SOIL CARBON, LIFE CYCLE ASSESSMENT, AND THE NEW ZEALAND APPLE

Edouard Périé[1,2,3], Brent Clothier[1,2], Markus Deurer[1], Steve Green[1], Karin Müller[1], Roberta Gentile[1], Sarah J. McLaren[2,3]

1 New Zealand Institute for Plant & Food Research Ltd, Palmerston North, New Zealand
2 New Zealand Life Cycle Management Centre, New Zealand
3 Massey University, Palmerston North, New Zealand
Corresponding author: Edouard.perie@plantandfood.co.nz

Introduction

Soil carbon sequestration can mitigate climate change, enhances the provision of ecosystem services, contributes to global food security, and ensures the sustainability of food production systems.(Lal 2004; 2008; 2010) But it could also benefit farmers by reducing the carbon footprint (CF) of their products (Périé et al. 2012). The CF is part of a Life Cycle Assessment (LCA); it is a measure of the sum of greenhouse gas emissions during the life cycle of a product. However, due to current CF methodologies and practical measurement difficulties, to date, soil carbon is not integrated into accredited schemes of carbon footprint calculations, such as, for example, the PAS 2050 (BSI 2011). Figure 1 shows the potential for tree and wood accounting in the carbon footprint of a kg of New Zealand (NZ) apples. The potential for orchard soil is calculated on the basis of a 1 tonne/hectare per year change in the soil carbon stock. The potential for tree wood depends on the size of the trees (e.g. dwarf) but also on what happens to the trees at their end of life (e.g. burning, bio-energy, biochar). Overall, accounting for soil and tree carbon in the CF of NZ apples could compensate for the NZ based emissions (Orchard, packhouse and port emissions), assuming carbon storage in soil and trees.

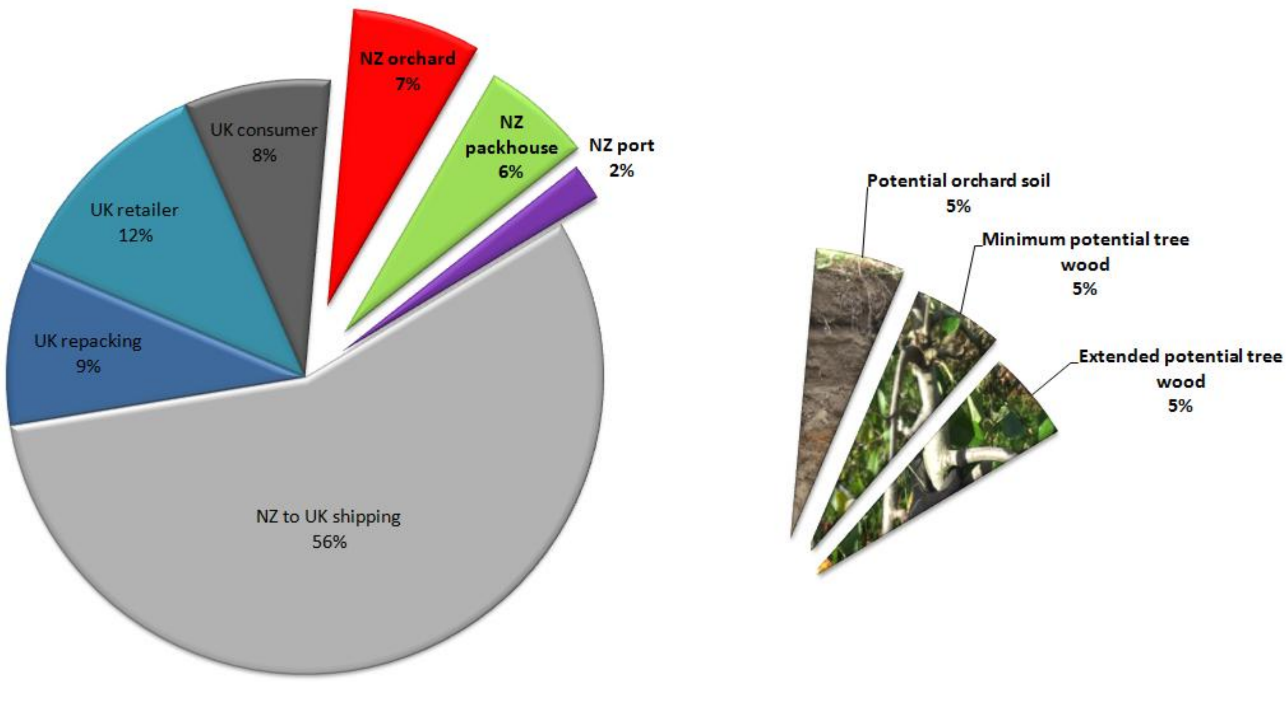


Figure 1: (Left) GHG emissions distribution for New Zealand integrated apples (Royal Gala) consumed in the UK in June using PAS 2050 approach (MAF, 2009) and (right) potential of orchard soil and tree wood accounting (Périé et al. 2012).

