

# Soil Carbon Monitoring

Farmer protocol to measure change

June 2023



**South West NRM**  
Building Healthy and Productive Ecosystems

# Contents

<b>Contents</b>	<b>2</b>
<b>Background</b>	<b>3</b>
<b>Preparation</b>	<b>4</b>
When to sample	4
Materials and equipment	4
Laboratory selection, storage and posting	6
<b>Protocol</b>	<b>7</b>
Soil sampling and processing	7
Calculating soil volume	9
Converting Percentage of Carbon into Tonnes per Hectare	10
<b>Appendix: Calculating Bulk Density and Volumetric Gravel In-House</b>	<b>11</b>
Additional equipment required	11
Processing samples	11
Calculate Bulk Density	12
Calculate Volumetric Gravel	13
<b>Acknowledgements</b>	<b>13</b>

# Background

Soils vary in their physical, chemical and biological properties. To understand how management interacts with soil, monitoring techniques such as soil testing are required.

The value of monitoring for changes in soil properties has become more important with the development of carbon markets. However, a barrier to farmers entering the carbon market is uncertainty around how easy it is to sequester carbon in soil at a range of depths, and therefore the risk associated with carbon farming projects. This is mostly due to a lack of long-term monitoring using a repeatable and robust method.

This Soil Sampling Protocol describes a robust but simple method to help farmers establish a soil monitoring site. The protocol is based on CSIRO's [SCaRP \(Soil Carbon Research Project\) method](#) but includes more detail in step-by-step procedures. It details how to convert the percentage of carbon to tonnes of carbon per hectare, which is the best measure of soil carbon.

The same method (including timing and equipment) can be replicated at several locations across the farm and into the future to assess changes in carbon. It is recommended to establish at least three monitoring plots on each soil type on a farm, with more plots (e.g. five) where more confidence in results is required. It is also recommended to revisit sites every five or more years.

It is important to note that this method is specifically to establish soil monitoring sites and is not appropriate for whole-farm nutrient testing.

It is also important to note that while the method is similar to [standards](#) required under the Clean Energy Regulator's Emission Reduction Fund (ERF), this protocol differs mainly by having more replication at a monitoring point to increase the level of confidence in the result.

# Preparation

## When to sample

It is important to sample at the same time each year to minimise any seasonal influences on soil properties. By sampling during the **non-growing period of summer**, the influence of plant growth and microbial activity on soil organic carbon will be minimised. However, sampling dry or hard soil can be difficult. Sampling closer to the end of the growing season (e.g., December) may be easier before soils dry out completely.

Sampling of the same plots can be done every five years or more.

## Materials and equipment

In this protocol, we use a 2-inch stainless steel exhaust pipe with an internal diameter of 48 mm to collect samples. This is above the minimum recommended diameter of 38 mm required for an ERF project, and the SCarP protocol which uses a 40 mm diameter corer. The corer should be more than 30 cm long so that it can be hammered 30 cm into the ground and extracted. A much longer corer (e.g. 1.3m) may reduce kneeling and bending. The same corer should be used in the future assuming it hasn't deteriorated.

