U V M E X T E N S I O N

A G R I C U L T U R E

SOIL HEALTH

UVM Extension Fact Sheet: Champlain Valley Crop, Soil and Pasture Team

The Living, Breathing Soil: Farming with Soil Biology

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Soil health is the cumulative soil condition based upon chemical, physical and biological properties. While measures of soil often focus on chemical properties, and to a lesser extent physical properties, biological properties may be overlooked. However, your soil is alive! One cup of soil may hold as many individual bacteria as there are people on Earth! *The complex of living organisms in soils plays a critical role in the processes that create and maintain soil health and impact crop yields, quality and vigor.*

∗ Carbon cycling and retention:

Organic matter is the foundation of the soil food web which is constantly being transformed through soil organisms. Many kinds of soil organisms are involved in the process of shredding and decomposing complex plant residues into constituent parts. Different soil organisms are particularly adapted to process different kinds of organic matter.

∗ Nutrient cycling and retention:

When soil organisms decompose plant residues, nutrients such as nitrogen and phosphorus may also become more available to plants. Decomposers transform plant matter and release nitrogen, which is subsequently transformed by other bacteria and chemical processes (see Figure 1). Organisms are like a slow release fertilizer. Soil fauna that consume bacteria often consume and excrete excess nitrogen, thereby transforming it into plant available forms (either ammonium or nitrates). Organisms also hold nutrients in their bodies which are released upon death – this can help hold nutrients in the soil, particularly during periods of slower crop uptake.

∗ Soil physical properties:

As biota transform and ingest soil organic matter, soil particulates, and other organisms, they exude sticky binding agents (polysaccharides and glomalin) which hold soil particles together and create spaces in the soil. Soil biota can increase soil aggregation and porosity, and therefore can improve both infiltration and water-holding capacity, providing a more habitable environment for plant roots.

∗ Disease Suppression and Plant Health:

It's easy to get into the trap of thinking of soil biota as "enemies" because we are often focused on agricultural pests. However, most organisms are beneficial to crops. You might even think of them as *mediators* of plant health. Beneficial soil biota can aid plant health both

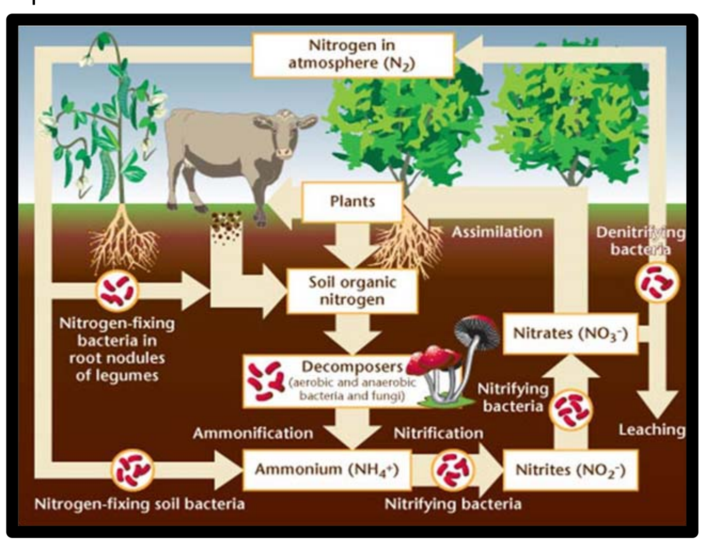

Figure 1. The Role of Soil Organisms in the Nitrogen Cycle.
Source: Washington State University - http://cahnrs.wsu.edu/alumni/connections/nspire/

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indirectly and directly. Indirectly, they can create a better growing environment for crops through the processes described above. Directly, soil organisms have been shown to stimulate root growth and development. Soil organisms can also compete with and prey on pest species.

∗ <u>Environmental protection:</u>

Healthy soil provides many functions that are of great service to both farmers and the larger human communities that agriculture supports. Soils are an important source of biodiversity, which serve many functions in creating stable ecosystems. Soil biota are involved in soil-water filtration; soils can retain and break down pollutants before they reach surface or ground waters. Soil biota are also part of the long term process of soil formation.

Food webs are a way to envision how nutrients and energy are transmitted and recycled from one group of organisms to another (see Figure 2). <u>Trophic level</u> is how many steps a group is from the primary producer. The base of the soil food web is plant litter, exudates, roots and animal residues. Soil food webs are composed of bacteria and fungi (soil flora, or soil microbes), and many types of soil animals (soil fauna) including protozoa, nematodes, earth worms, and arthropods.

