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Soil Health and Conservation: Making Connections for Management

Introduction

Soil is one of our nation's most critical resources, and healthy soil forms the foundation of productive, resilient farms. Soil health is defined by the United States Department of Agriculture Natural Resources Conservation Service (USDA-NRCS) as "the continued capacity of a soil to function as a vital living ecosystem that sustains plants, animals, and humans."

While soil conservation efforts have focused on preventing erosion and maintaining topsoil, soil health goes further. Soil health expands stewardship beyond conserving soil; it also includes enhancing soil quality to produce food, fiber, and fuel, as well as promoting other beneficial functions. Healthy soil functions, as described by the Food and Agriculture Organization (FAO) of the United Nations, include nutrient cycling and storage, habitat for organisms, flood regulation, and water purification.

Further, soils serve as a source of pharmaceutical and genetic resources, provide a foundation for human infrastructure, provide construction materials, protect cultural heritage, and contribute to climate regulation and carbon (C) sequestration.

Soil health management principles aim to reduce degradation while maintaining or improving crop productivity and enhancing other essential soil functions. However, the NRCS definition does not recognize how important it is to ensure soil fertility and aeration in the root zone at levels that support crop production and consider practical management tradeoffs. This publication provides an overview of soil health principles and practical considerations to address immediate and long-term soil resource concerns in agricultural systems.

Understanding Soil Health

Soil is comprised of four key components: minerals (sand, silt, and clay), organic matter (living and dead organisms and decaying material), air, and water. The proportion and interaction of these materials determine how well a soil supports plant growth, and impacts the strategies required to maintain or improve its productivity.

Soil properties are typically categorized as:

- **Physical**: texture, structure, and porosity
- **Chemical**: pH, nutrient content, and cation exchange capacity (CEC)
- **Biological**: microbial activity, organic matter decomposition, and biological diversity

Soils are formed based on several soil-forming factors, including parent material, relief or slope of the landscape, climate, weather, time, and living organisms that inhabit the soil ecosystem. Some of these properties, or characteristics arising from a suite of properties, are inherent or unchangeable, while others are dynamic, meaning they can be influenced by management and are subject to change over time.

- **Inherent soil properties** include texture, parent material, depth to bedrock, and drainage class.
- **Dynamic soil properties or characteristics** include soil organic matter (SOM), bulk density, soil structure, infiltration rates, microbial activity, and nutrient storage and release from organic material.

Soil health management systems aim to influence dynamic soil properties or characteristics over time, maximizing root growth, water use efficiency, nutrient cycling, biological activity, and the use of existing on-farm resources (plant material, compost, manure, crop residue, etc.) to maintain and enhance soil productivity, while also providing various soil ecosystem services.

However, improvements in soil health take years to see the effects and may not align with immediate soil fertility and production system concerns. When emergent production concerns arise, like pests, diseases, and nutritional deficiencies, it becomes critically important for farmers to address these issues to prevent economic losses. As a result of immediate risks to farm viability, it becomes challenging for landowners and operators to focus on long-term goals like soil health and conservation.

Soil Health Principles and Practices

These four guiding principles from the USDA-NRCS are designed to promote soil health and conservation:

1. **Minimize soil disturbance**: Protect soil structure and biology by reducing mechanical, chemical, and physical disturbances. Practices associated with minimizing soil disturbance include reducing tillage, rotating livestock to avoid overgrazing, and following chemical labels to ensure effective and efficient use of chemicals (refer to Figure 1).

Figure 1. A cover crop drilled into soybean (*Glycine max* (L.) Merr.) residue using minimal tillage in a field in Noxubee County, MS.

