Soil Quality Indicators

Reactive Carbon

Soil organic matter (SOM) contains C compounds with different levels of degradability, from very easily decomposable to extremely resistant (recalcitrant) to decomposition. Each C component has a different residence time in the soil and performs different functions. Reactive carbon (RC), also known as permanganate oxidizable carbon (POxC), is a fraction of the SOM pool that is oxidizable in the presence of potassium permanganate in solution. Carbon oxidized by this compound includes the C most readily degradable by microorganisms as well as that bound to soil minerals, making RC interpretation somewhat difficult. Because of this association to the mineral fraction, RC is considered a chemical indicator, not a biological indicator. Nevertheless, a recent research project conducted across a range of environments and management conditions (12 studies) showed that POxC was significantly related to particulate organic carbon, soil microbial biomass carbon (BMC), and, in one study, soil organic carbon.

The residence time of RC is estimated to be 2 to 5 years, in contrast to recalcitrant C (e.g., humus) that has a turnover time of several hundred to thousands of years. Reactive carbon originates from the various fractions of SOM. These fractions include fresh organic material, soil microbial biomass, particulate organic matter, and other easily metabolized organic compounds, such as carbohydrates (sugars) and proteins (amino acids), as well as C loosely bound to soil minerals. Because of its relatively short turnover time, RC is more sensitive to management changes affecting soil C in agro-ecosystems than total organic carbon (TOC). Reactive carbon may be used as an indicator of change produced by cropping and soil management practices that manipulate SOM content.

Factors Affecting

Inherent — Soil climatic conditions (soil moisture and temperature) influence the mineralization rates of organic carbon and, concomitantly, the accumulation or decline of the quantity of RC in SOM. Clay minerals can strongly bind SOM and so protect that organic matter and the associated RC from rapid mineralization, whereas sand and silt are non-binding. Very poor drainage creates anaerobic conditions that favor the formation of methane (CH_4), inducing a systemic loss of carbon and decline in TOC and RC contents.

Dynamic — Figure 1 shows a significant positive relationship between TOC and RC, with POxC increasing with increasing TOC content, which occurred in one study. In recent studies however, the relationship was not so strong. Similarly, a positive relationship between RC, microbial biomass levels, and aggregate stability has been reported in the literature. The beneficial effect of SOM on aggregate formation is well established. These relationships may be due to the accumulation of carbon inside the aggregates, where it is protected from oxidation.

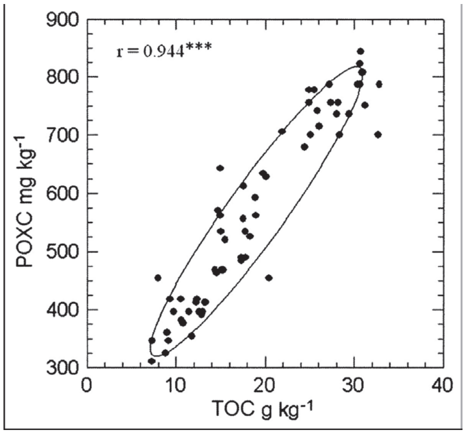

Figure 1. Relationship between total organic carbon (TOC) and permanganate oxidizable carbon (POXC) (adapted from Lucas and Weil, 2012).

Relationship to Soil Function

It is well documented that many soil functions are strongly influenced by SOM and, due to its association with TOC and microbial biomass, are likely to be related to RC as well. However, as the exact nature of the C fraction extracted by the potassium permanganate oxidation method has not been fully characterized, the functions affected must be addressed in general terms. Enhanced water aggregate stability by high levels of SOM (and, concomitantly, high levels of RC) improves water infiltration, reducing soil degradation by water and wind erosion. Reactive carbon is linked to a number of soil processes, including microbial biomass growth/activity and nutrient cycling. Researchers have found that POxC is significantly related to MBC and in few cases SOC and, thus, may be equally well suited to track management practices that promote C sequestration.

Problems with Poor Activity

Due to the relatively short turnover time of RC, significant decreases in RC may signal a decline in SOM and indicate the deterioration of physical, chemical, and biological properties and processes related to SOM. The adverse effects caused by the decline in RC include reduced aggregate stability, increased bulk density, and reduced water infiltration, water-holding capacity, microbial activity, and nutrient availability.

Improving Management

All practices that increase SOM will likely increase RC. Figure 2 shows changes in RC content under two different soil management practices. As expected, no-till (NT) resulted in a significant increase in SOM and RC when compared to conventional tillage (CT). Some practices beneficial for increasing SOM (and potentially RC) are:

- Reduced tillage (no-till);
- Adoption of crop rotations, cover crops, or other crop diversity measures;
- Addition of manure, fresh residues, and compost; or
- Combinations of the above.

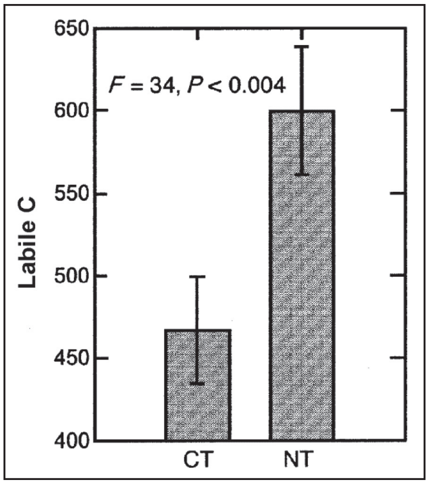

Figure 2. Effects of soil tillages on labile carbon (adapted from Weil et al., 2003). CT=conventional tillage; NT=no-till.

Measuring and Interpreting

The potassium permanganate oxidation method is currently used to measure reactive carbon. See the NRCS Active Carbon Field Test Kit (contact the Kellogg National Soil Survey Laboratory in Lincoln, Nebraska, for more information). Cornell University has developed a scoring curve (only valid for the region of New York) based on the research work of Andrews et al. (2004) to interpret soil quality indicator values for RC in the New York area. Figure 3 shows the scoring for RC (red=constraint, yellow=potential constraint, blue=no constraint).

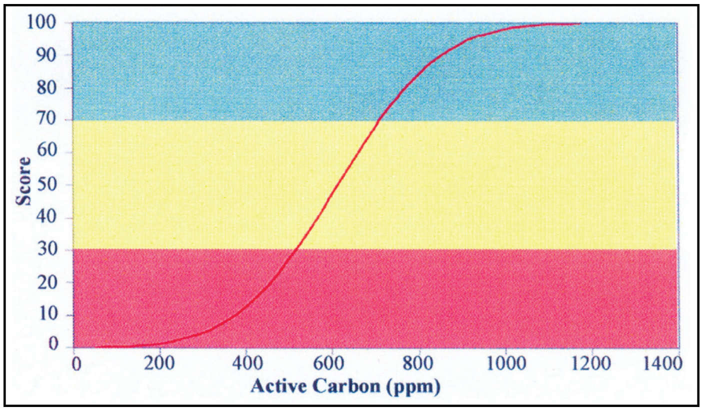

Figure 3. Reactive carbon interpretation (Cornell University Soil Health, unpublished).

References

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