QUANTIFYING SOIL CARBON SEQUESTRATION IN KIWIFRUIT ORCHARDS: DEVELOPMENT OF A SAMPLING STRATEGY

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Summary

In offshore markets there is growing concern that many existing land management practices for food production are releasing additional carbon into the atmosphere thereby contributing to greenhouse gas emissions. If it can be demonstrated that in New Zealand the production of perennial fruit crops such as kiwifruit can enhance or maintain carbon storage then this may allow greater differentiation of our products in environmentally concerned markets such as Europe.
Currently, there is no standard methodology to verify any claims of carbon storage in kiwifruit orchards. One of the objectives of a current SFF project is to develop a robust sampling protocol to quantify soil carbon stocks (SCS) in kiwifruit orchards.
Our hypothesis was that the depth distribution of SCS will be different in 'young' and 'old' kiwifruit orchards and that the vine row and grass alleyway have to be separately sampled. We identified two blocks that are representative for many kiwifruit orchards in the BOP on a property in Te Puke. The soil is a typic orthic allophanic soil with a loamy texture. One of the blocks was established 10 years ago ('young') and the other 25 years ('old') ago. The blocks are besides each other and have the same soil type and climate, and receive the same management. We sampled the SCS of each block from the soil surface to 1 m depth in six depth increments.
These were our key results and preliminary conclusions:

(1) The 'young' kiwifruit block stores about 139 t C/ha and the 'old' one about 145 t C/ha to 1 m depth. For both, the young and old block, 80-90% of the SCS are stored in the top 0.5 m, and 89-95% in the top 0.7 m. A maximum sampling depth to 0.5 m is sufficient for a general SCS inventory and to 1 m if the temporal or spatial dynamics of SCS are of interest.
(2) With a maximum sampling depth of 0.5 m there was no significant difference between the SCS in row and alley. In orchard blocks without herbicided rows the vine row and grass alleyway need not be separately sampled.
(3) We found a CV of 5-15% and, therefore 4-10 cores are needed to have at least 80% confidence in the estimated SCS.
(4) We recommend separating each core from the top to the bottom into the depths 0-0.1, 0.1-0.3, and 0.3-0.5 m for a general inventory. If the dynamics of the SCS is of interest we recommend adding another increment 0.5-1 m depth.

We could detect a weak spatial pattern of the SCS only for the 'old' kiwifruit block. The pattern had a size (=range) of about 3 m. Additionally, the pattern periodically recurred every 5.5 m which is about the distance between kiwifruit vines in the row. We recommend that a sampling bay along a vine-row should have a maximum length of 3 m.

Introduction

There is growing concern that many existing land management practices for food production are releasing additional carbon into the atmosphere, contributing to greenhouse gas emissions.
If we can show that producing perennial fruit crops can enhance or maintain carbon storage, this may allow greater differentiation of New Zealand products in environmentally concerned markets such as Europe.
Generally, higher soil carbon contents increase the soil's ability to filter excessive amounts of nutrients and contaminants, to reduce the run-off of nutrients and erosion, to act as a net sink for greenhouse gases, and to reduce the need for precious water resources. Regional Councils already monitor soil carbon contents as a public good in the sense of soil health and its environmental benefits.
Currently, there is no standard methodology to verify claims of carbon storage in kiwifruit orchards, which might be needed in future stewardship initiatives or to participate in carbon trading schemes.

Objectives

To develop a robust methodology to quantify carbon storage in kiwifruit orchards. We needed to resolve the following five key questions:

1. **What should be the maximum sampling depth?**
2. **How many zones (e.g. row, alley) do we need to sample?**
3. **Into which depth increments do we need to divide each core?**
4. **How many cores do we need per orchard block?**
5. **What should be the spatial dimension of a sampling bay?**

Methods

Site

We selected two Te Puke 'Hort16A' blocks representative of kiwifruit orchards in the Bay of Plenty (BOP) (Figure 1). The soil is a typical orthic allophanic soil with a loamy texture ('Te Puke sandy loam'). One of the blocks was established 10 years ('young') and the other 25 years ('old') ago. The blocks are adjacent, have the same soil type and climate, and receive the same management.

