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# Futures for New Zealand’s arable and horticultural industries in relation to their land area, productivity, profitability, greenhouse gas emissions and mitigations

Clothier B, Müller K, Hall A, Thomas S, van den Dijssel C, Beare M, Mason K, Green S, George S

**March 2017**















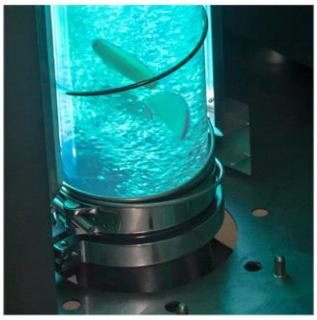


## Report for:

New Zealand Agricultural Greenhouse Gas Research Centre



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March 2017

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# CONTENTS

# EXECUTIVE SUMMARY

## Futures for New Zealand's arable and horticultural industries in relation to their land area, productivity, profitability, greenhouse gas emissions and mitigations

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**March 2017**

This report has been requested to address two main issues in relation to greenhouse gas emissions from non-pastoral agriculture.

1. On-farm reduction options for the arable and horticultural industries
   - On-farm practices and total LCA (Life Cycle Assessment) based greenhouse gas (GHG) emissions (TGE).
   - The fraction of TGE emissions that emanate from biological GHG emissions (BGE) due to emissions of methane ($CH_4$) and nitrous oxide ($N_2O$).
   - Mitigation options, and the magnitude of potential emissions reductions and net GHG benefits for both TGE and BGE, and their net impact on profitability.
   - Number of hectares or number of farms where those mitigation options apply.
2. Alternative land-use systems involving arable and horticultural enterprises
   - What is the potential land area that arable and horticultural enterprises could cover, and what area do they currently cover? What is the current trend in the expansion/contraction of these land-uses, and where are these changes occurring?
   - What is the current profitability per hectare, and trends, for arable and horticultural farming?
   - What are current GHG emissions per hectare from each land-use? Do we know typical levels of (steady state) soil carbon under each land-use, and above-ground carbon storage?
   - What have been the changes in the productivity and net revenue for the arable and horticultural industries, and what are the prospects for future growth?
   - What is the prospect for mixed-crop livestock farming, wherein livestock farms also encompass arable and horticultural blocks as part of their enterprise? Will such aggregated blocks be capable of forming a distributed and profitable industry? More generally, are there minimum/maximum scales for profitable operations of alternative land-uses, and what would be the major infrastructure and market requirements?
   - What would be the co-benefits of future growth in arable and horticultural farming, and mixed-crop livestock farming, in relation to water (National Policy Statement for Freshwater Management, NPS-FW) and biodiversity?

Key findings are that the total GHG footprints of both the horticultural and arable industries is relatively modest; ranging from 2 T $CO_{2\text{-}e}$ $ha^{-1}$ for arable farming through to 3-6 T $CO_{2\text{-}e}$ $ha^{-1}$ for horticulture. The biological emissions of GHG averages 13% of TGE for horticulture, with a range from 6 to 19%. The proportion of BGE of the TGE for arable farming is reported to be 40%.

 

Because of the intensity of on-farm practices, there is a range of total and biological GHG mitigations that can be adopted, and many of these would improve farm profitability. Despite this, there seems little enthusiasm to consider these efficiency and economic gains, as the focus of the growers appears to be elsewhere. If soil sequestration of carbon were to be considered, the total GHG footprints of these industries would likely be reduced, especially for deep-rooted trees and vines in horticulture. There are challenges in quantifying and verifying these changes in soil carbon.

If the price of carbon were to be set at \$50 T $CO_{2\text{-e}}$, and applied to easily mitigated TGE, then this would negatively affect farm EBIT by 2% for horticulture and 5% for arable farming. If the price of carbon were applied only to BGE, then the impact on EBIT would be on average 0.3% for horticulture, and 2% for arable farming.

The EBITs of the arable and especially the horticultural industries are high. There is potential for these industries to spread onto new lands, as across New Zealand there are many valuable and versatile soils in regions with favourable climates. Commodity prices, water resources, human capacity and infrastructure might poses limits on the expansion of these industries. There is biophysical potential across New Zealand's diverse landscapes to enable expansion of horticulture and arable farming, should entrepreneurs and the market see opportunities to do so.

