The soil is more than meets the eye

by Shane Tutua

Soils are very important for the survival of our land-based or terrestrial ecosystems. Not only do we live, build and grow our food on the soil, it is the lifeline of plant communities on our islands. However, soils are more than what we see; they are the habitats of many organisms that play important roles in our ecosystems. In fact, the soil is called soil because of the living organisms that live in it; remove these organisms and we are left with just sediments. Too often, biodiversity conservation efforts are focussed on aboveground species, and belowground species do not get much attention. This is probably because most soil organisms are invisible to the human eye due to either the organisms' size or the opaque nature of the soil. This article, therefore, highlights soil organisms and their roles in sustaining ecosystems. It is hoped that it will encourage us to conserve or manage soils, not just as a medium for food production, but also as a habitat for a diverse range of species, and therefore, a range of functions that contribute to the wellbeing of an ecosystem.

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Soils accommodate more organisms than what is above the ground level. For instance, one gram or a teaspoonful of soil could contain up to 1 billion bacteria, 10 million actinomycetes, and 1 million fungi. At least 147,800 species of soil organisms has been described but estimates of more than 1.8 million species has been reported. Due to the huge number of species, soil organisms and their ecological functions are best discussed when they are classified into a number of groups. The main groups of soil organisms, classified according to size, are the (1) micro-flora; (2) micro-fauna;(3) meso-fauna; and (4) macro-fauna.

Soil micro-flora or microbes are mainly the bacteria and fungi populations. These organisms have a body diameter of less than 2.0 µm (that is 0.000002 m). They are mostly decomposers, which break down dead plants and animals or organic materials into soil organic matter (SOM), a chemically active product of decomposition. The SOM influences soil properties such as soil structure, drainage, aeration and fertility. It also influences soil functions such as to purify water and store carbon (C) away from the atmosphere. During decomposition, microbes also release C in the form of carbon dioxide (CO_2) into the atmosphere - about 55 million tons of C per year, compared to fossil fuel emissions of just 6.3 million tons C per year. Therefore microbes are important in the global C cycle and climate change. Thirdly, they recycle nutrients into the soil for the next generation of living plants. Our island ecosystems depend largely on this process for plant communities to grow, as many of our soils are highly weathered and poor in nutrients, and that most nutrients are stored above ground in the forest biomass. These nutrients need to be recycled to the soil for living plants to use. In addition, without decomposers, we will have a huge organic waste problem in our environment; dead materials will pile up and we will have no space to live and work.

Some fungi team up with certain living plant species on their roots, and are known as mycorrhiza fungi (root fungi). In this partnership the fungi scavenges for water and nutrients in the soil and transfer them to the plant, while the plant supplies the fungi with carbohydrates through photosynthesis. The mycorrhiza fungi increases the capacity of plants beyond their root lengths (through the fungi's hyphal extensions) to access and concentrate limited amounts of nutrients, and therefore, greatly enhance the survival of plants in nutrient poor soils. These plants, can colonize nutrient-poor landscapes, concentrate the nutrients in their tissues, and then recycle them through the litter (dead leaves or other plant parts), thus improving soil fertility for other plants to colonise the landscape.

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Soil bacteria also play an important role as nutrient transformers. They change elements from one form to another, particularly to the forms that are useful for plants. The nitrogen (N)-fixing rhizobia or root nodule bacteria in legumes are the most commonly known. However, equally important are the free-living (not associated with any plants) N-fixing bacteria. Together with the rhizobium bacteria, they convert nitrogen gas (N_2) from the atmosphere into nitrate (NO_3) or ammonium (NH_{4+}) – the forms of nitrogen plants use. Soil organisms fix about 140 million tonnes of N per year worldwide, much larger quantity than the 50 million tons per year fixed by industrial N fertiliser production. Denitrifying bacteria, on the other hand, recycles unused NO_{3-} and NH_{4+} back to the atmosphere as gaseous nitrous oxides (N_2O) and N_2. This process minimises NO_{3-} leaching into our river, reefs and lagoons. The process of N-fixation and denitrification establishes a balance between N in the soil and in the atmosphere. Some bacteria also release enzymes that dissolve phosphorus from soil mineral particles to plant available forms.

