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Soil Organic Carbon – Discussion of analytical methods and CFI (Carbon Farming Initiative) in Australia

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EAL Background

- EAL is an independent University owned - research, teaching and commercial analytical laboratory.
- Founded around 1992 as self funded analytical facility – now 80+ staff, heading towards $10M/yr turnover.
- NATA (National Association of Testing Authorities) and ASPAC (Australasian Soil & Plant Analysis Council) quality assurances.
- Large range of services (water, soil, leaf, compost, biochar, hair, fertiliser, etc) - 'State of the Art' equipment.
- Helped SCU with new Science Degree majoring in Regenerative Agriculture (inc. Post Graduate/ Diploma options).

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Soil Carbon Testing and CFI

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- EAL involved with Biological farming for last 30^{+} yrs initially with Elaine Ingham – Soil Foodweb.
- With early soil tests EAL always provided Total LECO Carbon and Nitrogen results with all routine Ag soil tests.
- The CFI is the Carbon Farming Initiative which is a program setup by the Government for soil carbon credits for farmers

AUSTRALIA

Carbon Credits (Carbon Farming Initiative—Estimation of Soil Organic Carbon Sequestration using Measurement and Models) Methodology Determination 2021

Soil Carbon Testing and CFI

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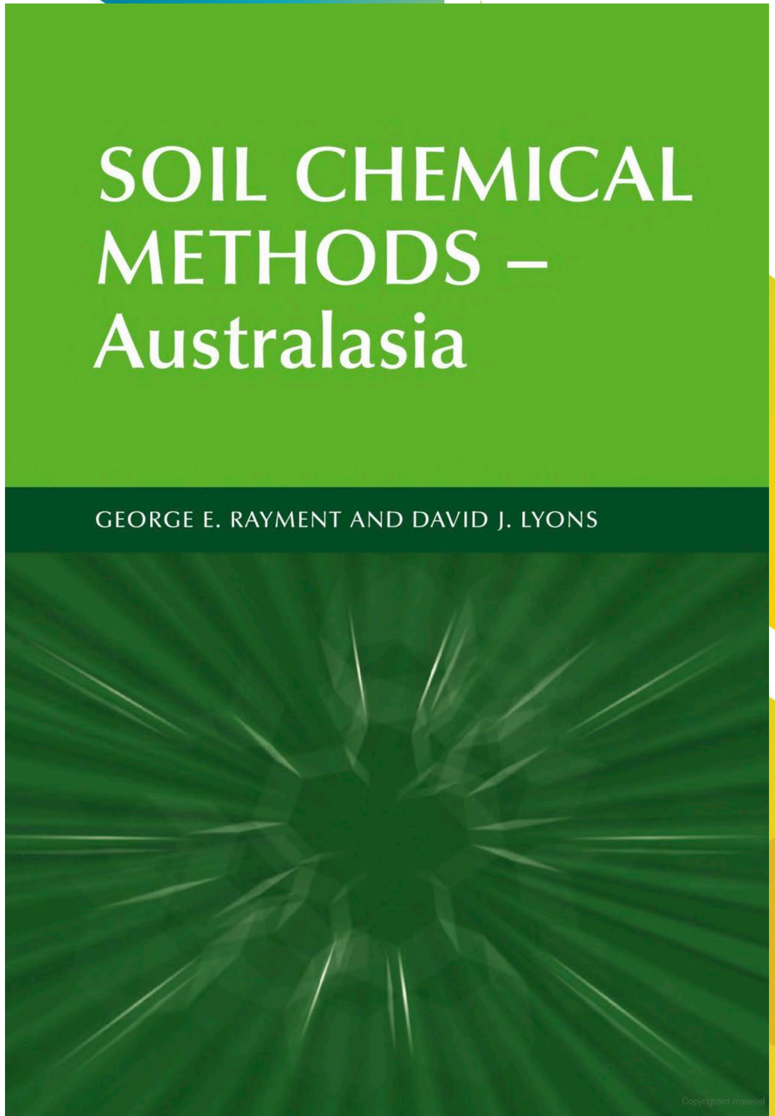
- Currently testing over 1000 soils per week for Soil Organic Carbon- CFI testing.
- Below Soil Carbon testing suites.
- Use FIZZ test (Rayment & Lyons method 6B3) so only ACID treat carbonates where indicated necessary.

ITEM CODE	SOIL CARBON SUITES	PRICE excl. GST	PRICE incl. GST
SS-PACK-179	**Total Organic Carbon (TOC) on Topsoils under 2021 CFI Methodology** In CFI methodology topsoil refers to the 0–30 cm layer, however, this should be selected on individual depth layers up to 30 cm in total. Includes Total Organic Carbon by LECO, gravel content, air-dry mass and gravimetric water content on the air-dry soil.	$60.00	$66.00
SS-PACK-180	**Total Organic Carbon (TOC) on Subsoils under 2021 CFI Methodology** In CFI methodology subsoil refers to the 30+ cm layer however this should be selected on a depth layer of 30–100 cm only. Includes Total Organic Carbon by LECO, gravel content, air-dry mass and gravimetric water content on the air-dry soil.	$90.00	$99.00

Soil Organic Carbon Testing Methods:

- From Rayment and Lyons, 2011, CSIRO Publishing:
  - 6B2b – LECO with no acid treatment
  - 6B3- LECO with sulfurous acid treatment to remove carbonates
- ASPAC now working with Authors - Rayment, Lyons and Hill to produce an updated Green Book later this year!

6B2b	Total organic C – Dumas high-temperature combustion, infrared/thermal conductivity detection (no soil pretreatment)
6B3	Total organic C – Dumas high-temperature combustion, infrared/thermal conductivity detection (with prior physical removal of charcoal and chemical removal of carbonates)



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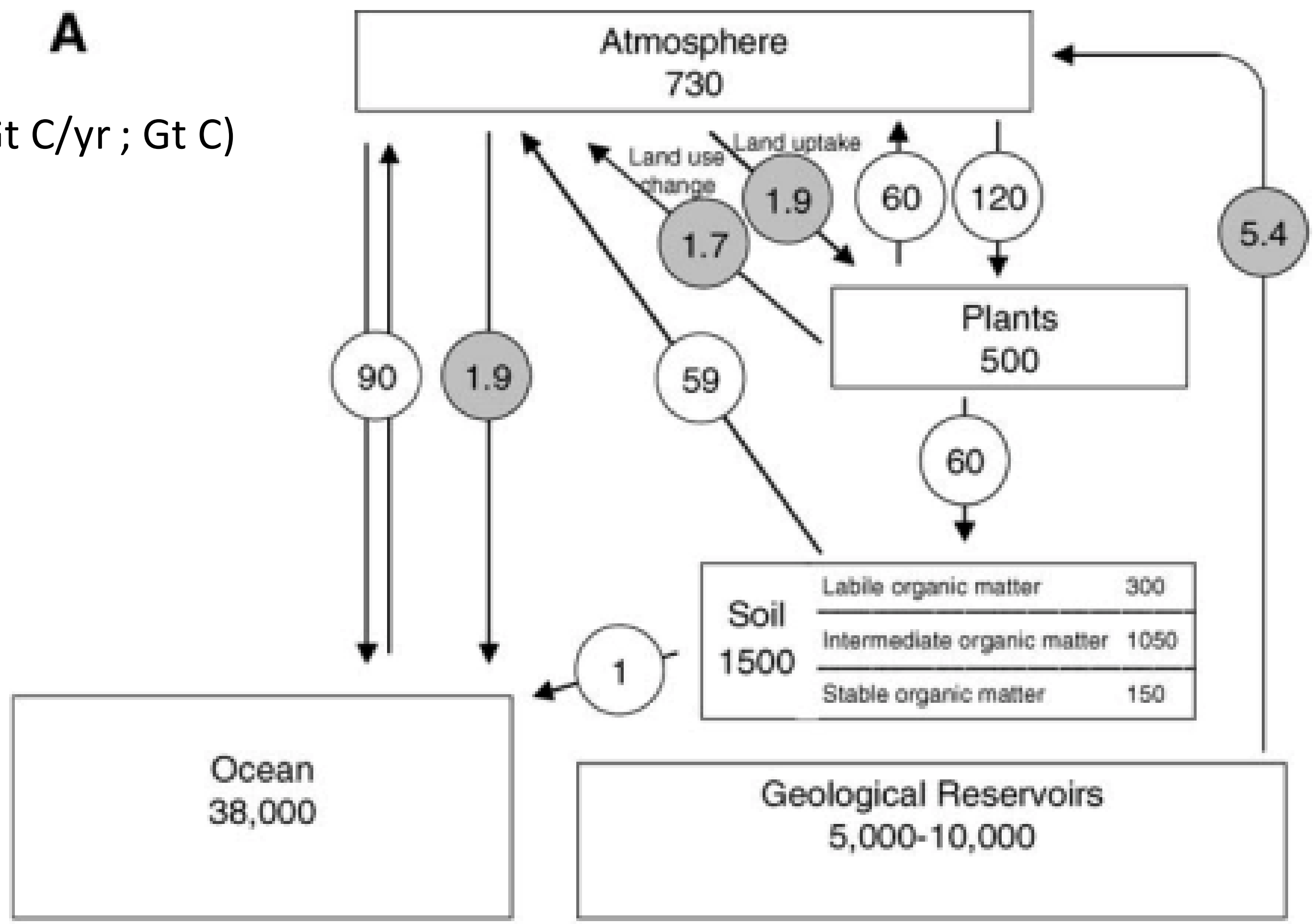
Global Carbon Cycle-basis of Carbon Farming

(Gt C/yr ; Gt C)



Lehmann, J., Gaunt, J. & Rondon, M. Bio-char Sequestration in Terrestrial Ecosystems – A Review. *Mitig Adapt Strat Glob Change* **11**, 403–427 (2006).

