

The Effects of Soil Health Management on Soil and Water Relations

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Soil health, sometimes referred to as soil quality, is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. Soils have inherent characteristics or qualities which are not readily changed by management. These would include the soil texture, depth to impermeable layers and position in the landscape. Within these parameters a soil's performance can be improved by maintaining and improving its health which can be done by following good soil health management practices.

Only "living" things can have health, so viewing soil as a living ecosystem reflects a fundamental shift in the way we care for our soils. Soil is not an inert growing medium, but rather is teeming with billions of bacteria, fungi, and other microbes that are the foundation of a symbiotic ecosystem. One gram of soil can contain over 1 billion micro-organisms.

The physical nature of a typical mineral soil contains about 50% solid particles and 50% pores on a volume basis. The pore space is made up of varying amounts of air and water. In mineral soils, of the 50% solid portion about 45 - 48% is minerals. Soil texture refers to the mineral component of the soil in terms of the proportion of small, medium, and large particles (clay, silt, and sand, respectively) in a specific soil mass. The larger the particle size the more permeable and the lower the water holding capacity is; and the more organic matter is needed to affect soil water relations. Soil structure is defined by the way individual particles of sand, silt, and clay are assembled. Single particles when assembled together appear as larger particles. These are called aggregates.

About 2 - 5% of mineral soils is organic matter and of that organic matter about 5 percent represents the living portion. It is the organic matter and the living portion of the soil that can be managed to improve soil health. The living part of soil organic matter includes a wide variety of micro-organisms such as bacteria, viruses, fungi, nematodes, protozoa and algae. The living component of the soil also includes plant roots, insects, earthworms, and larger animals such as moles, mice and rabbits that spend part of their life in the soil. Organisms occur wherever organic matter occurs. Therefore, soil organisms are concentrated: around roots, in litter, on humus, on the surface of soil aggregates and in spaces between aggregates.

Abundant and stable aggregation is important for good soil tilth which is technically defined as the physical condition of soil as related to its ease of tillage, fitness of seedbed, and impedance to seedling emergence and root penetration. In terms of improving soil structure (aggregation), the active and some of the resistant/stable soil organic components, together with micro-organisms (especially fungi), earthworms and plant roots are involved in binding soil particles into larger aggregates. Some of these aggregates fit closely together and some do not, thereby creating spaces of many different sizes in the soil. These spaces, or pores, within and between soil aggregates are essential for storing air, water, microbes, nutrients and organic matter. The use of intensive tillage destroys the aggregates and the natural channels made by the worms and roots, and temporarily aerates the soil while burning up soil organic matter. Soil microorganisms are responsible for armoring or stabilizing these aggregates to resist their breakdown from rainfall and ponding water. Aggregation is important for good soil structure, aeration, water infiltration and resistance to erosion and crusting.

Micro-organisms, earthworms and insects help break down crop residues and manures by ingesting them and mixing them with the minerals in the soil, and in the process recycling energy and plant nutrients. Thus, the living part of the soil is responsible for keeping air and water available, providing plant nutrients, breaking down pollutants and maintaining the soil structure.

Soil health management practices are agronomic practices which follow the following principles: 1) Keep the soil covered as much as possible with crop residues; 2) Disturb the soil as little as possible, preferably with perennial forages, continual no-till or strip-till; 3) Keep plants growing throughout the year with double cropping or cover cropping to feed the soil microorganisms; and, 4) Diversify plants as much as possible using crop rotation, perennial forages and cover crops.

Soil and water relationships can be described by soil porosity, water infiltration, permeability and available water capacity. Soil porosity refers to the space between soil particles, which consists of various amounts of water and air at any time dependent upon rainfall and evapotranspiration. Porosity depends on both soil texture and structure. Water infiltration is the movement of water from the soil surface into the soil profile. Soil texture, soil structure, and slope have the largest impact on infiltration rate. Permeability refers to the movement of air and water through the soil and is related to porosity. Available water is retained in the soil after the excess has drained, from field capacity to wilting point. Unavailable water is soil moisture that is held so tightly by the soil that it cannot be extracted by the plant. Water remains in the soil even below a plant's wilting point. Soil and water relationships can be adversely affected by soil compaction.

Coarse soil (sands) with large pore spaces have high infiltration rates and permeability but low water holding capacity. Fine soils (silts and clays) with small pores have slower infiltration rates and permeability but higher water holding capacity. Infiltration, permeability and water holding capacity all can be enhanced by improved soil aggregation and increased soil organic matter. Infiltration and permeability (drainage) can be increased by the macropores developed by plant roots, earthworms and other soil macro-invertebrates which can be maintained by no-till systems and perennial forages. Soil health management increases organic matter and aggregate formation and stability, which influences soil water relations.