Considering soil carbon in CF calculations demands accurate monitoring of soil carbon stocks and statistically significant and powerful detection of small carbon stock changes over time. The number of samples required depends primarily on the spatial variability of soil carbon stocks. Inputs of carbon into the soil are predominantly from the rhizosphere, particularly in the deeper soil horizons (Fig 2). Very little soil carbon stock data are available for orchards. The objective of this study is to investigate the spatial variability of soil carbon stocks at the scale of trees and an orchard block. This information is required to determine the minimum sampling intensity and frequency to accurately observe changes in carbon stocks over time, which is a prerequisite for integrating soil carbon in the carbon footprint of New Zealand apples.

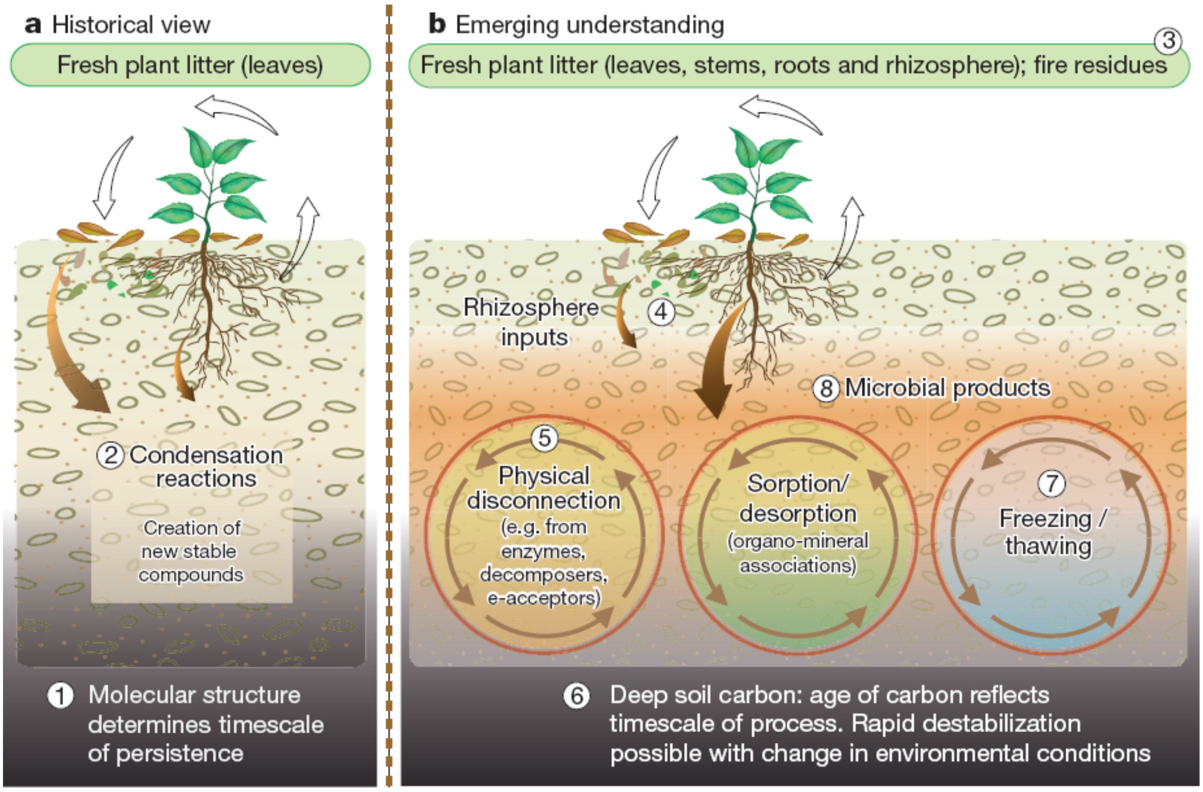
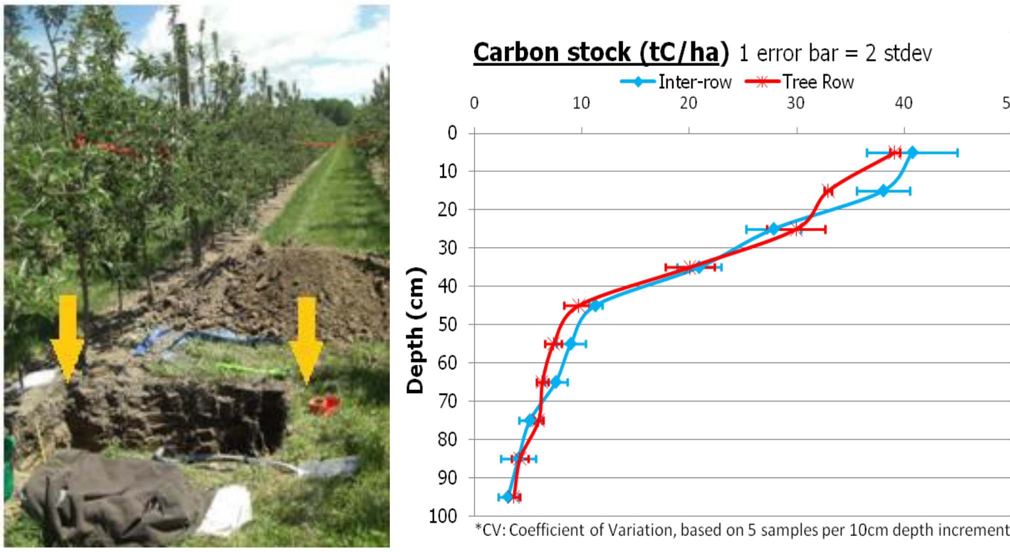