Mixed farming systems, and diverse-crop rotations offer future potential to extract value from New Zealand's natural capital assets, with moderate GHG emissions.

There are critical gaps identified by these analyses. These include: how can soil-carbon sequestration and standing biomass accumulation can be better accounted for in GHG emissions; why do growers not adopt climate-smart options even when they would improve farm EBIT; why with high horticultural EBIT, and export markets strong, are there not more conversions to horticulture and arable? It would be worthwhile also to examine the barriers to the adoption of profitable, climate-smart farming system. Such enquiries are beyond the ambit of this report as they would not only require the biophysical analyses carried out here, but also socio-economic surveys and interpretations of the behaviour of individuals, communities and industries.

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# INTRODUCTION

The lead article in a recent **Guardian Weekly** (11-17 November, 2016) was headed "*Climate 'crunch point' looms*". The report focussed on a recent review just released by Lord Nicholas Stern, an economist and erstwhile Permanent Secretary of the United Kingdom's Treasury. He noted that "… it has taken only 11 months to get the Paris (climate) agreement ratified [whereas] it took eight years to get its predecessor, the Kyoto Protocols, into force". Lord Stern considers that "… we have reached the point where we can now see that the alternative route is not really something that should be regarded as a cost. It is actually a much better way of doing things".

Within this context, we have been asked to consider alternative futures for New Zealand's arable and horticultural industries in relation to their land area, productivity, profitability, greenhouse gas emissions, and mitigation impacts.

In this draft report the industries considered are:

- Horticulture: Apples, kiwifruit and wine grapes
- Arable: Forage, maize, cereal, potatoes and seed crops

We have carried out industry engagement with Pipfruit NZ, Zespri, New Zealand Winegrowers, AgFirst, and the Foundation for Arable Research. This report considers three issues:

**On-farm reduction options for the arable and horticultural industries**

- On-farm practices and total LCA-based greenhouse gas (GHG) emissions (TGE).
- The fraction of TGE emissions that emanate from biological GHG emissions (BGE) due to emissions of methane ($CH_4$) and nitrous oxide ($N_20$).
- Mitigation options, and the magnitude of potential emissions reductions and net GHG benefits for both TGE and BGE, and their net impact on profitability.
- Number of hectares or number of farms where those mitigation options apply.

**Alternative land-use systems involving arable and horticultural enterprises**

- What is the potential land area that arable and horticultural enterprises could cover, and what area do they currently cover? What is the current trend in the expansion/contraction of these land-uses, and where are these changes occurring?
- What is the current profitability per hectare, and trends, for arable and horticultural farming?
- What are current GHG emissions per hectare from each land-use? Do we know typical levels of (steady state) soil carbon under each land-use, and above-ground carbon storage?
- What have been the changes in the productivity and net revenue for the arable and horticultural industries, and what are the prospects for future growth?
- What is the prospect for mixed-crop livestock farming, wherein livestock farms also encompass arable and horticultural blocks as part of their enterprise? Will such aggregated blocks be capable of forming a distributed and profitable industry? More

generally, are there minimum/maximum scales for profitable operations of alternative land-uses, and what would be major infrastructure and market requirements?

- What would be the co-benefits of future growth in arable and horticultural farming, and mixed-crop livestock farming, in relation to water (National Policy Statement for Freshwater Management, NPS-FW) and biodiversity?

### Critical gaps

In answering the two issues above, what are critical gaps in moving towards future sustainable options for New Zealand's agricultural systems?

# 1 PART 1: ON-FARM REDUCTION OPTIONS FOR THE ARABLE AND HORTICULTURAL INDUSTRIES

The first part of this project addresses the GHG emissions and their potential for reduction options and their economic impacts.

We have been asked in Part 1 of this project to evaluate:

On-farm reduction options for the arable and horticultural industries

- On-farm practices and total LCA-based greenhouse gas (GHG) emissions (TGE).
- The fraction of TGE emissions that emanate from biological GHG emissions (BGE) due to emissions of methane ($CH_4$) and nitrous oxide ($N_2O$).
- Mitigation options, and the magnitude of potential emissions reductions and net GHG benefits for both TGE and BGE, and the net impact on profitability.
- Number of hectares or number of farms where those mitigation options apply.

Here we provide responses to these questions for the horticultural industries of kiwifruit, wine grapes and apples, plus the arable industry.