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Carbon Sequestration

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- EAL initially worked with Dr Christine Jones- Founder of Amazing Carbon and touring the world talking about carbon, surface to depth.

- Points emphasized by Christine:

  - ❖ The worlds soils hold 3 times as much carbon as the atmosphere and over 4 times than held in vegetation.

  - ❖ Soil also holds 95% of terrestrial diversity with only 5% above ground – soil carbon essential for this biomass.

  - ❖ <500 million tonnes of CO_2 emission in Australia in 2023.

  - ❖ Only 0.5% increase in soil carbon on 2% of Aust agricultural land would sequester all the Australian annual emission.

Soil Carbon Losses – <30yrs (DAFF, 2013)

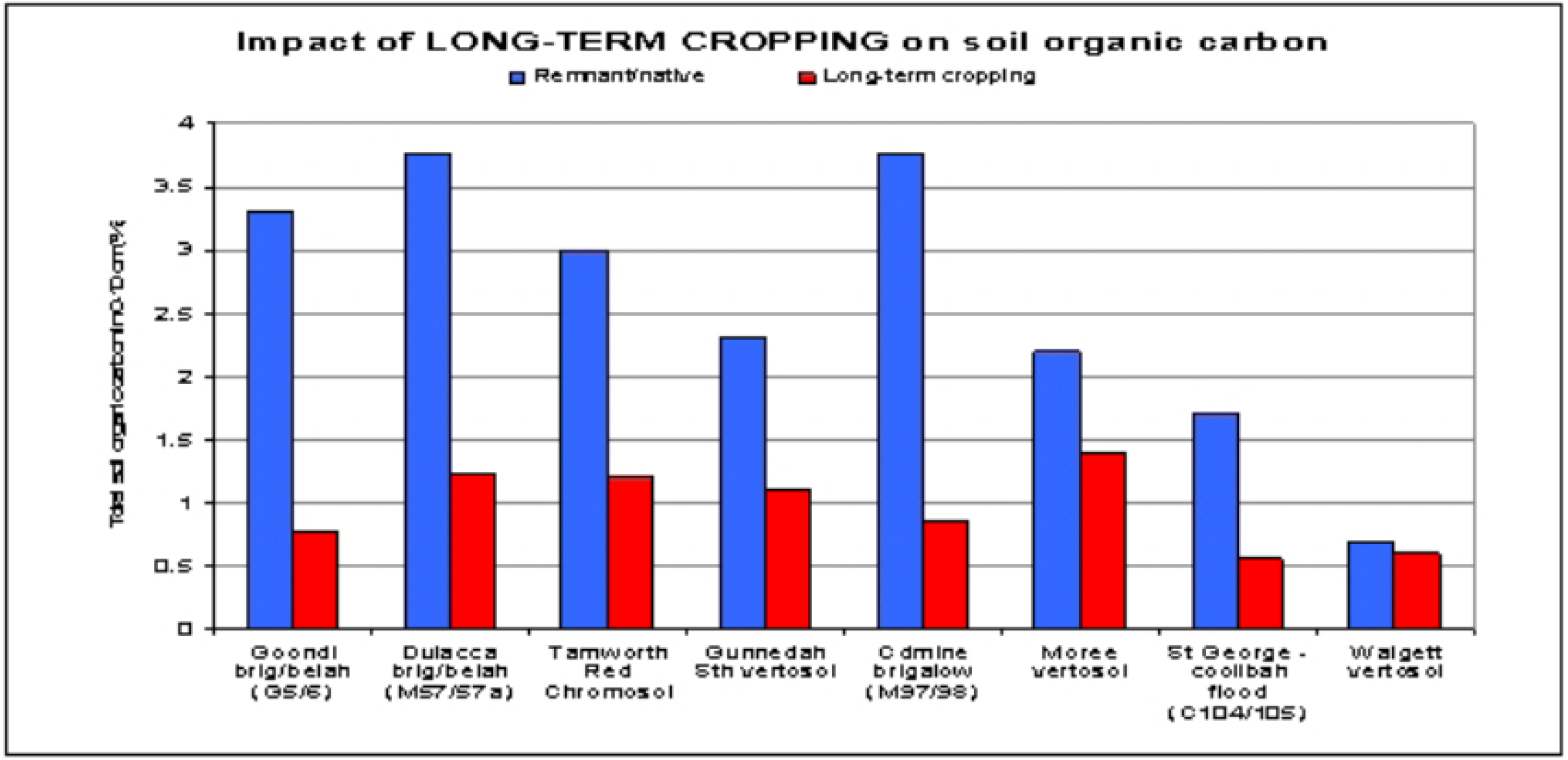

Figure 1. The decline of soil organic carbon with long-term cropping systems

Management practices that can increase soil carbon

Management category	Management practices to increase soil carbon
Crop management	Soil fertility enhancement Better rotation Erosion control Irrigation
Conservation tillage	Stubble retention Reduced tillage No-tillage
Pasture management	Fertiliser management Grazing management Earthworm introduction Irrigation Improved grass species Introduction of legumes Sown pasture Introduction of perennial pastures
Organic amendments	Animal manure Green manure Recycled organics

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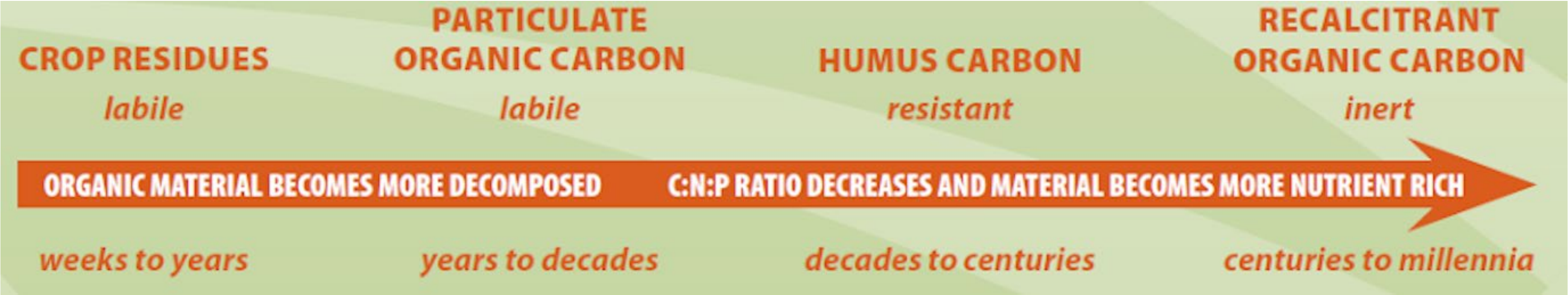
Defining Carbon in Soil

- Labile Pool – easily decomposable organic materials which stay in soil for short periods (days to months)(Food source for organisms, plant nutrients, soil aggregate formation – includes microorganisms)

- Humus- Slow pool of well decomposed and stabilised organic materials (Stabilising soil structure, improving water holding capacity, increasing nutrient holding capacity)

- Inert Pool – very resistant carbon but due to charge properties and porosity, still assists soil processes.