Figure 2: Comparison between historical and emerging understanding of soil carbon cycling (Schmidt et al. 2011)

Measurements at the "tree" scale

At the tree scale, we measured carbon stocks in the top metre of a soil in both the tree row and the inter-row of a four year old commercial apple orchard block (variety Jazz, M.9 (dwarf) rootstock) located in Hawke's Bay. Five samples per treatment (tree row and inter-row) and per 10 cm depth increment were taken for both % carbon analysis with a LECO analyser and soil bulk density, in order to calculate the total carbon stock (in tonne of carbon per hectare, t C/ha) of the soil. Soil carbon stocks decreased rapidly with increasing depth and ranged from 40.7 t C/ha in the top 10-cm layer to 3.1 t C/ha in the bottom 10-cm of the soil profile. Coefficients of variation increased with depth and were between 1% (10-20cm depth increment - tree row) and 40% (80-90cm depth increment - inter-row). This indicates that the number of replicates required for accurate carbon stock measurements also depends on the depth considered.



Depth (cm)	CV* Inter-Row	CV* Tree Row
0-10	10%	1%
10-20	7%	1%
20-30	9%	9%
30-40	10%	11%
40-50	5%	14%
50-60	15%	10%
60-70	14%	9%
70-80	21%	8%
80-90	40%	19%
90-100	30%	16%

*CV: Coefficient of Variation, based on 5 samples per 10cm depth increment

Figure 3: (Left) A soil pit in a commercial orchard in Hawke's Bay. The yellow arrows point at the tree row and the middle of the alley (inter-row) where samples were taken from 0m (surface) to one metre depth. (Right) Carbon stocks as a function of depth (Graph). Coefficients of variation per 10cm depth increment (Tables).

For both treatments, about 64% of the total carbon stock in the top metre was present in the top 30 cm of soil, underlining that deeper depths need to be considered when monitoring soil carbon stocks. Indeed, it was required to consider the top 50 cm of soil in order to account for at least 80% of the carbon present in the top one metre (0-1m) of soil (Fig 4). Therefore, in order to reflect the reality of soil carbon stock changes, particularly in orchard systems it is important to consider deeper depth, as stated by e.g. (Schmidt et al. 2011; Syswerda et al. 2011; VandenBygaart et al. 2011).

Depth increments (cm)	Cumulative carbon stock* Inter-Row	Cumulative carbon stock* Tree Row
0-10	24%	25%
10-20	47%	45%
20-30	64%	64%
30-40	76%	77%
40-50	**83%**	**83%**
50-60	88%	87%
60-70	93%	91%
70-80	96%	95%
80-90	98%	98%
90-100	100%	100%

* As % of top meter

Figure 4: Cumulative carbon stock as a function of depth

Measurements at the "orchard block" scale

An orchard block is defined by a single variety, with a common rootstock, planted with a constant tree and row spacing, and managed as one unit by the grower. At the scale of an orchard block, the variability of carbon stocks to one metre depth was assessed by intensively sampling ten locations across the orchard block. Sixteen one metre long soil cores (0 to 1 metre depth), arranged in a 4x4 grid and avoiding the wheel tracks, were sampled for each of the ten locations. One bulk density profile (0 to 1 metre depth, by 10 cm depth increments) was sampled in the middle of each sampling location and assumed to represent the bulk density for the sampling location. Figure 5 shows the soil carbon stocks for each 1 metre soil core.