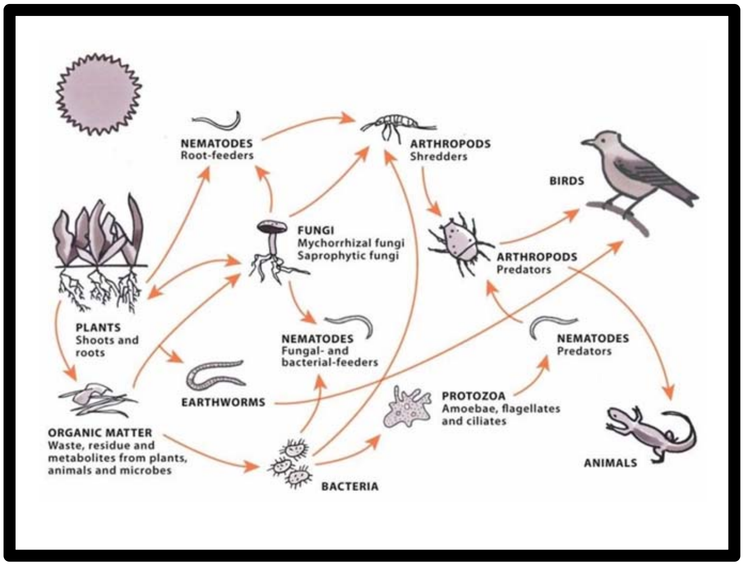

Figure 2. An Illustration of the Soil Food Web.

Original source: NRCS, http://www.nrcs.usda.gov/Internet/FSE_MEDIA/nrcs142p2_049822.jpg
Adapted from: http://www.agriculturesnetwork.org

Management Practices Impact & Enhance Soil Biota

The great news is that the actions we take to remediate phosphorus pollution or enhance nitrogen uptake can also benefit soil biology. Both physical and chemical disturbances can affect the abundance and diversity of soil organisms, and in particular soil fauna that are higher up on the food web. The complexity and type of a soil food web can vary substantially from one soil and management practice to another. Generally speaking agricultural soils tend to have a greater population of bacteria, and therefore more soil organisms that feed on bacteria, in comparison to forest soils, which tend to have a greater number of fungi and soil organisms that feed on fungi. However, within agricultural soils, management practices can shift the dynamics of the soil food web over time in either direction. <u>Complexity</u> is an important concept in studying soil biology, because it relates to how many kinds and groups of organisms there are. More complex and diverse food webs usually confer more benefits to plants.

Increasing quantity and complexity of soil habitat and food sources, and maintaining water-air balance generally increases biological complexity. For example, providing a diverse array of food sources from organic matter applications, plant rotations and cover crops allows for more diversity in soil biota that feed on the organic matter. Similarly, decreasing compaction and increasing soil structure encourages soil biota. This is both due to increased water infiltration and to diversity in soil pores – allowing for a range of pore sizes that support a range of soil biota. Owing to the fact that soil organisms are so tiny and soil is complex, physical space is a really important piece of maintaining soil biology. Places of high biological activity in soil are mainly near plant roots, in plant litter and earthworm and arthropod burrows. Therefore, increasing soil quality for root growth development can also benefit soil biota. Also, if your soils are permanently saturated only anaerobic organisms- those that do not need oxygen to survive – will be able to live there. This is important for nitrogen cycling because lack of oxygen can lead to denitrification. Many organisms, including nematodes, live in water films; if you have a soil that is in serious drought conditions on a regular basis, many will die, or go into a kind of temporary stasis until more water is available. Soil organisms can also be sensitive to chemical disturbances and low pH to differing degrees by species; however earthworms and other soil animals are usually more sensitive.

While tillage can lead to a bloom of soil activity as organic matter is incorporated into the soil, this activity is generally bacterial in nature and short lived. Every time you till the soil, you are shifting back the soil community either by direct damage or by homogenization of the habitat. Reducing tillage can have positive effects on biology and in particular fungi and larger animals. Reducing tillage leaves more roots intact, and allows more stable, slowly decomposing organic matter and physical structure to develop through time. While a no-till system might not be ideal or practical in all farming situations, reduction and better management of tillage can benefit soil biology. Research has suggested that reducing tillage and increasing plant residues may be a mechanism for suppression of plant disease by supporting a complex food web with organisms that compete with or control the pest of concern. Developing an IMP approach may be particularly important with no-till as the environment near cash crops changes.