Carbon partitioning in Soil



-Labile Carbon

-Humus resistant carbon

-Recalcitrant Carbon (ie. Charcoal, Phytoliths)

Conceptualising Carbon in Soil

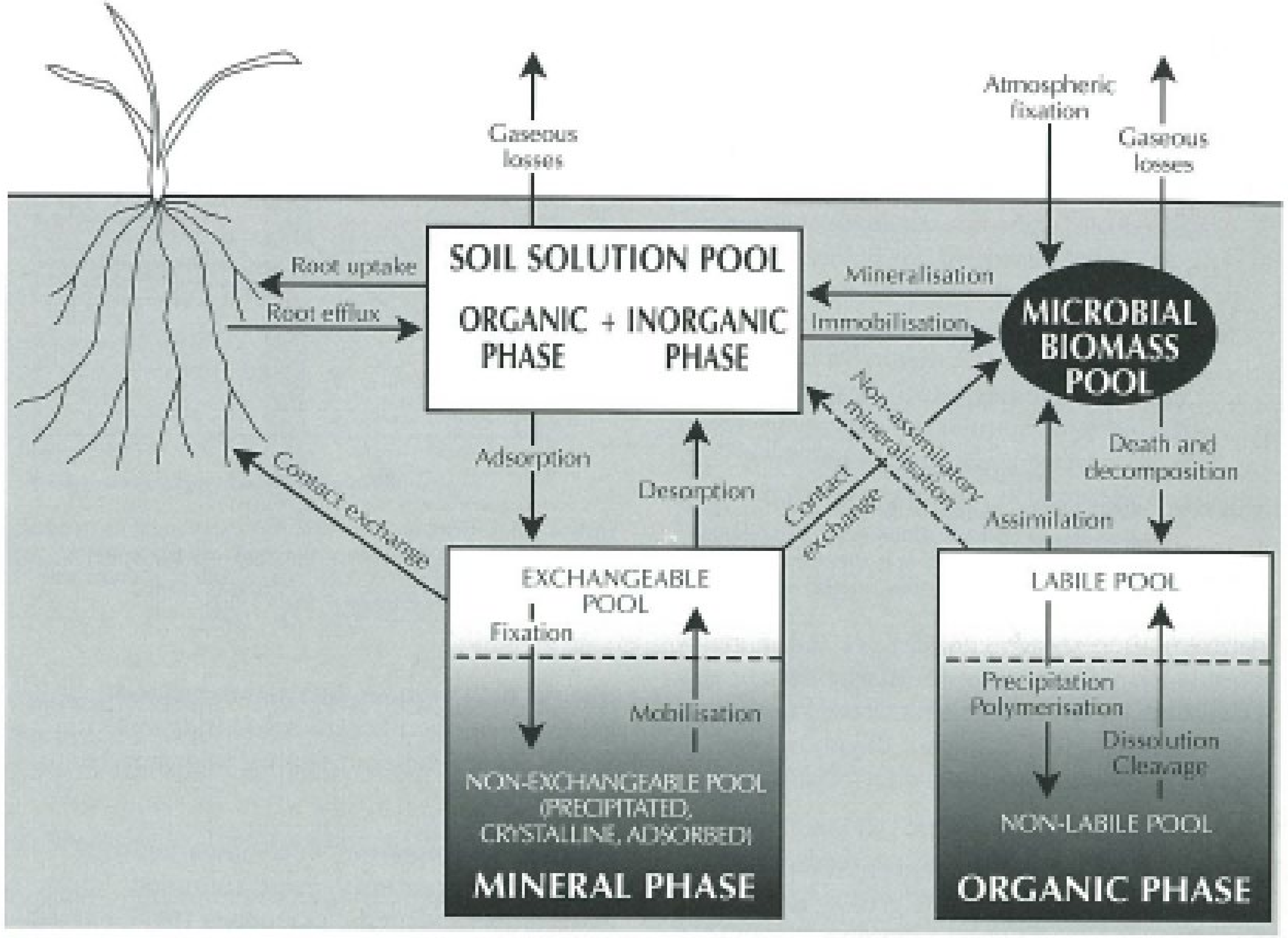


Figure 1.2 Conceptual diagram of major nutrient pools and pathways in soil.

CSIRO – Soil Analysis an Interpretive Manual

Carbon Testing – SCaRP

National Soil Carbon Research Program – CSIRO 2011

TOC

- Total Organic Carbon
- <2mm (LECO C with carbonate removal if required)

POC

- Particulate Organic Carbon
- LECO C after >50µm with dispersion

HUM

- Humus Carbon
- LECO C after <50µm with dispersion

For charcoal, requires NMR Spectrometry with HF Treatment, and Mid- Infrared Spectrometry

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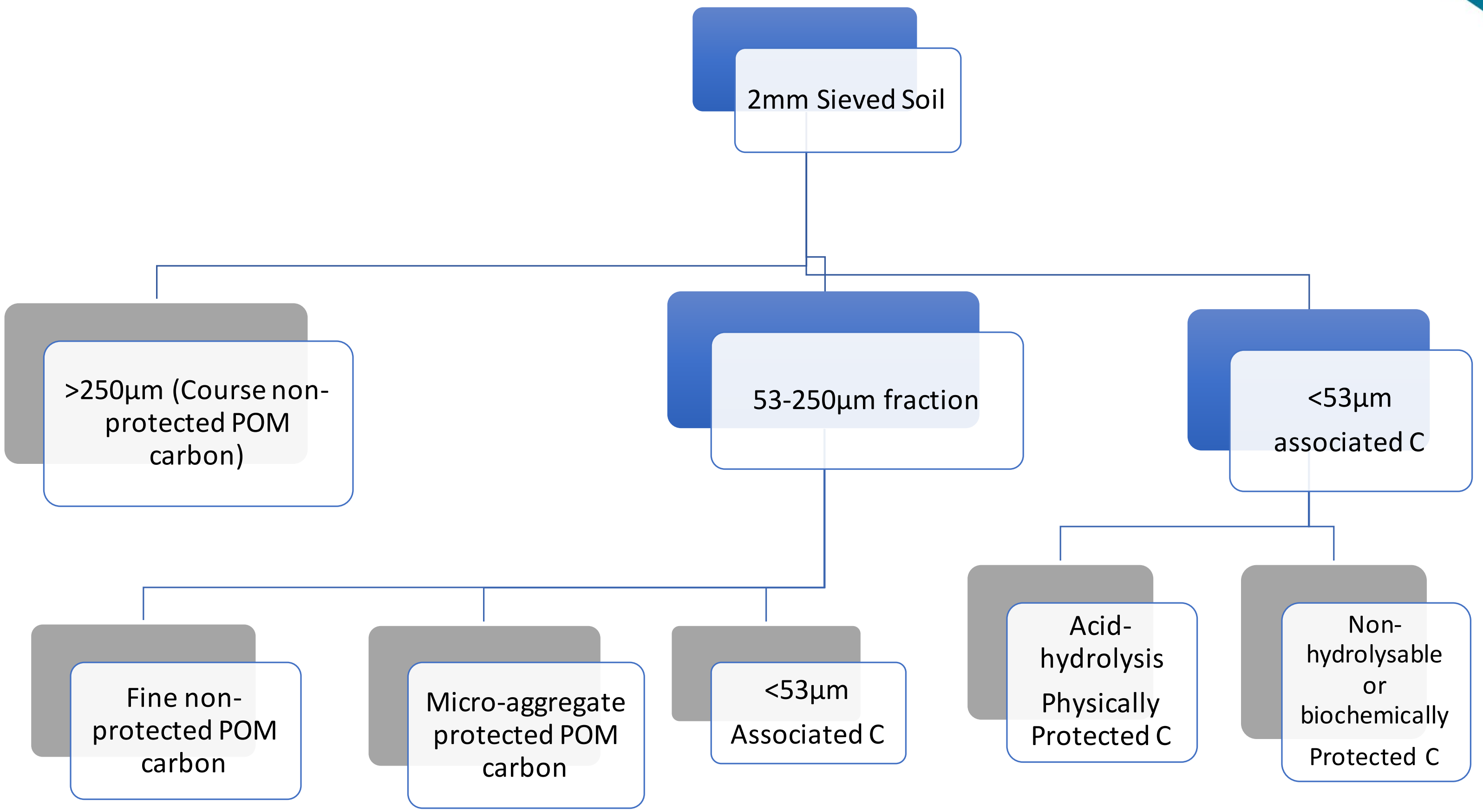
SOM Fractionation
(Six, et al, 2002)



SOM= Soil Organic Matter
POM= Particulate Organic Matter

Soil Carbon Method Summary:

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- Total Carbon – LECO Combustion CNS Analyser
- Organic Carbon – LECO after acid treatment if required to remove carbonates (OC x 1.75 = Organic matter)
- Organic Carbon after soil separation into fractions, <2mm, 250-53micron, <53micron (SCaRP)
- Organic Carbon – Walkley Black Dichromate
- Labile Carbon – CSIRO Permanganate oxidation
- LOI- Loss On Ignition (combustion @550˚C – issues!)
- (NIR – Near Infrared – estimate only of organic C)

Soil CFI Testing method

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3.1 Dry Combustion analysis

The following requirements and recommendations apply for the dry combustion analysis technique for measuring gravimetric soil organic carbon content, including the analysis of soil samples used to derive the spectroscopic model.

> Note: The calculations included in this Section apply to any sample of soil where dry combustion analyses are being performed (e.g. individual or composite soil samples).

Requirements:

1. It is a requirement that dry combustion analysis is undertaken on a soil sample prepared as per Section 2.1 of this Part.
2. It is a requirement that analysis of organic carbon content is undertaken by a laboratory that is certified for organic carbon analysis by the Australasian Soil and Plant Analysis Council (ASPAC).
3. It is a requirement that the method used to analyse organic carbon content is a dry combustion approach which has been certified by ASPAC (such as ASPAC code 6B2b (Total organic carbon by Dumas high-temperature combustion with no soil pretreatment) for soils that do not contain carbonate and a modified version of 6B3 (Total organic carbon by Dumas high-temperature combustion carbon with prior chemical removal of carbonates) for soils that do contain carbonate. The modification required to the 6B3 method is to not physically remove charcoal.
4. It is a requirement that the method used to analyse organic carbon content is a dry combustion approach and has been accredited, for that laboratory, by the National Association of Testing Authorities (NATA) under ISO-IEC 17025 (chemical testing).

