The Soil is Alive!

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'Essentially, all life depends upon the soil ... There can be no life without soil and no soil without life; they have evolved together.'

Charles E. Kellogg, USDA Yearbook of Agriculture, 1938.

"It is to the microorganisms of the soil that the human race owes its existence. If the unseen and lowly soil microorganisms cease functioning, plants would not grow, empires and republics, old order and new order, would fall to dust and proud Homo sapiens would pass out of existence."

Martin Frobisher, Jr., Fundamentals of Soil Microbiology, 1953

Introduction

Grab a handful of soil. . . . . What does it look like? What does it feel like? It may seem rather ordinary; but look closer. What are you holding in your hand? A mixture of minerals and air with some water and organic matter? Is that all? No. There's so much more to soil than that. For a soil scientist in general and a soil microbiologist in particular the soil is a living thing, a mixture of living and dead organisms in an organic/mineral matrix. Not every organism is identical, or as abundant, or does the same things, or is active at the same time. Some you can see and some you can't, although we have various tools we can use to prove even the microscopic ones exist. Soil is the most immensely complicated and diverse ecosystem on the planet. And as the quotations above suggest, its care and feeding are vital to agriculture and vital to life.

Why Soil Biology Matters

The skin is the largest organ in the human body. Without it we would die. The soil is the skin of the Earth. Without it the Earth - ourselves included - would also die. The soil provides our food, recirculates our air, and purifies our water. It does so constantly, quietly, and through agents mostly unseen. It is the stomach, lungs, and kidneys of Earth and we quickly realize it when something goes wrong.
The soil teems with life. In every square yard of soil there may be thousands of different species (Atlas, of Diversity, 2016). If you think about bacteria alone, a single gram of soil (about as much as a raisin) can have as many as 10,000 unique genetic signatures. Consider all the cattle and ranchers above-ground and how much they weigh. A good

grassland soil will have 2 to 4 tons of biomass per acre. There is as much life below-ground - 25 to 50 rancher's worth – as above it, perhaps more.

The Setting

As much as the soil is just a thin layer covering terrestrial ecosystems, the truly active region of soil is even thinner. Most biological activity in soil occurs in the upper foot, the zone of the greatest root activity and organic matter content (Fig. 1). Below that, the number of soil organisms and their activity rapidly declines. Fortunately, that upper zone is the one most easily managed.

The soil is structured, much like a house is structured, with many interconnected rooms of various sizes in which different things occur. The soil is somewhat unique in that some of these rooms are formed without any outside connections, These 'rooms' represent the pore space in soil and soil organisms play a critical role in both forming the pores and keeping them stable so they can hold air and water. The pore size also plays a critical role in determining which organisms are going to be present – if you're too big to fit through the pore neck, you can't make it into the pore; and if you're in the pore you're protected from decomposition and predation. Physically beating up that structure makes the environment unfavorable for soil life.

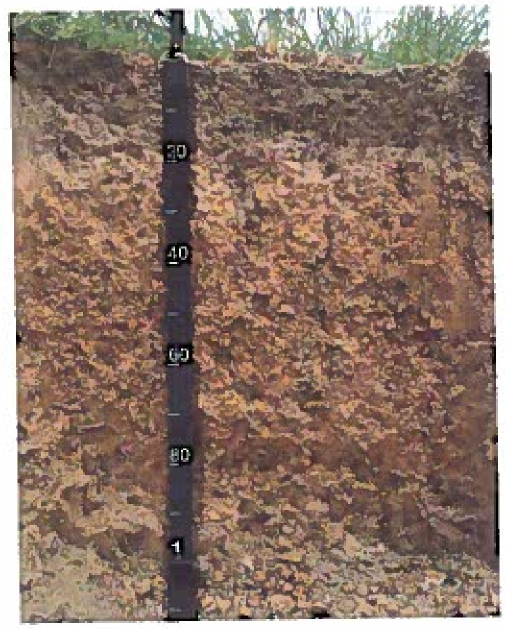

Figure 1. A soil profile is a vertical cross section of the soil environment and typical consists of three layers: A, B, and C overlying parent material. The dark colored 'A' horizon is the zone of greatest biological activity.

