Laboratory Tests for Soil Carbon

Introduction

Carbon moves constantly between the atmosphere, plants, and soil in what is known as the carbon cycle. Plants, in the presence of sunlight, use carbon dioxide and water to make sugars (carbohydrates) via photosynthesis. Carbon enters the soil from decaying plant matter and via animal excreta. Plant roots actively exude carbon and living organisms in the soil excrete carbon, both processes providing a food source for soil microbes. These microbes release carbon back into the atmosphere via respiration, although some carbon remains in the soil and binds soil minerals, forming soil aggregates which are protected from decomposition. Gain and loss of carbon in soils depends on the balance of photosynthesis by plants and respiration by soil and plants.

Soil carbon (as the most dominant component of soil organic matter) has many beneficial effects on soils: improving soil structure and texture which improves water holding capacity; retention of nutrients resulting in greater growth of plants; allows plant roots to penetrate soil more easily and reduces erosion therefore improving water quality of surface and ground water. In summary organic matter improves productivity and lessens negative impacts on the ecosystem. New Zealand topsoils are generally quite high in soil carbon compared to other countries, with an average of 90 – 100 tC/ha when measured to 30cm depth.

Factors that interact to determine the amount of soil carbon stored in the soil include soil type, topography, climate, and land-use practices. Depletion of soil carbon over time signals changes that may lead to poor productivity and consequential negative impacts on a range of soil properties.

This technical note outlines the tests available at Hill Labs for measuring carbon contents in agricultural soils and should be read in conjunction with Technical Note – Assessing Soil Quality (The Organic Soil profile).

All agriculture soil sample jobs requesting Total Carbon and/or Hot Water Extractable Carbon tests are now measured by Near Infra-Red Spectroscopy (NIRS). Sample types with carbon content which cannot be accurately predicted by NIRS are “code-swapped” to the Dumas combustion method. Refer to Hill Labs Technical Note: Analysis of Soils Using Near Infra-Red Spectroscopy (NIRS) for a detailed discussion on this technique for soil carbon tests. The conventional reference method (wet chemistry) tests are available on request, at a small additional charge.

Total Carbon (tC) and Organic Matter (OM)

The total Carbon (tC) test measures the entire pool of carbon in the <2mm dried and sieved sample and does not differentiate between forms of carbon present. The tC test is used to calculate the Carbon:Nitrogen (CN) ratio of soils as well as used to calculate soil organic matter. The convention in New Zealand whereby tC is used to calculate Organic Matter in agriculture soils is acceptable since NZ soils are generally very low in carbonates. If soils contain significant concentration of carbonates, the alternate Total Organic Carbon (TOC) test should be used.

It is important to understand the naturally high spatial variation in many soils (by location and sample depth), and to recognise the test is carried out on the <2mm soil fraction. A robust and reproducible sampling protocol would be required to evaluate soil carbon stocks at a paddock or block scale.

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General interpretive guidelines are shown in the table below.

Level	Organic C (%)	Organic Matter (%)
Very Low	< 2	< 3
Low	2 – 4	3 – 7
Medium	4 – 10	7 – 17
High	10 – 20	17 – 35
Very High	> 20	>35

Reference Method

Total Carbon is determined by the Dumas method of combustion, using dry soil that has been passed through a 2mm sieve (<2mm fraction). Each sample is combusted to produce varying proportions of CH4 and CO gas. The CH4 and CO gas is oxidised to CO2 using the catalysts Copper Oxide and Platinum. The CO2 is then measured using a Thermal Conductivity detector.

The total C measured is converted to organic matter using the Van Bremmelen factor of 1.724 (based on the assumption that soil organic matter contains 58% C)

Organic Matter (%) = Organic Carbon (%) x 1.72 [where tC is substituted for OC in NZ soils]

Total Organic Carbon (TOC)

Prior to analysis for Total Carbon, the sample is acidified. This causes the inorganic carbon, commonly found in the form of carbonates, to be removed from the sample as CO_2. By analysing the Total Carbon, and subtracting the TOC, the Total Inorganic Carbon levels can be determined.