Soil Composite or whole soil core

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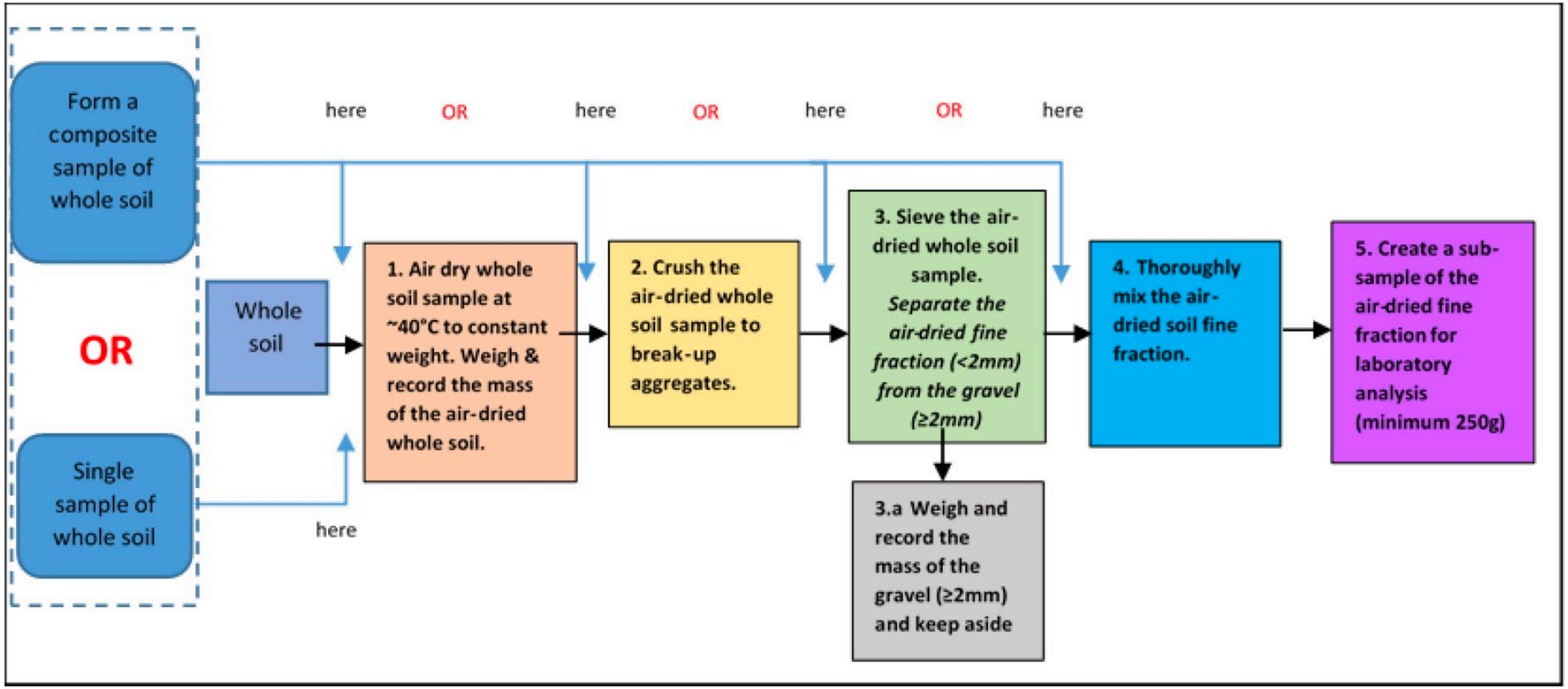
Section 2.1- Homogenised sample (The Supplement, 2021)



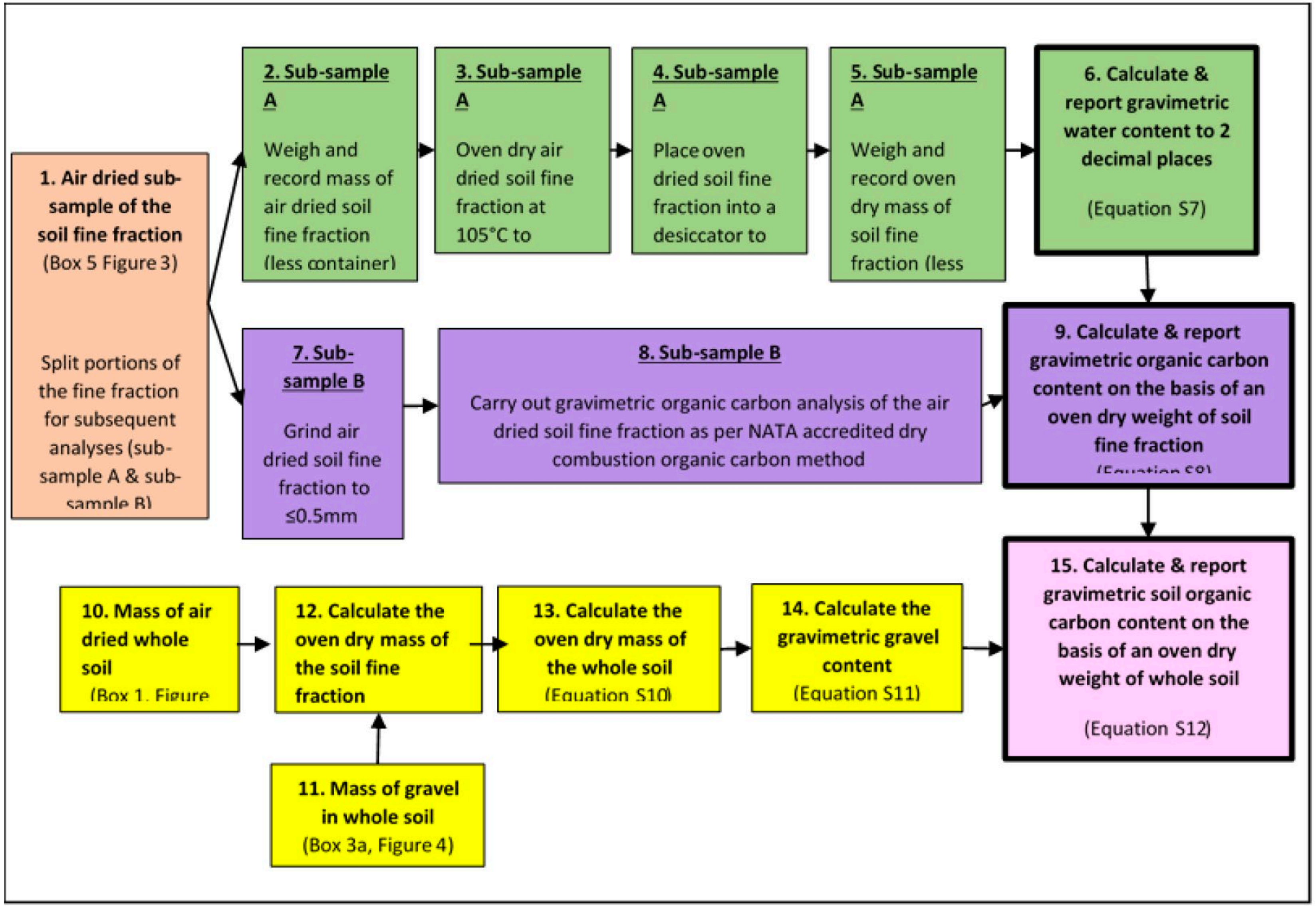
Supplement to the Carbon Credits (Carbon Farming Initiative – Estimation of Soil Organic Carbon Sequestration using Measurement and Models) Methodology Determination 2021

Australian Government
Clean Energy Regulator

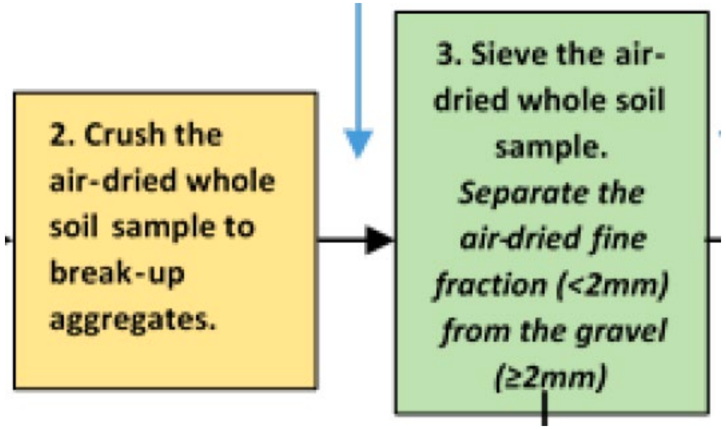
EMISSIONS REDUCTION FUND

Subsample A and B for testing

Section 3.1- Dry Combustion Analysis (The Supplement, 2021)

