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Basic Principles of Soil Health

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Importance of Soil Health

Healthy soils are paramount to thriving agriculture and critical for food and fiber production. Soil health is defined as the ability of the soil to provide services that maintain or improve the quality of water and air, farm and grazing lands, and forests and wildlife. Healthy soils provide these services by performing the following functions:

- Regulating water – controlling the flow of rain, snowmelt and irrigation water.
- Supporting plant and animal life.
- Filtering pollutants – limiting environmental pollutants from entering waterways.
- Providing nutrients – storing nutrients and helping with nutrient cycling.

Characteristics of Healthy Soils

Healthy soil has good drainage, adequate levels of essential nutrients, low weed and pest pressure, good soil tilth, and a robust population of microorganisms. Soil organic matter is the key to soil health. Soil organic matter is the portion of the soil that includes decomposing plant and animal residues, and is the storehouse for plant nutrients. Many nutrients in soil organic matter are in forms that are unavailable for plant uptake and must be converted to plant-available forms through decomposition and mineralization by soil microorganisms.

Organisms vary in size and function, and include bacteria, fungi, nematodes, earthworms and insects. Their functions include decomposing organic compounds, cycling soil nutrients, enhancing soil aggregation and porosity, and preying on crop pests. Most organisms are beneficial, but some are pathogens that cause plant disease. Beneficial soil organisms often limit the populations of undesired soil pathogens by preventing any one type of organism from being dominant and maintaining a healthy equilibrium. Because soil organic matter affects several critical soil functions, increasing soil organic matter typically increases soil health.

Maintaining healthy soils is crucial to meet the growing demands for food production and helps reduce the need for costly inputs, such as nutrients from fertilization and demand for irrigation water. Healthy soils allow producers to improve profitability by decreasing chemical inputs (fuel, fertilizers, pesticides), while benefiting from higher crop yields and increasing the overall sustainability of production.

Fundamental Principles of Soil Health

The five principles that influence soil health are:

1. maximize soil cover or armor,
2. minimize soil disturbance,
3. maximize plant diversity,
4. maximize living roots, and
5. integrate livestock.

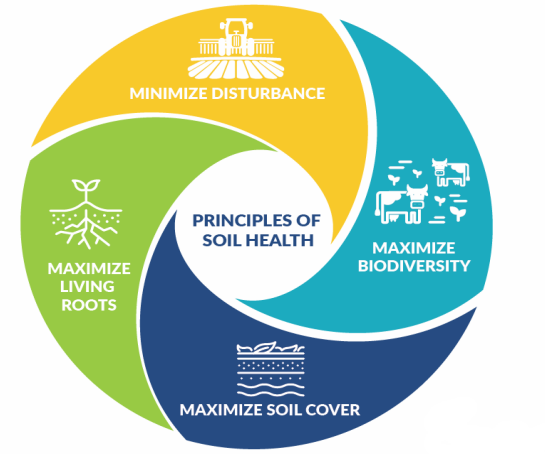

Figure 1: Soil health principles. Adopted from USDA NRCS.

These principles complement each other and are integrated; therefore, implementing these principles together, to the extent possible, is one of the most effective ways for farmers to increase crop productivity and profitability while improving the environment.

Maximize Soil Cover or Armor

Maximizing soil cover is aimed at decreasing the time the field is bare and exposed. Soil cover should last until the next crop is fully canopied and includes living plants such as cover crops and mulches or crop residues left on the ground.

Soil cover provides multiple benefits to growers by conserving soil, water and nutrients, which often reduces the cost of inputs.

Soil cover also provides a habitat for soil organisms necessary for soil health. Soil cover protects soil from wind and water erosion, preventing the loss of valuable soil organic matter and nutrients. Cover reduces evaporation rates, leaving more moisture available for plants to use and reducing overall irrigation demands, thus conserving limited water resources, which are especially important in Nevada's arid climate. Soil cover also reduces impact from rainfall by dissipating energy from raindrops falling on bare soil and preventing soil particles from being dislodged and water from running off, allowing more water to infiltrate the soil.

Soil cover helps to moderate soil temperatures by keeping the soil warmer in cold weather and cooler in hot weather. Covering the soil limits weed growth by reducing the amount of sunlight that reaches the soil surface, thus limiting the need for herbicides.

Minimize Soil Disturbance

Soil disturbance occurs in three forms. The first is *biological* disturbance that results from improper grazing. The loss of plant biomass due to overgrazing limits the plant's photosynthetic capacity and reduces net productivity. The second is *chemical* disturbance that results from the overapplication of chemical inputs, such as fertilizers and pesticides, disrupting soil food webs, including microorganisms necessary for soil health. The third is *physical* disturbance, such as tillage, which is the mechanical manipulation of soil. Soil tillage breaks down soil aggregates, compacts the soil and reduces soil pore spaces, restricting water and air infiltration and leads to the loss of soil organic matter. Long-term tillage results

in degraded soils through increased water and wind erosion, soil organic matter depletion, and crusting. Transitioning from continuous conventional tillage to minimum tillage, conservation tillage or no-tillage systems minimizes soil disturbance, thus improving soil health and reducing annual fuel and labor investments.

