Soil Organic Carbon in Kiwifruit Orchards

– *Contribution to Carbon Footprint Analysis, Soil Health and Mitigating the Effects of Climate Change*

Organic carbon, deep within New Zealand soil, holds the potential to protect against the effects of climate change.

By adapting orchard management practices to maximize and enhance soil organic carbon, kiwifruit growers can contribute to the long-term sustainability of the New Zealand kiwifruit industry by *'growing'* soil. The contribution of soil organic carbon to carbon footprint analysis may also provide potential for growers to ecoverify their production and even to receive carbon credits.

Soil Organic Carbon is Critical Natural Capital

Soil Organic Carbon (SOC) refers to the carbon stored in soil and is critical natural capital stock for primary producers. Photosynthesis converts atmospheric carbon dioxide gas (CO_2) to plant material some part of which decomposes into SOC. The ability of soil to sequester carbon provides numerous production benefits and natural advantages to growers. It is the main component of soil humus.

Carbon concentrations in soils are the result of carbon inputs driven by plant productivity and carbon management practices, such as compost and manure applications along with tillage practices, as well as the process of decomposition of plant tissue.

Soils with high levels of SOC have a greater capacity for water and nutrient storage, they promote high levels of healthy microbial activity, and they may contribute to the natural control of potential agricultural pests and impart resilience to the effects of climatic extremes such as drought or high rainfall events.

SOC stock is the biggest terrestrial carbon reservoir in the world and maintenance and enhancement of these carbon reserves would help mitigate atmospheric CO_2 increases and anticipated changes in climate. This natural capital stock underpins our economic future.

Understanding SOC Contributes to the Sustainability of the NZ Kiwifruit Industry

Kiwifruit is one of the New Zealand's highest earning horticultural exports, accounting for $1.122 billion in exports over the 2011-12 year. Zespri International Limited, New Zealand's kiwifruit exporter and international marketer, has projected that the kiwifruit export industry will be worth $3 billion by 2029. The green-fleshed *Actinidia deliciosa* cultivar Hayward is the most common kiwifruit variety and contributes to the bulk of New Zealand's production and export volume.

The gold-fleshed fruit, *Actinidia chinensis* Hort16A, and the new variety Gold3 'SunGold' which is proving to be less susceptible to Psa, command a price premium in global markets and carry significant export value for the New Zealand industry.

The major kiwifruit growing areas in New Zealand are Te Puke, Tauranga, Katikati, Eastern Bay of Plenty, Gisborne, Hawke's Bay, South Auckland, Northland, Waikato and Motueka. The soil in many of these regions are allophanic Andisols and carry distinctive properties including a high content of organic matter, high porosity, low bulk density and a high water holding capacity. These soils also have high P-retention and the tendency to bind organic carbon.

The measurement of SOC and the investigation of carbon sequestration rates in soils of integrated and organic Kiwifruit orchards across New Zealand has, for the first time, provided an assessment of New Zealand's carbon stocks in orchards and presented potential strategies to enhance carbon sequestration rates and boost SOC through orchard management practices.

A long-term approach to harnessing and enhancing SOC will contribute to the sustainability of kiwifruit orchards, the continued economic viability of the horticultural industry and the protection of the environment for future generations.

The Research Study

The study set out to quantify both the above- and below-ground carbon storage, including its environmental and economic implications in New Zealand kiwifruit orchards. The study investigated soil samples from 104 kiwifruit orchards across different kiwifruit growing regions of New Zealand. Both Hayward and Hort16A orchards were sampled at various depths. The individual orchard management regimes were noted, as well as the age of the blocks sampled. A number of different study parameters were investigated as part of this multi-disciplinary study; including sample depth, vine row vs. alleyway, adjacent young and old blocks, and adjacent orchards and pastures.

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Key Outcomes of the Research Study