## 1.1 Horticultural areas

In response to the last query about land areas, we have used recent information provided in Fresh Facts (2015) and updated by more recent information.

The area of kiwifruit in Fresh Facts (2015) is given for 2012 as being 12,757 ha, which is down from 13,250 ha in 2007, due probably to the *Pseudomonas syringae actinidiae* (Psa) incursion. This is likely to have increased more recently with the advent of the Zespri® SunGold Kiwifruit variety.

Wine grapes covered 29,616 ha in 2007, and 34,562 ha in 2012 (Fresh Facts 2015), a rise of 17%. The 2016 NZ Winegrowers Report indicated that there were 36,192 ha of wine grapes in 2016.

Apple orchards covered 8845 ha in 2012, down from 9247 ha in 2007 (FreshFacts, 2015). However a recent report by AgFirst indicated that there are now 9308 ha under apples, and growth through until 2020 is expected to see this rise to 10,995 ha.

The land area growing kiwifruit, grapes and apples exceeds 58,000 ha, and these industries generated $3.2 billion of export revenues. This equates to export-revenue generation of $55,100 per hectare of horticulture.

Furthermore, as we discuss elsewhere, growth prospects in terms of areal expansion and market growth appear strong.

## 1.2 Kiwifruit GHG footprint

### 1.2.1 Total emissions

The first carbon-footprinting study of horticultural crops funded by (the then) MAF was for kiwifruit (Mithraratne et al. 2008). It was carried out in 2008 by considering the PERF footprint protocol (Product-Related GHG Emissions Reductions Framework V2-0) of the Carbon Trust in the UK. The PAS 2050 of the British Standards Institute was used in subsequent studies, but at the time of writing the kiwifruit report (Mithraratne et al. 2008) it was only in draft form.

In this first carbon footprinting project, there was no economic assessment, nor was consideration given to the option that the efficiency of fuel and electricity use could be further improved, nor better driving practices and vehicle-use habits for machinery, nor more fuel-efficient tractors and other forms of machinery (e.g., lighting systems and pumps).

The GHG footprint was standardised to a tray equivalent (TE), where it was considered that 1 TE contained 33 kiwifruit, each weighing 100 g. In order to convert the GHG footprint from the functional unit of 1 TE to area based emissions, the study considered average yields for green kiwifruit of 6275 TE $ha^{-1}$, gold kiwifruit at 8390 TE $ha^{-1}$ and for organic green of 5,199 TE $ha^{-1}$.

The system boundary for the life cycle assessment (LCA) of the footprint was for kiwifruit consumed in the United Kingdom, and therefore consideration was not only given to the orchard phase within the farm gate, but also emissions from the packhouse and coolstore, storage at the New Zealand port, shipping, repacking in Zeebrugge, the retailer in the UK, and the consumer at home. The TGE emissions for each of the LCA phases is shown in Figure 1 below.