2. **Maximize soil cover**: Keep the soil surface covered to reduce erosion, buffer temperatures, increase SOM, and conserve soil moisture. Practices associated with keeping the soil covered include planting a cover crop, using mulch, or leaving plant residue after harvest (refer to Figure 2).
3. **Maximize living roots**: Ensure continuous living roots to sustain microbial activity and enhance carbon cycling. Practices to increase living roots include reducing fallow periods, integrating compatible cover crops, and using diverse crop rotations (refer to Figure 3).
4. **Maximize biodiversity**: Encourage diverse plant and animal communities to enhance ecosystem resilience and function. Practices that enhance diversity include planting diverse crops, rotating crops, and integrating livestock across a farm and over time.

When applied together as part of a soil health management system, these principles promote various soil and water conserving benefits. However, there are some practical considerations to ensure immediate production and profitability goals are sustained.

Figure 2. Crimson clover (*Trifolium incarnatum* L.) and winter wheat (*Triticum aestivum* L.) cover crop mixture in Coahoma County, MS.

Figure 3. Living roots of a multi-species cover crop are shown in a field in Coahoma County, MS. The soil has earthworms, which are decomposers involved in carbon cycling.

Bridging the Gap between Soil Health and Soil Fertility

Soil health and soil fertility are sometimes viewed as having contrasting management goals, especially regarding the management strategies and time horizons—where fertility in high production systems focuses on external nutrient inputs and soil health focuses on biological and physical processes for regulating nutrients and making them available over a long-term horizon, among other ecosystem services. In practice, soil health and fertility can be highly aligned.

Soil fertility focuses on adequate nutrient availability that supports crop nutrition requirements. This depends on chemical, nutrients, and the biological and physical processes that regulate their availability for plant uptake. At its core, fertility depends on the presence of adequate chemical nutrients in inorganic forms and from organic matter decomposition. Biological processes are central to this relationship because they are responsible for nutrient cycling and transforming nutrients into forms plants can use. Not to be overlooked, soil structure with adequate drainage and aeration supports microbial activity. Together, these processes contribute healthy soil functions, ensuring nutrient availability and retention to support crop production.

Organic matter contains essential nutrients, including nitrogen (N), phosphorus (P), and potassium (K). These nutrients are required for plants and microbial life to produce energy and reproduce. Soil microbes, including both bacteria and fungi, decompose organic material into smaller, plant available forms of nutrients, such as ammonium and nitrate. The rate of decomposition and type of nutrient release depends on the quality of organic materials. Nutrient-rich organic material where carbon-to-nitrogen ratios are low, such as animal manures and nitrogen-rich biomass, are more likely to release nutrients into the system (via mineralization) quickly.

Other organic materials such as corn stalks and wheat straw have lower nutrient density, resulting in high carbon-to-nitrogen ratios, and break down more slowly or even immobilize nutrients. Bacteria or fungi decompose or break down organic matter, mineralizing nutrients and making them available for plant uptake.

Efficient recycling of organic residues to soil organic matter and subsequent nutrient mineralization aims to increase internal nutrient storage and cycling of residual nutrients for the next crop season. This cycling process provides nutrients throughout the system, but in current conventional production settings, it cannot fully replace the need for sound nutrient management to restore nutrients lost during crop harvest.

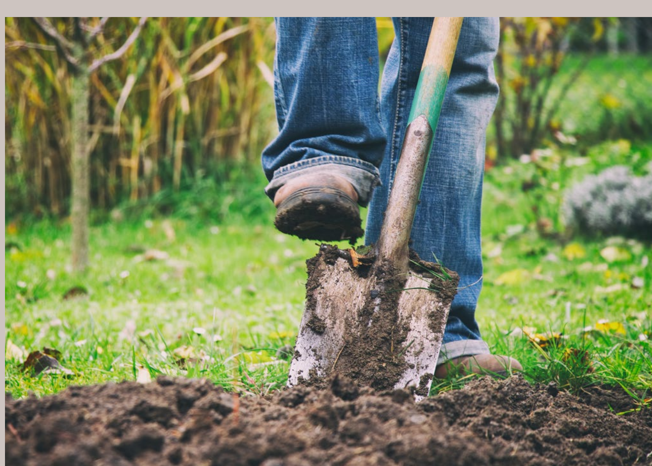
Soil health management systems highlight the use of living roots and cover crops to maintain or increase soil organic carbon and improve the retention and cycling of residual nutrients. For example, legumes in a crop rotation form nitrogen-symbiotic relationships with rhizobia, a group of soil bacteria that can fix nitrogen from the atmosphere, reducing nitrogen fertilizer needs, but phosphorus and potassium may still require supplementation based on soil test results. **Even with adopting soil health practices, nutrient management plans remain essential.** While optimizing soil health can improve nutrient use efficiency, farmers should continue to rely on yield history, yield goals, crop nutrient removal, and soil testing to guide fertility decisions.

