil texture, Cation Exchange Capacity, soil moisture
	Litter Decomposition	Litterbags
	Abundance of soil fauna	Nematodes, microarthropods, and macrofauna
	Soil Biomass	Substrate Induced Respiration
	Soil Respiration	Soil respiration
	Root traits	Root biomass
2	Taxonomic Diversity	Morphological characterization
	Root Traits	Root scans, total N
	Nutrient Cycling	N mineralization, Available & Total N, Total C, Organic C, Available P
	Soil biomass	Chloroform fumigation-extraction
3	Taxonomic and Intraspecific Genetic Diversity	16S, ITS, 18S sequencing, microbial amplicon sequencing and metagenomics
	Micro, Meso and Macrofauna taxonomic diversity	COI barcoding
	Functional Diversity	Shotgun sequencing, nematode maturity index

[#] SoilBON Essential Biological Variables (Guerra et al. 2021)

In **bold** are SOPs that have already been harmonized by GLOSOLAN (Global Soil Laboratory Network of FAO)

- Build capacities: develop national capacities to measure, map, monitor, and interpret soil biodiversity (equipment, technicians, landowners, policy makers, etc.).
- Monitoring: identify and monitor soil biodiversity sampling locations in managed lands and natural ecosystems and establish National Soil Information and Monitoring Systems (including soil biodiversity indicators).
- Mapping: map the distribution of soil biodiversity worldwide.
- Sharing data/information: countries share and contribute data and information to GLOSOB following the revised GSP Global Soil Data Policy that will be updated to include soil biodiversity information.
- Reporting: GSP will report on the global status of soil biodiversity and publish reports and policy briefs regularly.
- Updating: mainstreaming of soil biodiversity into conventional soil surveys (modification/updating of the FAO's Guidelines for Soils Description).

7. Information storage and access

The goal of GLOSOB is that each country manages a database where information can be easily entered, extracted, and visualized. Information should be easily imported where possible from current monitoring programs with compatible measurements. A biodiversity dashboard will be constructed with coordination from INSII to display key indicators for public accessibility for all stakeholders. Furthermore, a database will be constructed and housed within the GSP at FAO (GLOSI), including all variables, and be used to perform comparative analyses at the global level, and improve understanding of the global drivers controlling soil biodiversity and functioning, or GLOSOB will coordinate with the Global Biodiversity Information Facility (GBIF) to house GLOSOB data. Although this is a country-driven decision, we recommend that each member country of GLOSOB establish a node with the GBIF (GBIF 2006), an international data infrastructure already funded by governments aimed at providing open access to data about Earth's biodiversity (Telenius 2011).

This plan was approved by the Intergovernmental Technical Panel on Soils in March 2024, and approved by the Global Soil Partnership Plenary Assembly in June 2024.

References

- Adhikari, K., & Hartemink, A. E. (2016). Linking soils to ecosystem services—A global review. *Geoderma*, 262, 101–111. <https://doi.org/10.1016/j.geoderma.2015.08.009>
- Brown, G. G., Ferreira, T., Correia, M. E. F., Niva, C. C., Jesus, E. C., Oliveria, M. I. L., Antunes, L. F. S., Parron, L. M., Coelho, M. R., et al. (2025). Soil biodiversity knowledge and use worldwide: Results from a global survey. *Soil Organisms*, 97(SI), 7–31.
- CBD (2020). *Review of the International Initiative on the Conservation and Sustainable Use of Soil Biodiversity*. <https://www.cbd.int/doc/c/f25f/ac08/fac2443375cabc303ef45c22/sbstta-24-07-en.pdf>
- FAO (2020). *State of knowledge of soil biodiversity: Status, challenges and potentialities. Report 2020* (pp. 1–618). <https://www.fao.org/documents/card/en/c/cb1928en>
- GBIF (2006). *Terms of reference for the Participant Node Managers Committee (NODES)*. <https://www.gbif.org/composition/1aKAXGBtIAQwiEBzUjz9q6/nodes>
- Guerra, C. A., Bardgett, R. D., Caon, L., Crowther, T. W., Delgado-Baquerizo, M., Montanarella, L., Navarro, L. M., Orgiazzi, A., Singh, B. K., Tedersoo, L., et al. (2021). Tracking, targeting, and conserving soil biodiversity. *Science*, 371(6526), 239–241. <https://doi.org/10.1126/science.abd7926>
- Parnell, J. J., de Ruiter, P., Guerra, C., Montanarella, L., Rodriguez Eugenio, N., Ferreira, T., Correia, M. E. F., Niva, C. C., Jesus, E. C., Oliveira, M. I. L., et al. (2025) Combining science and policy for a unified global soil biodiversity observatory. *Nature Ecology and Evolution*, 9, 1302–1306. <https://doi.org/10.1038/s41559-025-02754-z>
- Telenius, A. (2011). Biodiversity information goes public: GBIF at your service. *Nordic Journal of Botany*, 29(3), 378–381. <https://doi.org/10.1111/j.1756-1051.2011.01092.x>