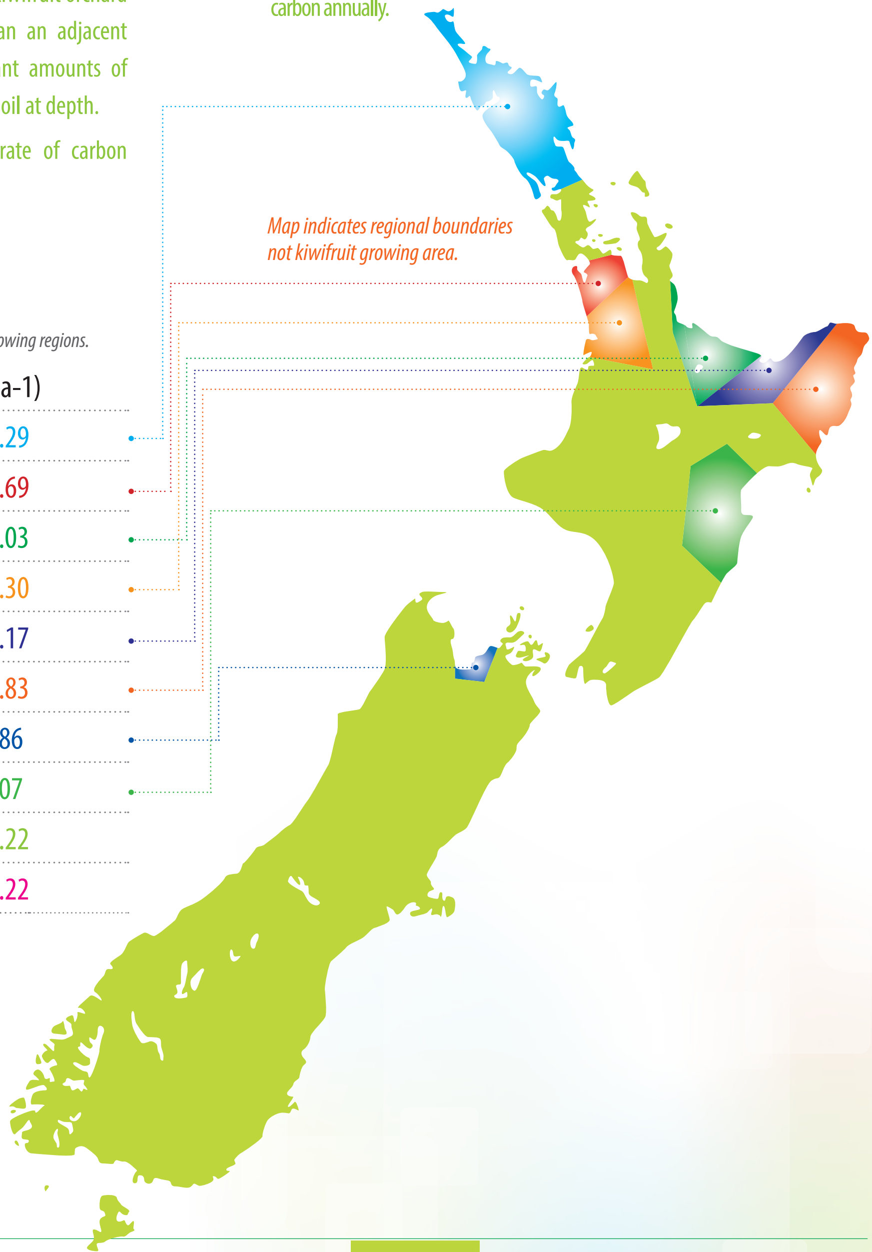
- The study showed that SOC varies greatly across New Zealand's kiwifruit growing regions, with the highest SOC recorded in Northland orchards and the lowest SOC readings in Hawke's Bay. *(Figure 1).*
- The ranking of the regions in decreasing SOC is:

  Northland > South Auckland > Western Bay of Plenty > Waikato > Eastern BOP > Gisborne > Motueka > Hawke's Bay.
- The total carbon stock in the top 1 metre of kiwifruit orchard soils in New Zealand was estimated to be 2,240,760 tonnes.
- Older, more established orchard blocks had sequestered more carbon than younger blocks, equating to an annual carbon sequestration rate of 400 kg carbon ha^{-1} year^{-1} in the top 1 metre of soil.
- Soil at a depth of nine (9) metres under a 30-year-old kiwifruit orchard sequestered 6.3 tonnes carbon ha^{-1} year^{-1} more than an adjacent pasture soil to the same depth. These are significant amounts of carbon sequestration. The kiwifruit vines are 'growing' soil at depth.
- There was no significant difference between the rate of carbon sequestration in Hayward and Hort16A orchards.

Figure 1. *Average SOC stock to 1 metre deep in New Zealand's kiwifruit growing regions.*

Region	Area (ha)	C (t ha-1)
Northland	456	451.29
South Auckland	500	258.69
Western BOP	8288	188.03
Waikato	469	171.30
Eastern BOP	1756	103.17
Gisborne	255	102.83
Motueka	511	68.86
Hawke's Bay	191	55.07
Other	77	179.22
TOTAL	12503	179.22

- Hayward kiwifruit caused significantly less greenhouse gas (GHG) emissions per kg of fruit in the orchard phase than Hort16A kiwifruit. This is mainly due to the higher levels of nitrogen fertilisers used in Hort16A and the GHG emissions associated with fertiliser production, application and transport.
- Comparing the GHG emissions of the two management systems, the carbon footprint of organic production was only slightly lower than that of integrated production. This environmental advantage was not reflected in eco-efficiency, due to the higher yields of integrated production.
- By extrapolating the nine (9) metre results of this study across the total landmass dedicated to kiwifruit production, it can be estimated that the New Zealand kiwifruit industry sequesters approximately 90,000 tonnes of carbon annually.