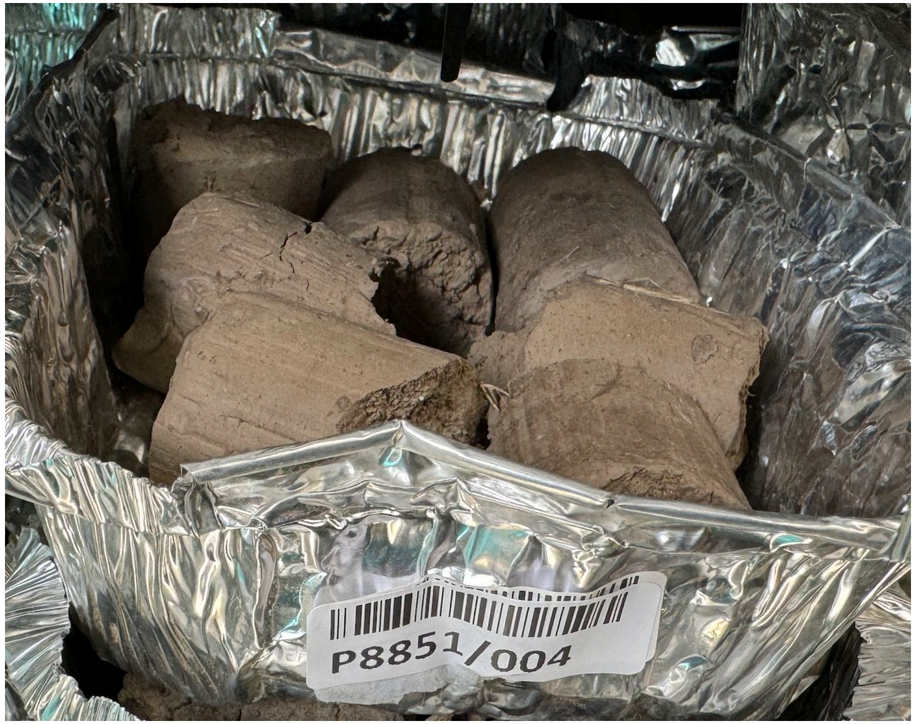


Crush the WHOLE sample then sieve!



So think of the workload:

- 0-30cm cores are around 1kg of soil
- 30-100cm cores around 3-4kg of soil



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This is the gravel >2mm that must be removed!

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3.a Weigh and record the mass of the gravel (≥2mm) and keep aside

Fine grinding for combustion analysis!

Expectation of soil subsample ‘ring mill’ ground sample <500µm (0.5mm) for combustion analysis (typically <100µm preferrable).

This has important implications for quality:

1. With acid treatment of the carbonates, the weak sulfurous acid used needs maximum surface area to react with all carbonates

2. Low mass analysis is taken for combustion analysis (ie. usually around 0.2g) hence fine grinding ensures a representative sample

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EAL Facilities – Ovens Air Drying 40˚c

1. Air dry whole soil sample at ~40°C to constant weight. Weigh & record the mass of the air-dried whole soil.

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2 x 20ft insulated containers – converted into Air Dry Ovens

Inside container ovens- high capacity

EAL Facilities – Dust extraction

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Dust Extraction Unit- Polex MDC-PC

Custom work stations with extraction

EAL Facilities – Sample grinding

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Jaw crusher- flow through

Ring Mill Grinder

2mm sieving and sample splitter

EAL Facilities for Carbon Testing

LECO Carbon, Nitrogen, Sulfur Combustion Analysers

- Currently 5 units
  - 2x LECO CNS2000 with autoloader
  - 1x LECO CN928 with autoloader
  - 1x LECO SC832 with autoloader
  - 1x LECO C832 with autoloader

- Below units waiting delivery:
  - 1x LECO CNS928 Simultaneous CNS Elemental Determinator with 100 position autoloader, Touch screen control
  - 1x LECO C832 Elemental Determinator with 100 position autoloader, Touch screen control

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LECO CNS2000

LECO CN928

LECO SC832

LECO C832

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Soil Carbon Methods CV Comparison

(CV - Coefficient of Variation)

