Soil biodiversity is essential for building environmental resilience

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The School of Agriculture and Environment and Institute of Agriculture at the University of Western Australia recognise the importance of soil biodiversity in managing soil conditions and building resilience against environmental changes

Soil is a biodiversity 'hotspot.' The diversity of organisms in soil is even greater than that found in above-ground ecosystems. Soil biodiversity is dictated by its surroundings, and the communities present comprise groups of organisms that are interdependent. Indeed, soil organisms are represented in all six Kingdoms (Monera, Archaea, Protista, Fungi, Animalia, and Plantae) and fulfill key roles in important processes relevant to soil health, including those that regulate global nutrient and climate cycles.

The animals that live in soil communities include larger but intermittent burrowing fauna, as well as many smaller inhabitants, including earthworms, insect larvae, arthropods (especially mites and springtails), and nematodes.

Soil microorganisms include fungi (most of which are microscopic, but some form very visible fruiting structures), bacteria and archaea (single-celled organisms), protists (e.g., amoebae), and viruses.

Plants as varied as algae, mosses, and roots of angiosperms and gymnosperms also contribute significantly to soil biodiversity, especially by stimulating the activities of other organisms.

Creating resilient soil

Soil conditions are dynamic due to events such as seasonal rainfall and disturbance by land management practices. Soil health in both agriculture and natural ecosystems is highly dependent on how organisms interact with one another in response to these events and in the transformation of elements from one form to another, especially during the mineralisation of organic residues.

Some soil processes mediated by soil organisms are very slow (e.g. the dissolution of parent rock materials). In contrast, other processes, such as the breakdown of plant organic matter, occur relatively rapidly, providing moisture levels, aeration, and temperatures are suitable.

A wide variety of soil organisms contribute to the regulation of global biogeochemical cycles. For example, a particular kind of soil microorganism may participate in early or later stages of organic matter degradation, depending on its capacity to produce enzymes that break down particular organic molecules.

On the other hand, other kinds of microorganisms that may not produce enzymes for early-stage breakdown of carbon molecules in organic matter can be opportunists that are effective at competing for carbon released during the degradation process.

Consequently, soil is a ‘rough and tumble’ environment, with competition for resources a significant driver. Even the minority of soil organisms that are able to obtain carbon from the gas CO2 may be influenced by those which depend on accessing carbon from soil organic matter. Therefore, there are ‘chain reactions’ within nutrient cycling processes that involve complex interactions among organisms within the soil community.

The release of greenhouse gasses during the decomposition of organic matter in soil depends on the capabilities of different members of the soil community; some may be involved in the release of CO2, but others release less oxidised forms of carbon, such as methane. While this highlights different biochemical pathways mediated by soil microbial communities, these activities depend on environmental conditions as well as the kinds of organisms present.

Indeed, at any time, some groups of soil microorganisms and soil fauna may be very active, while others are completely inactive due to a combined effect of their surrounding environmental conditions, the availability of carbon resources, and physiological pathways mediated by the organisms present. On the other hand, different soil microorganisms can contribute to the same biochemical processes, and this represents ‘redundancy’ in functional capability within the soil community.

Multiple pathway options provide a degree of resilience within the soil community against potentially negative impacts of seasonal events, land management practices, and even climate change.

Key characteristics of soil biodiversity

It is not easy to quantify soil organisms accurately. Many of the organisms that live in soil have not been identified or cannot be multiplied in non-soil conditions. However, it is well known that within groups of organisms, there is a very wide range of differences, even at the level of genera or species, with soil biodiversity made up of distinct groups (such as bacteria, nematodes, and insects) and within-group diversity (such as different kinds of fungi or arthropods).

The complex structure of the soil habitat makes it difficult to quantify all of the organisms present to assess overall biodiversity. Microorganisms that occur in inaccessible pores within stable soil aggregates can be difficult to access. Techniques required to estimate the abundance of soil organisms depend on the organisms under investigation.

For example, methods used to identify and quantify the wide variety of soil fauna may involve direct observations and microscopy. Molecular tools can be useful for complementing microscopic observation of some groups of soil fauna (e.g. nematodes).

In contrast, microorganisms such as bacteria and many fungi cannot be easily identified by direct observation, whereas molecular approaches provide insight into the extensive range of microorganisms that comprise soil communities.

Although the identification of many soil microorganisms remains unknown, molecular tools based on emerging DNA or RNA technologies facilitate the detection of related microorganisms and draw attention to the complexity of soil microbial communities. Genes that code for the same biochemical processes can occur in different organisms.

Therefore, molecular approaches enable the characterisation of functional biodiversity within the soil that is not directly linked to particular organisms. Furthermore, it is possible to detect whether the genes involved in biochemical transformations are active or inactive, thereby enabling predictions about the potential for activity in the future if soil conditions were to change.

Factors affecting soil biodiversity

Soil biodiversity is influenced by habitat diversity, including the diversity of plant species and their residues. Plants can form specific relationships with microorganisms, such as mycorrhizas. Soil biodiversity can also be influenced by physical disturbances associated with land management practices, as well as significant seasonal events such as heavy rainfall or drought.

However, the concept of biodiversity in soil could be more complex than for plant and animal ecosystems due to differences in scale. Soil is an extremely heterogeneous environment with extensive exposed surfaces. Very small organisms may be present in soil at levels of abundance below the level of detection, but they may still contribute significantly to soil biodiversity.

Finally, soil biodiversity is very visible in home gardens. Soil fauna and fungal networks are very obvious in compost bins and worm farms during the breakdown of household organic waste. These larger organisms are indicators of less visible microbial communities that make up an important component of soil biodiversity that contributes to soil health.

Soil health app

The SOILHEALTH app provides information about complex aspects of soil health in a digital format. It contains seven animated videos, an eBook, and podcasts, and it is available for both iOS and Android devices. This free app was designed by Cheryl Rimmer and funded by the Australian National Landcare Program Smart Farms Small Grants Round 2.

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