
INTRODUCTION

The Global Soil Biodiversity Initiative (GSBI), a scientific effort, held its first open meeting in London, UK, March 2012. International attendees, from 13 countries, evaluated current information and concluded that there is an urgent need to integrate the rapidly accumulating knowledge on soil biodiversity and ecosystem services into management and policy decisions of all global lands, both managed and natural. This paper summarizes the outcomes of the event, documents future plans of the GSBI and provides information and options to policy makers on the role of soil biodiversity in ecosystem services and global sustainability. Additional information can be found at: www.globalsoilbiodiversity.org.

BACKGROUND

Increasingly, sustainable development is being recognized as the solution to securing human well-being and ecosystem services in the context of global changes. Soil organisms provide a foundation for many of the areas requiring sustainable development, including food, fiber, biomass and energy and fuel provision in the long-term. Soil organisms are critical for the maintenance of ecosystem services such as, primary productivity, stable soil structure, regulating pathogens and parasites of plants, animals and humans, and ensuring a functioning and productive soil system. According to the Convention of Biological Diversity (CBD), biodiversity is defined as the variation in life from genes to species, to communities, to ecosystems up to landscapes. While there is ample evidence that the diversity of different life forms and traits of soil biota are needed for optimizing ecosystem services, there is less evidence at the species or genetic level. Increasing integration of current and needed knowledge of soil biodiversity into decisions related to land use planning can optimize ecosystem services; with corresponding increased direct and indirect benefits to society. Still, a disconnect remains between scientific findings and policy; there is an inability to disseminate this knowledge to a wider audience and when coupled with the remaining knowledge gaps in research, may result in large direct and indirect costs to society. One of the main goals of the GSBI is to enhance this process of synthesis and communication.

The Earth’s soils are living, dynamic interfaces that are supported by millions of microbial and animal species. Yet, despite the numerous benefits soil biodiversity delivers, it is often left out of policy decisions; indeed much of the public is unaware of the vast biodiversity beneath their feet. Moreover, worldwide destruction of soils through overuse, climate change, nutrient enrichment, desertification, deforestation, urbanization and other forms of soil sealing, as well as other land use changes, threatens the biodiversity of soils and the provisioning of ecosystem services crucial to sustaining life on Earth.

To sustainably meet the challenges of global change, soil biodiversity and the ecosystem services it produces must be integrated into land management and related policy decisions. In the light of rapidly progressing policy movements and accumulating scientific knowledge on soil biodiversity, now is the optimal time to inform scientists, managers and policy makers alike. Therefore, at this inaugural GSBI meeting, a united effort of participants, representing soil
scientists, biogeochemists, taxonomists, soil ecologists, agronomists, ecosystem scientists and policy makers, reached a consensus that there is a need to inform decision makers and enhance sustainable science-based management of the world’s soils. The GSBI will be guided by four focus areas, which were identified and discussed in detail by working groups at the meeting and are summarized here:

I. Key Challenges for Soil Biodiversity Science
The science of soil biodiversity has evolved rapidly over the last two decades. From this work a picture of the vast biodiversity within soils, and of the significant role that soil biota play in ecosystem processes, has become apparent. Still, amidst this work, three significant knowledge gaps were identified where the GSBI should focus efforts to best inform and advise policy makers on links between soil biodiversity and ecosystem services.

*Linking soil biodiversity and soil carbon sequestration:* Soil carbon (C) is of the utmost importance for the sustainable production of food and fiber, ecosystem health and climate change mitigation, and soil biota are intricately tied to the transformation, fate and forms of C in soils. However, it remains unclear how soil C quality and sequestration will be affected by environmental changes (e.g. climate change, N deposition, land-use change), or if a particular soil community structure has the potential to maximize soil quality and C sequestration. The GSBI can assist in improving communication of experimental findings to farmers and land managers with simple messages and easy to understand soil C threshold values for the provision of a multitude of ecosystem services.

*Scaling up to a global understanding:* To further improve the benefits of experiments, it is important to identify if links between biodiversity and ecosystem functioning found at small scales (i.e. most experimental units) can be used to restore soil communities and soil function on larger scales and ultimately global scales. The GSBI can synthesize available knowledge and ascertain when responses to environmental changes are predictable or not, and establish metrics and timelines to restore ecosystem services provided by soil biodiversity.

*Not all soils are equal:* A single soil does not deliver all ecosystem services, but identifying how reduced delivery of ecosystem services at smaller scales can be compensated for at larger scales needs to be addressed. One theme of the GSBI can be to address when and how soils can be optimally utilized across both temporal and spatial scales to increase provision of ecosystem services, and to determine this within an environmental change context. The GSBI could further assist by informing land managers and policymakers of land most suited for particular purposes or particular services.