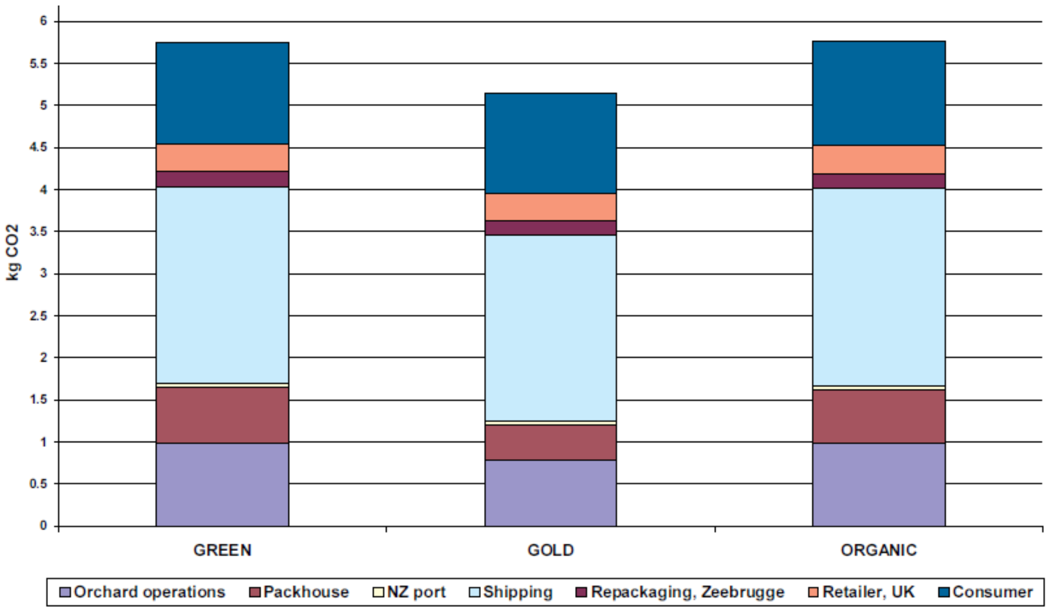



**Figure 1. The total greenhouse gas (GHG) emissions per tray equivalent (TE) for the two varieties of kiwifruit broken down by life cycle phase. Organic management is shown on the right.**

It can be seen that the orchard phase contributes about 20% of the emissions, and this relativity can be seen more clearly in the bar chart below (Figure 2) where the emissions are normalised to a kilogram of kiwifruit consumed in the UK.

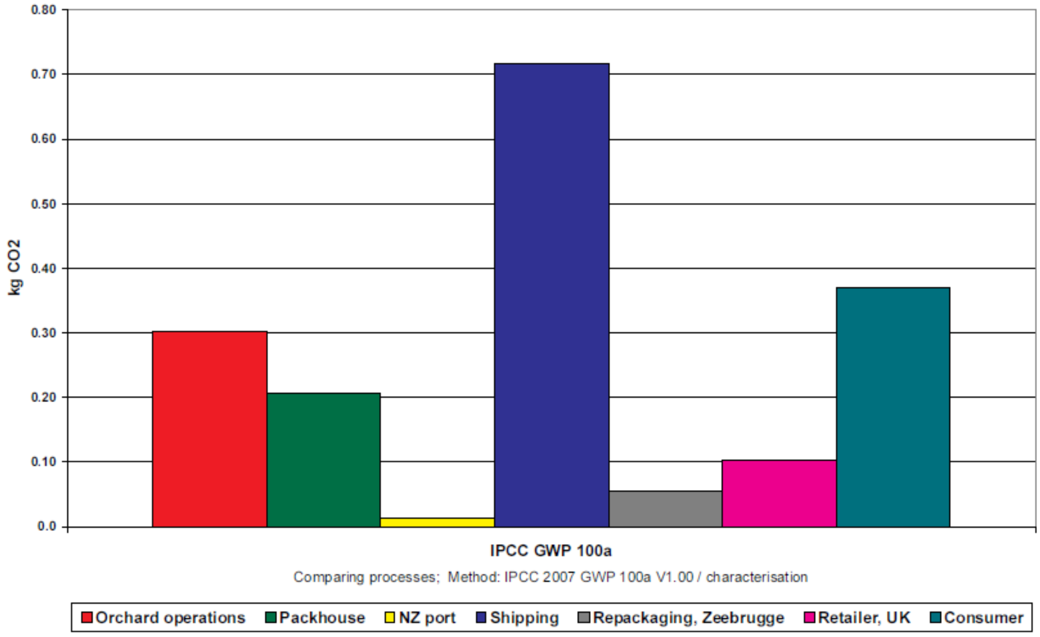



**Figure 2. The total greenhouse gas (GHG) emissions for the various life cycle phases for 1 kg of kiwifruit consumed in the United Kingdom.**

From these results, the areal emissions of TGE from the orchard-phase of kiwifruit production are estimated at 6.3 T $CO_{2\text{-}e}$ $ha^{-1}$ for both green and gold kiwifruit, and 5.2 T $CO_{2\text{-}e}$ $ha^{-1}$ for organic green.

### 1.2.2 Biological GHG emissions (BGE)

We now consider BGE as a fraction of TGE. Essentially because there are no animals, and orchards are on free-draining soils, we assume the $CH_4$ emissions are zero, so that the only BGE gases are nitrous oxide, and respired $CO_2$ from the soil and decomposing prunings are considered. We consider that the $CO_2$ emissions are assumed to be covered by our assessment in the net changes in soil carbon, and that the respired $CO_2$ from prunings is neutral because the carbon was first captured by the plant.

For nitrous oxide emissions, we have followed the standard IPCC protocols. We consider in IPCC calculations the amount of fertiliser N applied, and the addition of N to the soil system through leaf-fall, and via the return of prunings. We convert our estimate of nitrous oxide emission to BGE using the global warming potential (GWP) value of 298.

