Soil health management for sustainable crop production

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Soil health is defined as the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals, and humans. Healthy soil gives us clean air and water, bountiful crops and forests, productive grazing lands, diverse wildlife, and beautiful landscapes. Soil does all this by performing five essential functions:

- **Regulating water**: Soil helps control where rain, snowmelt, and irrigation water goes. Water flows over the land or into and through the soil.
- **Sustaining plant and animal life**: The diversity and productivity of living things depend on soil.
- **Filtering and buffering potential pollutants**: The minerals and microbes in soil are responsible for filtering, buffering, degrading, immobilizing, and detoxifying organic and inorganic materials, including industrial and municipal by-products and atmospheric deposits.
- **Cycling nutrients**: Carbon, nitrogen, phosphorus, and many other nutrients are stored, transformed, and cycled in the soil.
- **Providing physical stability and support**: Soil structure provides a medium for plant roots. Soils also provide support for human structures and protection for archaeological treasures.

Soil health testing is pursued as an assessment of this status but tends to be confined largely to agronomic objectives. Soil health depends on soil biodiversity (with a robust soil biota), and it can be improved via soil management, especially by care to keep protective living covers on the soil and by natural (carbon-containing) soil amendments. Inorganic fertilizers do not necessarily damage soil health if they are not used in excess, and if they bring about a general improvement of overall plant growth which contributes more carbon-containing residues to the soil.

The Four Principles of a Soil Health Management System

Implementing Soil Health Management Systems can lead to increased organic matter, more diverse soil organisms, reduced soil compaction and improved nutrient storage and cycling. As an added bonus, fully functioning, healthy soils absorb and retain more water, making them less susceptible to runoff and erosion. This means more water will be available for crops when they need it.Soil Health Management Systems allow farmers to enjoy profits over time because they spend less on fuel and energy while benefiting from less variable crop yields resulting from improved soil conditions. Healthy soils also provide a buffer for precipitation extremes (too wet or too dry).

1.Maximize Presence of Living Roots

Living plants maintain a rhizosphere, an area of concentrated microbial activity close to the root. The rhizosphere is the most active part of the soil ecosystem because it is where the most readily available food is, and where peak nutrient and water cycling occurs. Microbial food is exuded by plant roots to attract and feed microbes that provide nutrients (and other compounds) to the plant at the root-soil interface where the plants can take them up. Since living roots provide the easiest source of food for soil microbes, growing long-season crops or a cover crop following a short-season crop, feeds the foundation species of the soil food web as much as possible during the growing season. Healthy soil is dependent upon how well the soil food web is fed. Providing plenty of easily accessible food to soil microbes helps them cycle nutrients that plants need to grow. Sugars from living plant roots, recently dead plant roots, crop residues, and soil organic matter all feed the many and varied members of the soil food web.

2. Minimize Disturbance

Tillage can destroy soil organic matter and structure along with the habitat that soil organisms need. Tillage, especially during warmer months, reduces water infiltration, increases runoff and can make the soil less productive. Tillage disrupts the soil's natural biological cycles, damages the structure of the soil, and makes soil more susceptible to erosion.

The benefits of reduced till/no-till include:

- Aiding in Plant Growth – Soils managed with reduced/no-till for several years contain more organic matter and moisture for plant use. Healthy soils cycle crop nutrients, support root growth, absorb water and sequester carbon more efficiently.
- Reducing Soil Erosion – Soil that is covered year-round is much less susceptible to erosion from wind and water. For cropping systems, practices like no-till keep soil undisturbed from harvest to planting.
- Saving Money – Farmers can save money on fuel and labor by decreasing tillage. Improving nutrient cycling allows farmers to potentially reduce the amount of supplemental nutrients required to maintain yields, further reducing input costs.
- Providing Wildlife Habitat – Crop residue, grass and cover crops provide food and escape for wildlife.

3.Maximize Soil Cover

Soil cover can be maximized by planting cover crops, annual crops, and perennial crops and leaving crop residues and living mulches on the ground. Soil health practices that maintain cover year-round improve soil health and protect soil from wind and water erosion. Cover crops can be an integral part of a cropping system and provide soil cover during fallow seasons. Cover crops can be managed to improve soil health, as they help to develop an environment that sustains and nourishes plants, soil microbes and beneficial insects.

