Technical Note

ASSESSING SOIL QUALITY

THE ORGANIC SOIL PROFILE

Introduction

The Organic Soil Profile is offered in response to the growing demand for soil tests to provide more than just the adequacy/deficiency status of selected key nutrients. Growing concern about the biological health of the soil and sustainable farming practices has resulted in offering this new profile, which is intended to shed light on these important soil properties.

What is soil quality?

For agricultural and horticultural production systems, soil quality is a combination of *physical properties* such as soil texture, *chemical properties* such as pH and mineral nutrient content, and *biological properties* including living biomass and mineralisable N. All of these properties are profoundly influenced by the soil organic matter.

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.

The Basic Soil Profile reports *chemical properties* related to soil quality, namely pH, cation exchange capacity (CEC) and extractable nutrients. The new **Organic Soil Profile (OrgSP)** includes some additional tests that allow an assessment of the *biological properties.* Together, these soil profiles provide a minimum dataset for estimating and monitoring soil quality or health. The new OrgSP profile focuses on the soil organic matter fraction and comprises the following tests:

- organic matter (total carbon)
- anaerobically mineralisable nitrogen (potentially available nitrogen)
- total nitrogen
- carbon:nitrogen ratio
- anaerobically mineralisable nitrogen:total nitrogen ratio

Organic matter

The Organic Matter (OM) level in the soil is strongly correlated to the soil's CEC, and is a source of many plant nutrients, particularly nitrogen. It also plays a major role in determining soil physical characteristics; soils with medium to high levels would generally be expected to have good structure, moisture retention and water infiltration.

The quantity and nature of organic matter is highly dependent upon farming practices and climatic conditions. Factors known to affect the build up or depletion of soil organic matter are listed below:

Organic Matter Accumulation	**Organic Matter Depletion**
Grass/clover pasture	Bare soil/fallow
Moist summer growing conditions	Summer drought
Direct drill/no tillage	Intensive cultivation
Incorporation of crop residues	Removal or burning crop residues
Controlled Grazing	Overgrazing
Friable soil structure, good root density	Compacted soil, shallow root zone
Moderate N fertiliser application	Excessive N fertiliser applications
Green manure/cover crops	Erosion

The degree of decomposition of the OM determines the extent to which it forms a pool of mineralisable nutrients[1]. OM that has been broken down to humus is resistant to further decomposition and forms the '**passive fraction**' of the soil organic matter, typically 50 to 90% of the total. The soil properties associated with the 'passive fraction' OM are structure, CEC and water holding capacity. It is very resistant to mineralisation, making its nitrogen content unavailable to plants and micro-organisms.

OM consisting of microbial biomass and partially decomposed plant and animal residues is an energy source for soil organisms and the major source of mineralisable nitrogen. This is the '**active fraction**' of the OM and it is associated with soil structure, water infiltration rate, and fertility. In general this form of OM is rapidly depleted under cultivation and regenerated under good grass/clover pasture.

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There is also an intermediate fraction, that lies between these two extremes, known as the ‘**slow fraction**’. This very slowly mineralises, with a half-life measured in decades. In comparison, the active fraction has a half-life of a few months or years, and the passive fraction of hundreds, or even thousands of years.

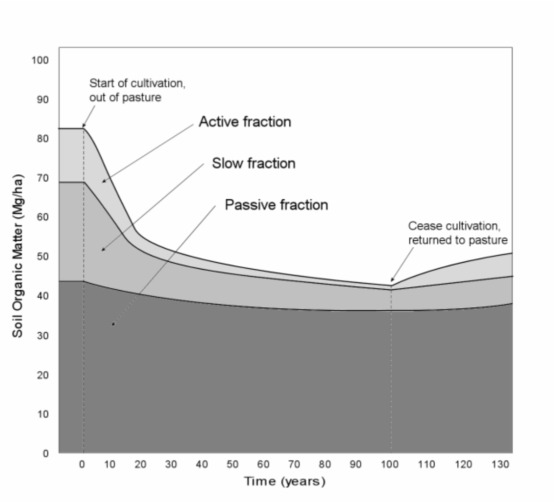

Figure 1. Different fractions of organic matter, and the changes with cultivation. (from Reference 1).

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

It is Organic Carbon that is directly measured in the laboratory, and OM is calculated from this using a standard factor derived for soils. (In New Zealand labs, Organic Carbon is routinely measured as Total Carbon because inorganic carbon is mostly very low.)

Organic Matter (%) = Organic Carbon (%) x 1.72

Anerobically Mineralisable N (also known as 'Potentially Available N')

This test[2] provides an indication of the quantities of nitrogen that can be readily mineralised from soil organic matter under ideal soil conditions. The actual amounts of nitrogen that will mineralise in the field will depend on factors such as soil temperature and moisture, which are impossible to emulate or predict in the laboratory. This test must therefore be interpreted with caution, realising that it is a measure of nitrogen mineralised under specific laboratory conditions.

The test measures the potential of soil to provide nitrogen to growing plants. It has been widely used for arable soils, but has not been widely used for pasture soils. Pasture soils usually show high levels with this test, but may still benefit from strategic use of nitrogen fertiliser because of unfavourable conditions for the mineralisation of these soil reserves at certain times of the year.