In a study of the water footprint of kiwifruit in the Bay of Plenty (Deurer et al. 2011), we modelled the nitrogen dynamics of orchards using our mechanistic model SPASMO. We considered that 130 kg N $ha^{-1}$ $y^{-1}$ was applied as fertiliser, with some 70 kg N $ha^{-1}$ $y^{-1}$ was added to the soil via prunings and leaf fall. The standard IPCC calculation of BGE for this system would suggest 1.03 T $CO_{2\text{-}e}$ $ha^{-1}$ $y^{-1}$, or 19% of TGE if we consider the average TGE to be 5.5 T $CO_{2\text{-}e}$ $ha^{-1}$ $y^{-1}$ for kiwifruit.

### 1.2.3 Total GHG reductions

Options for TGE reductions for the life cycle (LC) of kiwifruit were developed by Deurer et al. (2008). Seven orchard-phase reduction options were considered, with the first two relating to new orchard development from pasture were excluded from Table 1. The orchard-phase operational reduction options that would be feasible in the short term were given in relation to the base line emissions (BLE) from Mithraratne et al. (2008) and are shown Table 1 in both g $CO_{2\text{-}e}$ $TE^{-1}$ and % reductions.

**Table 1. Estimated reduction of the total greenhouse gas (GHG) emissions in the "Orchard operations" phase of the product-related lifecycle (LC) of a tray of kiwifruit (from Deurer et al. 2008). This is due to short-term options that would be immediately feasible.**

| | Estimated reduction [g $eCO_2$ $TE^{-1}$] | | | Reduction relative to LC-BLE [%] | | |
|---|---|---|---|---|---|---|
| **Reduction option (keyword)** | **GREEN** | **GREEN-Organic** | **GOLD** | **GREEN** | **GREEN-Organic** | **GOLD** |
| R3 (sheep grazing) | 42 | 39 | 28 | 0.6 | 0.6 | 0.5 |
| R4 (biodiesel) | 23 | 21 | 15 | 0.3 | 0.3 | 0.3 |
| R5 (productivity) | 101 | 219 | 78 | 1.5 | 3.3 | 1.4 |
| R6 (biochar prunings) | 44 | 59 | 35 | 0.7 | 0.9 | 0.6 |
| R7 ($N_2O$ emissions) | - | - | - | - | - | - |
| ***Total*** | 210 | 338 | 156 | 3.1 | 4.2 | 2.8 |

These short-term reduction options involve using sheep for grazing, rather than mowing, using biodiesel, increasing productivity, using biochar from the prunings, and reducing nitrous oxide emissions. In total these would enable orchard phase reductions of about 3–4% of total emissions, which is relatively modest, when considered alongside reduction options elsewhere in the life cycle (Table 2), which would enable reductions of TGE by 19–22%. Most of these reductions would affect TGE and would not result in large changes to BGE.

**Table 2. Estimated short-term reductions of the total greenhouse gas (GHG) emissions in the individual phases of the product-related lifecycle (LC) of a tray of kiwifruit.**

| | Estimated reduction [g $eCO_2$ $TE^{-1}$] | | | Reduction relative to LC-BLE [%] | | |
|---|---|---|---|---|---|---|
| **Phase** | **GREEN** | **GREEN-Organic** | **GOLD** | **GREEN** | **GREEN-Organic** | **GOLD** |
| Establishing a new orchard | 393 | 519 | 312 | 6.1 | 7.8 | 5.5 |
| Orchard operations | 166 | 279 | 121 | 2.5 | 4.2 | 2.1 |
| Packhouse and coolstore | 288 | 288 | 288 | 4.5 | 4.4 | 7.1 |
| Shipping | 399 | 399 | 399 | 6.2 | 6.0 | 7.1 |
| Repackaging in Europe | - | - | - | - | - | - |
| Retailer | - | - | - | - | - | - |
| Consumer | - | - | - | - | - | - |
| Waste management | - | - | - | - | - | - |
| ***Total*** | 1246 | 1485 | 1120 | 19.3 | 22.4 | 21.8 |

Deurer et al. (2008) also considered more strategic and medium-term reduction options and these are shown in Table 3.