Figure 1: **Left**: Dr Hasinur Rahman records the GPS location of the soil pit in the 'young' kiwifruit block. **Right**: The 'old' kiwifruit block. The tape marks the transect for analysis of the spatial structure of the SCS (Figure 5).

Figure 2: Soil pit in the kiwifruit blocks. **Left**: The pit in the 'young' block is 1.2 m x 1.2 m x 1.2 m. The vine-row is on the left and the alley on the right. **Right**: The topsoil under the row in the 'old' block (average thickness 22 cm). Note the diffuse boundary to the subsoil that is caused by root channels filled with soil organic matter.

Sampling and analysis

We sampled the soil carbon stocks (SCS) in depth increments from the surface to 1-m depth, along vertical lines 0.2 m apart. Along each line ('core'), we took undisturbed samples (bulk density) and the disturbed material surrounding them (soil organic carbon content) at depths of 7, 15, 25, 40, 60 and 85 cm, four cores for each row and alley. The soil organic carbon content (SOC) was analysed with a loss on ignition (LOI) technique calibrated using LECO. The regression calibration (N=80) had an R^2 of 0.94 and a standard deviation of 0.41.

The spatial structure was analysed for the top 0.1 m in the row by sampling every 0.5 m along a transect of 20 m. The SCS were calculated by multiplying the SOC by bulk density and the thickness of the depth increment.

Results

1. **<u>What should be the maximum sampling depth?</u>**

The 'young' kiwifruit block stores about 139 t C/ha and the 'old' one about 145 t C/ha to 1 m depth. We estimated that for both the young and old blocks, 80-90% of these SCS are stored in the top 0.5 m, and 89-95% in the top 0.7 m (Figure 3). Significant differences between the 'young' and 'old' block and between the row and the alley occur only below 0.5-m depth. We recommend ***sampling to 0.5 m for a general inventory and to 1 m if the temporal or spatial dynamics of SCS are of interest.***

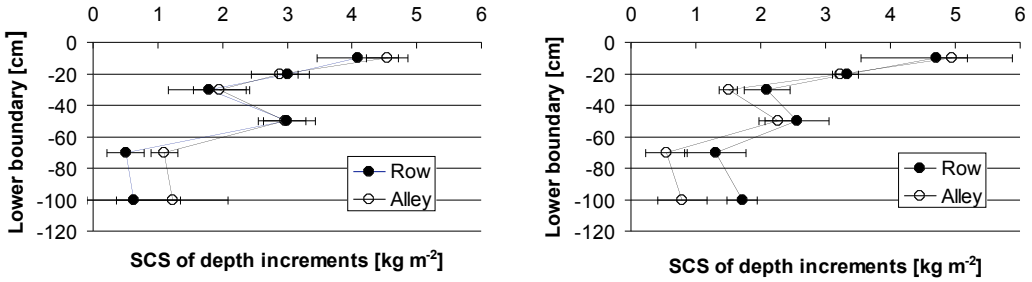

Figure 3: SCS in 'Hort16A' kiwifruit orchards of different ages. **Left**: 'Young' block. The total SCS to 1 m depth are 13±2.1 kg m^{-2} in the row and 14.7±0.5 kg m^{-2} in the alley. **Right**: 'Old' block. The total SCS to 1 m depth are 15.7±0.8 kg m^{-2} in the row and 13.3±0.3 kg m^{-2} in the alley.

2. How many zones (e.g. row, alley) do we need to sample?

With a maximum sampling depth of 0.5 m, there is no significant difference between the SCS in row and alley (Figures 1 and 3), and therefore ***no separate zones need be distinguished***. Below 0.5 m or in herbicided blocks, the SCS must be sampled separately for row and alley.

3. How many cores do we need per orchard block?

The CV of the SCS down to 1 m depth is 5-15%. The number of cores needed is a function of the CV and the statistical confidence of the mean. ***We recommend taking 4-10 cores*** (Figure 4)**.** The cores can then be divided into their depth increments. For an inventory, one mixed bulk sample for each depth increment is sufficient. To study the SCS dynamics, all cores need to be analysed separately.

