



TECHNICAL NOTE

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 to soil minerals forming soil aggregates which are protected from decomposition.

In this way soil carbon (as organic matter) has many beneficial effects on soils: improving soil structure and texture which improves water holding capacity, reduces erosion and allows plant roots to penetrate soil more easily. Organic matter also provides a source of plant nutrients.

Factors that interact to determine the amount of soil carbon stored in the soil include soil type, climate, and land-use practices. An increased importance on managing soil carbon is due to the fact that soil-carbon depletion can cause an increase in greenhouse gas emissions.

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

All agriculture soil samples requesting Total Carbon are analysed 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 Laboratories Technical Note: Analysis of Soils Using Near Infra-Red Spectroscopy (NIRS) for a detailed discussion on this technique for soil carbon tests. The conventional 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 Total C is used to calculate Organic Matter in agriculture soils is acceptable since NZ soils are generally very low in carbonates. Where soils contain significant carbonates, the alternate Total Organic Carbon (TOC) test should be used.

The total carbon test is often used as a means for evaluating carbon stocks and sometimes for the purposes of carbon trading. It is important to understand the naturally high spatial variation in many soils (by location and sample depth), and also to recognise the test is carried out on the <2mm soil fraction if using the total carbon test for this purpose. A robust and reproducible sampling protocol would be required. 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

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 CO₂. 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 sample.

For samples 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 fairly 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. Soil microbial biomass has been shown to be sensitive to changes in soil management, but analysis of soil microbial biomass is time-consuming and expensive. Trials 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 C. HWEC is now offered by Hill Laboratories.

The Hot Water Extractable Carbon (HWEC) test provides a robust measure of the more labile soil carbon fraction, and has been shown to be sensitive to subtle changes in soil quality that occur due to farm management practices and climactic effects.

Researchers have shown the HWEC test to be an indicator that 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, whereby HWEC 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 indicate the HWEC test is highly correlated with microbial biomass carbon, anaerobic mineralisable nitrogen and total soil carbohydrate levels. It is likely that a decline in HWEC will also indicate a decline in the other labile (biologically active) nutrient pools of nitrogen, sulphur and phosphorus.

Because interpretation of most soil tests must also consider temporal and spatial variability, it is recommended that monitoring for soil quality using HWEC 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



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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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