Soil Respiration

Introduction

Soil organic carbon (SOC) represents the carbon (C) component of organic matter in the soil. On average, SOC makes up about 55-60% of the organic matter but this percentage can vary depending on the origin of organic matter and the type of soil. Soil organic carbon is an essential soil health indicator, affecting soil's biological, chemical, and physical properties. The breakdown of SOC by plants, microbes, and other organisms causes the release of carbon as carbon dioxide (CO_2). This release, known as soil respiration, is a key part of the global carbon cycle. This factsheet explains the importance of soil respiration for soil health and biological activity and the influence of environmental factors and management practices on soil respiration.

Importance of Soil Respiration

Soil respiration is influenced by environmental factors such as temperature and moisture, as well as field management practices like tillage and irrigation (Figure 1).

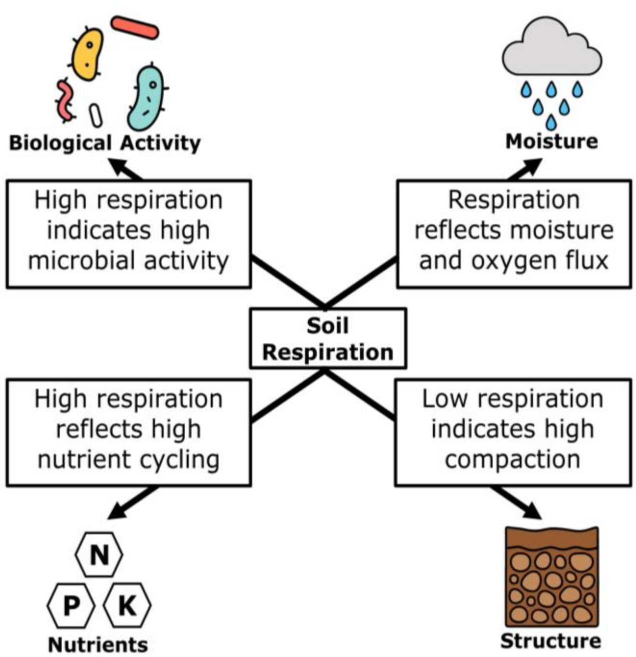

Figure 1: Relation of soil respiration with soil functions.

Because of the relationships between soil respiration, environmental and management practices, soil respiration measurements can provide useful insights into overall soil quality and help identify areas of a field that may need management changes to maximize production potential.

Management Practices

Field management practices can affect soil respiration in different ways, and the following are some examples:

1. Tillage affects soil structure and aeration, influencing microbial activity and soil respiration. Poor aeration can slow decomposition and nutrient cycling and result in carbon buildup. Intensive tillage disrupts soil aggregates, increasing short-term respiration but weakening structure and raising erosion risk over time.
2. Organic amendments supply soil with nutrients and carbon that support microbial activity and respiration. No-to-little amendment use may restrict nutrient availability and microbial activity, while too much can lead to nutrient imbalances or oxygen depletion, reducing soil respiration efficiency.
3. Crop rotation and cover cropping can provide soil structure and carbon inputs that support soil microbes and influence respiration rates. Leaving fields bare (no crop residue or cover crops) and poor root diversity reduce microbial substrates and soil respiration.
4. Pesticide use can affect microbial communities and soil's biological processes. High, untreated, pest pressure may reduce plant productivity, indirectly limiting root-derived carbon for microbes. On the other hand, excessive pesticide application can harm beneficial microbes and disrupt soil biota, decreasing microbial respiration.
5. Irrigation influences microbial activity and oxygen availability, both important for respiration. Too little soil moisture limits

microbial activity, decreasing respiration. Excessive moisture waterlogs soil and restricts oxygen diffusion, also decreasing respiration. An appropriate amount of moisture will stimulate soil microorganisms, increasing respiration in the short term.

Soil Respiration Testing

Soil respiration can be measured in the field and in the laboratory. Methods vary but laboratory measurements typically start with soil sampling, drying, and then rewetting followed by the measurement of CO_2 after 1-4 days of incubation. Soil sampling instructions for soil respiration typically suggest combining samples across an area of interest into one composite sample or consistently sampling locations within a field (separate samples) to take into account differences in topography and management practices.

Respiration tests can be sensitive to sampling method (depth, time, moisture, etc.) so sampling consistency is essential for interpretation of the results. Because soil health indicators, including soil respiration, are often slow to change with change in management, sampling across years may be necessary to see significant change.

Soil respiration results vary across methods, but results can typically be classified into three levels linking them to soil properties. (Table 1).

Table 1: General soil respiration interpretations.

Respiration Level	Soil Properties
Low	Poor soil health. Possibly too cold, dry, wet (e.g. compacted soil)
Medium	Suboptimal soil health. Likely stable and usable soil, but not ideal (e.g. need for crop diversity, proper drainage)
High	Healthy, fertile soil with sufficient organic matter and moisture. Can occur after input (e.g. manure/compost addition, conservation tillage) and rainfall

Soil sample preparation considerations

While testing methods use similar approaches, differences in each step in the method can impact soil respiration test results. Proper sample preparation and understanding of key differences will help with result interpretation:

1. Sampling depth affects the abundance of organic material, microbes, and moisture. For microbial activity related tests, sampling the top 0-4 inches (0-10 cm) is recommended. Sampling too shallow may result in failure to capture biological activity whereas sampling too deep can dilute biologically active soil with less biologically active soil.
2. Proper storage and handling of soil samples is critical. Soil samples should be air-dried, or oven- dried below 60°C as soon as possible after sample collection. This stabilizes the sample and prevents further change during sample storage without destruction of the organic matter in the sample.
3. Homogenizing samples is needed for laboratory testing. Large clumps should be broken down to form thin layers so that drying takes place evenly.
4. Length of incubation determines total CO_2 measured from microbial and root respiration. It is important to use the same laboratory and protocol each time a soil respiration test is conducted to properly interpret changes over time

In Summary

Soil respiration gives insight into soil microbial health of a field or location within a field. Respiration tests conducted in the laboratory based on the flush of CO_2 during the first few days following rewetting strongly relate to the nitrogen supplying capacity of soil, soil aggregation development, and potentially to soil biological diversity.

Additional Resources

- Karlen, D. L., Scott, D.E., Mikha, M.M. and Moebius-Clune, B.N. (2021). Soil health series. USDA Natural Resources Conservation Service.

Disclaimer

For more information

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