Level	Anerobically Mineralisable N ug/g (for 15 cm depth sample)	Potentially Available Nitrogen kg/ha (15 cm sample depth)
Very Low	<35	<50
Low	35 – 50	50 – 150
Medium	50 – 80	150 -250
High	80 – 240	250 – 350
Very High	> 240	>350

During the last few years, researchers have shown that the anaerobically mineralisable nitrogen (AMN) is a good indicator of biological activity and is closely related to microbial biomass[3].

Total Nitrogen

This test determines the total nitrogen (TN) content of the soil including that present in both passive and active organic matter fractions. The test gives some indication of the N supplying power of a soil, but it's primary use is to enable the expression of other, related parameters (Organic C, AMN) relative to this property.

Level	Total Nitrogen (%)
Very Low	< 0.1
Low	0.1 – 0.2
Medium	0.2 – 0.5
High	0.5 – 1.0
Very High	> 1.0

Carbon: Nitrogen Ratio

The ratio of total organic carbon and total nitrogen is the traditional guide to the nature of the organic matter present in the soil.

It is readily calculated as follows:

$$\text{Carbon:Nitrogen Ratio} = \frac{\text{Organic Carbon \%}}{\text{Total Nitrogen (\%)}}$$

The basic premise behind this ratio is that organic carbon is the primary source of energy for soil microbes, but these also require nitrogen to multiply and utilise this energy. The microbes utilise this carbon via respiration, with the consequent loss of carbon dioxide from the soil. As the *active fraction* of the OM is thus degraded, the C:N ratio drops until a steady state (the *passive fraction*) is finally attained.

The *active fraction* of the OM may have a C:N ratio between 15 – 30, the *slow fraction* typically 10 – 25, with the *passive fraction* stabilising around 7 – 10. [1]

Interpreting this ratio is complicated, as it also depends on the nature of the OM. Certain types of organic material are very resistant to decomposition, e.g. lignified material such as wood (C:N 100) [4] and leaf litter (C:N 40) [5]. If these are present, then a high C:N ratio may be found, and thereby give a false impression of the soil OM "activity".

Soils with high C:N ratios can also "immobilise" N in the soil, because of the need of the micro-organisms for nitrogen. However, once the ratio drops below 25, then further OM decomposition produces mineralised nitrogen that is surplus to the microbe's requirements[4].

The *passive fraction* of the OM can have a C:N ratio that is 'medium'[6]. Consequently, medium C:N ratio soils can have a wide variation in mineralisable N status, and this is a limitation when considering the C:N ratio in isolation.

Level	C/N Ratio
Very Low	< 8
Low	8 – 10
Medium	10 – 15
High	15 – 25
Very High	> 25

AMN:Total N Ratio

In addition to the C:N ratio, the ratio of AMN to Total N can be used to determine the proportion of the 'active fraction' organic matter in the soil. The AMN reflects the nitrogen in the active fraction of the Organic Matter, whereas the Total N is measured from the nitrogen in all fractions of Organic Matter. This ratio should be more sensitive to small changes in the OM *quality* than the C:N ratio.

High Ratio: A high AMN:TN ratio indicates that a high proportion of the soil organic matter is in the 'active fraction'. This indicates good reserves of partially decomposed organic matter, which are a substrate for micro-organisms and a source of mineralisable plant nutrients, particularly nitrogen.

Low Ratio : A low value indicates depletion of organic matter due to continuous cultivation/cropping or a combination of environmental factors that degrade organic matter. Such soils have lower nitrogen fertility and may show poorer soil structure and water infiltration rates.

Continuously cultivated/cropped soils will tend to have a low ratio, particularly in summer dry climates. Fertile grass/clover pastures in summer moist climates will tend to have a high ratio, indicating organic matter accumulation.

Level	AMN:TN Ratio
Very Low	< 1
Low	1 – 2
Medium	2 – 4
High	4 – 6
Very High	> 6

The proposed AMN:TN ratio should provide a more sensitive measure of the small changes that can occur in nature of the soil OM, and consequently, be a useful parameter for monitoring these changes over time.

Conclusion

A profile of related tests is offered, to better assess the overall quality of a soil. Most of the tests have been offered for many years, but one (AMN:TN ratio) is new. Consequently, interpretive guidelines are somewhat tentative at this stage, but will improve as experience with this test increases over time. Refer also to a related Technical Note – Laboratory Tests for Soil Carbon.

References

1 The Nature and Properties of Soils, Brady N.C. & Weil R.R. Prentice Hall, pp 521-526, 873 (2002).
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4 Soil Science. An introduction to the properties and management of New Zealand soils, McLaren R G and Cameron K C, Oxford University Press, (1990).
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6 Understanding the Carbon-Nitrogen Ratio, C Miller. Acres US, 30, No4 , (April 2000)

Potentially Available N or AMN? Same test, only different units….

The Potentially Available N test (expressed as kg/ha, 15 cm depth), which has been offered in NZ for over 25 years, measures the amount of mineral N produced after incubating the soil at 40°C for 7 days, under waterlogged conditions (ref 2). The same test has also been used at LandCare Research, but is expressed in the units ug/g. To differentiate these two result formats, the test expressed as kg/ha is called the Potentially Available N test, and when expressed as ug/g, the Anaerobically Mineralisable N test.

Having two different test names and result formats for essentially the same test is not ideal. The Potentially Available N test has a long history in NZ, and we are reluctant to withdraw it. The AMN test is a more descriptive name and the units are a more scientifically correct reporting format. We have decided to retain the Potentially Available N name and units as a routine test (for continuity) but will also state the alternative AMN result format on every report.

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