**Table 3. Estimated medium-term and total (short- and medium-term) reductions of the total greenhouse gas (GHG) emissions in the individual phases of the product-related lifecycle (LC) of a tray of kiwifruit.**

| | Estimated reduction [g $eCO_2$ $TE^{-1}$] | | | Reduction relative to LC-BLE [%] | | |
|---|---|---|---|---|---|---|
| Phase | GREEN | GREEN-Organic | GOLD | GREEN | GREEN-Organic | GOLD |
| Establishing a new orchard | - | - | - | - | - | - |
| Orchard operations | 44 | 59 | 35 | 0.7 | 0.9 | 0.6 |
| Packhouse and coolstore | 242 | 242 | 242 | 3.8 | 3.7 | 4.3 |
| Shipping | 545 | 545 | 545 | 8.5 | 8.2 | 9.6 |
| Repackaging in Europe | - | - | - | - | - | - |
| Retailer | - | - | - | - | - | - |
| Consumer | - | - | - | - | - | - |
| Waste management | - | - | - | - | - | - |
| ***Total (medium-term)*** | 831 | 846 | 822 | 13.0 | 12.8 | 14.5 |
| ***Total (short-term)*** | 1246 | 1485 | 1120 | 19.3 | 22.4 | 21.8 |
| ***Total (short- and medium-term)*** | 2077 | 2331 | 1942 | 32.3 | 35.2 | 36.3 |

Again, options in the medium term to reduce within-orchard gate GHG emissions are quite modest, relative to elsewhere in the life cycle phases where bigger reductions could be made. The shipping phase has the highest medium-term reduction potentials.

### 1.2.4 Soil carbon sequestration

Neither the PERF nor the early versions of the PAS 2050 allowed consideration of biogenic carbon or sequestered soil carbon. The new International Standards Organisation GHG protocol ISO-14067 does however suggest that soil carbon storage changes 'should' be considered. It does not rate them a 'must' however. In the GHG emission studies of Mithraratne et al. (2008) and Deurer et al. (2008) soil-carbon changes were not considered.

### 1.2.5 Regional assessment of carbon stocks in kiwifruit orchards

Holmes et al. (2015) examined regional carbon stocks under kiwifruit orchards. In this regional survey of kiwifruit orchards in New Zealand the soil organic carbon (SOC) stocks varied between 42.46 t $ha^{-1}$ and 600.84 t $ha^{-1}$, with the greatest average regional SOC stock recorded in Northland and the lowest in Hawkes Bay (Figure 3).

In more than 60 kiwifruit orchards throughout New Zealand the average carbon storage to 1 m depth was 174.9 ± 3 t C $ha^{-1}$.

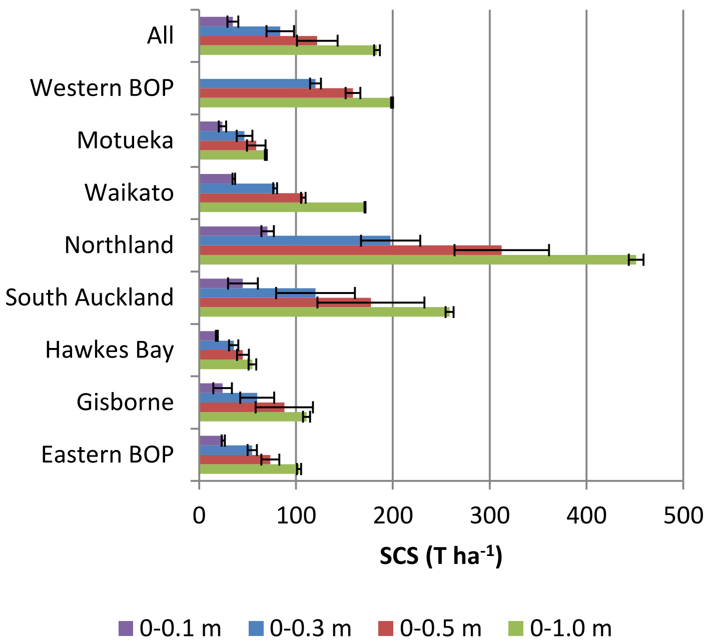



**Figure 3. Soil carbon stocks (SCS) integrated to four different depths (0–0.1, 0–0.3, 0–0.5, 0–1 m depth) in *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit orchards under integrated management located in the eight most important kiwifruit growing regions in New Zealand. In every region, three representative orchards were sampled with six samples taken per depth (0–0.1, 0.1–0.3, 0.3–0.5, and 0.5–1 m depth). Exceptions were Waikato and Gisborne, where we sampled six and two kiwifruit orchards respectively, and the Bay of Plenty where we sampled 10 kiwifruit orchards. The bars represent the standard error of the measurements.**

However in this regional study, no correlation was found between age of the orchards and SOC stocks in top 1 m.

