Virginia Cooperative Extension
Virginia Tech • Virginia State University

Part VII.

Soil Health Management

Characteristics, Priorities, Principles, and Holistic Systems Thinking

Authored by:

Eric S. Bendfeldt, Extension Specialist, Community Food Systems, Plant and Environmental Sciences, Virginia Tech

Farmers, ranchers, market gardeners, and land managers must constantly assess and know their operation, values, and resource concerns in order to balance and achieve their overall objectives. For many people, soil is a starting point and basis for viability, profitability, sustainability, and regenerative agriculture. Soil is a foundational resource to farming, conservation, and health in the 21st century.

Interest in the health of a soil and its quality and function as a holistic system has continued to grow among farmers, ranchers, gardeners, and land managers the past 30 years. Soil health is defined as the continued capacity of soil to function as a vital living ecosystem with integrated chemical, physical, biological, and ecological properties, processes, and boundaries, that sustains plants, animals, and humans (USDA-NRCS 2018; Doran et al. 1994).

This publication reviews and discusses why soil health is critical, the characteristics of influence and consideration, the key soil management priorities, and four core soil health principles that should guide and inform different farm and land management practices as within a system.

Why Soil Health?

Adoption of principles and implementation of soil health practices are management decisions, but they are also tangible expressions of who farmers and land managers are as people and what they believe are critically important social, economic, and ecological values. With soil management, overall context of the farm operation, and values matter. Soil health is critical for the following social, economic, and environmental reasons; however, individuals may have additional personal reasons for building soil health to add to this short list.

- Improved long-term sustainable, regenerative agricultural production.
- Enhanced economic viability.
- Improved environmental, ecological, and climatic resilience.
- Continued loss of prime arable farmland to urban and suburban development.
- Improved biodiversity and wildlife habitat.
- Rapidly increasing world population.
- Increased food supply requirements.

Soil Characteristics of Influence and Fundamental Consideration

Within soil science, there continues to be research and discussion on the natural and human factors influencing soil formation and development, particularly fundamental considerations of how farmers, ranchers, market gardeners, and land managers can directly and indirectly influence soil through their management. Authors Fred Magdoff and Harold Van Es (2021), in their book “Building Soils for Better Crops: Ecological Management for Healthy Soils,” identified seven distinct soil characteristics and attributes that people’s management can affect and influence, particularly in building topsoil and increasing the possible rooting zone for plants. These characteristics provide a baseline for management consideration and overall thinking about soil as an integrated holistic system. As research continues, scientists and the agricultural community are learning more about other characteristics and relationships in the soil environment.

The characteristics of soil, distilled by Magdoff and Van Es (6-7), that influence and distinguish how soil is managed for productive yields and healthful plants for high positive and low negative environmental impacts are as follows:

1. **Fertility** – The ability of a soil to cycle nutrients so the nutrients are available to plants at specific growth stages. Therefore, soil testing is integral to knowing nutrient content, pH, soil organic matter levels, and other soil properties.
2. **Structure** – Farmers and producers often talk about tilth and the mellowness of soil having good aggregate stability, being absorptive, taking less effort to work, not crumbling into a powder, and allowing water and air to infiltrate without being blocky or clod-forming.
3. **Depth** – Crops and plants need an adequate rooting zone to allow for growth and expansion without being unnecessarily impeded by a hardpan and compacted soil.
4. **Drainage and aeration** – Of course, there are a few plants that can tolerate living in perpetual wet conditions, but adequate drainage and aeration is needed for water and air flow and the exchange of carbon dioxide and oxygen as part of evapotranspiration. Soil compaction can influence structure, depth, drainage, and aeration by compressing soil pore spaces; therefore, it is imperative to know and evaluate when a soil is too wet and plastic for foot and equipment traffic.
5. **Minimize pests** – As a living ecosystem, the soil should have a balance of beneficial insects for defense and to suppress infection and limit predation. Planting and rotating diverse crops can break up disease cycles and pest pressures.
6. **Free of potential pollutants and toxins** – A healthy soil would be free of pollutants and toxins but should also have the ability to buffer and detoxify potential pollutants.
7. **Resilience against stresses** – Some soils are more naturally forgiving than others, some soils are less forgiving, and other soils are fairly unforgiving to poor management. However, in setting priorities and adhering to core management principles and sound soil health-building practices, the resilience of soils can be increased to be able to withstand drought, heavy rainfall, and other stresses to the ecosystem for a longer duration.

Five Priorities of Soil Management

Key concepts of soil health and ecological soil management include

- Protecting the soil habitat.
- Managing more by disturbing less.
- Keeping soil covered.
- Diversifying food and carbon sources for soil microorganisms with cropping rotations.
- Integrating diverse plant and animal communities.
- Growing living roots throughout the year.

Additionally, there are priorities and principles for overall management of soil that adhere to these concepts that need to be remembered and followed, no matter the soil type, to build internal strengths into the system. Eliminate erosion: Keeping soil in place and preventing soil movement from the field and

landscape is essential to maintaining productivity and building soil health. Soil eroded by rain or wind results in nutrient loss, diminished growing potential, and other off-site environmental impacts such as sedimentation of local roads and waterways. Keeping soil covered and armored can eliminate erosion.