Maximize Plant Diversity

Growing a diverse mix of plant species will also increase soil microbial diversity. Plants use sunlight to convert water and carbon dioxide into carbohydrates. Different plant species produce unique carbohydrates, and to support a diversity of soil organisms, a diversity of plant carbohydrates is necessary. Carbohydrates are building blocks for the plant and are also released through their roots, feeding soil organisms in exchange for nutrients and water which increases soil organic matter. This, in turn, improves water infiltration and nutrient cycling, while decreasing disease and pest pressure.

Maximize Living Roots

Continual living plants aboveground and their associated roots belowground feed carbohydrates to soil microorganisms throughout the year. In the absence of living plants and their roots, the soil microorganism population wanes.

Growing cover crops and perennial crops increases the amount of time living plants and their associated roots are present in the field. This in turn supports the first two soil health principles – maximize soil cover and minimize soil disturbance. The addition of cover crops to a cropping system also increases plant diversity – the third soil health principle.

Livestock Integration

Integrating livestock into cropping systems increases biodiversity and also balances carbon-nitrogen ratios. The top half of the aboveground growing plant contains more protein and energy than the lower half, so allowing animals to graze only on the upper half provides them with the most nutrition and leaves the lower half as soil armor.

Conclusion

Healthy and fully functioning soil is essential to maximizing long-term profitability. While each of these five principles can be used in isolation, using all five at the same time when possible increases the rate and magnitude of improvements to soil health. Implementing these soil management principles into production systems will not only improve soil health, but will also protect natural resources for future use.

References

Anguelov, G. et al. 2020. Conservation tillage systems in the Southeast - production, profitability and stewardship. Sustainable Agriculture Research & Education. https://www.sare.org/wp-content/uploads/Conservation-Tillage-Systems-in-the-Southeast_compressed.pdf

Fahrer, J. Soil Health: Principle 1 of 5 Soil Armor. USDA Natural Resources Conservation Service – North Dakota. https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/north-dakota/soil-health-principle-1-of-5-soil-armor

Fahrer, J. Soil Health: Principle 2 of 5 Minimizing Soil Disturbance. USDA Natural Resources Conservation Service – North Dakota. https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/north-dakota/soil-health-principle-2-of-5-minimizing-soil

Fahrer, J. Soil Health: Principle 3 of 5 Plant Diversity. USDA Natural Resources Conservation Service – North Dakota. https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/north-dakota/soil-health-principle-3-of-5-plant-diversity

Fahrer, J. Soil Health: Principle 4 of 5 Continual Live Plant/Root. USDA Natural Resources Conservation Service – North Dakota. https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/north-dakota/soil-health-principle-4-of-5-continual-live

Fahrer, J. Soil Health: Principle 5 of 5 Livestock Integration. USDA Natural Resources Conservation Service – North Dakota. https://www.nrcs.usda.gov/conservation-basics/conservation-by-state/north-dakota/soil-health-principle-5-of-5-livestock

Kamadar, K. 2020. The Heart of Soil: The Importance of Soil Health Principles. USDA Natural Resources Conservation Service – Wisconsin.

Owens, C. 2017. Unlocking the Secrets in Soil: How soil works and the management principles of high functioning soil. USDA Natural Resources Conservation Service. https://wmswcd.org/wp-content/uploads/2017/05/201704APR08_SoilSchool.pdf

Poole, T. 2001. Soil Organic Matter. University of Maryland Cooperative Extension Service, Fact sheet 783.

Reduction in Annual Fuel Use from Conservation Tillage. 2016. USDA Natural Resources Conservation Service. https://www.nrcs.usda.gov/publications/ceap-crop-2016-reduction-in-annual-fuel-use-from-conservation-tillage.pdf

USDA Natural Resources Conservation Service. 2013. Unlock the secrets in the soil Basics & Benefits. https://nrcspad.sc.egov.usda.gov/DistributionCenter/pdf.aspx?productID=968

USDA Natural Resources Conservation Service. 2021. Unlock the secrets in the soil Principles for High Functioning Soils. https://s30428.pcdn.co/wp-content/uploads/sites/2/2018/10/NRCS_SecretsSoil_Principles_HighFunctioning_Factsheet-2021.pdf

Walia, M.K. 2019. Benefits of cover crops. University of Nevada, Reno Extension, FS-19-11. https://extension.unr.edu/publication.aspx?PubID=2850