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International Acceptance of Methodology

One of the key objectives of this study was to define a soil collection and evaluation methodology that allowed for the rapid collection of samples at various depths in orchards with minimal soil disturbance. The methodology developed for this study was based on European Commission EUR 21576 EN/2 Protocol and met the requirements of the international guidelines such as PAS 2050: 'Specification for the assessment of the lifecycle greenhouse gas emissions of goods and services'.

Accurately Calculating the Carbon Footprint of New Zealand Kiwifruit

Existing carbon footprint studies of the New Zealand kiwifruit industry have measured the carbon emissions associated with the harvest, packing, storage and transportation of kiwifruit (from orchard gate to consumer plate) using 2011 international guidelines for 'the assessment of the lifecycle greenhouse gas emissions', known as PAS 2050. This methodology does not yet account, however, for carbon sequestration that occurs during the growing phase.

By measuring carbon stores and the carbon sequestration rate of soils in kiwifruit orchards across New Zealand, we may be able to claim offsets against some of the GHG emissions associated with production and transportation of New Zealand kiwifruit to international markets. The inclusion of on-orchard carbon sequestration data has allowed a more accurate quantification of carbon footprint of New Zealand kiwifruit, taking into consideration the entire lifecycle of the kiwifruit.

This study investigated the carbon footprint of kiwifruit production, expressed as CO_2 equivalents (CO_2e). By relating the GHG emissions to the land area (one hectare) and the product (one kg of kiwifruit), results provided an environmental footprint.

This research study found that kiwifruit orchards sequester 400 kg carbon ha^{-1} year^{-1} in the top 1 meter of soil. When converted to CO_2 equivalents (CO_2e) this equates to 4% of the GHG emissions associated with the production of Hayward kiwifruit for consumption in the UK.

If the top 9 meters of soil were included in the calculations (6.3 tonnes carbon ha^{-1} year^{-1}), then the amount of carbon sequestered equates to approximately 42% of the GHG emissions associated with the production of Hayward kiwifruit in New Zealand and shipping to the UK for consumption. This is significant, and highlights the need for protocols to account for deep soil-carbon.

Figure 2. *Contribution of SOC to the Carbon Footprint of New Zealand Kiwifruit*

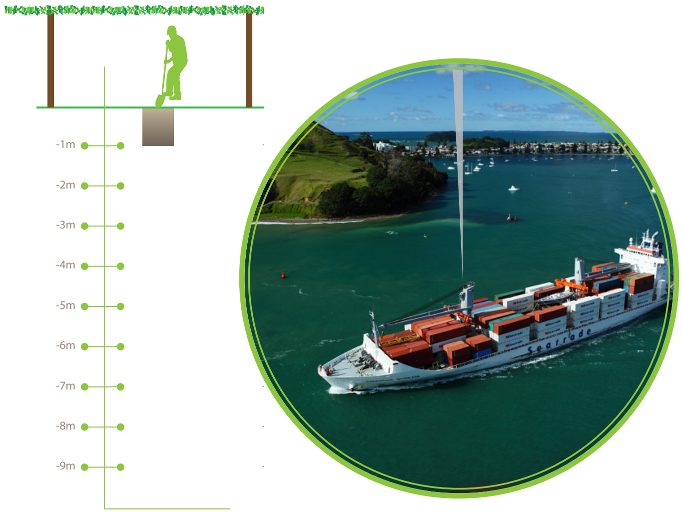

Image shows soil depth at 1m at LHS being equivalent to 4% of emissions on RHS

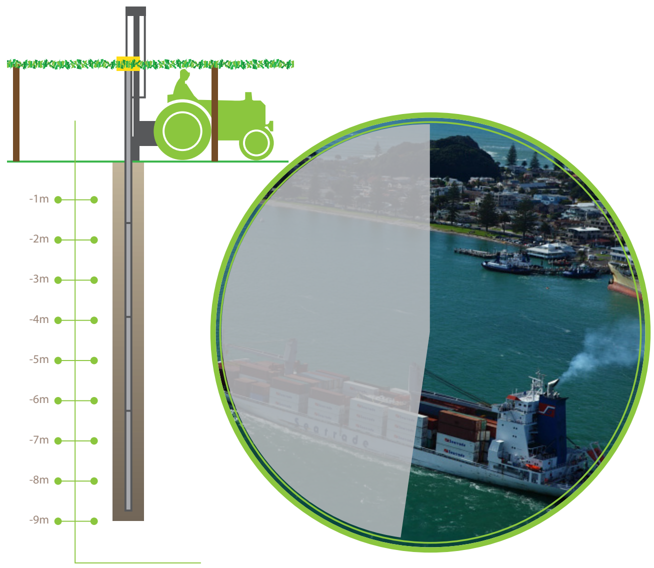

Image shows soil depth at 9 m at LHS being equivalent to 42% of emissions on RHS

Taking into consideration orchard inputs during the production phase for Hort16A and Hayward, and GHG emissions due to orchard management practices, organic kiwifruit had a slightly lower carbon footprint than that of integrated production. As integrated production results in a higher yield of kiwifruit per hectare, the adjusted carbon footprint of about 0.15 kg CO_2e kg^{-1} confers a similar environmental advantage for organic kiwifruit as for integrated production.