Practical Indicators of Soil Health

There are over 40 ways to measure soil health, and no agreed upon metrics. Recently, a Soil Health Institute study assessed more than 30 soil health metrics—including physical, chemical, and biological parameters—to determine a minimum suite of three key indicators that are suitable at scale and responsive to management practices. These key indicators include:

1. **Aggregate stability**: Measures soil's ability to resist wind and water erosion and allow infiltration. Higher stability means better structure.
2. **Soil organic matter/organic carbon**: Influences microbial activity, water holding capacity, and nutrient cycling. Increases slowly but is a cornerstone of soil health.
3. **Carbon mineralization potential (burst of carbon dioxide)**: Indicates soil microbial activity and organic matter breakdown. Useful for comparing biological activity over time and across fields.

While these measures can complement traditional fertility tests to provide a more complete picture of soil condition and trends over time, a shovel remains a low-tech, high-value tool for farmers to get familiar with what is happening beneath the soil surface, providing visual insights about structure, compaction, root growth, and biological life.



Considerations

Soil health management is not a one-size-fits-all program but requires a context-specific approach that includes farming operation type, scale, climate, soil conditions, and risk tolerance. Local ecology and farm-specific conditions play a significant role in determining which practices are most suitable. Consider the following:

- Vegetable growers can more readily integrate compost, cover crops, and diverse rotations to recycle nutrients than large row-crop operations.
- Livestock operations can more readily integrate rotational grazing and forage crops to improve soil cover and diversity than small vegetable operations without animals on site.
- Large-scale, row-crop growers may face more economic challenges and risk related to variable soil types, equipment, or time constraints, but they can start with practices like reduced tillage, cover crops, cash crop rotations, or conservation buffers on field margins in lower-risk fields.

Improving soil health takes time and often requires incremental change. Start small, monitor outcomes, and adjust. A practical approach to soil stewardship requires first addressing urgent concerns or limiting factors, like compaction, drainage, severe erosion, soil fertility concerns, pest pressure, or other risks to farm economic viability. Soil health principles should be part of a broader toolbox, alongside other management and structural practices that support drainage water management and reducing soil loss. Adopting conservation practices often requires financial investment.

Technical and financial assistance is available through NRCS conservation programs such as the Environmental Quality Incentives Program (EQIP) and Conservation Stewardship Program (CSP) to help offset the costs of adopting improved practices. Farmers should evaluate return on investment (ROI) through government incentives, winter cash crops, livestock forage, or participation in value-added markets. Farm economic viability is the cornerstone of sustainability. Soil health and stewardship should support, not hinder, a profitable operation.

Conclusion

Soil health and conservation aim to support productive and profitable agricultural systems while protecting and sustaining resources for future generations. By understanding and managing dynamic soil properties, farmers can improve soil function and water and nutrient use efficiency. Integrating soil health principles into existing operations does not require abandoning conventional practices. Rather, it means implementing thoughtful changes that enhance soil properties, reduce risks, and support farm profitability in the context of each farm operation.

For site-specific recommendations, consult with your local MSU Extension office, conservationist, natural resources professional, and/or agronomist.

Additional Resources

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