Evaluating Soil Quality and Health

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The ability of soil to function and sustain biological productivity depends on its quality and health. Soil quality is defined by inherent soil properties such as soil texture and cation exchange capacity (CEC) that change little, if at all, with land use management practices. Soil health is dynamic and is characterized by properties such as tilth, aggregation and microbial activity which may be subjective to measure. Soil health and quality are sometimes used interchangeably. Measuring, monitoring, and improving soil health takes time, but can be worth the effort for potential benefit in sustainability and productivity. Healthy soils have increased nutrient and water availability, and provide farms more resilience to uncontrollable factors such as weather and markets. They support greater root and plant growth, which, in turn, feeds soil microbial activity, further increasing soil health and productivity.

Soil productivity is influenced by its chemical characteristics, physical structure, and biological activity. Measurements of these properties provide an estimate of the soil's ability to function and produce healthy plants. Indicators of soil productivity can be tracked over time, compared in side-by-side fields, or compared to a reference soil, and are useful to assess the effect of management or evaluate problem areas.

Chemical soil characteristics, including pH, soil organic matter (SOM), CEC and nutrient levels are often part of routine soil analyses done by analytical labs. The physical properties such as available water holding capacity (AWHC, also called plant available water, PAW), bulk density, porosity, infiltration rate and aggregate stability, are also most reliable if measured by an accredited lab, yet not all labs perform these measurements. Field tests are available for many of these soil properties but they often rely on subjective interpretation of results possibly obtained with non-standardized methods. Microbial activity is also important, yet has the least defined set of measureable factors by which it can be quantified.

CHEMICAL CHARACTERISTICS

Electrical conductivity, nutrient levels, CEC and pH are routinely included in lab tests and will not be discussed further.

Potentially mineralizable nitrogen (PMN) is the amount of organic N that can be converted to nitrate-N (NO_4^--N) or ammonium-N (NH_4^+- N) under specific climactic conditions. It is a measure of N available for crop growth throughout the growing season and a good indicator of soil fertility. Although adding PMN to soil nitrate-N test results increases the accuracy of fertilizer N requirements, to date, calibration between PMN test results and fertilizer recommendations are not available for the Northern Great Plains.

Soil organic matter can provide substantial nutrients for plants, while soil organic carbon (SOC), the carbon stored in SOM, is the main source of energy for soil microorganisms. Although SOC makes up roughly 60% of SOM, only a portion the water soluble part of SOC (also called water extractable organic carbon) is food for microbes. The rate at which nutrients become available from SOM is influenced by SOM particle size. High SOM and SOC support larger microbial populations. Low SOC tends to reduce aggregate stability, infiltration, drainage, and aeration. Levels of SOM below 2% are considered low and should be increased. No-till, cover crops, perennial crops, and manure all can increase SOM and SOC.

PHYSICAL INDICATORS

Available water holding capacity (AWHC) is the difference between field capacity, which is the maximum amount of water the soil can hold after draining for 1 day, and wilting point, the water content where the plant can no longer extract water from the soil. AWHC is highly dependent on soil texture and varies for different crops. Accurate calculations of available water holding capacity are complicated and require specialized equipment, but some laboratories can measure it, and others can provide approximate measures based on soil texture. It can be improved by increasing SOM and reducing compaction.

Bulk density is the mass of dry soil in a given volume. It *is* dependent on soil texture and how tightly soil minerals and organic matter particles can pack together. As bulk densities increase above 1.6 g/cm^3 plant growth can become limited. Organic matter improves bulk density, while compaction increases bulk density.

Porosity is the amount of pore space in the soil and is influenced by soil texture. An ideal soil has 50% solids and 50% pore space, with half the pore space filled with air, the other half filled with water about a day after a rainstorm or irrigation event. Porosity can be improved by reducing cultivation frequency, compaction, erosion and surface crusting, and increasing SOM.

Infiltration rate indicates how fast soils can absorb water. Reduced infiltration can cause excess water accumulation which reduces root growth, nutrient cycling and availability, air movement through the soil, and soil microbial activity, which all reduce plant growth. Infiltration rate can be improved temporarily with tillage, but in the long term requires increased SOM and aggregation. Surface crusting and compaction decrease infiltration rate.

Aggregation describes the soil's ability to resist disintegration when disrupted by water, wind, or tillage. Aggregation is generally less in coarse soils because sands don't stick together as well as clays do. It is important for maintaining porosity, infiltration and soil fertility. Changes in aggregate stability may serve as early indicators of soil recovery or degradation. Increasing residue returned and biological activity improves aggregate stability, while tillage reduces aggregation.

BIOLOGICAL INDICATORS

Biological activity can be measured in several ways. These include: soil respiration, the Solvita microbial activity test, soil enzyme activity, mycorrhizal colonization, and the PLFA (phospholipid fatty acid) test, which provides a broad description of the microbial population and its health. Most of these require specialized testing equipment. Biological activity varies with soil temperature and moisture, therefore, during the day and seasonally. This needs to be remembered when comparing measurements between sites or over time.

Soil organic matter is a good indicator of potential microbial activity. Increases in SOM enhance soil microbial activity while compaction, tillage and some agricultural chemicals can harm biological activity.

SOIL HEALTH TESTS

Some relatively new soil-testing methods are being developed, such as the Haney soil health test and the Cornell Soil Health test. These tests incorporate some of the above mentioned factors and adds tests for other soil characteristics such as water extractable organic N. The current limitations to using 'new' tests are standardized methods may not yet be in place and calibration is lacking between test results and calculating regionally appropriate fertilizer requirements. However, this may change in the next few years as soil health receives more attention.

For a quick assessment of soil health, get out a shovel and dig. Compare a cropped soil with undisturbed fence-line soil. How deep do roots go? Does it break apart easily? Does it smell earthy? Is there evidence of worms? Darker color indicates more SOM or SOC. The shovel test can give the grower an idea of their soil health and identify what problems they might be facing.

Soil health declines due to erosion, compaction, excessive tillage, loss of SOM, declines in biological activity, and increases in salinization. The key characteristics to improve soil health are increasing soil carbon, soil aggregation and water infiltration, water and nutrient holding capacity, and biological activity.

A first and major step towards increasing soil health in conventional systems is to reduce tillage. Tillage is detrimental to soil aggregation and microbial activity. No-till and perennial crops help keep the soil covered with residue which protects the soil surface and encourages microbial activity.

Next, increase crop diversity and reduce fallow time by including alternative crops or cover crops into the rotations. To build SOM and increase microbial activity requires plants. Finally, control heavy traffic to lanes and if at all possible, stay off fields when soils are wet.

For more information:

On soil health:

- Natural Resources Conservation Service (http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/soils/health/)
- Cornell Soil Health page (http://soilhealth.cals.cornell.edu/)

For other soil fertility information http://landresources.montana.edu/soilfertility.

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