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Achieving Competitive Advantage by Reducing Carbon Footprint

Global population increases, rising energy costs, vulnerability to extreme events and degradation of soil and water resources are creating global concerns about food security, land management practices and greenhouse gas emissions.

By demonstrating that the production of kiwifruit can enhance or maintain carbon storage and reduce overall carbon emissions associated with the land use, greater differentiation of our products may be achieved in environmentally concerned markets such as Europe and Asia.

Carbon storage within orchard systems could be recognised as a progressive step in environment management. Enhanced SOC will enable New Zealand kiwifruit producers to manage input costs while reducing environmental and climatic related risks. This in turn will position New Zealand as a leading supplier of sustainably produced food.

An ability to lower the carbon footprint of kiwifruit may become a means to enter specific markets or to maintain price premiums. Therefore, New Zealand kiwifruit growers could adapt a specific set of carbon-storage management practices as one of several possible strategies to achieve a lower carbon footprint and ensure "shelf access" in the world's premium supermarkets.

By incorporating this quantification into international and national certification standards, the risk of "green-wash" associated with weak environmental claims will be eliminated. In future, with markets that trade carbon, New Zealand kiwifruit growers may well profit directly from carbon sequestered in their soils.

Adapting Orchard Management Practices to Enhance SOC

The results of this study have immediate practical applications for New Zealand kiwifruit growers and future financial benefits.

Growers are continually looking for ways to reduce orchard inputs, such as fertilisers and protective sprays, without compromising fruit quantity, quality, size, and taste or storage life. By fully understanding the SOC profile of their orchard, a grower may be able to tailor orchard management practices to maintain and improve SOC, thereby harnessing the natural water storage capability and the nutrient and microbial activity of the soil, in order to maximise orchard productivity and increase profitability.

Any increase in SOC will improve soil drainage, root penetration, soil aeration and help to reduce compaction, especially critical in regions that have low levels of natural SOC such as Gisborne, Hawke's Bay and Motueka.

In practical terms this may mean:

→ Less nitrogen is required to be applied across the orchard;

→ Lower irrigation volumes are required as more water is retained within the soil; and

→ Soils are protected against the occurrence of root diseases such as Armillaria;

In order to enhance SOC, growers in regions across New Zealand are already implementing on-orchard practices such as:

→ Planting deep-rooting sward species such as chicory, plantain and clover under the kiwifruit canopy. These species create explorative root channels in the soil at depth and when these roots die, they create carbon rich channels that are explored by earthworms which draw carbon to a depth where it can be sequestered;

→ Planting fast-growing trees as natural shelterbelts. Trees produce a large amount of biomass and grow large explorative root systems. They also grow stem and leaf biomass suitable for mulching back into the soil when they are trimmed;

→ Maintaining vegetation cover under the canopy to buffer soil temperature, inhibit weeds, slow soil evaporation, increase transpiration and reduce erosion;

→ Reducing mowing to reduce the exposure of organic carbon to the air and sunlight and hence the decomposition to CO_2; and

→ Applying fertilisers and soil conditioners such as organic fertilisers, green manure crops and inoculants that promote the growth of soil microbes to enhance soil health and the build up of soil carbon.

These practices will also deliver significant ecological benefits to the surrounding land and downstream waterways and contribute to reducing the kiwifruit industry's carbon and water footprint.

Potential for Growers to Receive Carbon Credits

Perennial horticultural crops are not currently included in carbon trading schemes but this is a rapidly changing area of investment and payment. This poses opportunities for the future and potential value to kiwifruit growers. Agricultural and horticultural producers are already paying increased costs for inputs such as fuel, fertilisers and pesticides because of ETS schemes and carbon taxes. There is significant information that needs to be gathered before any decision will be made as to whether farmers may use soil carbon to participate in carbon trading.

Applications for Other Horticultural Industries

The methodology to measure soil organic carbon is immediately applicable to other perennial crop industries such as viticulture, avocado, pipfruit and summerfruit. Management practices to enhance soil organic carbon within these horticultural industries will also provide long-term benefits to the environment.

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