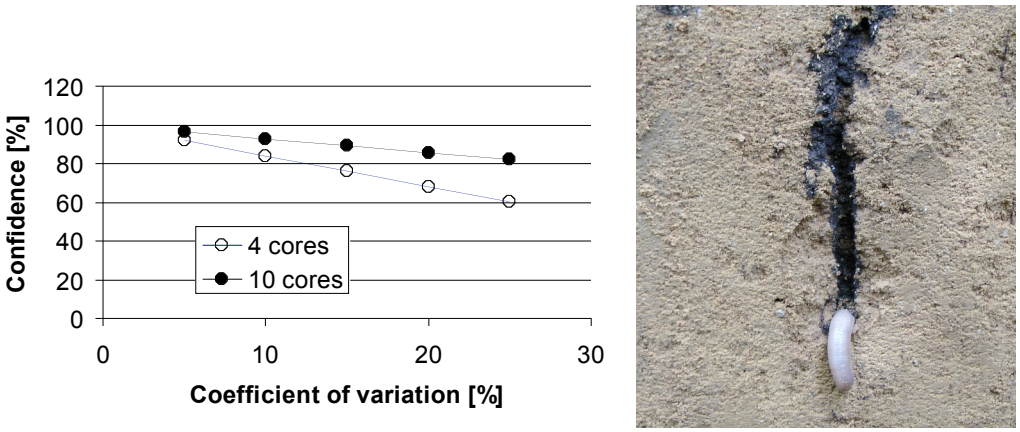

Figure 4: **Left**: Confidence level for the mean SCS to 1 m depth as a function of the coefficient of variation and the number of cores taken per block. **Right:** Earthworms and plant roots are a the main reason for the variability of the SCS in th subsoil.

4. Into which depth increments do we need to divide each core?

For an ***SCS inventory,*** we recommend ***separating a core into sampling increments 0-0.1, 0.1-0.3, and 0.3-0.5 m.*** The first increment is most sensitive to the impact of management. The sum of the first and second increments captures the SCS according to the Kyoto protocol. Including the third increment, the core represents 80-90% of

the SCS down to 1 m depth. For a study of the ***SCS dynamics,*** we recommend ***adding another increment of 0.5-1.0 m***.

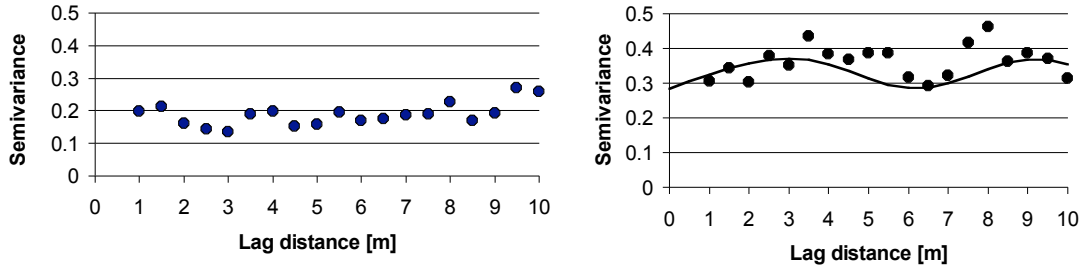

Figure 5: Spatial structure of SCS in the top 0.1 m of the row . **Left**: 'Young' block with no spatial pattern. **Right**: 'Old' block with weak spatial pattern. The range of the pattern is about 3 m and periodically recurs every 5.5 m – the distance between kiwifruit vines in the row.

5. What should be the spatial dimension of a sampling bay?

We detected a weak SCS spatial pattern only for the 'old' block. The pattern had a size (= range) of about 3 m (Figure 5). It periodically recurred every 5.5 m, about the distance between vines in the row (Figure 5). Statistically it is best to monitor the SCS dynamics by taking samples within the 'same' pattern. ***We recommend a maximum length of sampling bay of 3 m***.

We will next test our recommendations and conclusions on other kiwifruit orchards in the BOP and other regions.

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