The effects of soil health management on soil water relations was demonstrated using soil from the same soil types managed under different cropping systems. Healthy soils which were managed in long term no-till, long term sod or cover crops were compared to soils which were managed using long term conventional tillage with no cover crops.

For the "slake test demonstration" (Fig. 1) dried 1.5 inch clods of Collamer silt loam soil were placed on screens submerged in the top three inches of water in a 4 inch diameter by 11 inch tall clear plastic cylinder. Slaking occurs when aggregates are not strong enough to withstand internal stresses caused by rapid water uptake. A clump of the dried soil which has been managed under long term conventional tillage with low organic matter inputs dissolves or falls apart when placed in the water, with particles falling down through the water in the cylinder and leaving the water cloudy from the sediment. The healthy soil managed in sod or no-till with good aggregate stability holds together for, in some cases, many hours. This dissolving or slaking is an indication of poor aggregate stability.

The "columnar infiltration demonstration" (Fig. 2) uses a 4 inch diameter by 11 inch tall plastic cylinder. Two Collamer silt loam soils managed either in long term sod or long term conventional tillage were compared. Four inches of soil sieved to 0.4 inches was placed in each of the cylinders and equal amounts of water were placed in a perforated container on top of the cylinder to simulate rainfall. The sieved soil simulates the condition of soil after primary tillage and several passes of secondary tillage. The soil managed with long term conventional tillage has poor aggregate stability and the "rain drop" impact and the contact with the water results in the soil dissolving and sealing the soil surface. The sealing of the soil surface results in very low infiltration and most of the water ponding on the surface. The healthy soil has good aggregate stability and good micro and macro pore spaces which allows the water to infiltrate into and percolate through the 4 inches of soil and be caught in a

basin below. The water that infiltrates into the soil and is caught in the basin below signifies the water that can be used for the crop between rainfall events or used to recharge groundwater supplies. The ponded water is unavailable for plant use and will typically runoff resulting in erosion, sedimentation and an increase in flooding potential.

For the “table top rainfall simulator demonstration” (Fig. 3) Unadilla silt loam soil was used. Several soil plugs eight inches by four inches by 3.5 inches deep were cut directly from the field with no disturbance or drying. Each plug was cut and maintained in a stainless steel cutter/holder, which looks like a loaf pan without a bottom. This soil is also “rained” upon using a perforated plastic pan held in place and suspended approximately 6 inches above the soil surface, with a catch basin below to catch the water infiltrating through the soil, and in front to catch the runoff. The following soil management systems were used. Long term conventional tillage, long term sod, long term no-till, and conventional tillage with a cover crop planted. This demonstration shows how the soil after many months following tillage reacts to the water. The conventionally tilled soil surface has been sealed due to poor aggregate stability with all of the water applied running off, taking sediment with it into the runoff basin. The long term sod, no-till and cover cropped managed soils had crop residue or living plants on the surface which intercepts the raindrops and slows water movement over the surface and reduces erosion. The root channels and undisturbed earthworm and other macro-invertebrate channels allow for most if not all of the water to infiltrate into the catch basin. The water that infiltrates into the soil and is caught in the basin below signifies the water that can be used for the crop between rainfall events or used to recharge groundwater supplies. The little, if any, runoff from the soil health management systems were much cleaner than in the conventional tilled soil, indicating the water quality benefits of healthy soil.

The use of soil health management systems can improve nutrient cycling and soil and water relations. Soil health management can improve soil productivity over time, maintain the sustainability of the soil for future generations, improve water quality, reduce flood potential, and improve the resiliency of soil to extreme and variable weather events such as intense rainfall and droughts.



Fig. 1. The slake demonstration showing soil managed with conventional tillage on the left breaking apart, and soil managed with no tillage on the right with good aggregate stability holding together resulting in clear water.



Fig. 2. Columnar infiltration demonstration, with the long term conventional tillage system on the left resulting in less stable aggregates which seal the soil surface and reduce infiltration and permeability, resulting in ponding, compared to soil from long term sod which allows more infiltration and permeability.



Fig 3. The table top rainfall simulation demonstration, with the long term conventional tillage system on the left resulting in poor infiltration and more runoff carrying sediment. The no-till soil on the right results in more infiltration, percolation, water storage and cleaner runoff.

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