CONSERVATION TILLAGE FACTS

Soil Quality Indicators for Whole-farm Management in the Central Great Plains

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Soil quality (SQ) or soil health as it relates to the farmer/rancher/producer is the capacity of a given soil to sustain adequately plant and animal productivity without causing adverse effects on air and water quality. While air and water quality issues are more readily defined and quantified to protect human health, SQ issues are more subtle and difficult to quantify since many factors that cause soil degradation and a reduction in SQ come into play at the same time.

Soil Quality and Quality Soil

A quality soil (or a productive soil) is one with inherently good properties, and therefore, has good soil qualities. Most medium-texture soils from native grasslands without excessive slope fall under this category during the initial years of their cultivation. These soils, because of their near neutral pH, high soil organic matter (SOM) and nutrient content, degrade more slowly than sandy soils with low SOM content, or clayey soils which may become easily water-logged and compacted. Because of the continued use of the traditional clean-till winter wheat-summer fallow, top soils of the central Great Plains have lost about 40% of the original SOM content (2.2% to 1.3%). Much of this loss occurred in the first 10 years of cultivation with sandy soils losing SOM at a faster rate than loams and silt loams. As evidenced by the Dust Bowl of the 1930s, even quality soils can lose SQ because of severe erosion and decline in SOM and fertility. Thus, type of cultural and management practices will greatly determine the productivity and sustainability of a soil.

Signals of Soil Degradation and loss in SQ

Soil degradation is a slow process for most adversely affected soil properties. We readily observe erosional gullies, and light-colored soil surface on hillsides and knolls. Water ponding and salt crusts in low areas are also easily observed. On more level soils however, negative changes in SOM, pH, texture, fertility aren't visually observed as readily, and may require monitoring or making certain measurements. The Natural Resource Conservation Service (NRCS) Soil Quality Institute and the Agricultural Research Service (ARS) National Soil Tilth Laboratory in Ames, Iowa, and in Lincoln, Nebraska, have developed field kits and information on SQ issues that can be directly obtained through their offices, or from the NRCS Soil Quality team at Akron, CO.

Soil Quality Indicators (SQI)

Indicators are used primarily to assess changes in SQ from an earlier time to the present, or to compare an existing field against another with a different management scheme. Since climate and soil types influence changes, comparisons are best done with these factors held constant. Several SQ indicators can be qualitatively assessed in the field to conduct some of these comparisons. Some are readily assessed, and some may require the assistance of the Regional Soil Quality Team at Akron. This field evaluation does not negate the need from time to time for quantitative soil testing evaluation from a certified laboratory. Some indicators are presented below which represent various physical, chemical, and biological measurements:

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1. Soil Series and Family
2. Topography or slope
3. Texture or particle size distribution
4. Soil pH or reaction
5. Soil organic matter content, and residue
6. Presence of earthworms, and macropores
7. Depth to lime (solum depth)
8. Fertility (nitrates and SOM)
9. Salinity (electrical conductivity)
10. Aggregate Stability (turbidity)
11. Infiltration

Soil Series and Family

This information can be obtained directly from the soil survey provided by the NRCS. As an example, the Weld soil series, the most dominant in Washington County, can be a loam or a silt loam in the surface soil. The family group shows that it is montmorillonitic (clay type) and of the Mollisol order (high SOM). While the clay type usually refers to the layer below the top soil, this information on a whole can indicate the production potential of the soil, and is the first step to discern the potential for soil degradation and loss in SQ.

Topography or Slope

This information should be observed on the landscape even though it is described in the soil survey. Slope is important because it reflects runoff (water storage), soil depth (rooting volume), and general fertility. As an example, the Colby series is on knolls with weakly developed horizons (no B horizon) because of, among other factors, lack of water penetration from runoff, which results in low vegetation production. These soils are generally low in SOM, and calcareous (presence of lime) near the surface with fertility problems involving phosphorus, zinc, and iron. Unless residue can be increased (manures and legume cover crops), productivity potential of these soils will be low because of lack of water storage. On the other hand, depositional areas or toeslopes will be productive, and may require greater fertilization for maximum production because of the extra water accumulation.

Texture (Particle size distribution)

The percentages of sand, silt, and clay (texture) determine the physical and chemical properties, and ultimately, the biology of the soil. The amount and type of clay will determine fertility, water infiltration, organic matter accumulation, compaction and erosion potential, and workability of that soil. While the soil survey gives an approximation of the texture, quick field tests based on feel for clay/silt content in a moistened soil can be performed, but may require some practice. With time organic materials promote the grouping of the particles into what is referred to as aggregates. Thus, clay particles and other components join together to stabilize the soil against erosion, and to increase water infiltration. Generally clay content is directly related to SOM content.

Soil Reaction (pH)

Soil pH determines the availability of nutrients, and is generally a function of clay type and surfaces, and organic matter content. Certain pHs are diagnostic of certain problems. A soil pH around 7.7 indicates the presence of lime (requires a positive fizz test also). Phosphorus and micronutrient problems could exist on these soils. Above 8.4 without a fizz (application of acid on lime material releases a gas) may indicate the presence of high sodium concentration. Water infiltration could be a problem. Low pHs are associated with manganese toxicity (<5.5), and aluminum toxicity (<5.0), coupled with Ca deficiency. Plants are stunted and root growth is limited. An ideal pH is near neutral (6.5 to 7.0), even though pH limitations only become serious outside of the 5.6 to 7.6 range. Legumes generally prefer neutral to slightly alkaline soils. Many quick field tests using precalibrated probes exist for evaluation of soil pH. With increase in cropping intensity and no-till, and more frequent N fertilization, some surface soils are beginning to acidify, and may require addition of a calcium source in the future to avoid a decrease in production.

