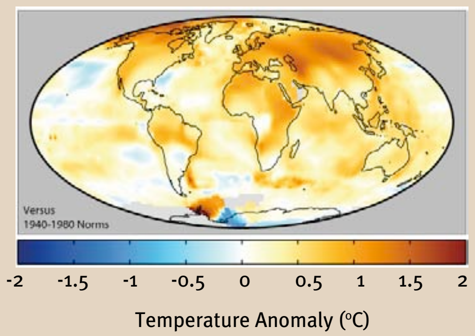
Threats to *soil biodiversity*

The Millennium Ecosystem Assessment (2003) listed the key threats to biodiversity worldwide as loss and damage of habitats, climate change, invasive non-native species and overexploitation of species. These apply equally to soil biodiversity.

Mean Temperatures, 1995-2004



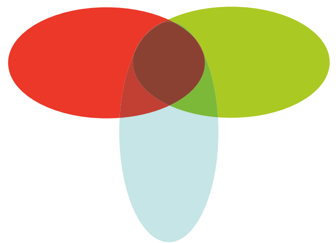
Any physical loss of soil can inevitably lead to loss of biodiversity and any change in land use or vegetation is likely to alter soil biodiversity. Several potential causes of the loss of biodiversity are related to the other soil threats.

Resistance vs. resilience

The graph on the right shows the impact of a perturbation event on soil biodiversity. This could be in the form of a contamination event, erosion, or land management practice such as tilling. The soil community **A** shows high resistance, but poor resilience and in fact never recovers to the pre perturbation level of biodiversity. Conversely, the soil community represented by line **B** shows poor resistance, but high resilience and after a large impact of the perturbation event, soon recovers back to the original levels of biodiversity. Community **C**, however, shows both poor resistance and poor resilience and it is likely that the level of biodiversity will remain reduced compared to pre-perturbation levels permanently.

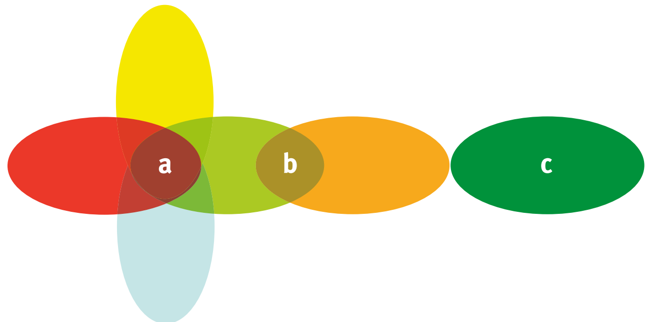
Functional redundancy

Each ellipse represents the range of functions that can be performed by one part of a given soil community, be it a certain species or group of organisms. Whilst some functions can be carried out only by a part of the community, overlap between the functions that each group performs exits.

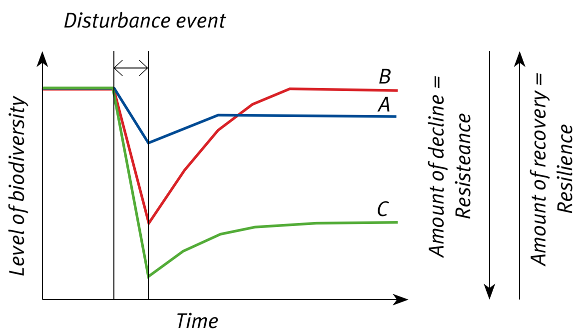


If one part of the community is removed, the some of the functions performed by that community is lost. However, due to the overlap in functions performed by different communities, not all functions are lost. This is known as "Functional Redundancy".

Some functions carried out in soil have more functional redundancy than others. For example:



a) High levels of functional redundancy exist
E.g. Breakdown of organic matter by many species of soil invertebrates, fungi and bacteria.
b) Some levels of function redundancy exists
E.g. Nitrogen fixation by Rhizobium, Cyanobacteria, actinomycetes.
c) No Functional redundancy exists
Loss of this part of the community means complete loss of this function. E.g. breakdown of some highly recalcitrant or xenobiotic compounds.



Design: JJ Blasco / IEC Unit

Life beneath our feet: research challenges for soil biodiversity

Simon Jeffery and Ciro Gardi

Soil is a dark, semi aquatic system consisting of minerals, organic matter, water, air and an incredible array of highly diverse organisms. Fungi, bacteria, nematodes, arthropods, earthworms and mammals form a complex food web that is still only partially known and described. Even the true extent of soil biodiversity, its origins and functional consequences are only just beginning to be understood. Increased understanding is vital to allow effective management of soil and its biota. This leaflet presents an overview of our current understanding of the key pressures on life in the soil, describe recent developments that have enhanced our understanding of this crucial, yet unknown ecosystem, and establish future challenges to the research community to support the sustainable use of this critical, non-renewable natural resource.