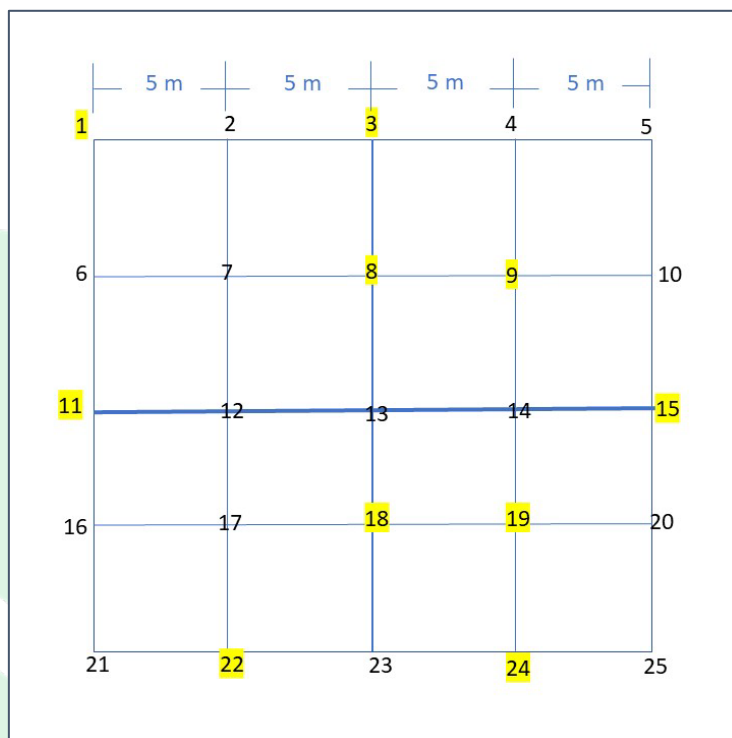
Sampling takes place at 10 random points in a 20 x 20 m plot, similar to the SCarP protocol. At each point, the sampling is split into 0-10 cm deep, 10-20 cm and 20-30 cm. The 10 samples from each depth are bulked together, resulting in three samples (1 x 0-10 cm, 1 x 10-20 cm and 1 x 20-30 cm).

Select random points on the 20 x 20 m grid before going into the field. **Figure 1** shows how this can be done by numbering 5 m intersects and using a random number generator (online) to select points to sample.

Materials and equipment required include:

- 2 x 20 m tape measures to identify random points.
- GPS or phone with GPS capabilities to save location, ideally connected to a Bluetooth GPS receiver to increase accuracy.
- Stainless steel exhaust pipe (not galvanised). 1.3 m length is recommended to reduce bending.
  - Mark the pipe at 10 cm, 20 cm and 30 cm from the bottom. This can be done with a permanent marker or small lines cut into the pipe e.g. with an angle grinder.

- To help safely extract the pipe from the soil, drill a hole through the pipe at waist height so a rod can be inserted, and the pipe twisted out of the ground (optional).
- Sledgehammer (shock resistant if possible) or post-hole driver.
- Personal Protective Equipment including hearing protection and work gloves.
- Three buckets labelled for each sample depth (0-10 cm, 10-20 cm, 20-30 cm), with large zip-lock bags labelled with site name, sample depth and date.
- Record sheet to record GPS coordinates, draw location of site within the paddock, and record weights.
- Scales to measure weights (up to 5 kg).



**Figure 1.** Random Sampling Grid. 5 metre intersects were numbered 1-25 and put through a random number generator. The first ten numbers are highlighted to show where sampling will take place. The grid is laid out at the site with two measuring tapes shown as darker crosshair lines.

## Laboratory selection, storage and posting

The laboratory chosen to analyse the soil samples must be accredited for the testing you are seeking, either through NATA (National Association of Testing Authorities) or ASPAC (Australasian Soil and Plant Analysis Council).

Select a lab that can do the following analyses:

- Total Organic Carbon (TOC) - dry combustion e.g. Leco Carbon test. This analysis is used in ERF soil carbon projects.
- Volumetric gravel content (sieved to 2 mm), and
- Moisture content (heated at 105 °C for 48 hours).

Note, the last two tests are used to calculate the soil's bulk density ( $\text{g}/\text{cm}^3$ ) and convert TOC into tonnes per hectare. Some labs may offer to measure bulk density, which would negate the need for the last two measures. However, for the lab to calculate bulk density, you will need the weight of the soil and the volume collected for each sample. Be sure to check lab requirements for this and other items such as collection and storage of samples.

Try to collect soil samples at the beginning of the week so samples don't sit in the postal system over the weekend. This is important when samples haven't been completely dried because moist soils will maintain microbial activity, which will continue to break down organic matter and release carbon.

However, if the sample is collected near the end of the week, it can be stored in a fridge over the weekend but should be sent early the following week.

