Soil Food Web

NYC Parks GreenThumb

Adapted from USDA NRCS[i]

SOIL BIOLOGY AND THE LANDSCAPE

An incredible diversity of organisms make up the soil food web. They range in size from the tiniest one-celled bacteria, algae, fungi, and protozoa, to the more complex nematodes and micro-arthropods, to the visible earthworms, insects, small vertebrates, and plants. As these organisms eat, grow, and move through the soil, they make it possible to have clean water, clean air, healthy plants, and moderated water flow.

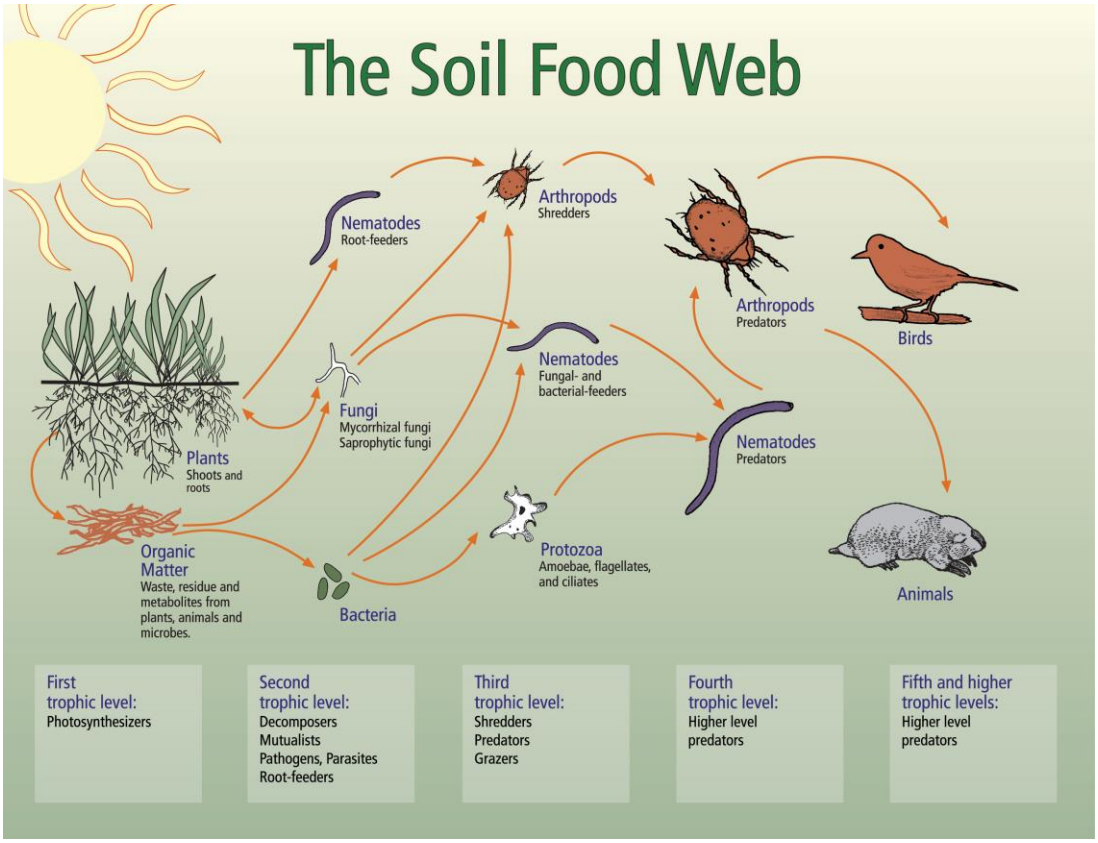
There are many ways that the soil food web is an integral part of landscape processes. Soil organisms decompose organic compounds, including manure, plant residue, and pesticides, preventing them from entering water and becoming pollutants. They sequester nitrogen and other nutrients that might otherwise enter groundwater, and they fix nitrogen from the atmosphere, making it available to plants. Many organisms enhance soil aggregation and porosity, thus increasing infiltration and reducing runoff. Soil organisms prey on crop pests and are food for above-ground animals.