Legislators and policy makers require relevant information from the research community in order to act effectively. But, as much of soil biodiversity is hidden, mostly unknown and poorly mapped, relevant information can often be lacking. Further research in soil biodiversity is therefore vital. However, many challenges remain to be overcome. These include:

- Finding ways of quantifying the incredible **levels of biodiversity and heterogeneity** which exist regarding soil biodiversity at a small scale.
- Unraveling the precise **interactions between soil biodiversity and ecosystem services** with sufficient precision to inform and drive policy.
- Evaluating the **feedback between environmental factors and soil community structure.**
- Producing effective models to allow accurate quantification of current levels of soil biodiversity and thereby allow accurate **forecasting regarding the impacts of anthropogenic forces.**

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Spatial scale *of* soil biodiversity *and its* functions

Global level

- Biogeochemical cycles (organic matter mineralisation, nitrogen fixation, carbon sinks and sources etc);
- Value of future possible but as yet unknown uses or functions associated with some aspects of soil diversity

Regional / national level

- Ensure short term and long term resilience of food security;
- Increases the aesthetic appeal of rural landscapes, assuming a positive relation between below- and above-ground diversity

Farm level

- Contributes to the productive capacity of the system by ensuring the mineralisation of nutrients from organic resources and nitrogen fixation;
- Buffers the functions of the soil and their resilience to climatic and environmental risks

Microscopic level

- The scale at which many soil organisms live and function is microscopic, and yet they drive processes at the global scale!
- Increases aggregate stability helping to reduce erosion as well as cycling nutrients and improving soil fertility.

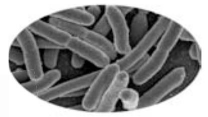
Soil biodiversity

The soil is home to a vast array of organisms. These include organisms which everyone is familiar with, such as rabbits and earthworms, down to microorganisms which can be as small as 1 µm in size. This is "very small", but how small exactly?

1 mm
100 µm
1 µm

Microfauna and microflora

- Includes: bacteria, fungi, protozoa, nematodes.
- Size range: 1-100 µm

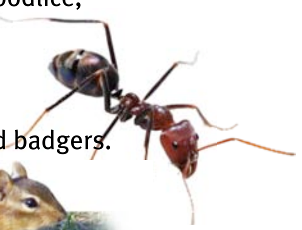


Mesofauna

- Includes: tardigrades, collembola, mites.
- Size range: 100 µm-2 mm

Macrofauna

- Includes: earthworms, ants, slugs, woodlice, and centipedes.
- Size range: 2 mm-20 cm



Megafauna

- Includes: moles, rodents, rabbits, and badgers.
- Size range: > 2 mm

Interactions *within and between* groups *of* soil organisms

Soil organisms fall into the same ecological groups as other organisms. Interactions between different species of soil organisms can be split into two types:
Horizontal interactions (within trophic levels) and Vertical interactions (between trophic levels).

Predator / Prey
One type of organism derives its energy source by consuming another type of organism.

Competition
Organisms strive for a goal or resource which cannot be shared.

Parasitism
One organism is helped but the other *is* harmed.

Vertical interactions

Trophic level

Consumers
E.g. nematodes, protozoa, moles.

Energy flow

Producers
E.g. plants, cyanobacteria.

Horizontal interactions

Mutualism
Both organisms derive benefit.

Competition
Organisms strive for a goal or resource which cannot be shared.

Commensalism
One organism is helped but other *isn't* harmed.

Indifference
Organisms do not affect each other in anyway.

Functional diversity

Biodiversity is often measured using a taxonomic approach, such as there are so many species of reptile, or so many plant species. For example, it is often said that more than half the world's estimated 10 million species of plant, animal and insects live in the tropical rainforests.

When this approach is applied to the soil, the level of diversity is often quoted as being in the range of hundreds of thousands to possibly millions of species living in just 1 handful of soil.

However, problems arise when we try to use the taxonomic approach to quantify soil biodiversity, especially when we move into the microscopic world of bacteria.

Firstly, only a small percentage of soil bacteria, probably < 10%, are currently culturable limiting the amount of research that can be undertaken on them in a laboratory.

Added to this, as bacteria can swap large amounts of DNA between themselves, the very definition of what makes a 'species' is unclear for bacteria. Indeed, there is no widely accepted consensus for defining species in bacterial systematics.

More importantly, we would be dramatically underestimating the value of soil biodiversity if we were to use only the taxonomic approach. It is the diversity of the processes, the "Functional Diversity" carried out by the soil biota which gives soil biodiversity such high value.

Why *is* soil biodiversity important?

Soil organisms perform many important functions including cycling of nutrients thereby aiding of soil fertility and structure, moving carbon from the atmosphere to the soil, cleaning of water supplies and removal of pollutants. It has been estimated that for humans to perform all of these 'ecosystem services' would cost in excess of $13 trillion. That is approximately 1/4 of the annual GDP of the entire planet!

Activity	Soil biodiversity involved
Waste recycling	Various saprophytic and litter feeding invertebrates (detritivores), fungi, bacteria, actinomycetes and other microorganisms
Soil formation	Diverse groups of soil biota facilitate soil formation, e.g. earthworms, termites, fungi, etc.
Nitrogen fixation	Biological nitrogen fixation occurs by diazotrophic organisms including bacteria and cyanobacteria
Bioremediation of chemicals	A diverse array of organisms, depending on the chemicals involved. Maintaining biodiversity in soils and water is imperative to the continued and improved effectiveness of bioremediation and biotreatment
Biotechnology	Ascomyctes and other soil organisms provide many antibiotics, nitrogen fixing bacteria aid the agricultural industry etc.
Biocontrol of pests	Soil provide microhabitats for natural enemies of pests. The soil biota contribute to host plant resistance and plant pathogens control (e.g. mycorrhizas)
Pollination	Many pollinators may have edaphic phase in their life-cycle
Source of food for other organisms	For example mushrooms, earthworms, small arthropods, etc.