The micro-fauna include the tiny nematodes (worm-like organisms), protozoa and amoeba (2-100 µm diameter). One still needs a microscope to see these organisms. They feed on the micro-flora, and are therefore, regarded as the carnivores in the soil. The feeding or 'grazing' activity of soil micro-fauna on the micro-flora is an important ecosystem function because they release nutrients within the tissues of the microflora. This greatly increases the turnover rate or recycling of nutrients, and therefore availability for plant uptake. Studies have shown that the grazing activity stimulates the growth of soil micro-flora and therefore is a positive feedback mechanism for the microbial population.

The meso-fauna include a large number of arthropods (insect-like organisms) and nematodes. Their sizes range from 0.1 – 2 mm, and many of these organisms can be seen by the naked eye. The meso-fauna can be described as carnivores, omnivores or scavengers since they feed on fungi and litter (dead plant materials). Their feeding behaviour recycles nutrients from live organisms, thus increases nutrient turnover rates. The feeding on and excreting of litter as wastes causes these organisms to behave like 'little factories', where they process and package a product for fungi and bacteria to convert to SOM and CO_2. In effect, they increase the surface areas of the litter so that more fungal and bacterial enzymes attach to the litter surfaces and therefore increase the rate of decomposition and nutrient cycling. On the other hand, some studies show that wastes or faecal pellets from mites act like slow-release fertilisers in the soil. Slow release nutrient sources prevent a quick flush of nutrients, which may be washed away through the leaching process.

The macro-fauna are soil organisms with body diameters of more than 2 mm. These include earthworms, ants, mites, nematodes, crabs and insects that live in the soil. They also feed on the litter, and therefore, carry out the role of shredding or fragmenting large litter into smaller sizes as part of the feeding process. However, the most important function of macro-fauna is through their burrowing, tunnelling, and channelling activities. These activities form pores or structures in the soil, thus soil ecologists often refer to the macro-fauna as the "soil engineers". Pore formation allows air and water to flow through the soil. In forest soils especially, the infiltration of water through pores prevents surface water runoff and flooding. It allows water to pass through the soil and gets slowly released into streams, a process that provides clean stream water. Airflow through the soil provides oxygen for microorganisms, such that most microbial activities occur along these tunnels, where water and air are abundant. Macro-fauna such as earthworms and crabs also act as transporters in the soil. They move litter or organic materials from the soil surface to sites in the soil where microbes are present. Some earthworms also transport fungal spores to 'resource-rich' areas in other parts of the soils, thus are actively inoculating the soil with decomposers. All these activities and interactions greatly enhance soil processes. The interactions between different soil species shows that while the microbes are the main drivers of energy flow and nutrient cycling, the soil engineers provide the conditions for microbes to drive the flow of energy and biogeochemical processes.

These few examples demonstrate the importance of soil organisms in regulating important soil processes. The more diverse or rich in species the soil is the more stable and effective it is, through species interactions, to carry out its ecosystem functions such as providing nutrients for plants, storing C from the atmosphere, providing clean water and contributing to the overall ecosystem biodiversity. Forest clearance through logging and agricultural activities not only increases the loss of soil, it also increases the loss of organic matter, which is the source of energy for these organisms. This can affect the community structure or activities of these organisms. Forest clearance also increases greenhouse gas emissions (CO_2 and N_2O) largely due to increased microbial activities. Soil organisms can also be harmed by some chemicals and pesticides we use. In agro-ecosystems, management that includes the conservation or encouragement of soil organisms is critical for sustainable food production due to their influence on soil fertility maintenance. This, in turn, will allow farmers to use the same land for a longer period, therefore extending the fallow period in other sites or minimising the clearance of virgin forests. Sustainable production systems are necessary for environmental protection in this sense. So, let's be conscious of what we do to the soil and protect its mostly invisible inhabitants. This is because soil biodiversity is key to soil quality, which is the capacity of the soil to perform its ecosystem functions, including the provision of food and other products for humans.