



ARECA Soil Health Initiative

This article is part of a series to promote better understanding of our agricultural soil resources along with practices that can influence soil health.

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Understanding Soil Health: WHAT SHOULD WE KNOW ABOUT IT

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The terms “soil quality” and “soil health” are often used synonymously. Although they are used interchangeably, it is important to distinguish the differences between them. Soil quality has been defined as *“the capacity of a soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation.”* Soil health is defined as *“the continued capacity of soil to function as a vital living system, within ecosystem and land-use boundaries, to sustain biological productivity, promote the quality of air and water environments, and maintain plant, animal, and human health”*. Soil health recognizes soil resilience (“the continued capacity of”) and the biological properties (“as a vital living system”). They reflect the importance of the soil being able to continue to function over time by self-regulation, stability and by maintaining its biological integrity. Soil quality is related to the soil’s inert capacity to function. It is mainly used to evaluate a soil’s physical and chemical properties related to soil formation factors in support of plant growth. Soil health better addresses more the interactions among those properties with emphasis on the biological. These interactions are indivisible, interdependent interactions within the soil ecosystem. When one of these properties is off balance (by human intervention for example), it will adversely impact the rest, reducing the potential contribution to ecosystem service for food production.

For the purpose of understanding soil health, basic information on composition and properties of soil as well as their intrinsic interactions in creating a healthy soil environment needs to be discussed.

Soils differ widely and they are formed by many processes. They have developed over thousands of years and are also highly influenced by environmental conditions, parent material, interactions among microorganisms and plants, management, as well as the topography where they were formed. Ideal distribution of soil components have been reported to be 50% pore space (air & water) and 50% solid material (mineral particles & organic matter). Soils have physical, chemical and biological properties. Interactions among these properties play an important role on soil health stability, having consequences for the ecosystem sustainability. Figure 1 shows the main soil property interactions with their most reliable soil health indicators.

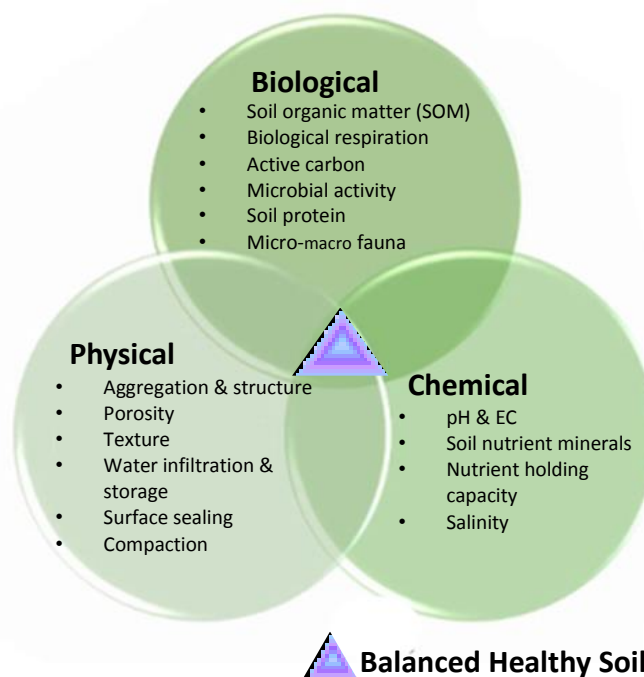


Figure 1. Properties and Indicators of Soil Health

Soil physical properties relate to the composition and proportion of the soil components, described as the texture (silt, clay and sand), structure (patterns of large aggregates) and porosity (pore space). These aspects will influence soil water infiltration, storage and air movement, all of which are important for soil health.

Figure 2 shows different soil structures with their respective water infiltration movements (cited by Colorado State University-Extension). Management practices can negatively impact soil structure.

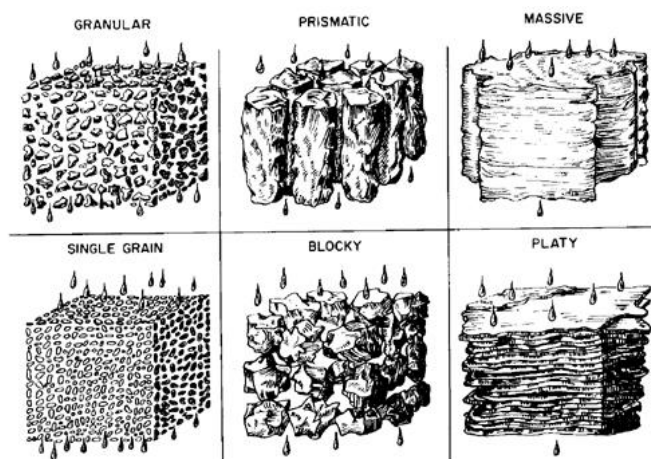


Figure 2. Soil water infiltration movement affected by soil structure

Soil porosity refers to the amount of pores or open spaces between/within the soil aggregate. Aggregates are very important for soil stability against water and wind erosions, and maintaining soil porosity for water along with oxygen supply for roots and

microbial communities. Aggregation can occur in different patterns, influenced by chemical and biological soil properties along with the cropping system, resulting in different soil structures.

