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Measuring Soil Quality: Indicators of Soil Quality - Developing a Quantitative Index

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From ON- CENTER- Updates and news items concerning sustainability issues in Washington State from the Washington State University Center or Sustaining Agriculture and Natural Resources WSU CSANR (Special to the Tilth Producers Quarterly)

In my last article, I proposed that soil quality is essentially a value judgment about the fitness of the soil for a particular use rather than an inherent property. There are numerous ways to evaluate soil quality and none are universally accepted. Most approaches rely on a set of soil quality indicators. These indicators generally describe specific soil properties or attributes. Indicators can be sensory, physical, chemical and biological. Soil quality assessments often rely on indicators from several of these categories, and one of the challenges is how to integrate them together. The use of a quantitative index is described in this article as one approach for doing this.

Indicators and Functions
A sensory indicator, such as visual condition, is simple to use. One may see gullies in a field after a rain, or changes in soil color by depth. Taking photographs of the same location over time can be a useful method for tracking soil quality change.

Physical indicators reflect the size, stability, and arrangement of the soil particles and soil pore space. These properties directly influence water relations, gas exchange, resistance to degradation, and root growth. Often physical indicators such as water infiltration are used to integrate several of the properties and provide information on a process important for human use.

Most of us are familiar with chemical indicators, such as the analytical tests done in a normal soil test. These indicate current nutrient status, organic matter level, pH, salinity, and cation exchange capacity. Tests can be done for the presence of contaminants which might be an important indicator for a particular site. Chemical processes such as leaching can also be measured.

There is increasing interest in biological indicators of soil quality. These can include measurements of the kind and numbers of microbes and macro-fauna (e.g. springtails, earthworms), their activity, and their by-products. The soil food web is often used to find a trophic level that will yield the most useful information. Many indirect tests are used for microbial status (e.g. respiration, enzymes) and function (e.g. nitrogen mineralization, organic matter decomposition).

The choice of indicators is based on the particular soil functions of interest. These functions include:

• providing suitable conditions (physical, chemical, bio- logical) for organisms to live in the soil

• providing mechanical support for living organisms (e.g. roots for trees)

• storing and cycling nutrients and other elements

• regulating the water cycle

• supporting biological activity and diversity for plant and animal productivity

• acting as an environmental filter for organic and inorganic materials (e.g. pesticide breakdown).

Most people are interested in more than one function and thus indicators that reflect on several functions are helpful.

Approaches to Measuring Soil Quality — An Integrative Index
Wouldn't it be nice if, when we went to the doctor, he or she could give us a single number that indicates our health status! The same desire exists for measuring soil quality, but so far, this has been difficult to achieve for both situations. Most of the time we go through a battery of tests at the doctor. If one or two results fall outside a range considered normal (based on previous research), then we discuss possible corrective action. Similarly, many studies of soil quality rely on a battery of tests (often different from study to study as no consensus exists on the best set). Results are generally compared across the experimental treatments (e.g. different tillage, different rotation) to see how the treatments affected the soil quality indicators. But it may be hard to substantiate that one soil is "better" than another.

Researchers have proposed various soil quality index schemes to attempt to integrate information from multiple indicators. Several years ago, Jerry Glover, John Reganold, and Preston Andrews from Washington State University developed a quantitative soil quality index (Glover et al., 2000). Their system, described below, illustrates the many challenges of developing an index. They had a replicated field experiment with three different management systems and they collected data for the index after four years.

The first step is to determine the framework, or se- lect the soil functions of interest. They chose four functions:

• accommodate water entry

• facilitate water movement and availability

• resist surface structure degradation

• sustain fruit quality and productivity

Each function received a weight of 0.25 so that the "perfect" soil would get a score of 1.0. Then for each function, a set of level 1 indicators was developed. For example, for "accommodate water entry", the indicators chosen were:

• aggregate stability (0-7.5cm) 0.40

• bulk density (0-7.5cm) 0.40

• earthworms (0-7.5) 0.20

Each of these indicators was directly measured.

So a scoring function needed to be developed for each, which was probably the most challenging and data intensive aspect of the index approach. For a given indicator, the scoring must reflect whether higher numbers are better, lower numbers are better, or if there is an optimal zone between low and high. The shape of the response curve must be determined (straight-line, sigmoid curve, bell curve) and lower and upper threshold and baseline values must be set. Once done, a specific measurement from the field can be placed on the appropriate curve to produce a normalized score that is combined with all the other scores.

Some indicators were used in more than one function (e.g. earthworms). The level 1 indicator “microbial processes” was made up of three level 2 indicators, which were the actual measurements. All these received a weighting (see above) which was multiplied by the score to come up with a value for the final calculation.

As you can see, there is a large degree of subjectivity that goes into creating a quantitative index. What functions do you choose? What indicators? What scoring functions? What weighting? This approach is particularly well-suited to comparing different treatments within the same study where intensive data collection is occurring. And the integration of several test results into a score makes interpretation much easier.

The results of the study are summarized below in Table 1. It is helpful to see how different aspects of soil quality are affected by management. The addition of organic amendments in the Integrated and Organic treatments, but not in the Conventional, improved water entry and resistance to degradation in the former compared to the latter (not always statistically significant) . But the use of tillage in Organic (versus some herbicide in Integrated) had a negative effect on both water transfer and resistance to degradation. Overall, this index suggests that the Integrated system has soil quality advantages over the other two systems and that increasing organic matter inputs and reducing tillage are key aspects.

Table 1. Soil quality index for three orchard management systems in Zillah, Washington.

Function	Conventional	Integrated	Organic
Water entry	0.153a	0.235b	0.213ab
Water transfer	0.208a*	0.235a	0.205a
Resist degradation	0.185a	0.245a	0.225a
Sustain productivity	0.225ab	0.213a	0.238b
Total	0.783a	0.923b	0.878ab

Means in a row with the same letter are not signficantly different (0.05).

Summary

While most people cannot make direct use of a quantitative soil quality index as illustrated above for their own measurements, many studies have been done that pro- vide quantitative soil quality comparisons for various systems, soils, and locations. These results can be useful to growers in evaluating their own situations and choosing their own indicators to track over time. In the next article, I will describe another soil quality evaluation system that may be increasingly useful in the future.

References

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