THE FOOD WEB: ORGANISMS AND THEIR INTERACTION

The soil food web is the community of organisms living all or part of their lives in the soil. A food web diagram shows a series of conversions (represented by arrows) of energy and nutrients as one organism eats another (see food web diagram below).

All food webs are fueled by the primary producers: the plants, lichens, moss, photosynthetic bacteria, and algae that use the sun's energy to fix carbon dioxide from the atmosphere. Most other soil organisms get energy and carbon by consuming the organic compounds found in plants, other organisms, and waste by-products. A few bacteria, called chemoautotrophs, get energy from nitrogen, sulfur, or iron compounds rather than carbon compounds or the sun.

As organisms decompose complex materials, or consume other organisms, nutrients are converted from one form to another, and are made available to plants and to other soil organisms. All plants – grass, trees, shrubs, agricultural crops – depend on the food web for their nutrition.



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A Soil Food Web Glossary

Arthropods Invertebrate animals with jointed legs. They include insects, crustaceans, sowbugs, arachnids (spiders), and others.

Bacteria Microscopic, single-celled organisms that are mostly non-photosynthetic. They include the photosynthetic cyanobacteria (formerly called blue-green algae) and actinomycetes (filamentous bacteria that give healthy soil its characteristic smell).

Fungi Multi-celled, non-photosynthetic organisms that are neither plants nor animals. Fungal cells form long chains called hyphae and may form fruiting bodies such as mold or mushrooms to disperse spores. Some fungi, such as yeast, are single-celled.

Saprophytic fungi: Fungi that decompose dead organic matter.

Mycorrhizal fungi: Fungi that form associations with plant roots. These fungi get energy from the plant and help supply nutrients to the plant.

Grazers Organisms, such as protozoa, nematodes, and microarthropods, that feed on bacteria and fungi.

Microbes An imprecise term referring to any microscopic organism. Generally, "microbes" includes bacteria, fungi, and sometimes protozoa.

Mutualists Two organisms living in an association that is beneficial to both, such as the association of roots with mycorrhizal fungi or with nitrogen-fixing bacteria.

Nematodes Tiny, usually microscopic, unsegmented worms. Most live free in the soil. Some are parasites of animals or plants.

Protozoa Tiny, single-celled animals, including amoebas, ciliates, and flagellates.

Trophic levels Levels of the food chain. The first trophic level includes photosynthesizers that get energy from the sun. Organisms that eat photosynthesizers make up the second trophic level. Third trophic level organisms eat those in the second level, and so on. It is a simplified way of thinking about the food web. In reality, some organisms eat members of several trophic levels.

WHAT DO SOIL ORGANISMS DO?

Growing and reproducing are the primary activities of all living organisms. As individual plants and soil organisms work to survive, they depend on interactions with each other. By-products from growing roots and plant residue feed soil organisms. In turn, soil organisms support plant health as they decompose organic matter, cycle nutrients, enhance soil structure, and control the populations of soil organisms including crop pests. (See table of functions of soil organisms below.)

Type	Examples	Major functions
Photosyntesizers	Plants Algae Bacteria	**Capture energy** Use solar energy to fix carbon dioxide Add organic matter to soil (biomass such as dead cells and plant litter)
Decomposers	Bacteria Fungi	**Break down residue** Immobilize (retain) nutrients in their biomass Create new organic compounds (cell constituents, waste products) that are nutrients for other organisms Convert forms of nitrogen Compete with or inhibit disease-causing organisms
Mutualists	Bacteria Fungi	**Enhance plant growth** Protect plant roots from disease-causing organisms Some bacteria fix nitrogen Some fungi form mycorrhizal associations with roots and deliver nutrients and water to the plant
Pathogens Parasites	Bacteria Fungi Nematodes Microarthropods	**Promote disease** Consume roots and other plant parts, causing disease
Root-feeders	Nematodes Macroarthropods (cutworm, etc.)	**Consume plant roots** Potentially cause significant crop yield loss
Bacterial-feeders Fungal-feeders	Protozoa Nematodes Nematodes Microarthropods	**Graze** Release plant available nitrogen and other nutrients when feeding on bacteria Control many root-feeding or disease-causing pests Stimulate and control the activity of bacterial & fungal populations
Shredders	Earthworms Macroarthropods	**Break down residue and enhance soil structure** Shred plant litter as they feed on bacteria and fungi Provide habitat for bacteria in their guts and fecal pellets Enhance soil structure as they produce fecal pellets and burrow through soil
Higher-level predators	Nematode-feeding nematodes Larger arthropods, mice, voles, birds	**Control populations** Control populations of lower trophic-level predators Larger organisms improve soil structure by burrowing and by passing soil through their guts Larger organisms carry smaller organisms long distances

