How Do Soils Work?

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"Land, then, is not merely soil; it is a fountain of energy flowing through a circuit of soils, plants, and animals." *Aldo Leopold, A Sand County Almanac, 1949*

"Despite all our accomplishments, we owe our existence to a six-inch layer of topsoil and the fact it rains." *Paul Harvey*

The Issue Today

The global food supply network is a vast human accomplishment. Nearly all the plants in this food network are grown in soils that were previously the grasslands of the planet and are now converted to cropping systems. In addition to growing plants for human food consumption many of the plants grown today are converted to livestock food and biofuel. In all cases soil is the foundation on which we all depend for food and in some cases fuel. Wheat, rice, and corn account for over 50% of calories consumed by humans annually (FAO, 2004) and soil is the seemingly endless source of fertility leading to massive commodity production. Is the soil a renewable resource?

Understanding Soil

Most soils form very slowly, on the order of several hundred years per inch of topsoil in natural systems. Global degradation of topsoil is well documented leading to ever increasing dependence on chemical fertilizer inputs to maintain crop yield. Why do soils form so slowly? Soil development is dependent on geologic parent material, climate, topography, biological activity, and time. All these soil forming factors are essentially unchangeable except biological activity which is responsible for capturing, mobilizing, and cycling nutrients to plants. The primary plant nutrients required include nitrogen, phosphorous and potassium and are needed by plants in large amounts while micronutrients iron, boron, copper, zinc, manganese, molybdenum, and chlorine are essential yet needed in lower quantities. The alkaline earth elements calcium and magnesium are also required, as well as sulfur, as secondary nutrients. Along with carbon, hydrogen, and oxygen, these 16 elements are required for plant growth along with sunlight and water to fuel photosynthesis. All plant nutrients except for nitrogen – from the atmosphere – hydrogen and oxygen, which come from water as rainfall and snowmelt, come from the mineral soil and are seemingly magically dissolved by biogeochemical processes and made available for uptake by plant roots.

The ecology of soil is dependent on many different life forms including bacteria, viruses, fungi, and insects. In one gram of soil there may be 10,000 different bacterial species and billions of individual organisms. Viruses may exceed those numbers. In a North Carolina research project the authors estimated 124 million (!) insects per acre occupied the upper five inches of soil (Smithsonian, 1996). Clearly the soil is teaming with life. All living organisms require food sources (most typically types of carbon), and all living organisms produce waste products that are stored as organic matter in the soil. Not surprisingly the highest quality soils on the planet are those with the highest amounts of soil organic matter and the highest amount of biological activity.

Plant-Soil Dynamics

The biological function of all soils is driven by photosynthesis where plants convert sunlight and carbon dioxide into sugars, proteins, and carbohydrates. Some of these products are converted to above ground biomass as plants, some are converted to root matter. Importantly, some of the sugars produced by the plant are traded through the roots with soil organisms for mineral nutrients from the soil. The transfer of the soil-derived nutrients to the plants often occurs with the assistance of soil fungi that extend the reach of plant roots to distant resources and the fungi grow using the sugars traded by the plant. Collectively these soil processes at the boundary of the plant root and the soil are called the rhizosphere (Hiltner, 1904). The rhizosphere is the biological reservoir of microbes, root exudates and microfauna. It is the penultimate microscopic engine for plant growth, soil carbon capture, gas exchange and nutrient mobilization from the mineral soil to the plant. Importantly, rhizosphere processes result in the formation of dissolved organic carbon (DOC) which fuels the growth of microbes and the dissolution of the mineral soil by weak organic acids like humic, fulvic and oxalic acid. Synergistically, more plant growth leads to more plant sugars in the roots, which leads to more biological activity, that leads to more DOC, and leads to more nutrient mobilization to the plant, which leads to more plant growth and more carbon stored in the soil reservoir.

Soil degradation is the unfortunate reverse where less and less plant growth leads to less biological activity, less DOC in soil, less nutrient availability, and less soil carbon. The reduction in soil carbon in agricultural cropping is well documented. Globally, agricultural soils have lost 20% to 75% of their antecedent soil organic carbon (SOC) pool (Lal et al., 2015) because of continuous cropping. The decline of human civilizations attests to the risk of environmental degradation (Diamond, 2005) and especially the effects of soil degradation (Montgomery, 2007). Several related causative factors contribute to these observed declines including tillage, use of annual crops with shallow roots and short growing seasons, crop fallow, and prevalent industrial fertilization strategies employing heavy application of nitrogen fertilizer derived from natural gas feedstocks. Regenerative agriculture proponents envision new methods for rebuilding soil quality emphasizing no-till methods combined with cover crops, rotational planting and returning livestock into cropping systems. While comprising a small fraction of the agricultural sector, regenerative agriculture is a promising method of restoring soil health and the biological function of soil.

Parting Message

In addition to losses in soil carbon attributable to soil degradation, the loss of mineral nutrients can also lead to invasive plant (e.g., weed) colonization. Weeds are a prevalent problem in cropping systems and an unavoidable consequence of soil depletion since weeds are best adapted to soil with low levels of mineral nutrients. Restoring natural soil resilience to retard weed invasion requires commitment to restorative processes that result in higher mineral nutrition to plants and higher levels of DOC fueling nutrient cycling.

Natural soil processes have been greatly disrupted through conversion of global grasslands to cropping. Soil degradation has been widely increased through conventional agricultural processes to greatly increase global food supply and population. Vast acreages of cropland require rehabilitation and conversion to regenerative practices that fuel increasing levels of soil carbon, nutrients and biological activity. Weed control also needs to be reimagined in a more sustainable and less petrochemical configuration. Edaphix brings novel approaches using unconventional fertilizer formulations to promote higher mineral fertility that results in nutrient-dense soil, nutrient-dense food, healthy soil, and reduced weed pressure.

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