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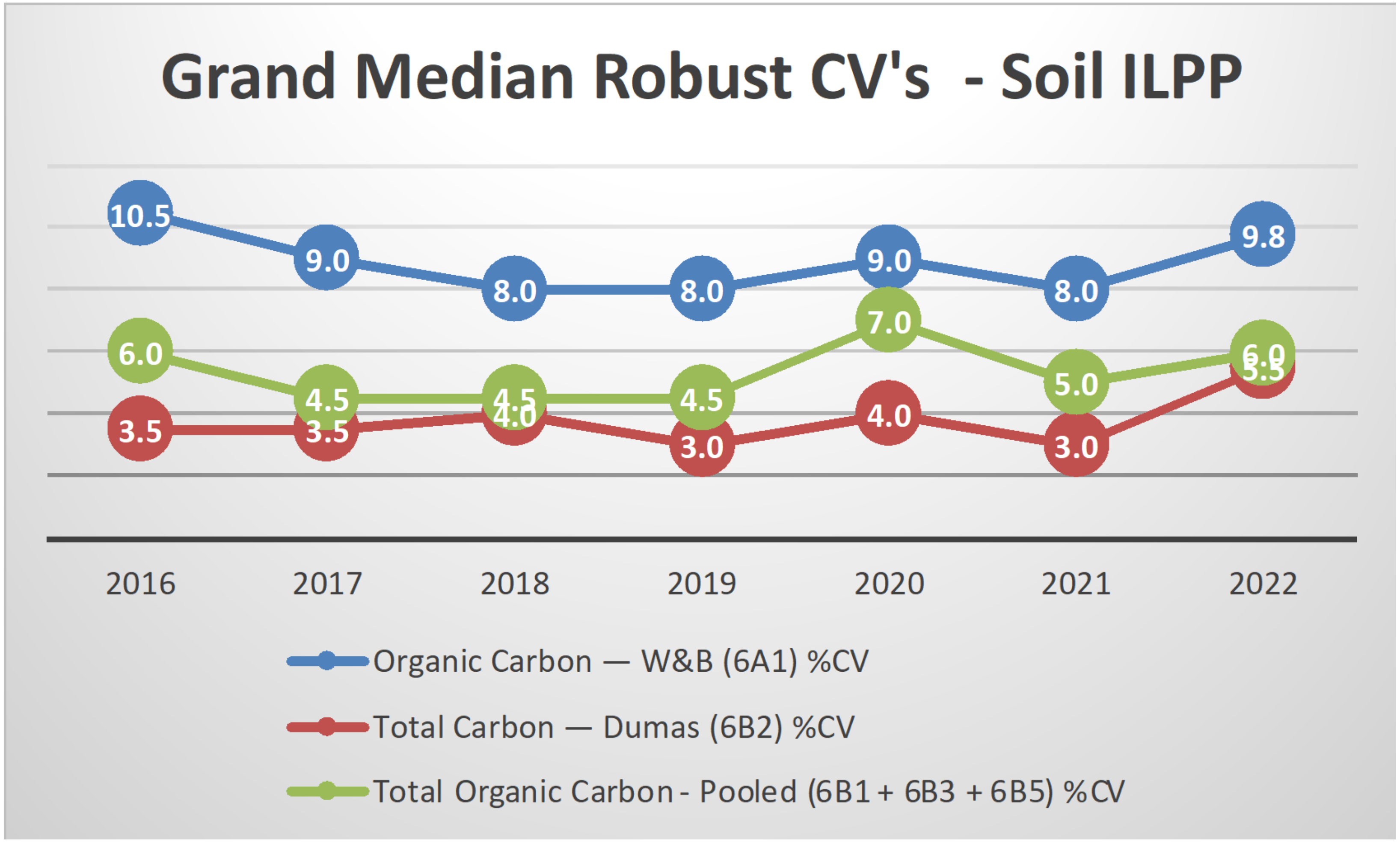
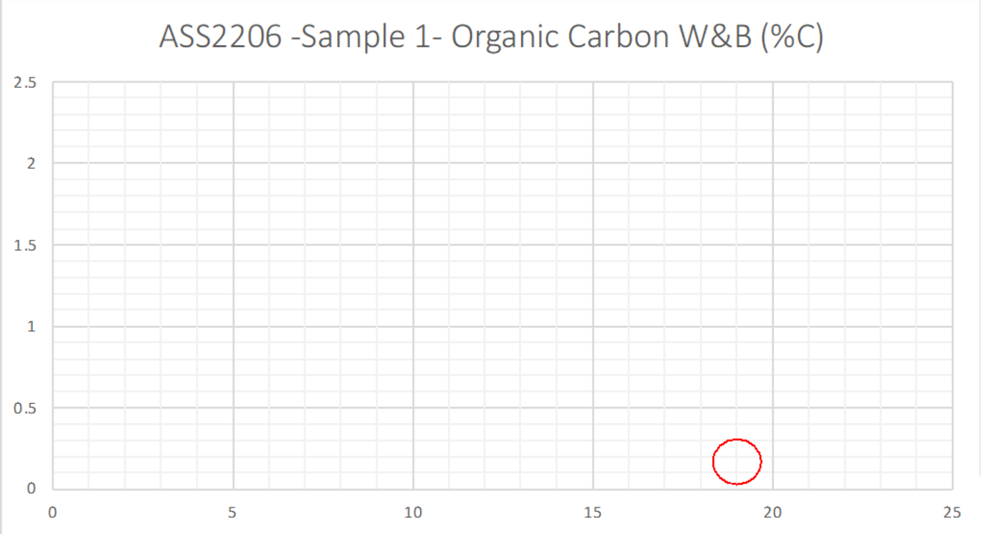
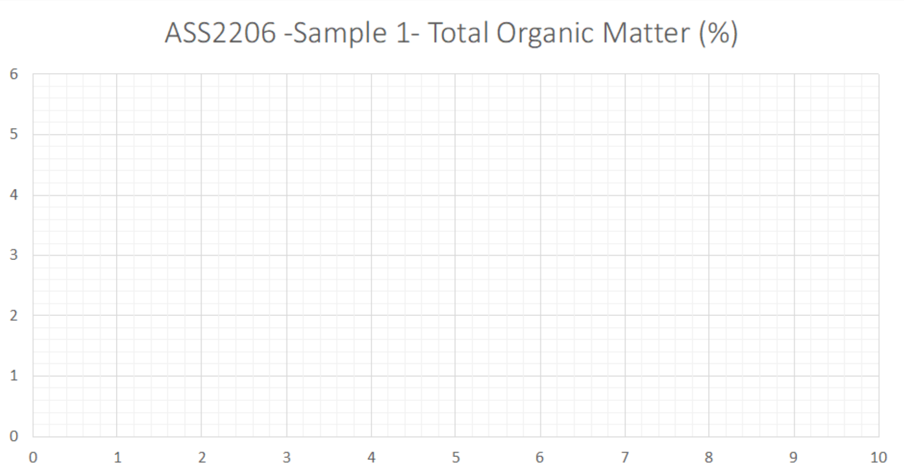
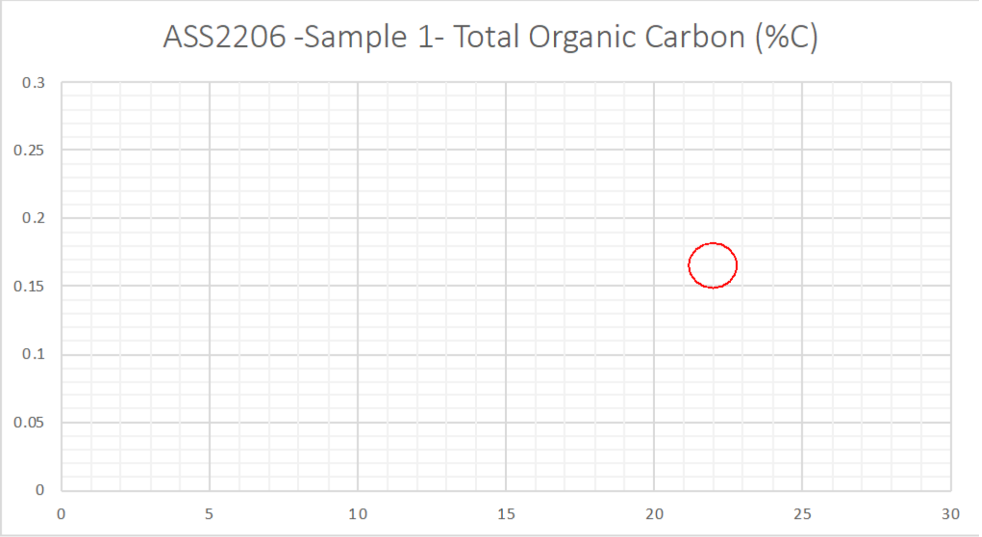
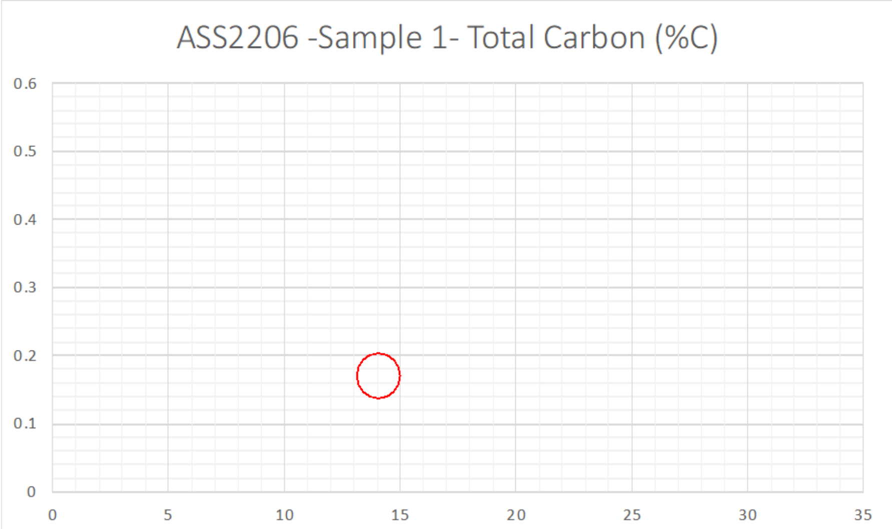


