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CALL FOR COLLABORATION

# Unearthing soil ecological observations

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An integrated, whole-ecosystem perspective is required to appreciate and address the most pressing challenges humankind is facing in terms of climate and biodiversity change (Guerra et al. 2021a, Pörtner et al. 2021). Scientific, political, and public awareness is rising on the status and fate of soils as the center of the challenges ahead. While several pressures on soil communities, systems, and functions have already been highlighted (Tibbett et al 2020, Montanarella et al. 2016; FAO et al. 2020), the conditions, extent, and magnitude to which soils are under threat are still subject to discussion (Rillig et al. 2019), particularly in the context of global climate and land-use change (Guerra et al. 2021b). In order to overcome existing knowledge gaps, standardized global monitoring systems (Maestre & Eisenhauer 2019) that target soil biodiversity and ecosystem functions are urgently needed. This will produce valuable information on the state and trends of soil-specific essential biodiversity variables [EBVs; (Guerra et al. 2021a)], as well as allow the use of these EBVs to assess the conservation status of many soil organisms and ecosystem services.

In the past, multiple initiatives have been initiated (Maestre & Eisenhauer 2019), but none of those has established itself as a concrete and sustainable global monitoring effort of soils. This requires connecting partners representing a range of stakeholders, including researchers, educators, and policy advisors from academic, governmental, and private sectors. To create the building blocks for the establishment of such a monitoring system for soil biodiversity and ecosystem functions, the Global Soil Biodiversity Observation Network (SoilBON: https://www.globalsoilbiodiversity.org/soilbon) was established in 2018 as a thematic network of GEO BON in partnership with the Global Soil Biodiversity Initiative (GSBI) and other global and regional partners (Guerra et al. 2021a). The goal is to further connect multinational partners and initiatives in a coordinated worldwide effort to understand soil biodiversity, document how it is changing, how these changes affect ecosystems and people who rely on soil-living resources for their well-being and livelihoods, and how the sustainable use of ecosystems can safeguard soil biodiversity.

SoilBON is now initiating a search for globally distributed sampling sites that can be continuously monitored as part of this global effort to identify spatial patterns and temporal trends of multiple soil-specific EBVs. To do that, we aim to monitor 1000 locations across the world using a simple soil sampling protocol (see www.soil-organisms.org acrticle supporting information). All these soil samples will not only be collected using the same sampling protocol, but also will be analyzed in a strictly standardized way, with single laboratories across the world performing individual analyses on all samples, i.e., guaranteeing more robust results and interregional comparisons (a full list of current partner laboratories can be found here: https://www.globalsoilbiodiversity.org/soilbon). While we are aware that a small number of local soil samples cannot provide small-scale information, it does i) establish a backbone for future monitoring, e.g., by standardizing comparisons across regions, and ii) facilitate calibration exercises using other remote sensing techniques that expand the type of data available on soil biodiversity and ecosystem functions.

Participation in this global effort is possible under some key principles:


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i) each collaborator is required to sample soils in at least two paired sites (i.e., for the same ecosystem type, ideally a sample should be taken inside a conservation area, and one outside conservation areas);

ii) for this first stage, site selection does not include urban nor industrialized areas, this may be added in the future; also ongoing experimental sites (i.e., sites or plots with experimental manipulation of environmental conditions like nutrient addition [e.g., Nutnet), precipitation reduction (e.g., Drought-Net), application of pesticides (e.g., BugNet), etc.] are not the focus of this call;

iii) soil sampling needs to be conducted using a standard sampling kit provided by the SoilBON;

iv) SoilBON works under the principle that both the soil and the data coming from the analyses belong to the individual collaborator, but SoilBON is allowed to use it and publish it as an open-access dataset for the purpose of large-scale ecological analyses and assessments, e.g., in the context of open databases like GBIF (www.gbif.org) or Edaphobase (www.edaphobase.org, www.eudaphobase.eu);

v) SoilBON works under the principle of equality of treatment among collaborators; therefore, given the high level of standardization required for both the sampling and the analyses on the samples taken, for samples coming from Africa, developing countries, or from 'global blindspot' areas [sensu, (Guerra et al. 2020), excluding developed countries], specific funding to cover all shipping costs related to the transport of soil samples and sampling kits will be provided; and

vi) all laboratory analyses done in the scope of this activity (Fig. 1) are free of charge to any collaborator.

Site selection will be primarily based on an assessment of the overall environmental coverage of the proposed sites [sensu Guerra et al. (2020)]. This will ensure that a balanced coverage of the world is achieved, i.e., without a focus on densely covered regions like Europe, Australia, or the United States, and an effective support and integration of researchers from developing countries. For each soil sample, multiple analyses will be conducted (Fig. 1). These include genetic sequencing ('nametag' gene, e.g., 16S ribosomal RNA and/or 18S rRNA genes, ITS and metagenomics sequencing) with the purpose of identifying soil biodiversity, non-genetic soil functional properties (e.g., soil respiration, substrate-induced respiration, microbial biomass, enzyme activity, litter decomposition, and soil aggregate stability), and root properties. Other important analyses (e.g., heavy metals and pesticides) are being considered. Environmental characteristics like elevation, temperature, precipitation, or climatic variability will be collected for future analysis.