The Roles

Decomposition and predation are two important roles soil organisms play. They are critical to nutrient cycling. Truth be told, predatory organisms in soil are rather messy eaters and leave behind many nutrients for plants to take up. That's one reason why predators, such as nematodes, are actually very beneficial to plant growth. In terms of soil ecosystem functions critical to grasslands, decomposition and carbon cycling, nutrient cycling, biological population regulation, and soil structure and maintenance are key roles organisms play. The major organisms involved in decomposition and nutrient cycling are the bacteria and fungi. The major organisms in regulating population are the nematodes and microfauna. The major organisms affecting soil structure and large pores are earthworms, ants, and beetles burrowing into the soil profile.

The Players

One of the important things to remember about the life in soil is that the bigger you are, the fewer of you there will be. Figure 2 shows the various groups of organisms in soil arranged on the basis of size. In terms of numbers, while you might have dozens of earthworms in a gallon of soil, the number increases exponentially as the organisms get smaller, until in a single teaspoon of soil there might be billions of bacteria and miles of fungal hypha. Even when organisms die in soil they aren't yet finished playing an active role. There are proteins called extracellular enzymes excreted into the soil environment by living and dead organisms that maintain biological activity. Which turns out to be very useful in nutrient cycling for elements such as phosphorus (P), for example.

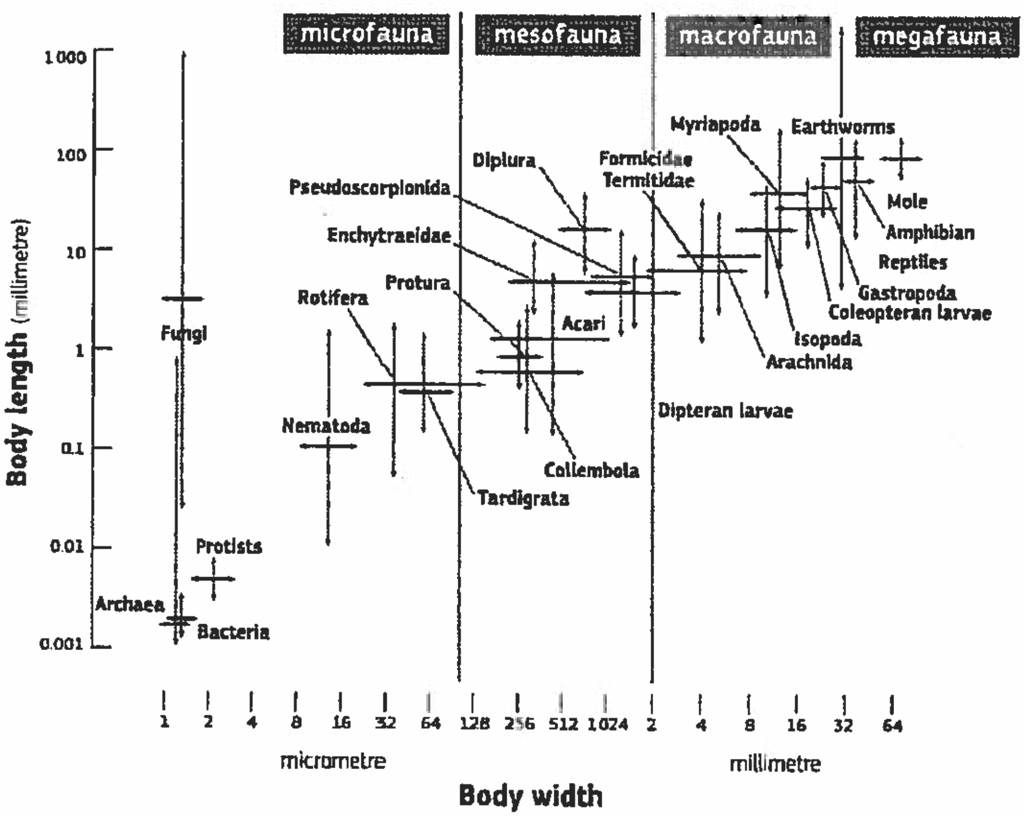

Figure 2. The relationship of body length and width to the type of soil organism present.

Large organisms such as earthworms and ants are ecosystem engineers. They burrow into soil making channels, mix organic matter (like dung beetles), and help bring leached nutrients up to the soil surface (Fig. 3). Isopods like pillbugs (Fig. 4) play a critical role in chewing up plant litter to make it accessible for microorganisms such as fungi (Fig. 5) and bacteria, which are ultimately responsible in soil for turning the complex polymers in plant and animal material into soluble compounds microorganisms can use and free nutrients that plant roots can absorb.