## 1.2.6 Carbon accumulation in kiwifruit orchards

In a preliminary study Deurer et al. (2010) examined the impact of orchard age on soil carbon storage under kiwifruit. They studied young (10 year) and old (25 year) kiwifruit blocks on orthic allophanic soil in the Bay of Plenty (BoP) and showed they stored in the rows about 13 ± 2.1 kg $m^{-2}$ and 15.7 ± 0.8 kg $m^{-2}$ to 1 m depth. A more detailed analysis showed that there was actually no difference in the C stocks between the orchards if only the top 50 cm were considered. Between 80 and 90% of the soil carbon stocks were stored in the top 0.5 m irrespective of the orchard's age (Figure 4). The changes in soil-carbon were only significant below 0.5 m (Deurer et al., 2010).

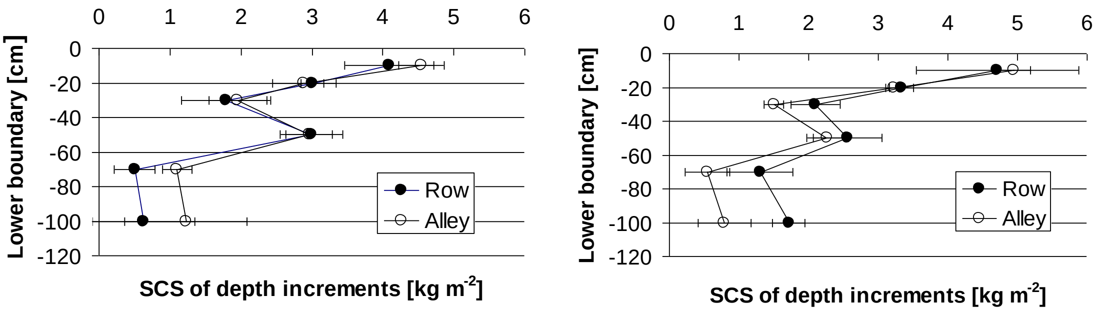



**Figure 4. Soil carbon stocks (SCS) in 'Hort16A' kiwifruit orchards of different ages. Left: 'Young' block. The total SCS to 1 m depth are 13 ± 2.1 kg m$^{-2}$ in the row and 14.7 ± 0.5 kg m$^{-2}$ in the alley. Right. 'Old' block. The total SCS to 1m depth are 15.7 ± 0.8 kg m$^{-2}$ in the row and 13.3 ± 0.3 kg m$^{-2}$ in the alley.**

This led to a deeper study (Holmes et al. 2014) to determine whether deeper roots, beyond 1 m, were sequestering carbon. In another study comparing two sites, down to a depth of 9 m a kiwifruit orchard (30-year-old) in the BoP on a deep well-drained allophanic soil it was found that the soil sequestered 6.3 tons of C ha$^{-1}$ yr$^{-1}$ more than the nearby pasture.

These findings contradict the following authors, who postulated that: "Pasture systems are considered the optimal land use for soil C accumulation in the topsoil" (Davis & Condron 2002; Ross et al. 2002) [references in Holmes et al. (2015)].

We found that in this single site comparison, in the first subsurface soil layer (0.3–0.5 m) SOC concentrations were identical between kiwifruit and pasture soil. However, in all other lower subsurface horizons to the layer at 9 m deep, SOC concentrations tended to be greater in the kiwifruit orchard than under pasture land.

So a comparison of soil carbon stocks (SCS) under kiwifruit in different sampling depths indicates that it is likely that SOC is more stable in kiwifruit orchards than under pasture management, because a greater percentage of it is present at depth in the profile.
The conversion into perennial horticulture and desirable land use and management practices could increase the SOC pool and mitigate climate change. A sum value of this sequestration is presented in Table 4 below.