One important mention is to the modular and expanding nature of this project, being open to future collaborations from partners and other laboratories that want to support SoilBON in expanding the number and type of elements being analysed. Working on the principles of open data

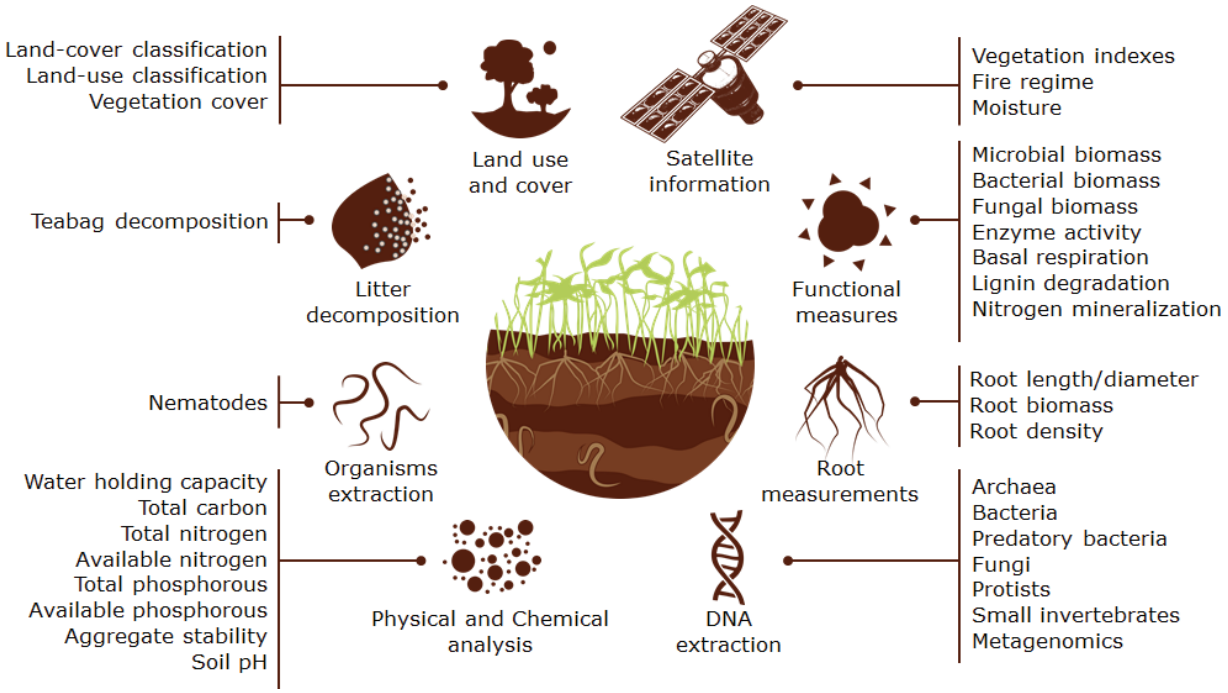


**Figure 1.** Analyses expected to be done across all soil sampling sites in Soil BON, being related to soil-specific essential biodiversity variables (Guerra et al. 2021). More analyses can be added through strategic partnerships in the future.

and open science, SoilBON aims to support an open community for soil macroecology. Specific focus will thus be put on the open and fair publication of data, papers, and code [sensu (Eisenhauer & Xylander 2019)]. It also aims to support all developments related to expand the focus of nature conservation to soil ecology and soil biodiversity.

While participation is open to all, due to the complexity of the analysis, and the fact that many countries are signatory partners of the Nagoya declaration, it is necessary to follow all the legal requirements from each country and in particular their specific Access and Benefit Sharing (ABS) mechanism. SoilBON will manage this, but we are looking for committed partners to support us in navigating local languages and legal requirements. This is a time-consuming process, but such collaboration is essential for this project to succeed and to establish long-lasting relationships that allow the implementation of effective and sustainable benefit-sharing mechanisms. By contacting us, collaborators are not only participating in a global collaborative project targeting soil ecology and specifically soil biodiversity, but they will also be invited to take part as co-authors in collaborative papers and exploring opportunities for other potential research projects. Aiming at a global representation of sampling locations, a site selection process based on coverage of environmental conditions might be necessary. However, interested partners can get engaged, receive regular updates through the SoilBON network, and suggest additional analyses and scientific projects. We are excited to start this global endeavour to produce crucial data for science and policy (Guerra et al. 2021a) and to establish the basis for healthy ecosystems and soil-based transformative change.

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