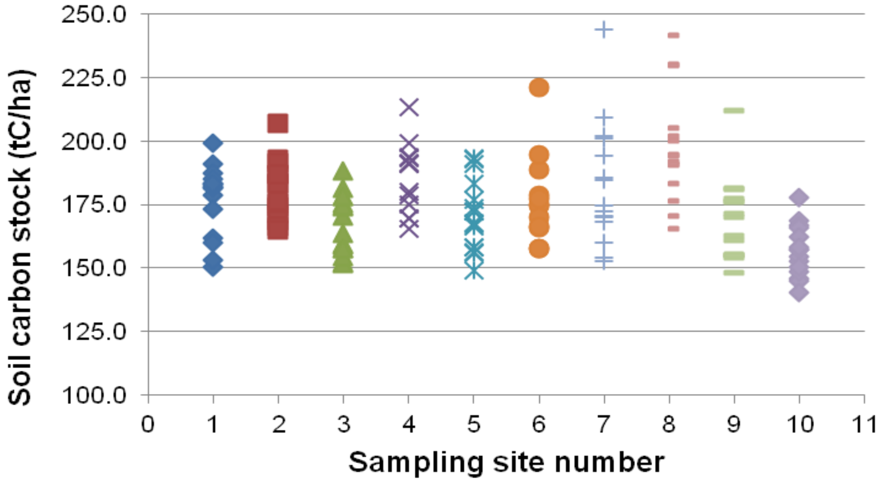


Figure 5: Soil carbon stock for each 1 metre deep soil cores ((one colour = one sampling site = 16 soil cores (data points)

Coefficients of variation were between 6.5% and 13% within sampling locations, which means that between 500 and 2100 soil core samples, respectively, are needed to detect a 1%-change in carbon stocks. However, a change of 5% would be observable with only 15 to 59 samples, respectively (Fig 6).

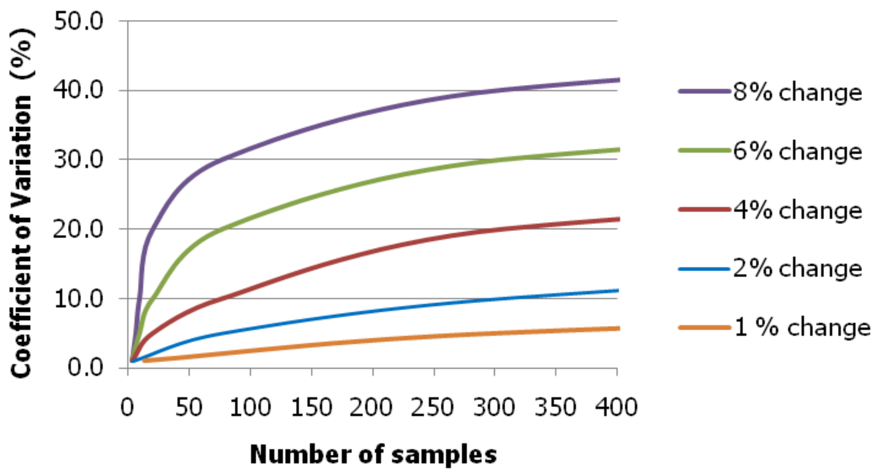


Figure 6: Number of samples required for various coefficient of variation, to detect a 1% to 8% change in the soil carbon stock.

Conclusions

Accounting for soil and tree carbon stocks in the CF of apples could compensate for a substantial part, if not all, of the NZ based emissions. However, sampling depth needs to be representative of the majority of the carbon embedded in the soil, and a depth of 30cm is not sufficient for orchards. Furthermore, the variability of soil carbon stocks both laterally and with depth encourages cautious estimation of sampling intensity, in order to satisfy minimum statistical significance and power requirements, that lead to meaningful results.

The common understanding is that annual changes in soil carbon stocks are usually smaller than 3%. As a result, observing a change over time in soil carbon stocks, even at the small spatial scale of an orchard block, may require a minimum sampling interval of several years. In the future, we will develop guidelines for verifying changes in soil and tree carbon stocks, which are urgently required to allow the incorporation of all carbon stocks in CFs.

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