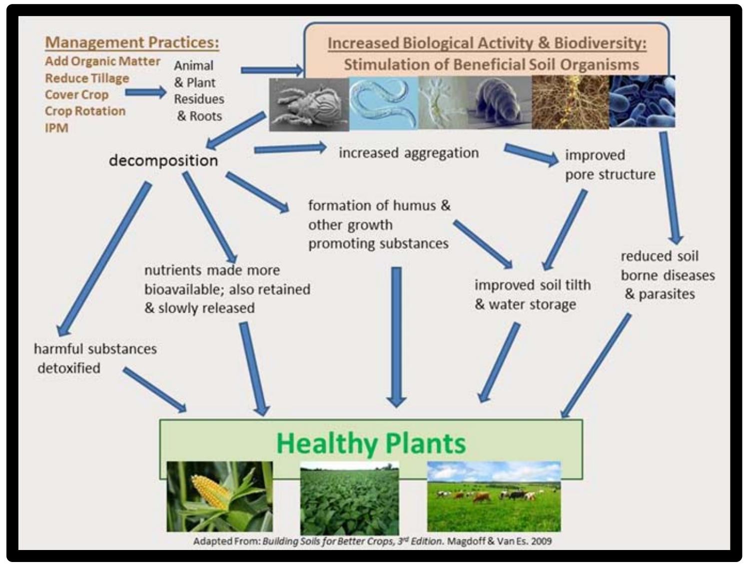

Figure 4. Management techniques that lead to healthy plants are mediated by soil biota.

In summary: Practices that increase the quantity and quality of organic matter and physical habitat have beneficial impacts on soil biota. *A diverse array of foods and habitats generally leads to a more complex and stable food web.*

Supply diverse sources of organic matter – *which provides both food and habitat for soil biota.* Practices that increase diversity of food sources, encourage beneficial biota, and interrupt pest cycles include:

- applying compost & manure
- planting cover crops and legumes (using species specific *Rhizobium* inoculation)
- utilizing increased crop rotation
- planting a diversity of crops or forages
- maximizing plant residues

Protect the soil habitat. *Soil organisms need space to live, and they need a balance of air & water. Soil organisms also need intact root structures.* Practices that can preserve and improve soil habitat include:

- reducing tillage
- minimizing compaction
- maximizing living roots (perennials & overwintering plants)
- improving drainage (in wet soils) or supplying moisture or cover (in dry soils)
- managing pesticides & fertilizer use (IPM & NMP)
- optimizing pH (as with agronomic crops)
- managing grazing to increase plant root biomass

Developing healthy soil biota in your soil is a feedback process on your farm. When conditions are more favorable for soil biota they will begin to sustain and enhance their own habitat and provide conditions more conducive to other organisms. The long term biological goals on agricultural soils would be to establish a set of management practices that maintain a semi-stable condition for soil biota, so that the community is less affected by more extreme conditions that farmers cannot control – like a drought or flood. Management would focus first on the farm or field specific soil properties that are most limiting for soil biota. A healthy soil community – just like a healthy agricultural community – will be more capable of bouncing back from a disturbance than one that is already highly stressed before the disturbance occurs.

See more on reverse →

Measuring Soil Biology:
Estimations of soil activity can be made through indirect means that measure activity (e.g., enzymes or respiration), the community as whole (e.g., DNA or RNA), or direct extraction and identification of individuals (usually requires a microscope). Unlike soil chemistry, there is no 'standard' test for soil biology, and testing usually costs more money. Research and development is still underway to make soil health and soil biology tests more accessible to farmers. Being attentive to pH and organic matter in a basic soil test is a good starting place. There are a number of laboratories that estimate microbial biomass based upon respiration, and many also give an assessment of nitrogen and carbon, as well as other soil properties (e.g. Cornell, U. of Maine, Dairy One, Ward Labs, Wood Ends Lab; many of which use Haney/Solvita ®). We appreciate Cornell's soil health test because of the lab protocol of assessing chemical, physical and biological properties. Physical properties can be limiting in heavy clay or compacted soils (lab conditions may artificially stimulate microbial growth). Thus far we have found it more useful to compare management changes in one field over years, rather than to compare fields with different inherent properties. Measuring soil biology and soil health is still an evolving process and UVM Extension is in the process of determining the most useful approach.

On-Farm Tests:
Respiration sticks, slake test (simple aggregate stability), soil moisture probes, and penetrometers (soil compaction) can all be used on site. Being attentive and observant to how much and what kind of plant residue is left on the field can be very informative. Visual field observations of organic matter and manure decomposition rates can also give you a qualitative understanding of soil biology activity. Visual inspection of soil for earthworms and their burrows and casts is another simple way to get a qualitative understanding of soil biology. Scouting for beneficial insects that have soil phases or prey on pests in addition to scouting for crop pests can be very informative.

More Reading:
NRCS Soil Biology Website: http://www.nrcs.usda.gov/wps/portal/nrcs/main/soils/health/biology/
Building Soils for Better Crops (Chapter 4: The Living Soil), (2010) online at:
http://www.sare.org/Learning-Center/Books/Building-Soils-for-Better-Crops-3rd-Edition
Cornell Soil Health Website: http://soilhealth.cals.cornell.edu/
University of Minnesota, Extension Service Website: http://www.extension.umn.edu/agriculture/tillage/soil-management/soil-management-series/soil-biology-and-soil-management/