1. **Match land use to landscape:** Land use should consider soil capability and the potential for soil erosion based on soil type, slope class, land cover, crop rotation, potential fallow, and transitions in crop rotations. As the slope of the landscape steepens, the likelihood of erosion and soil loss increases. Similarly, land use decisions should consider distance to streams, creeks, and other sensitive environmental areas that would be impacted by soil erosion and increased sediment loads.
2. **Enhance soil biology:** Good soil biology begins with principles and practices that enhance and promote soil as a habitat and an ecosystem. Soil management inherently means providing habitat, shelter, and food for belowground employees and volunteers. Biology is critical to how the soil food web functions, so microbes, bacteria, and fungi can biologically mediate chemical and physical processes to assist in making nutrients available and giving structure for water and air cycling.
3. **Build soil organic matter:** Soil organic matter is a source of carbon and other essential nutrients made available and exchanged through solid, liquid, and gaseous phases (Lal 2016). Magdoff and Van Es (2021, xiii) state that "building and maintaining good levels of organic matter in our soils are as critical as managing physical conditions, pH, and nutrient levels." Soil organic matter affects many soil properties and is made up of plant and animal residues, root exudates, and amendments added to the soil. Soil is a living ecosystem that experiences gains and losses of soil organic matter. Farmers, gardeners, and soil managers should minimize losses that can occur when soil is disturbed or left bare, and build organic matter through management of plants, rotation of crops, integration of livestock, and the addition of plant nutrients and soil amendments such as compost, manures, poultry litter, and fertilizers.
4. **Think systems, not shortcuts:** Soil is a living system with biological, chemical, and physical properties. Some properties are inherent to the soil type and how the soil was formed. However, management or neglect can affect all soil properties, so a holistic systems-based approach is needed for long-term health and vitality. Thinking of soil as an ecosystem with various parts and players can help soil managers understand all soil change processes are integrated and interactive. Shortcuts in decision-making may be shortsighted, only addressing symptoms of poor management, and short-changing the system in the long run (Karlen and Rice 2015).

Four Core Soil Health Principles

1. **Keep soil covered:** It's the first step in protecting it from erosion but also buffers soil temperature, slows rainfall runoff, aids rainfall infiltration, and limits evapotranspiration of crucial moisture.
2. **Minimize soil disturbance,** both physical and chemical. Being proactive to reduce physical and chemical disturbance can heal and protect properties of the soil and ultimately enhance the habitat and home of the biological component of soil life. Physical and chemical disturbance can adversely affect the home of microbes and their living environment (Karlen et al. 1994).
3. **Maximize living roots:** Having roots growing and living throughout the year fuels biological activity, aids nutrient cycling, and contributes to improved soil structure because roots provide food, water,

oxygen, and shelter for soil microbes. The more diverse and complex the cropping and cover crop system, the more diverse the root structure will be to support a diverse microbial community.

4. **Energize with diversity:** Use different crop species, crop rotations, and livestock integration where possible for specific purposes to enhance chemical, physical, and biological aspects of the soil. Diverse crop species and rotations can maximize plant surface area and groundcover to better fully capture sunlight. Also, do not underestimate the positive synergies and impact that a diverse population of beneficial insects and pollinators can have on the whole system.

Holistic Systems Thinking

Soil has biological, chemical, physical, and ecological properties as part of living ecosystem affected by natural factors and human influences. As previously mentioned, some of these properties are inherent to the soil type and how the soil was formed through time. All soil properties can be positively and negatively affected. Some effects may be experienced relatively rapidly and others may occur long-term. Soil health management, therefore, requires a holistic systems-based approach for long-term health and vitality. A sole focus on current symptoms may ultimately be shortsighted and short-change the system in the long run. Thinking of soil as an ecosystem with various players, employees, and volunteers working at different scales in soil, liquid and gaseous phases can help soil managers understand all soil change processes need to be thoughtfully considered because the processes are integrated, interactive, interdependent, and dynamic.

References

Doran, J. W., T. B. Parkin, J. W. Doran, D. C. Coleman, D. F. Bezdicek, and B. A. Stewart. 1994. "Defining and Assessing Soil Quality." *In Defining Soil Quality for a Sustainable Environment*, edited by J. W. Doran, D. C. Coleman, D. F. Bezdicek, and B. A. Stewart. Soil Science Society of America Special Publication 35:3-21. Madison, WI: SSSA.

Karlen, D. l., N. C. Wollenhaupt, D. C. Erbach, E. C. Berry, J. B. Swan, N. S. Eash, and J. L. Jordahl. 1994. "Long-Term Tillage Effects on Soil Quality." *Soil & Tillage Research* 32:313-27.

Karlen, D. L., and C. W. Rice. 2015. "Soil Degradation: Will Humankind Ever Learn?" *Sustainability* 7 (9): 12490-501. https://doi.org/10.3390/su70912490.

Lal, R. 2016. "Soil Health and Carbon Management." *Food and Energy Security* 5 (4): 212-22. https://doi.org/10.1002/fes3.96.

Magdoff, F., and H. Van Es. 2021. *Building Soils for Better Crops: Ecological Management for Healthy Soils*. 4th ed. Sustainable Agriculture Research and Education (SARE) Handbook Series 10. College Park, MD: SARE.

USDA-NRCS (U.S. Department of Agriculture. National Resources ConservationService, Virginia). 2018. "Soil Health in Virginia: The Next Frontier of Conservation." www.nrcs.usda.gov/wps/portal/nrcs/detailfull/va/soils/health/?cid=stelprdb1248422.