Indicator	Test	Function
B	F	D/N

Soil Quality Indicators

Soil Respiration

Carbon dioxide (CO_2) release from the soil surface is referred to as soil respiration. This CO_2 results from several sources, including aerobic microbial decomposition of soil organic matter (SOM) to obtain energy for their growth and functioning (microbial respiration), plant root and faunal respiration, and eventually from the dissolution of carbonates in soil solution. Soil respiration is one measure of biological activity and decomposition. The rate of CO_2 release is expressed as CO_2-C lbs/acre/day (or kg/ha/d). It can be measured by simple field methods (e.g. fig. 1) or more sophisticated field and laboratory methods. During the decomposition of SOM, organic nutrients contained in organic matter (e.g., organic phosphorus, nitrogen, and sulfur) are converted to inorganic forms that are available for plant uptake. This conversion is known as mineralization. Soil respiration is also known as carbon mineralization.

Figure 1. Draeger-Tubes® are used to measure CO_2 released from the soil surface as an indicator of decomposition and soil respiration.

Factors Affecting

Inherent - Like all organisms, soil microbes have optimal conditions in which they thrive. Soil respiration rate depends on the amount and quality of SOM, temperature, moisture, and aeration. Biological activity of soil organisms varies seasonally, as well as daily. Microbial respiration more than doubles for every 10°C rise up to an optimum of about 35 to 40°C (95 to 104°F), beyond which high temperature becomes limiting. On the other hand, SOM decomposition and microbial activity virtually cease below about 5°C (41°F) (biological zero).

Soil respiration increases with increasing soil moisture up to the level where low oxygen concentration (lack of aeration) interferes with an organism's ability to respire (fig. 2) The optimum soil moisture content for soil respiration varies from site to site, but values as high as 60% water- filled pore space have been reported. In dry soils, respiration declines because the soil moisture deficit limits microbial activity. Conversely, in extremely wet soils, low oxygen levels results in poor organic matter decomposition and respiration rates. In these soils, anaerobic by-products are produced, such as methane or sulfides. Medium textured soils (silt soils) are often favorable to soil respiration because of their good aeration and moisture content. In clay soils, a sizeable amount of SOM is protected from decomposition by clay particles and other aggregates. In reality, soil respiration responds to the coupled action of temperature and moisture, especially to the most limiting of either factor.

Dynamic - Soil management practices that affect SOM, moisture, aggregation, and pH influence soil respiration. Practices that leave crop residues at the soil surface, such as no-till, use of cover crops, or other practices that add organic matter, usually promote soil respiration. Crop residues with a low carbon to nitrogen (C:N) ratio, such as that from legumes, decompose faster and produce higher CO_2 rates than residues with a high C:N ratio (e.g. wheat straw). High C:N ratio crops coupled with added N (from any source) increase decomposition and accrual of SOM. Practices that increase SOM also improve soil aggregation and porosity, and therefore, aeration and soil moisture content. Conversely, continuous cultivation and other conventional tillage methods that remove, bury, or burn crop residues diminish SOM content and microbial activity by reducing aggregate stability and porosity, and increasing erosion of surface layers that are normally highest in SOM and populations of organisms that are the key to soil respiration. Irrigation in dry conditions and drainage of wet soils can significantly boost soil respiration.

Soil pH regulates nutrient availability and distribution, activity of soil organisms responsible for SOM decomposition, and other processes contributing to soil respiration. Chemical fertilizer may stimulate root growth and nourish microbes; however, at high concentrations, some fertilizers can become harmful to microbes responsible for soil respiration because of changes in pH and their potential toxicity. Similarly, organic amendments with high concentrations of heavy metals, as well as pesticides and fungicides, may be toxic to microbial populations leading to reduced microbial diversity, abundance, and respiration.