ORGANIC MATTER FUELS THE FOOD WEB

Organic matter is many different kinds of compounds – some more useful to organisms than others. In general, soil organic matter is made of roughly equal parts humus and active organic matter. Active organic matter is the portion available to soil organisms. Bacteria tend to use simpler organic compounds, such as root exudates or fresh plant residue. Fungi tend to use more complex compounds, such as fibrous plant residues, wood and soil humus.

Intensive tillage triggers spurts of activity among bacteria and other organisms that consume organic matter (convert it to CO_2), depleting the active fraction first. Practices that build soil organic matter (reduced tillage and regular additions of organic material) will raise the proportion of active organic matter long before increases in total organic matter can be measured. As soil organic matter levels rise, soil organisms play a role in its conversion to humus—a relatively stable form of carbon sequestered in soils for decades or even centuries.

WHERE DO SOIL ORGANISMS LIVE?

The organisms of the food web are not uniformly distributed through the soil. Each species and group exists where they can find appropriate space, nutrients, and moisture. They occur wherever organic matter occurs – mostly in the top few inches of soil, although microbes have been found as deep as 10 miles (16 km) in oil wells.
Soil organisms are concentrated:

Around roots. The rhizosphere is the narrow region of soil directly around roots (see next section). It is teeming with bacteria that feed on sloughed-off plant cells and the proteins and sugars released by roots. The protozoa and nematodes that graze on bacteria are also concentrated near roots. Thus, much of the nutrient cycling and disease suppression needed by plants occurs immediately adjacent to roots.

In litter. Fungi are common decomposers of plant litter because litter has large amounts of complex, hard-to-decompose carbon. Fungal hyphae (fine filaments) can "pipe" nitrogen from the underlying soil to the litter layer. Bacteria cannot transport nitrogen over distances, giving fungi an advantage in litter decomposition, particularly when litter is not mixed into the soil profile. However, bacteria are abundant in the green litter of younger plants which is higher in nitrogen and simpler carbon compounds than the litter of older plants. Bacteria and fungi are able to access a larger surface area of plant residue after shredder organisms such as earthworms, leaf-eating insects, millipedes, and other arthropods break up the litter into smaller chunks.

On humus. Fungi are common here. Much organic matter in the soil has already been decomposed many times by bacteria and fungi, and/or passed through the guts of earthworms or arthropods. The resulting humic compounds are complex and have little available nitrogen. Only fungi make some of the enzymes needed to degrade the complex compounds in humus.

On the surface of soil aggregates. Biological activity, in particular that of aerobic bacteria and fungi, is greater near the surfaces of soil aggregates than within aggregates. Within large aggregates, processes that do not require oxygen, such as denitrification, can occur. Many aggregates are actually the fecal pellets of earthworms and other invertebrates.

In spaces between soil aggregates. Those arthropods and nematodes that cannot burrow through soil move in the pores between soil aggregates. Organisms that are sensitive to desiccation, such as protozoa and many nematodes, live in water-filled pores.

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[i] Read more about the soil food web at nrcs.usda.gov/wps/portal/nrcs/detailfull/soils/health/biology/?cid=nrcs142p2_053868