If samples are not able to be sent quickly, the samples should be air-dried to avoid the decomposition of organic matter. To do so, spread the sample out on a plastic sheet or bag in a cool dry environment away from likely contamination. Ensure the samples are clearly labelled to avoid mix-ups later. Alternatively, if drying ovens are available, samples should be dried at 40 °C for at least 48 hours.

# Protocol

## Soil sampling and processing

### 1. Establish the site:

- a) Lay out two measuring tapes to 20 m in a crosshair (+) formation as pictured in Figure 1.
- b) Record the GPS coordinates for the mid-point.
- c) Draw a map of the paddock showing the location and grid orientation.
- d) Locate or step out the random sampling points (see Figure 1).

### 2. Take the sample:

- a) Move vegetation to one side without disturbing the topsoil. Excess plant material in the sample can over-represent carbon levels.
- b) DON'T scuff the soil surface. Scuffing can under-represent the carbon levels.
- c) Hammer the pipe into the ground until it reaches the first increment (10 cm).
- d) Gently remove the pipe, trying not to disturb the surrounding soil.
- e) Check that the soil core has been removed cleanly. If the whole core is not present, discard it and try again in a predetermined new spot, e.g. one step to the left.



### 3. Remove the sample:

- a) Tap out the soil into the correct bucket. You may need a screwdriver to dislodge the core.
- b) Carefully repeat for the remaining two depths (10-20 cm and 20-30 cm) from the same hole.
- c) Loose soil often falls into the hole when removing the 0-10 cm core. Remove it from subsequent cores by tilting the corer backwards to tip out the loose soil onto the ground before emptying the sample into the correct bucket.
- d) Once all 10 points have been sampled, transfer the soil to the labelled zip-lock bags and record the number of cores collected.
- e) Place the bags into a cooler with ice bricks to keep the samples cool until they can be processed and posted or stored in a fridge.



#### 4. Process samples:

- a) Process samples in the paddock or immediately after returning from the paddock.
- b) Weigh each sample and record as “Total soil wet weight”, deducting the weight of the bucket.
- c) Calculate the total volume of the soil sample. This is explained below.
- d) Mix the sample thoroughly and take a subsample from different parts of the bucket, transferring 500 g into a labelled bag to send to the laboratory.
- e) Post the samples with any documentation required by the lab, ensuring it is posted early in the week to reach the lab that same week. Otherwise, store in a fridge over the weekend (no longer) and post early the following week.





## Calculating soil volume

We need to know the volume of each soil sample weighed above. First, we need to calculate the volume of the corer:

Corer Volume =  $\pi \times r^2 \times D$ , where  $\pi$  is 3.142,  $r$  is radius of the corer (cm) and  $D$  is the depth of the core, which in this case is 10 cm.

For example, a corer with a 48 mm internal diameter (2.4 cm radius), this is:

$$\text{Core Volume} = 3.142 \times 2.4 \times 2.4 \times 10 = 180.97 \text{ cm}^3.$$

To calculate the volume of the total sample, multiply the volume of the corer by the number of cores collected. For example, if 10 cores made up the total sample, the total volume is:

$$\text{Total volume} = 10 \times 180.97 = 1809.7 \text{ cm}^3.$$

## Converting Percentage of Carbon into Tonnes per Hectare

Soil carbon projects registered under the ERF report carbon in tonnes per hectare, not as a percentage. This is a more accurate measure of carbon stocks. To convert Total Organic Carbon (TOC) percent into tonnes of carbon per hectare, we need to know the soil's bulk density and its volumetric gravel percentage. Gravel does not store organic carbon, so this needs to be extracted from calculations.

If your lab has measured bulk density and volumetric gravel, they may also calculate your carbon in tonnes per hectare. If not, use the following equations.

Soil carbon (tonnes per hectare) = TOC % x Bulk Density (g/cm<sup>3</sup>) x depth of sample (10 cm)

For example, if your TOC is 5% and your bulk density is 1.5 g/cm<sup>3</sup>, your carbon in tonnes per hectare is:

Soil carbon = 5 x 1.5 x 10 = 75 t/ha

To exclude gravel, we then use the following equation.