Relationship to Soil Function

Soil respiration reflects the capacity of soil to support soil life including crops, soil animals, and microorganisms. It describes the level of microbial activity, SOM content and its decomposition. In the laboratory, soil respiration can be used to estimate soil microbial biomass and make some inference about nutrient cycling in the soil. Soil respiration also provides an indication of the soil's ability to sustain plant growth. Excessive respiration and SOM decomposition usually occurs after tillage due to destruction of soil aggregates that previously protected SOM and increased soil aeration. Depleted SOM, reduced soil aggregation, and limited nutrient availability for plants and microorganisms can result in reduced crop production in the absence of additional inputs. The threshold between accumulation and loss of organic matter is difficult to predict without knowledge of the amount of carbon added.

Problems with Poor Function

Reduced soil respiration rates indicate that there is little or no SOM or aerobic microbial activity in the soil. It may also signify that soil properties that contribute to soil respiration (soil temperature, moisture, aeration, available N) are limiting biological activity and SOM decomposition. With reduced soil respiration, nutrients are not released from SOM to feed plants and soil organisms. This affects plant root respiration, which can result in the death of the plants. Incomplete mineralization of SOM often occurs in saturated or flooded soils, resulting in the formation of compounds that are harmful to plant roots, (e.g. methane and alcohol). In such anaerobic environments, denitrification and sulfur volatilization usually occur, contributing to greenhouse gas emissions and acid deposition.

Improving Soil Respiration

The rate of soil respiration under favorable temperature and moisture conditions is generally limited by the supply of SOM. Agricultural practices that increase SOM usually enhance soil respiration. The following practices have the potential to significantly improve SOM and indirectly soil respiration when other factors are at an optimum:

- Conservation tillage (no-till, strip-till, mulch till, etc.)
- Application of manure and other organic by-products
- Rotations with high residue and deep-rooted crops
- Cover and green manure crops
- Irrigation or drainage
- Controlled traffic

Measuring Soil Respiration

Soil respiration is measured using the Draeger-Tube® method described in the Soil Quality Test Kit Guide, Chapter 2, p 4 - 6. See Section II, Chapter 1, p 52 - 54 for interpretation of results.

References:

Parkin TB, Doran JW, and Franco-Vizcaíno E. 1996. Field and Laboratory Tests of Soil Respiration. In: Doran JW, Jones AJ, editors. Methods for assessing soil quality. Madison, WI. p 231-45.

Zibilske LM. 1994. Carbon Mineralization. In: Weaver WRW et al., editors. Methods of soil analysis. Part 2. Microbiological and biochemical properties. Madison, WI. p 835-63.

Buchmann N. 2000. Biotic and abiotic factors controlling soil respiration rates in *Picea abies* stands. Soil Biology and Biochemistry 32:1625-35.

Specialized equipment, shortcuts, tips:

Draeger-Tubes® (fig. 1) contain chemical reagents that change color in the presence of CO_2. The length of the color change indicates the measured concentration of CO_2. Before using a Draeger-Tube®, check its expiration date and always store them at the recommended temperature. Another popular assessment method is the Solvita® Soil test. *Mention of commercial products does not constitute an official endorsement by the U.S. Department of Agriculture.*

Time needed: 30 minutes

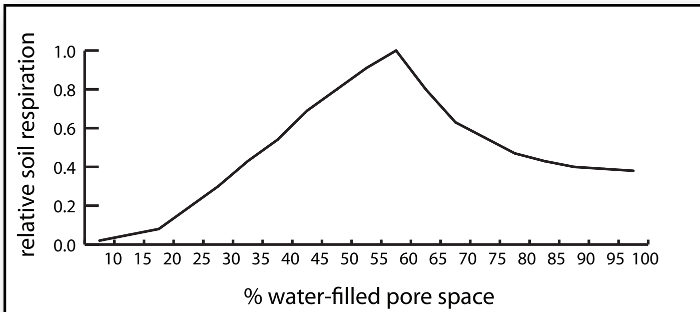

Figure 2. Soil respiration in relationship to water-filled pore space. After Parkin et al., 1996.