

Selecting Soil Health Indicators

Once you understand the principles of soil health, how do you know if you have healthy soil and how do you track changes? The answer depends on why soil health is important to you and what you want to do with the information.

What do you want to do with the information?

Understand soil

Develop a sense of how healthy soil looks, feels, and acts

- Use a shovel
- Infiltration tests
- Rainfall simulation demonstrations
- Qualitative field assessments

Make management decisions

Choose measures that give you quick results, and that have science supporting the interpretation of those results. In fact, there is not yet much data behind using soil health indicators to make management decisions. Instead, we recommend other information sources with a longer history of management interpretation data.

- For fertilizer decisions: use standard soil nutrient tests, and consider check strips.
- For herbicide and pesticide decisions: use weed and pest monitoring
- For cover crop management decisions: consider soil moisture, equipment compatibility, compatibility with the crop rotation and herbicide program

Evaluate impact

Select indicators that match your soil management goal or motivation. Some examples of goals and metrics:

- SOC storage: measure SOM and SOC
- weed/pest management: measure pest levels, chemical use
- reduced inputs: calculate cost or amount of input relative to yield
- water management: less water stress (either excess or inadequate) relative to fields on similar soils
- field work or labor management: measure the window for field operations; track seasonal stress levels
- erosion: observe soil movement through sheet erosion, gullies, or wind.

Track progress

Desired outcomes can take a while. What are the “leading indicators” to tell you if you are moving in the right direction?

- Qualitative field assessments
- Track practices that are known to lead to desired outcomes: longer and more diverse rotations, longer cover throughout the year, use of animal grazing or manure, fewer tillage passes. On how many acres are they used? How are they performing?

For any particular indicator, there are multiple ways to measure it. Consider how much confidence you need in the results how to validate and interpret the results.

Select the right method

Precision

How much of a change will you consider meaningful?

Spatial and time scale of sampling

- If the measure varies a lot across a field or across the seasons or over the day or with weather (moisture conditions), then you need a lot more samples and need to sample at exactly the same time and place.
- Landscape position matters
- Are you making decisions about a single field or for managing programs across a large area. Even though we can't say a change is happening in a specific field, we can still say something about average impacts across a large area like a watershed.

Should I model or measure?

Models are simplified representations of how different parts of the real world are related to each other. (e.g. how are tillage and vegetation related to erosion rates?)

Models and measurement are used together.

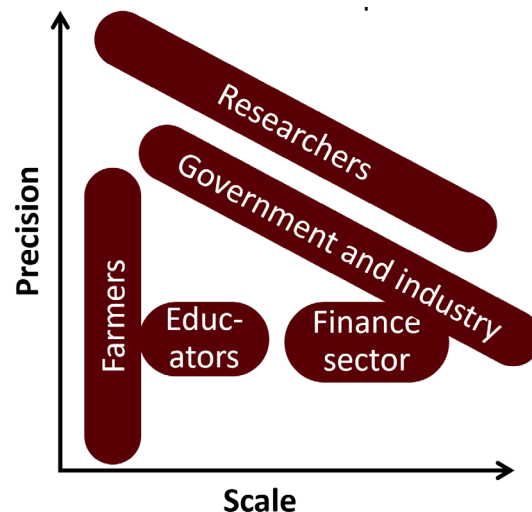
- E.g. measurements of soil P and K are put into a model to estimate whether crops will respond to fertilizer and how much fertilizer would be optimal.
- Real world measurements are needed to build and test the usefulness of models
- Models are used to extrapolate from a few measurements to estimate soil conditions across larger areas.

Standard for comparison

To interpret results, choose a standard for comparison, such as:

- Other measurements in similar landscapes. Consider soil type, and position on the hillslope
- Baseline measured on the same location before a management change
- An undisturbed site

Different interest groups measure soil health at different geographic scales and levels of precision



Why is soil health important: Four perspectives

How you measure soil health also depends on why soil health is important to you. The Minnesota Office for Soil Health led discussions with four different groups of people interested in soil health. They broadly agreed on the principles and general definitions of soil health, but when pressed for details, somewhat different goals and indicators emerged.

Farmers

Why are soil health indicators important?

- To focus management. Assessing soil health can help identify trouble spots that need attention, or processes that aren't working the way they should like soggy or dry areas, erosion, compaction, crusting, or nutrient availability.
- Farmers would like to use soil health indicators to help make management decisions about nutrients, weeds, tillage, crop varieties, or timing of operations.
- "Soil health" is a concept that non-farmers understand, so it can be useful for communication. Farmers may use soil health language to explain why they use certain practices or how their operation is changing.
- Soil health indicators can also be useful in showing industry and government what improvements have already been achieved on a farm.
- Some producers use soil indicators to track long term changes to ensure they are preserving or improving the productivity of their land for future farmers.
- To some producers, "soil health" and soil health indicators are not important. They prefer to focus on the practices that are successful for them.