II. Standardize Methods and Data Synthesis for Global Scale Analysis
As research into soil biodiversity rapidly expands, so too does data accumulation, scaling from gene sequences to remote sensing. It is essential to use these available data to inform land management and to assist future global experiments in linking soil biodiversity and ecosystem services.
To relate scientific findings and best inform policy a number of actions can be initiated and steered by the GSBI, including: standardization of site and soil description, organism retrieval, reporting matrix and key functions of soil biota to be assessed. The GSBI can also guide in specific areas where inconsistencies between studies are common or key knowledge gaps remain, such as sampling design, trait selection and analysis, choice of organisms to be addressed and selection of molecular genetic methods. Further, a science based management approach would be improved with the development of guidance documents to contribute to future experimental data sets, such as a glossary on location (region, landscape, etc.) and functionality terms (engineer, services, natural capital, goods, etc.) to clarify terms for other scientists. Other areas that would benefit from guidance include: documentation of ecosystem services and biodiversity conservation as a component of global programs.

Consistent and reliable metrics will allow for comparable datasets, and overall improved detection of regional and global trends. The harmonization of methods and data synthesis will clarify for scientists and policy makers how soil biodiversity affects ecosystem services at a global scale.

III. Manage Soil Biodiversity for Delivering Ecosystem Services
Maintaining soil biodiversity can have a positive impact on many global, large-scale challenges currently facing society, including food systems sustainability, reduction of erosion, water filtration and storage, and reduction of greenhouse gas emissions by regulating the cycling of nutrients. However, management of soil, its biodiversity, and the services provided by soil biodiversity, can only be achieved at a local scale. Attempts to apply blanket soil management solutions on top of these mosaics are unlikely to be successful.

Further, and also in line with the CBD definition, biodiversity is more than just the number of species (species richness) in soil: the many species interactions that occur within the soil food web, and between plants and the soil food web, influence its ability to deliver ecosystem services. Disruption to soils, through disturbances including land use and climate change, can decrease species numbers and alter soil food web composition. For optimal management implementation the GSBI can outline how best to integrate ecosystem service delivery with knowledge of biodiversity metrics.

Some target areas to incorporate into a science based management approach include: identifying soil biodiversity management strategies to enhance their ecosystem services, providing successful case studies and examples of strategies for biodiversity management to enhance ecosystem services, classifying ecosystem services vulnerable to decline that are dependent on specialized functions of soil biodiversity (e.g. nitrogen fixation) versus those dependent on generalized functions (e.g. decomposition), and identifying examples of connected refugia across less intensively managed landscapes that could be corridors to conserve soil biodiversity and ecosystem services.
IV. Inform Policy on Soil Biodiversity and Ecosystem Services

Soil biodiversity has had little attention in global environmental policies, despite the numerous ecosystem services it provides to society and to the economy of nations. The role of the GSBI is to promote the maintenance and functionality of soil biodiversity in managed and natural systems.

Currently, several opportunities exist for soil biodiversity science to inform international policies and scientific efforts such as, the Global Soil Partnership (GSP), the Food and Agricultural Organization (FAO) led soil biodiversity initiative, the Convention on Biological Diversity (CBD), the Intergovernmental Panel on Climate Change (IPCC), the United Nations Convention to Combat Desertification (UNCCD), the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES), DIVERSITAS and other organizations. Further, the GSBI will play an active role at Rio+20 and elsewhere, to raise awareness and establish official recognition and participation by the international community. Finally, the GSBI will continue to outline immediate deliverables with respect to policy needs, develop the scientific strategy to deliver these and to address the evidence gaps.

The first major activity of the GSBI will be the development of the **Global Soil Biodiversity Assessment (GSBA)** that will involve participants from all over the world. This assessment, the first ever, will provide a basis for information that will be useful to the public and any interested groups, especially policy makers. The goals of the GSBA will be to organize global participation through an international network in an effort to synthesize present knowledge of crucial taxonomic groups in soil, identify how soil biodiversity and its services can be measured across the wide range of ecosystems in the world, address vulnerabilities of soil biota and ecosystem services and recommend future management applications based on scientific knowledge.

**CONCLUSIONS**

Here we have presented the Global Soil Biodiversity Initiative (GSBI), an internationally coordinated effort promoting the importance of soil biodiversity and ecosystem services for Earth’s continued sustainability. The GSBI has been initiated as a bottom-up initiative to a) synthesize current and new knowledge on soil biodiversity and ecosystem services and encourage and enhance communication and use of this knowledge in policy development and land management; and b) create an assessment of soil biodiversity and ecosystem functions and services, the Global Soil Biodiversity Assessment. This document represents a synthesis of discussion topics from 4 working groups at the first GSBI meeting. The topics of the four working groups, presented in more detail on the website (www.globalsoilbiodiversity.org), are intended to act as a flexible framework to address global environmental and societal challenges affecting provision of food, water, climate change and desertification.
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