The benefits of planting cover crops in between cash crop season include:

- **Restoring Soil Health**- Cover crops help increase organic matter in the soil and improve overall soil health by adding living roots to the soil during more months of the year. Cover crops can improve water infiltration into the soil. Deep rooted crops like forage radishes create natural water passages. Legume cover crops serve as natural fertilizers while grasses scavenge nutrients that are often lost after harvest or during winter.
- **Natural Resource Protection** – Along with crop residue above ground, cover crops protect the soil against erosive heavy rains and strong winds. Cover crops trap excess nitrogen, keeping it from leaching into groundwater or running off into surface water – releasing it later to feed growing crops.
- **Livestock Feed** – Cover crops can provide livestock producers with additional grazing or haying opportunities.
- **Wildlife Habitat** – Cover crops provide winter food and cover for birds and other wildlife. During the growing season, they can provide food for pollinators.

4 Maximize Biodiversity

Biodiversity is the variation of life forms within a given ecosystem or field. The different life forms include all of the plants, animals and microorganisms. Increasing the diversity of a crop rotation and cover crops increases soil health and soil function, reduces input costs, and increases profitability. For Soil Health Management Systems, biodiversity can be increased through a variety of approaches including: plant diversity through the use of diversified crop rotations, cover crop mixes, proper integration of grazing animals (e.g. livestock) into the system and includes animals living within the soils or microbial diversity, as well as direct additions with biological amendments. **Impact on Crop Productivity**

- Improved soil health results in increased crop productivity, leading to higher yields and enhanced food production.
- Healthy soils provide essential nutrients to plants, improving the nutritional content and quality of agricultural products.
- A balanced soil ecosystem strengthens plant resistance to pests and diseases, reducing the need for chemical interventions.
- Healthy soils act as carbon sinks, sequestering carbon dioxide and contributing to climate change mitigation efforts.

Sustainable Agriculture and environmental benefits

1. Reduces the reliance on chemical inputs, such as synthetic fertilizers and pesticides, minimizing environmental pollution and preserving soil health.
2. Protect water quality by preventing runoff of harmful chemicals and nutrients into water bodies, ensuring cleaner and healthier water resources.
3. Fosters biodiversity, providing habitats for various organisms and supporting ecosystem balance and resilience

Management Practices to Improve Soil Health –

- **Reduce Inversion Tillage and Soil Traffic:** Excessive tillage increases soil oxygen, stimulating biological activity and decomposing organic matter. It disturbs soil aggregates, exposing organic particles to microbes. This reduces soil health over time and increases erosion risk.

- **Balanced Crop Nutrition:** Seventeen essential nutrients are required for optimal plant growth. Deficiency in any nutrient affects crop life cycles. Balanced crop nutrition, incorporating the 4Rs (Right source, Right rate, Right time, Right place), ensures maximum yield and improved plant health.
- **Implement the 4Rs:** The 4Rs framework (Right source, Right rate, Right time, Right place) enhances production, farm profitability, environmental protection, and sustainability.
- **Increase Organic Matter Inputs:** Maintaining or improving soil organic matter is crucial. Healthy crops and crop residues, along with cover crops, animal and green manure, and compost, can enhance soil organic matter.
- **Use Biofertilizers:** Biofertilizers, or microbial bioinoculants, are organic sources of plant nutrients. They increase nutrient availability, enhance soil fertility, protect plants from pathogens, and improve soil health with minimal environmental impact.
- **Use Cover Crops:** Cover crops reduce erosion, increase organic matter, create macropores, enhance soil aggregation, and support beneficial fungi. Legume cover crops also fix nitrogen in the soil.
- **Reduce Pesticide Use:** Broad-spectrum insecticides harm beneficial insects. Enhancing biodiversity supports beneficial organisms and improves pest control.
- **Crop Rotation:** Diverse crop rotations break pest and disease cycles, manage weeds, and reduce nutrient excesses, improving overall crop health.

Conclusion

All four soil health management principles contribute to biodiversity. Biodiversity helps to prevent disease and pest problems associated with monocultures. Using cover crops and increasing diversity within crop rotations improves soil health and soil function, reduces costs, and increases profitability. Diversity above ground improves diversity below ground, which helps create healthy productive soils. Lack of biodiversity severely limits the potential of any cropping system and increases disease and pest problems. Biodiversity is ultimately the key to the success of any agricultural system. A diverse and fully functioning soil food web provides for nutrient, energy, and water cycling that allows a soil to express its full potential.

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