Key indicators and considerations

- Think about your standard for comparison such as measuring a baseline and tracking change over time. Or having another site under different management for comparison each time you test. In both cases, It is critical to be consistent in the timing, location, and method of measurement.
- Is the soil moving? This is the first soil health indicator to address. Look for tillage erosion, water erosion, and wind erosion.
- Is production (relative to inputs) improving?
- Is profitability improving or more stable?
- Are yields less variable across a field and from year to year?
- Visual observations: shovel test, worm counts
- Indicators of soil structure: compaction, crusting, infiltration rates [need guidance on interpreting], standing water, ability to do field work soon after a rain or snowmelt, lack of ruts and traffic patterns.
- Indicators of water availability: crops tolerate drought and excess water conditions. Lower irrigation demand.
- Indicators of fertility potential: soil chemistry (nutrient levels, pH, salinity/sodicity); biological activity (C and N mineralization)
- Meeting management goals such as reduced weed pressure or reduced input costs.
- Soil organic matter is a core aspect of soil health, but it is a "lagging" indicator, meaning it is one of the last attributes to change. Also, it is hard to measure because it must be sampled down to at least 30" and account for changes in bulk density.

Food and agriculture industry

Why are soil health indicators important?

- Industry is a translator between farmers and the wider public, helping non-farmers understand agriculture.
- They want to track and demonstrate they are moving towards corporate sustainability goals. This requires aggregating progress at a regional scale. Tracking sustainability goals helps them demonstrate to suppliers, buyers, and the public that their business model is supporting healthy soil management.
- To make progress, they need to support farmers. This includes learning about farm-scale soil health indicators.
- Industry needs to manage risks to their supply chain and improve supply chain resilience.
- They also need to prove to themselves that investments in soil health yield business and environmental results.
- Companies working to build ecosystem services markets are essentially trying to sell soil function, whether that is storing carbon or protecting water quality.

Key indicators and considerations

- Industry works at many different scales. They may need information at a global scale, regional, watershed, atmosphere, or field. At the regional scale, they may want to track trends in farming practices, and the yield stability/resilience of their suppliers. At the farm scale, they may want to track impacts on birds, insects, or soil carbon.
- Modeling GHG impacts.
- Measuring soil organic carbon. Meaningful SOC measurement requires accounting for high variability across the landscape, changes in bulk density, and changes to depths of at least 30”.
- Modeling soil organic carbon.
- Indicators of carbon cycling (infiltration, POXC, Haney, deep SOC) require benchmarks for interpretation
- Remote sensing-based indicators.
- Track risk, e.g. farming practices vs. yield stability, production failures, or product quality
- Input and service providers need to study the section for farmers. At this point, soil health tests have limited payoff for making farm management decisions. It may be more informative to monitoring soil health outcomes (water movement, plant growth and tissue tests, erosion, weeds, pests, etc.).

State and local agencies

Why are soil health indicators important?

- Program design. Agency staff need to determine whether programs, rules, and incentives are indeed having the desired effects of reducing levels of nitrate, phosphorus, sediment in groundwater, lakes and streams. Changes in soil health may be measurable before changes are seen in water resources.
- Program implementation. Soil health considerations may be useful in ranking projects, conducting environmental reviews, and more.
- Demonstrate progress to taxpayers and other funders and decision-makers.
- Like industry, government is interested in developing marketplaces for ecosystem services including carbon storage.
- Like industry, government is interested in expanding practice adoption by supporting farmers management goals.

Key indicators and considerations

- Society-scale economics. What is the return on investments in soil health for preventing and treating water quality? For example, compare soil health management systems vs. nitrogen management vs structural practices.
- Farm-scale economics.
- Demonstrations of function such as infiltration and rainfall simulations. Like farmers, agency farm advisors need to be clear about whether their goal for soil health measurement is learning and facilitating conversations, or in informing farm management decisions.
- Nutrient budgets
- Water quality and quantity outcomes
- Residue management
- Number of acres and farms implementing key practices
- Persistence of practices after the end of a program

Researchers and Extension

Why are soil health indicators important?

- Measure impacts of agronomic practices on water quality/quantity attributes.
- Explain how land management impacts land productivity and water resource outcomes.
- Provide guidance to farmers on the full range of practical agronomic issues.

Key indicators and considerations

- High priority indicators and methodologies have been identified by the USDA Natural Resources Conservation Service and the Soil Health Institute. See also, the umbrella review of indicator research written by Dr. Hava Blair.
- Research is needed to correlate soil health metrics to management decisions related to crop diseases, weed dynamics, and soil fertility.
- Research is needed to define the mechanisms linking soil metrics to soil functions.