ASPAC Global Interlab results 2022 – Sample 1

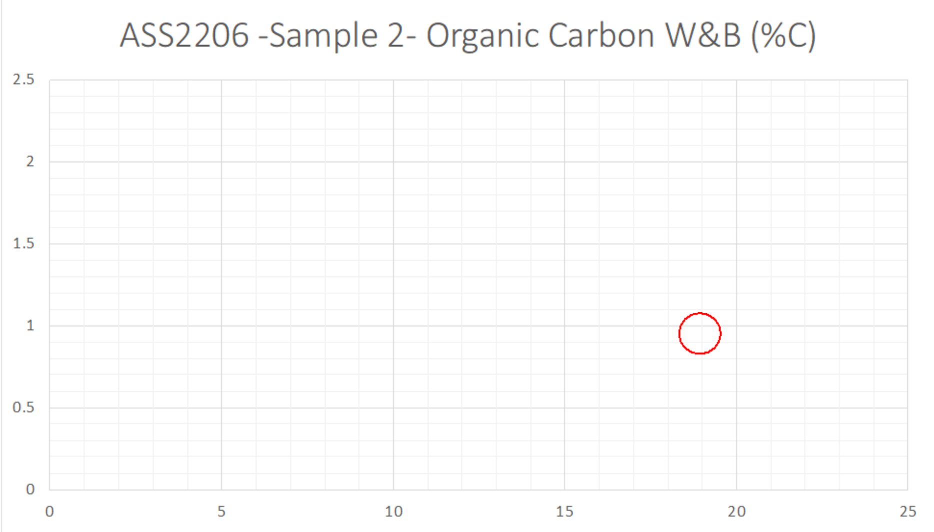


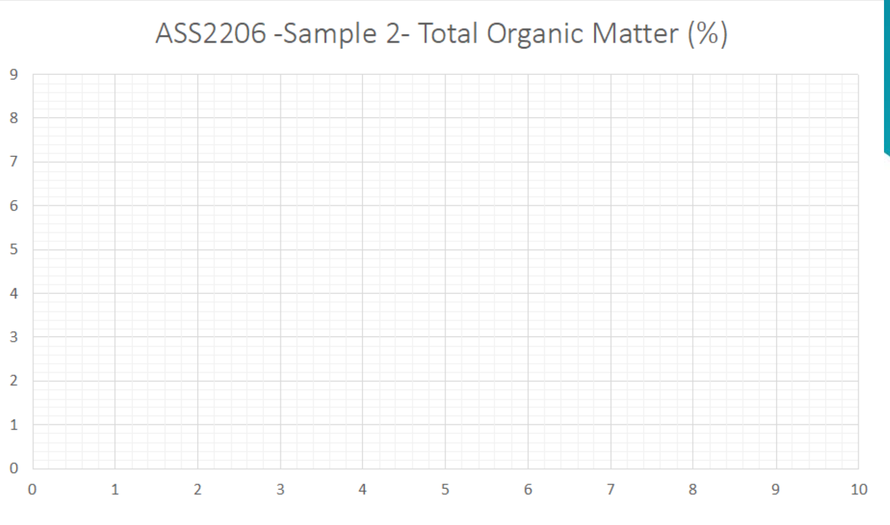


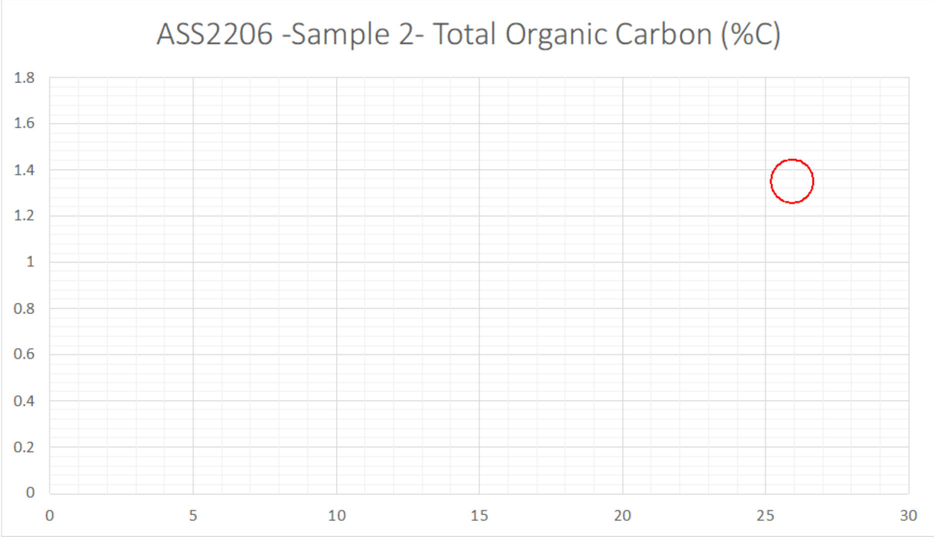


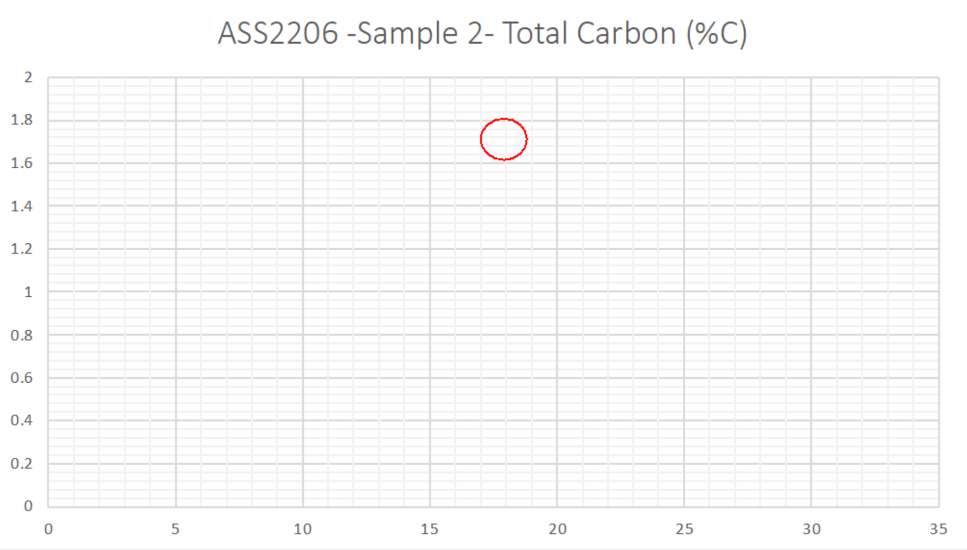


ASPAC Global Interlab results 2022 – Sample 2

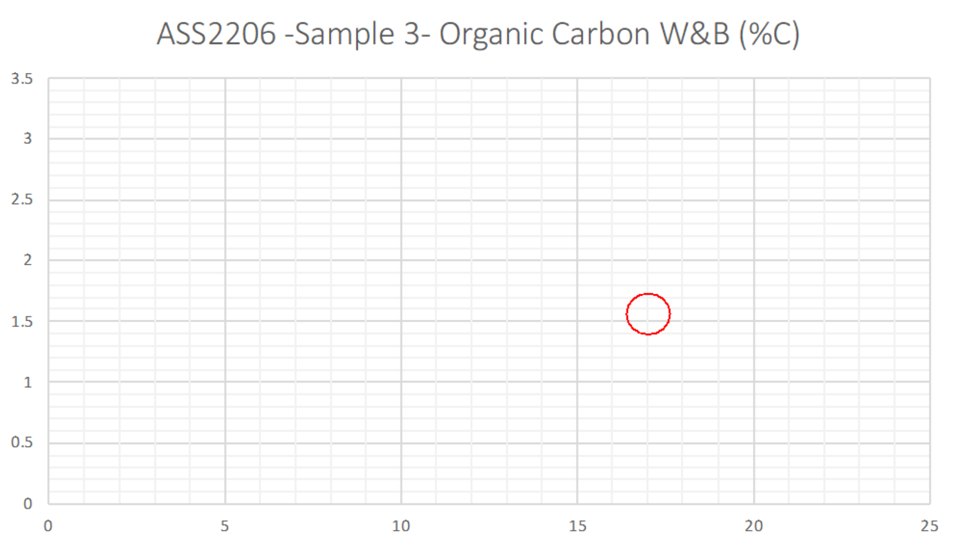


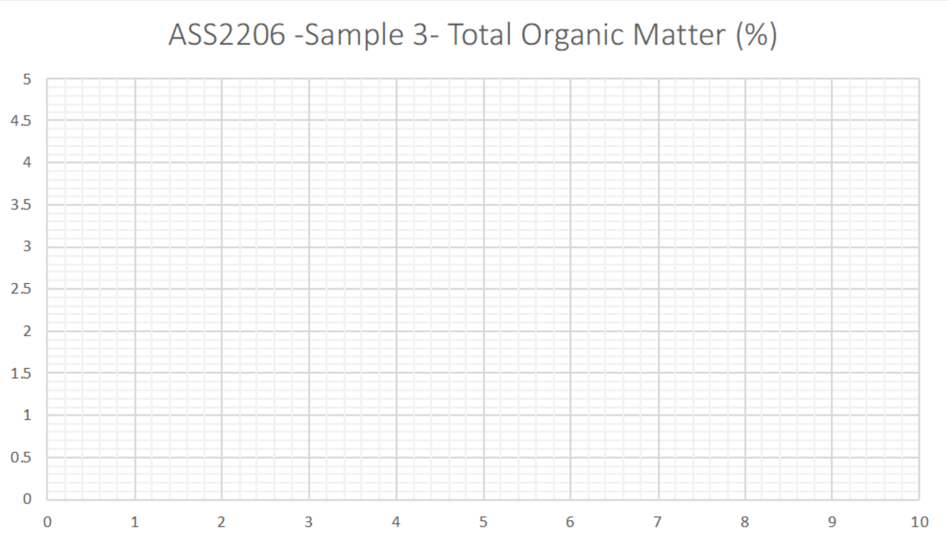


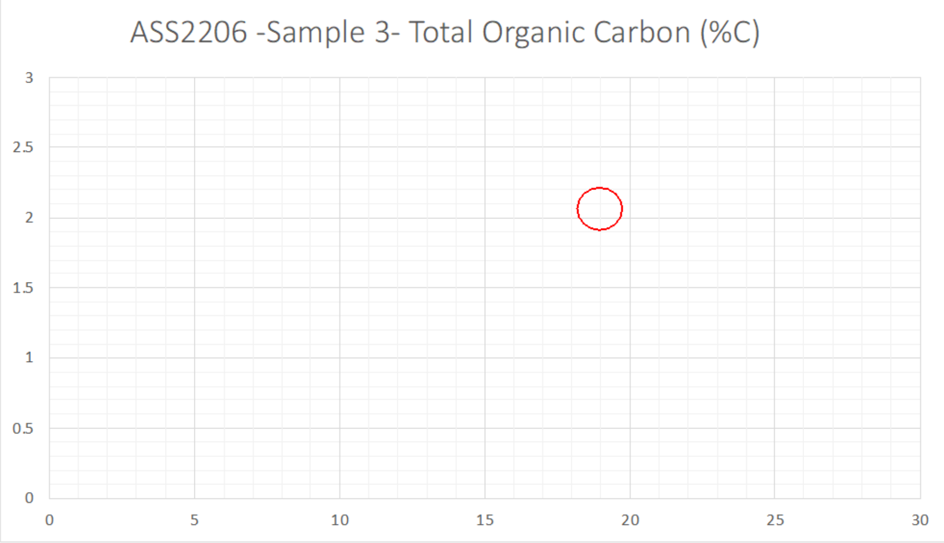


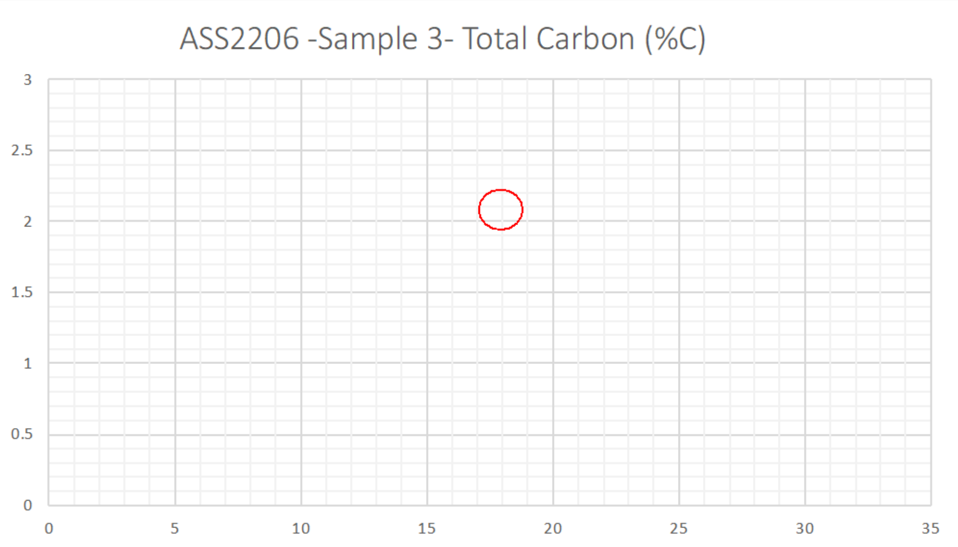


ASPAC Global Interlab results 2022 – Sample 3

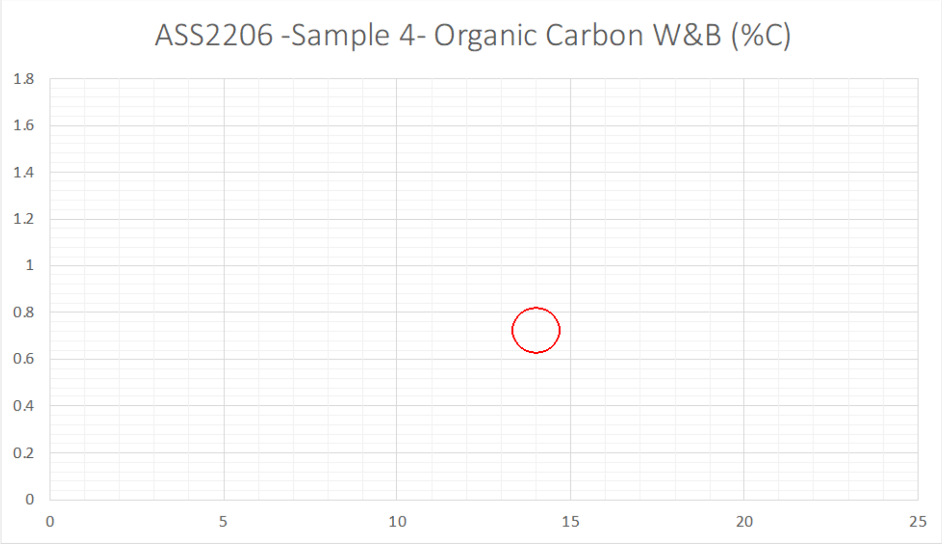


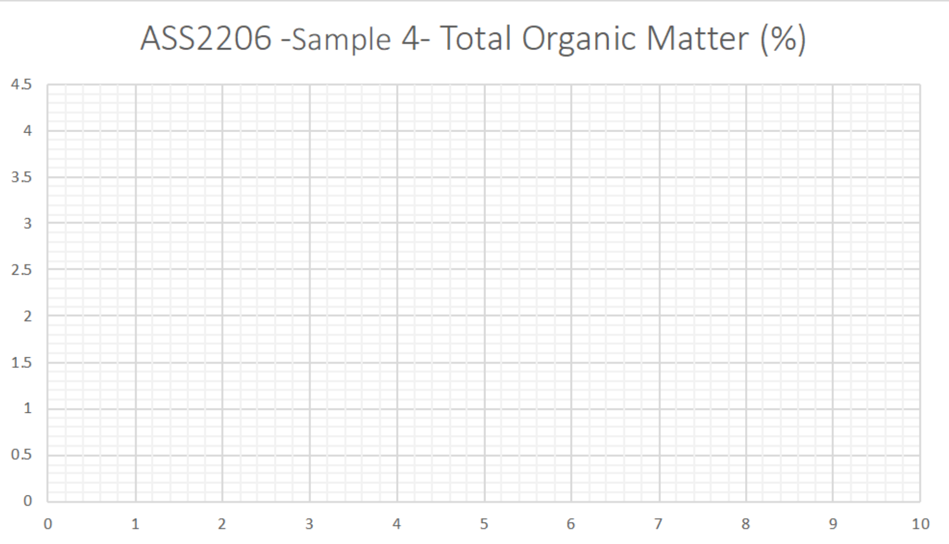


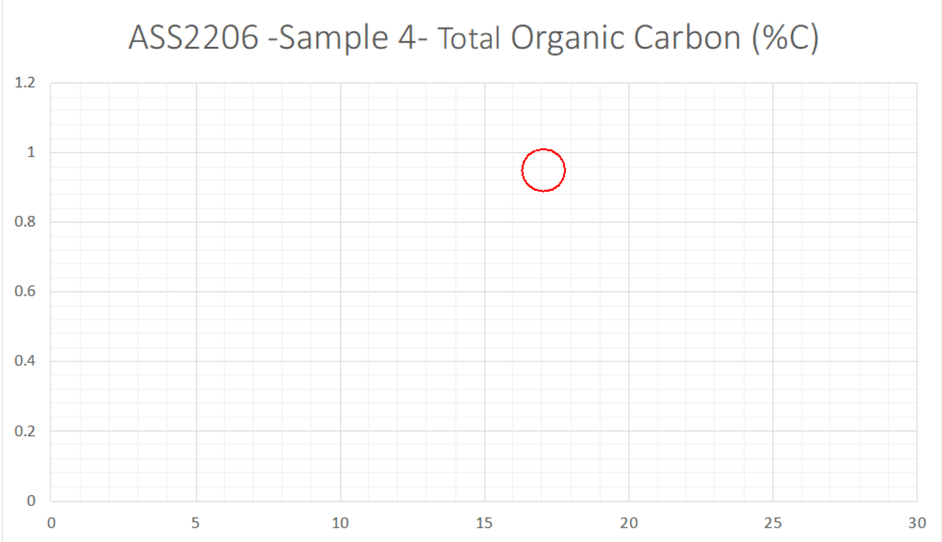


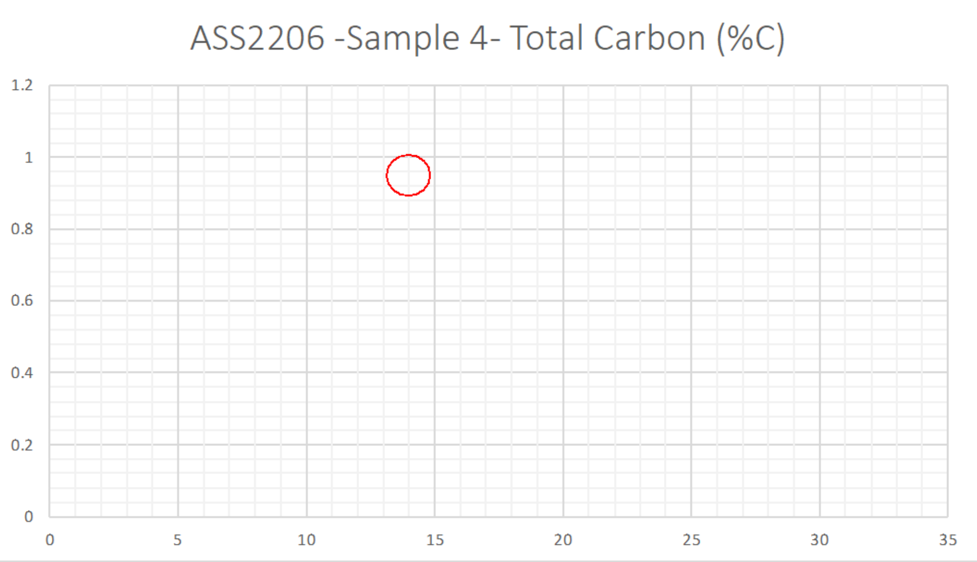


ASPAC Global Interlab results 2022 – Sample 4









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SUMMARY

- Very specific methodology for CFI - specific sampling 0 - 30cm, 30cm - 100cm
- Option for NIR in field or lab (10,000's of calibration points)
- Combustion (LECO, Elementar, Cube, etc) is the reference technique for Carbon TOC analysis.
- Walkley and Black (W&B 1934; Walkley 1947) is not an accurate technique but has a place in Pacific Islands and as an estimate.
- LOI (Loss On Ignition) by combustion of sample at approx. 500˚c is an estimate ONLY and over 100% errors in Australian soils
- %SOM from measured %SOC concentrations. Conversion factors range from 1.72 to 2.2 (1.724 suggested)

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