Soil carbon excluding gravel = Soil carbon (t/ha) x [1- (% gravel volume/100)]

For example, if your soil sample was 10% volumetric gravel, this would be:

Soil carbon (ex gravel) = 75 t/ha x [1-(10/100)] = 75 x 0.9 = 67.5 t/ha.

This is your final figure that can be stored and compared with the result of your next assessment.

Because changes in soil carbon can take years to detect, it is recommended that you re-sample your monitoring plots every five or more years.

If you were unable to find a lab to calculate bulk density and gravel content, see Appendix for more guidance.

# Appendix: Calculating Bulk Density and Volumetric Gravel In-House

## Additional equipment required

- 2 mm soil sieve
- Smaller zip-lock bags
- Foil trays

## Processing samples

- Weigh each sample and record as "Total soil wet weight", deducting the weight of the bucket.
- Take one small scoop of soil e.g., 100 g and put in a foil tray of known weight.
- Empty the remaining sample into a 2 mm sieve with a tray beneath to catch all material less than 2 mm. Ensure any soil aggregates are broken up to fit through sieve. All that should remain in the sieve are the coarse fragments (e.g. gravel) and plant material >2 mm.
- Empty the coarse fragments into a bucket with a known weight and weigh. Record the net weight.
- Calculate the volume of soil collected, as detailed in Section C.
- Taking the part of the sample that passed through the 2 mm sieve, mix thoroughly and take a subsample from different parts of the bucket, transferring 500 g into a labelled bag to send to the laboratory.
- Using the handful of soil in a foil tray from step 1. Weigh this sample and record the net weight as "Soil sample wet weight".
- Dry the sample in an oven at 105°C for 48 hours. If you do not have access to a drying oven, your home oven will work.
- After drying, re-weigh the sample and record the net weight as "Soil sample dry weight".



## Calculate Bulk Density

Bulk Density is the weight of **dry** soil divided by the total volume of the soil.

To calculate bulk density, first calculate the moisture content of the soil using the wet and dry weight of the soil sample dried at 105°C (D.2g-i above)

$$\text{Moisture content (\%)} = [(\text{wet weight} - \text{dry weight}) / \text{dry weight}] \times 100$$

For example, if the wet weight was 100g and the dry weight 90g:

$$\text{Moisture content (\%)} = [(100-90)/90] \times 100 = 11.1\%$$

Next, calculate Total Soil Dry Weight (wt):

$$\text{Total Soil Dry Wt} = \text{Total soil wet wt} \times [(100 - \text{moisture content \%})/100]$$

For example, if the total soil wet weight (from D.2a above) is 2400 g:

$$\text{Total Soil Dry Wt} = 2,400 \text{ g} \times [(100 - 11.1)/100] = 2,133 \text{ g}$$

To calculate Bulk Density:

$$\text{Bulk Density} = \text{Total soil dry weight} / \text{volume collected (g/cm}^3\text{)}$$

For example, using the examples above where volume was 1807.9 cm<sup>3</sup>:

$$\text{Bulk Density} = 2,133 \text{ g} / 1809.7 \text{ cm}^3 = 1.18$$

## Calculate Volumetric Gravel

A conversion factor of 2.65 is used to convert gravel weight to gravel volume:

$$\text{Gravel volume} = \left[ \frac{\text{Gravel weight}}{2.65} / \text{volume collected} \right] \times 100$$

For example, a gravel weight of 200g (measured in D.2d above) in a volume of soil of 1809.7 cm<sup>3</sup> is converted as:

$$\text{Gravel volume} = \left[ \frac{200\text{g}}{2.65} / 1809.7 \right] \times 100 = 4.17\%$$

You can now calculate carbon in tonnes per hectare following the process outlined above.

## Acknowledgements

This project is delivered by South West NRM for the Landcare Farming Program, a joint partnership between Landcare Australia and the National Landcare Network, funded by the Australian Government's National Landcare Program, and supported by Western Beef Association Inc.

We would like to acknowledge Jen Clausen, South-West WA Regional Soils Coordinator, for her assistance in the development of this protocol.



National  
Landcare  
Program