A preliminary “fizz test” is used to determine the sample weight used in the method for TOC, to ensure an adequate acid pre-treatment to remove any carbonates present in the soil. For soils with high shell content, the acid pre-treatment may be insufficient to fully remove the carbonate in the shell fraction and therefore could overestimate TOC, so an alternate method is required in that instance.

Hot Water Extractable Carbon (HWEC)

For many years the total organic matter and the C:N ratio (determined from total carbon and total nitrogen) have been used as a guide to soil quality and the likely rate of organic matter mineralisation. These are imprecise indicators however, as small changes in the quantity and nature of the soil organic matter can substantially affect soil quality and fertility.

A better determinant of soil quality is soil microbial biomass carbon (MBC). Soil microbial biomass carbon has been shown to be sensitive to changes in soil management, but analysis of soil MBC is time-consuming and expensive. Studies by Ghani et al. have shown that Hot Water Extractable Carbon (HWEC), the labile fraction of the soil organic carbon pool, correlates strongly with microbial biomass carbon. Most agricultural soils in New Zealand contain between 2 to 6 % of the tC as HWEC. Hill Laboratories are now offering the HWEC test as a surrogate of microbial biomass carbon. An estimated soil microbial biomass carbon (MBC_{est}) value will be reported using this correlation equation:

$$MBC_{est} = HWEC\ (mg/kg) \times 0.13 + 26$$

Note that the MBC is of lower magnitude than the HWEC test fraction. This is because the hot water extraction test, as a measure of the labile C pool in soils, will include C from soluble carbohydrates, amino acids and root exudates as well as from microbial sources. Studies have shown MBC to range from 80 – 1200 mg C/kg in topsoils.

The correlation equation above is obtained from comparison of the HWEC test with measured MBC using the fumigation and extraction difference method. Some researchers use a correction (k) factor when reporting MBC, in the assumption that the fumigation may not flush all of the microbial carbon. A k factor of 0.4 or 0.5 has been cited. The above equation would not be valid (to compare MBC values) where different methods have been used.

The HWEC test provides a robust measure of the labile fractions of soil C. It has been shown to be sensitive to subtle changes in soil quality that occur due to farm management practices. Researchers have shown the HWEC content in soils is sensitive to changes due to fertilisation and grazing as well as physical modification to soils e.g. humping/hollowing and flipping.

Differences between ecosystems have also been described using HWEC in soils. HWEC concentration is generally higher in low intensity soil-plant systems than those under intensive usage, following a decreasing pattern for soils: native>drystock>dairy>cropping>market gardens (for the same soil type).

Studies by Ghani et al (2003) and Sparling et al. (1998) indicate that the HWEC in soils is also strongly correlated with anaerobic mineralisable nitrogen and total soil carbohydrate levels. The latter is responsible for soil aggregation. It is likely that a decline in HWEC will also indicate a decline in the biological activity and organic matter bound labile nutrients such as nitrogen, sulphur and to some extent phosphorus.

The interpretation of most soil tests must also consider impact of temporal and spatial variability on its concentration, therefore it is recommended that monitoring for soil quality using HWEC as a test for soil biological quality along with the more traditional tests be carried out on samples collected at the same time of year, and in similar environmental conditions. Record-keeping to retain this information will be helpful in understanding trends over time and the impact of changing farm practices (and perhaps climate change) to underpin sustainable farm management. Typical measurements for HWEC in New Zealand soils range from 500-13000 mg/kg, but general interpretive ranges are shown in the following table.

Level	**Hot Water Extractable C (mg/kg)**
Very Low	<350
Low	350- 1000
Medium	1000-3500
High	3500-7500
Very High	>7500

Method

A sub-sample of dry, sieved (<2mm) soil is extracted in hot water overnight, then filtered and the filtrate measured by TOC analyser as non-purgable organic carbon. Using the dried and sieved soil as used for other standard nutrient tests is an accepted modification to the reference method as described by Ghani et al. This compromise means the test can be offered routinely and can be interpreted alongside the other reported soil quality tests, as all are carried out on the same prepared sub-sample.

References

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