Knowing the type of soil structure can tell us something about soil health. For example, soils with a platy structure indicate a compaction and poor soil aggregate stability issue. Picture 1 shows a platy soil structure and water infiltration pattern (Figure 3). Here, water infiltration rate will be reduced and surface run off may increase, contributing to water erosion risks. There will be less pore space for water storage and air exchange due to aggregate destruction, diminishing growth and interactions of plant roots and microbial communities. Also, nutrients uptake will be impaired and microbial community diversity will also be reduced over time, compromising soil health.



Picture 1. Platy structure and **Figure 3.** soil water infiltration movement pattern

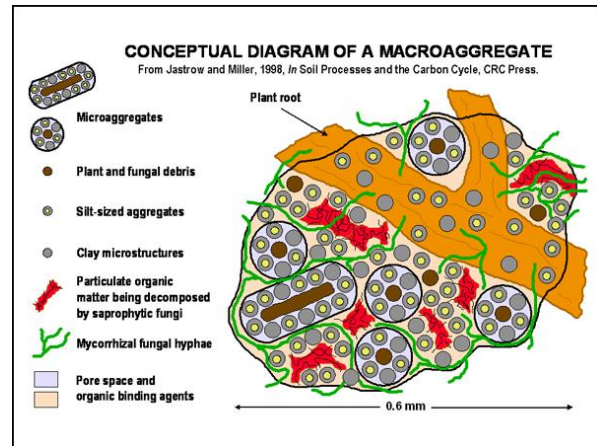
Biological interactions maintain soil life and they are considered the most important soil activities. Many different types of organisms are involved: plants (flora), animals (microfauna, mesofauna and macrofauna) and microorganisms (bacteria and fungi). Most of these organisms are so small that they are only visible using specialized microscope (Picture 2).



Photo by V. Behan-Pelletier

Picture 2. Soil acari's diversity

The role of soil organisms is to keep the soil healthy by improving and maintaining soil aggregation. Plants provide food for microbial communities by root exudates and soil organic matter (SOM) from shoot and root residue. Root decay creates an avenue for water and air movement through the soil profile. The rhizosphere, the soil zone surrounding plants roots, contains the most biological active area of the soil (Picture 3). Figure 4 shows where lots of the aggregates start forming; it contains secreted chemicals (sugar, organic acids), soil particles and fungal hyphae, among other organic materials.



Picture 3 and Figure 4. Soil rhizosphere and aggregate formation

Why are aggregates important?

They are important because soil pores exist between and within aggregates. They are occupied by water and air providing a favorable habitat for soil organisms and plant roots to grow into them. Aggregates are the site where many important biological soil interactions takes place, which in turn contribute to aggregate stability to help prevent run off, erosion, surface crusting and to improve overall soil health. Well-aggregated soils are best suited for supplying crops with oxygen, water and nutrients. They have enough macropores to provide drainage and aeration during wet periods, but also have adequate amounts of micropores to store water for crops and organisms during drought conditions.

Importance of soil biological activities

A few of the main biological activities are:

- 1) Soil organisms decompose plant residuals, soil organic matter (SOM). They use the carbon and mineral nutrients present in the SOM for their growth. They then release those minerals into the soil when they die.
- 2) Some microorganisms fix nitrogen (bacteria, rhizobia) from the atmosphere through a symbiotic relationship with legume plant roots. Rhizobium makes nitrogen (N) available to the roots in exchange for carbon (sugar) from the legume. Other microorganisms such as the arbuscular mycorrhizal (AM) fungi are able to increase phosphorus (P)

availability to the majority of plants but not Brassica species (for example, canola). The hyphae of AM fungi extend from plant roots into soil and have access to P, water and other minerals making them available for the plant.

3) Most of the bacteria and fungi in the soil produce compounds during the breakdown of plant residues. These compounds physically and chemically bind soil particles into micro-aggregates. They will form, maintain and stabilize aggregates, improving soil structure.

4) Some microorganisms can produce enzymes that will break down or help in the degradation of agricultural pesticides or other toxic substances added to the soil,

5) Soils with a high diversity of organisms have the ability to help control plant pathogens through predator and prey relationships with every organism either eating or being eaten by another organism. This is thought to be an important mechanism to reduce soil borne diseases in healthy soils.

Summary

Having a better knowledge of soil components, properties and their interactions is the basis for understanding soil health. Soil health indicators can be assessed separately as chemical, physical and biological properties, but what it is important to know is their interactions. They are the driving force to create and sustain healthy soils. In a healthy soil, all the soil properties are interacting without being detrimental to each other. Healthy soils have good tilth, adequate root depth, enough nutrients, good water storage and drainage, low soil borne disease pressure and quick recovery from adverse climatic events (resilience).

Basic principles reported to build soil health in a cropping system are: minimize soil disturbance, keep soil covered all the time, maintain a living root system for as long as possible during the year, use plant diversity to increase soil biological diversity and integrate livestock into the cropping system. Increasing plant diversity above ground will result in greater biological diversity below ground. This biological diversity will help to improve SOM turn over, soil aggregation, water use efficiency and nutrient release, among others. Soil health will improve the plants ability to gather more sunlight to continue powering vital soil interactions that are highly influenced and dependent on good land management. Following the above principles will allow the ecosystem to increase its productivity by improving and sustaining the soil health.