Soil Organic Matter

The SOM content, and its direction of change over time, can be diagnostic of the health of the soil. Generally, high SOM content is associated with good soil physical properties and good productivity. Quick field tests based on the intensity of the dark color (humic carbon) extracted from soils with sodium hydroxide exist for relative comparisons among soils with different treatments. The level of soil SOM is also used as a surrogate for sulfur needs and nitrate contribution, and its exact quantification once every three to five years is recommended. Organic matter changes are a direct function of crop residue, tillage intensity, and climate (water and temperature which affects decomposition). Crop residue is a direct function of cropping intensity, fertilization, tillage, and sanitation. The ratio of SOM (%) to silt and clay (%) has also been used as an indicator of SQ.

Presence of Earthworms and Macropores

Litter and root residue are the food earthworms need to proliferate. Their presence is rarely found in conventional dryland wheat summer fallow systems. After seven years of intensive cropping and more residue production, plots at Akron, CO, are finally showing the presence of earthworms. Their presence can be verified directly in the late spring since they are usually within the top foot of the soil, or can be verified from their castings which they leave behind on the soil surface. These earthworms to some extent through their mixing alleviate some of the problems of fertilizer stratification created by no-till systems. Macropores are usually created from the decaying roots under no-till conditions. These residue and decaying roots also serve to promote important fungal associations which increase water, phosphorus, and micronutrient uptake. Pores also increase infiltration rate, and worms may help to break plow pans.

Depth to Lime

Depth to lime is the depth where carbonates have been leached by rainfall over many centuries. This is also the depth into which the bulk of the roots proliferate (especially cereal roots), and can demarcate the boundary between the solum (A and B horizons) and the parent material (C horizon). In Colby soils, for instance , the depth to lime is 7 inches, the Weld, 20 inches, and the Rago, which has a buried horizon, 30 inches. The productivity of these soils is usually directly related to the depth to lime.

Fertility (Nitrates and Soil Organic Matter)

Fertility assessment is best carried out at a soil and plant testing laboratory. However, certain quick field tests exist for soil nitrates and SOM which can be used as surrogates of soil fertility in a comparative manner. Knowing the texture and the soil pH, the depth to lime, and the topography, the previous crop and yield, can assist in the interpretation of the nitrate and SOM levels. Soil can be taken from the top foot or two feet, and the nitrate and organic matter tested for those depths. A 1% SOM in the top 6 inches generally contributes about 20 to 30 lb of N to the crop. Double this amount is produced if the previous crop was a legume. Knowing that about 1.8 lb of N is required per bushel of wheat, one can estimate the N fertilizer needs based on N in the soil profile and organic matter N contribution.

Salinity (Electrical Conductivity)

Crops differ in their tolerance to salts. While beans are sensitive, wheat is more tolerant. Salts usually accumulate from fertilizers and manures, and at times from the natural geology (shales). Low areas can show salt crusting (white deposit, saline seeps); these areas are usually devoid of plants. If the water table is not near the surface, salts can be leached, and appropriate crops can be grown. Quick field tests with electrical conductivity probes exist for salt evaluation. Where manure is rarely used and the parent material is not overlain by shales, salinity does not present a problem.

Aggregate Stability and Infiltration

Soil aggregation is the process whereby primary soil particles (sand, silt, clay) are bound together, usually by substances derived from root and microbial activity. Its stability is based on its (the soil aggregate) resistance to withstand wind and water forces. Thus, stable aggregates are less erosive, reduce crusting and increase water infiltration. Field tests usually employ dry sieving or aggregate disintegration in water. While some turbidity evaluation can be visually seen with the field test (grassland soils in water are less turbid than soils under cultivation) tests among cultivated sites are not as readily discerned and may require laboratory evaluation. Infiltration tests basically measure the time added water takes to disappear from the soil surface, and can indicate the presence of compaction or an impermeable subsurface layer.

Soil Quality Indices

Since many of the parameters (texture, pH, depth to lime) of a quality soil are difficult to alter, it would appear that the direction of change in certain intermediate-term parameters such as the SOM, aggregate stability and infiltration could serve as field indices. It is hoped that a useful indicator for the Great Plains can be obtained from a combination of the SOM, texture, and the depth to lime.

Measures to Improve SQ

Soil quality in the central Great Plains can be maintained or increased by: 1) increasing the cropping intensity from wheat-summer fallow to 4-year rotations, 2) decreasing or eliminating tillage, 3) increasing broadleaves and legumes in the rotation, 4) proper fertilization and pest control, (weeds as a major one since 4-year rotations usually minimize insect and disease problems) and 5) proper sequencing for water use. We need a system whereby we keep as much cover and residue on the soil surface as possible. We cannot improve soil structure, stable aggregates, and increase water infiltration unless we build SOM; we cannot build SOM unless we produce and conserve more crop residue; and we cannot build crop residue unless we capture and conserve more water, and use that water efficiently.