Rangeland Soil Quality

National Park Service
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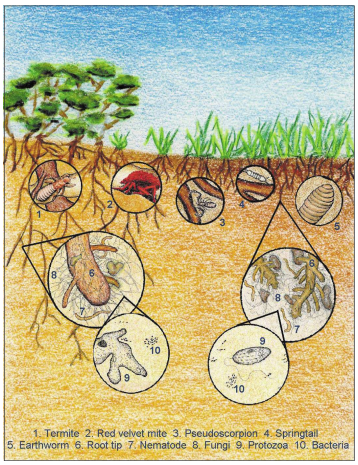
Natural Resources Program Center
Geologic Resources Division

Soil Biota

Soil biota, the biologically active powerhouse of soil, include an incredible diversity of organisms. Tons of soil biota, including micro organisms (bacteria, fungi, and algae) and soil "animals" (protozoa, nematodes, mites, springtails, spiders, insects, and earthworms), can live in an acre of soil and are more diverse than the community of plants and animals above ground. Soil biota are concentrated in plant litter, the upper few inches of soil, and along roots. Soil organisms interact with one another, with plant roots, and with their environment, forming the soil food web.

What do soil biota do?

As soil organisms consume organic matter and each other, nutrients and energy are exchanged through the food web and are made available to plants. Each soil organism plays a role in the decomposition of plant residue, dead roots, and animal remains. The larger soil organisms, such as millipedes and earthworms, shred dead leaves and residue, mix them with the soil, and make organic material more accessible to immobile bacteria. Earthworms can completely mix the top 6 inches of a humid grassland soil in 10 to 20 years. Ants and termites mix and tunnel through soils in areas of arid and semiarid rangeland. Predators in the soil food web include scorpions, centipedes, spiders, mites, some ants, insects, and beetles. They control the population of soil biota. The smaller organisms, including mites, springtails, nematodes, and one- celled protozoa, graze on bacteria and fungi. Other organisms feed on dead roots, shredded residue, and the fecal by- products of the larger organisms. The smallest soil organisms, microscopic bacteria and fungi, make up the bulk of the biota in the soil. They finish the process of decomposition by breaking down the remaining material and storing its energy and nutrients in their cells. Algae and fungi are the first organisms to colonize rock and form "new soil" by releasing substances that disintegrate rock.



What affects soil biota?

Soil biota multiply rapidly when organic material, roots, and plant litter, their food source, are available and the soil is moist and warm. Seasonal patterns of biological activity coincide with plant growth stages, litter fall, and root die- off. To be active, bacteria require films of water in soil pores, whereas fungi can function in drier conditions. When the soil is too dry, bacteria and fungi become less active or temporarily shut down, protozoa form dormant cysts, and the number of most other organisms declines. When the soil is saturated and anaerobic, the number of denitrifying bacteria increases. Organisms affect each other through predation and competition for food and space. Small soil pores can restrict the movement of large soil organisms. Different types of vegetation produce different types of litter and plant residue and thus provide different food sources for soil biota. Changes in the vegetation or the pattern of plant distribution affect the soil organisms.

Why are soil biota important?

Through their interactions in the soil food web, the activities of soil biota link soil with the plants and animals above ground. Soil organisms perform essential functions that allow soil to resist degradation and provide benefits to all living things.

Residue decomposition.—Without the soil food web, the remains of dead plants and animals would accumulate on the earth's surface, making nutrients unavailable to plants. Soil biota decompose these organic residues and some forms of organic matter in the soil. They convert these materials into new forms of organic matter and release carbon dioxide into the air. Many of the biota can break down pesticides and pollutants.

Nutrient storage and release.—Most of the annual nutrient needs of rangeland plants are supplied through decomposition of organic matter in the soil. As soil organisms consume organic materials, they retain (immobilize) nutrients in their cells. This process prevents the loss of nutrients, such as nitrogen, from the root zone. When fungi and bacteria die or are eaten by other organisms, nutrients are mineralized, that is, slowly released to the soil in plant- available forms. Nutrient immobilization and mineralization occur continuously throughout the year. Some bacteria and fungi provide nutrients to plants in exchange for carbon. Special types of bacteria, called nitrogen fixers, infect the roots of clover and other legumes, forming visible nodules. The bacteria convert nitrogen from the air in the soil into a form that the plant host can use. When the leaves and roots die and decompose, nitrogen levels increase in the surrounding soil, improving the growth of other plants. Fungi produce hyphae that frequently look like fine white entangled threads in the soil. Some fungal hyphae (mycorrhizal fungi) attach to plant roots and act like an extended root system, providing nutrients and water to the plant.

Water storage, infiltration, and resistance to erosion.—Soil biota form water- stable aggregates that store water and are more resistant to water erosion and wind erosion than individual soil particles. Threads of fungal hyphae bind soil particles together. Bacteria and algae excrete material that "glues" soil into aggregates. As they tunnel through the soil, the larger soil biota form channels and large pores between aggregates, increasing the water infiltration rate and reducing the runoff rate.

Management considerations

Grazing.—Proper management of the plant community is the best strategy for maintaining the benefits of the soil food web. Plant production and the supply of organic matter can be maintained or enhanced by timely grazing, the proper frequency of grazing, and control of the amount of vegetation removed. If the plant community is overgrazed, a reduction in the amount of surface plant material and roots will result in less food for soil organisms. As biological activity decreases, a downward spiral of the important functions of soil organisms results in a lower content of organic matter and impedes nutrient cycling, water infiltration, and water storage. Heavy grazing also can reduce the abundance of nitrogen- fixing plants, causing a decrease in the supply of nitrogen for the entire plant community.

Erosion.—Erosion removes or redistributes the surface layer of the soil, the layer with the greatest concentration of soil organisms, organic matter, and plant nutrients. Runoff and wind erosion redistribute litter from one area of rangeland to a surrounding area. The loss of organic matter reduces the activity of soil biota in the areas from which the litter has been removed.

Compaction by grazing animals and vehicles.—Soil compaction reduces the larger pores and pathways, thus reducing the amount of habitat for nematodes and the larger soil organisms. Compaction can also cause the soil to become anaerobic, increasing losses of nitrogen to the atmosphere.

Fire and pest control.—Fire can kill some soil organisms and reduce their food source while also increasing the availability of some nutrients. Pesticides that kill above- ground insects can also kill beneficial soil insects. Herbicides and foliar insecticides applied at recommended rates have a smaller impact on soil organisms. Fungicides and fumigants have a much greater impact on the soil organisms.

For More Information

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More information can also be found on the Soils website at: www2.nature.nps.gov/geology/soils

The National Park Service, Soil Inventory and Monitoring Program is partnering with the USDA-Natural Resources Conservation Service, and the USDA Agricultural Research Service, Jornada Experimental Range, to develop a series of assessment and monitoring protocols to assist NPS Vital Signs Monitoring Networks in understanding and evaluating the important role soils play within ecosystems.