Figure 3. Ant mounds are a common scene in grasslands showing the extent to which ants help excavate subsoil and return it to the soil surface (image courtesy of M.S. Coyne).

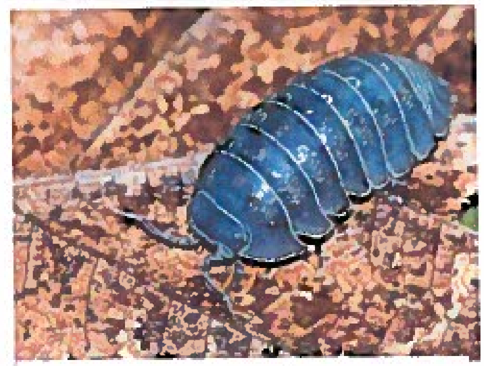

Figure 4. The isopod *Armadillidium vulgare*, is a species with worldwide distribution.

Managing Soil Biology and Diversity

If soil biology is as important as I've implied, then soil stewards of soil are life stewards. Is it possible to manage a seemingly infinite number of different organisms in soil? Yes it is – at least indirectly. We manage soil organisms all the time by choosing the crops we grow and the various inocula we add to them. Rhizobia are added to clover and other forage legumes to increase their capacity to fix nitrogen (N) (Fig. 6). Mycorrhizal fungi respond to the type of crops present, and by infecting the plant roots create a 'second' root system that can exploit insoluble nutrients, like P, in the environment.

Figure 5. Fungi are the main decomposers of organic matter in soil. Mushrooms are just the above-ground manifestation of miles of fungal hyphae beneath the soil surface (image courtesy of M.S. Coyne).

Figure 6. The bright pink color of clover nodules is a sign that the rhizobia inside are probably actively fixing N.

Feeding the soil population means providing it with enough carbon (C). That can take many forms: plant litter, compost and manures, and plant root exudates. The important thing is to maintain crop cover at all times. While crops harvest C from the atmosphere and feed it to the soil organisms in the rhizosphere, those organisms churn up soil organic matter and transform minerals to make nutrients plant available. Unhealthy looking plants are unlikely to sustain an active soil biology. Likewise, soil organisms thrive on diversity, so a diverse selection of plants growing in the soil environment makes for a greater diversity of soil organisms.

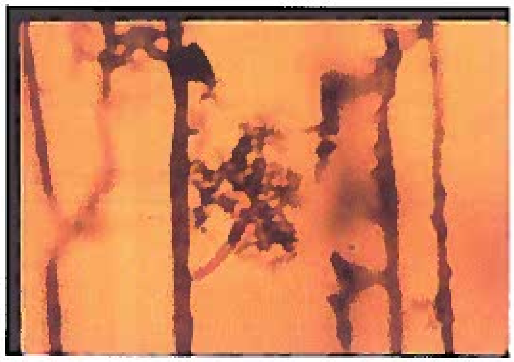

Figure 7. Arbuscles inside plant root cells are the structures by which mycorrhizal fungi exchange nutrients and C with plant roots (image courtesy of J. Hendrix).

The concept of 'Soil Health' holds that optimizing the biological, physical, and chemical environment of the soil will promote the most sustainable environment for biological activity. Physical management includes reducing compaction and foot traffic. Both reduce porosity and create smaller pores. In addition to making it more difficult for plant roots to grow in that environment, compaction reduces aeration and slows the rate of biological activity in the soil environment. Soil organisms need air too in order to thrive. Chemical management includes optimizing fertilizer additions and particularly optimizing pH. Managing for soil health indirectly does the things that will manage for healthy soil life.

Conclusion

"If you build it, they will come." That's not necessarily true of the organisms in soil. They are already most likely there already (in one form or another). Rather, "If you manage it, they will thrive." The soil is alive and living things respond to good management. A living soil requires management to function best for the ecosystem services it provides in terms of producing food, fuel, fiber, and forage. The better the management, the better the function.

References

Orgiazzi, A., et al. (Eds.), 2016, Global soil biodiversity atlas. European Commission, Publications Office of the European Union, Luxembourg.

Credits and Acknowledgements

Unless noted, pictures from: Orgiazzi, A., et al. (Eds.), 2016, Global Soil Biodiversity Atlas. European Commission, Publications Office of the European Union, Luxembourg.

The writing of this manuscript was supported by grants from the following sources:

NRCS

USDA-ARS FAPRU, the Hatch program, NCERA59 Multistate Project: Soil Organic Matter - Formation, Function and Management.