IDENTIFY KEY CHALLENGES FOR SOIL BIODIVERSITY SCIENCE

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We identified and discussed three major areas in which significant knowledge gaps exist and where the GSBI should focus efforts to best inform and advise policy makers on links between soil biodiversity and ecosystem services. These areas include: links between soil biodiversity and soil organic matter (SOM), experimental design to link ecosystem services to soil biodiversity, and how to reconcile scaling issues between what can be measured or modeled at particular scales and then translated to policy-relevant scales. It is also acknowledged that these are not exclusive priorities, and other issues are likely important – however, it is notable that within this group they came to the fore at the outset.

The first area we identified involved knowledge about the mechanistic links between soil carbon (C) and soil biodiversity. Many questions remain about how different C pools and forms affect the functioning of the soil biota, and whether total soil C content is the critical property, or that specific fractions of SOM are also of particular significance, for instance humic substances which represent the largest pool of recalcitrant organic carbon. This is very pertinent in the context of mitigation, both in terms of maximizing soil quality for ecosystem services and for C sequestration. It seems that at this point, policy has mainly focused on total soil C content, which may not be appropriate – an extreme example would for instance give grounds for putting biochar made out of car tires into the soil. Little research actually supports methods such as these, and effects on the soil properties and biota remain unclear. Moreover, effects of soil C and its different forms on soil biota are likely soil type and ecosystem specific. Overall, there are many unknowns in how abiotic factors like soil physical properties affect the relationship between soil C and soil biota. A final question is the link between soil biodiversity or soil organisms and soil C sequestration; does a more diverse soil food web help to sequester soil C? Therefore, there is a need to disentangle the mechanistic links between soil C, soil biodiversity, and ecosystem functioning. However, although this mechanistic understanding is of importance, we need to come up with simple messages for policy makers, and easy to understand threshold values for farmers about the amount of C that they need in their soils. This is challenging since there is likely a degree of context dependency on such relationships, i.e. no single threshold will be universally applicable, and research needs to address ways of simplifying this approach.

The second area in which major knowledge gaps exist is whether links between biodiversity and ecosystem functioning in small-scale experiments also exist on larger, ultimately global, scales, and how this knowledge can be used to restore soil communities and soil function. Although there are many studies describing soil biodiversity on landscape, continental, or even global scales, most of these studies are correlative. Moreover, the vast amount of data that is available about the distribution (biogeography) would be more valuable if integrated into a coherent database, similar to the TRY plant traits database. Scientists could then apply to have access to the database and freely use the data stored. This coordinated effort to integrate data on soil communities would give

a strong message about an organized scientific community. The information from such a database could then be used to set up global experiments to link soil biodiversity to ecosystem functioning. Another possibility would be to set up a soil bank, and store soil samples in a central archive, making them available for scientists to analyze, akin to microbial culture collections or herbaria. Soils would need to be stored in such a manner to preserve bimolecules. DNA extracted from such soils could also archived in this manner.

However, although there is a need for information on global patterns of soil biodiversity and relationships between soil biota and abiotic factors such as soil pH and C, these relationships are correlative. In order to inform policy, we ultimately need to know whether these relationships are causal, and whether different soils and systems respond in a similar way to environmental change. One option to obtain such information would be to set up simple experiments across the world, which could be done regardless of the country and of the system and resources available. A possibility would be to involve the general public in these experiments, through citizen science, for instance by distributing unified litter ('tea') bags or substrate-loaded ('Magnum') sticks, let people put them into the soil and measure decomposition. Another point that came up was how to restore degraded soils and their functions, and how little is known about this, for instance about the speed at which degraded soils can function again, and which functions to measure to assess whether a soil has been restored.

The final point we discussed was the issue of scale and ecosystem services delivered by soil, and multi functionality; does a single soil have to deliver all ecosystem services, or can ecosystem services, or disservices, be compensated for, on aggregate, at larger scales? Then we discussed the land sparing versus land sharing issue. We concluded that some zones/areas are better for delivering certain ecosystem services than others, and we should prioritize which ecosystem service we want where, and which ecosystem services are more important and can be easily maximized. Thus a policy of utilizing land most suited for particular purposes, for such purposes. The science questions that arise from this are then how do we define such suitabilities, and how do we organize soil utilization in time and space optimally. An approach to considering this could then be a thought experiment and ask: "what you would do if you could just take the land, and forget about any borders, current land use, or political boundaries, and how you would then plan land use, to maximize the delivery of ecosystem services across the piece?" We then thought that by doing this, we could identify the major questions for research to inform policy makers.