**Table 4. Soil carbon stocks in the New Zealand kiwifruit industry based on both 1 m and 9 m sampling depths.**

| Soil C stock in NZ kiwifruit industry based on different sampling depths | | |
|---|---|---|
| | T ha-1 | Industry (million t) |
| Soil to 1 m deep | 179.2 | 2.2 |
| Vines | 19.7 | 0.2 |
| Shelterbelts | 43.5 | 0.5 |
| ***Total (1 m deep)*** | 242.5 | 3.0 |
| Soil to 9 m deep | 295.8 | 3.7 |
| Vines | 19.7 | 0.2 |
| Shelterbelts | 43.5 | 0.5 |
| ***Total (9 m deep)*** | 359.1 | 4.5 |

The pattern of soil carbon with depth found by Holmes et al. (2015) is shown in Figure 5 below.

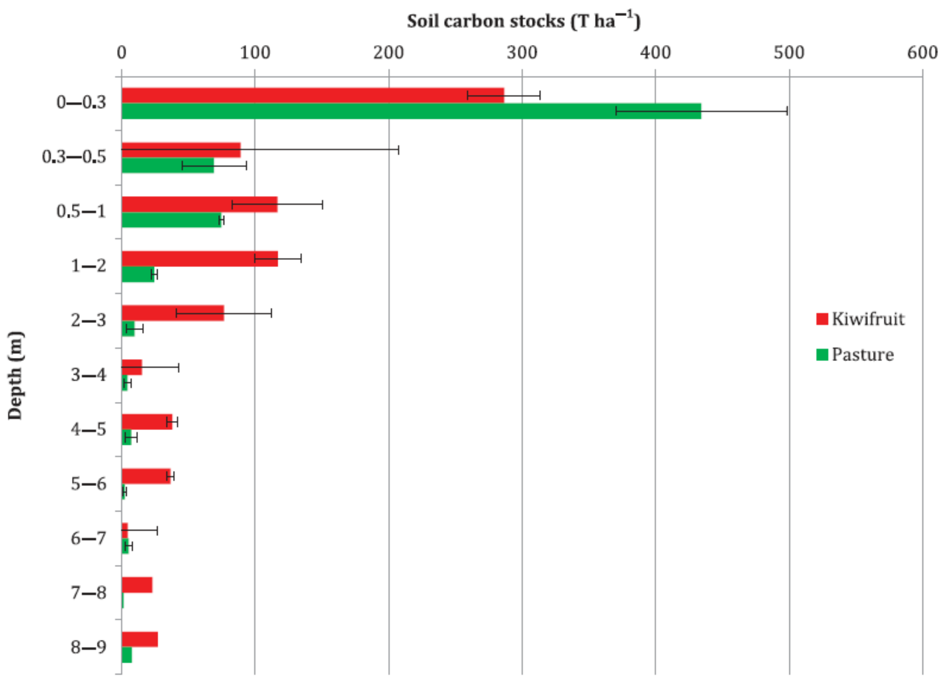



**Figure 5. Soil organic carbons stocks in an allophanic soil measured in eleven depths under an *Actinidia chinensis* var. *deliciosa* 'Hayward' kiwifruit orchard under integrated management in relation to an adjacent pasture. The standard deviation is shown (from Holmes et al. 2015).**

## 1.2.7 Total GHG Footprint Implications

If the results from this one site are extrapolated and top 9 m of soil are included in the calculation of the carbon footprint, then the amount of SOC sequestered equates to about 42% of the emissions associated with growing fruit in New Zealand for consumption in the UK. By extrapolating the findings of our study, we estimate that the New Zealand kiwifruit industry sequesters about 90,000 tons of C annually on orchard to 9 m deep.

In essence this soil C sequestration would mean that kiwifruit, harvested, stored and packaged, would be 'carbon-free' free-on-board (FOB) a ship in Tauranga Harbour. On-orchard mitigations would even further improve this footprint.

## 1.2.8 GHG Eco-efficiency of Kiwifruit Production

Müller et al. (2015) and Müller et al. (2016) showed that the carbon footprints at the farm gate for two kiwifruit cultivars (*Actinidia chinensis* var. *chinensis* 'Hort16A', *A. chinensis* var. *deliciosa* 'Hayward') and management systems (organic and integrated) were comparable. They also used the standard IPCC methods for calculating direct emissions. The integrated management system with higher inputs of pesticides, fertilisers and machinery had higher TGE in the orchard phase than the organic management system, but this difference was not significant (Figure 6).

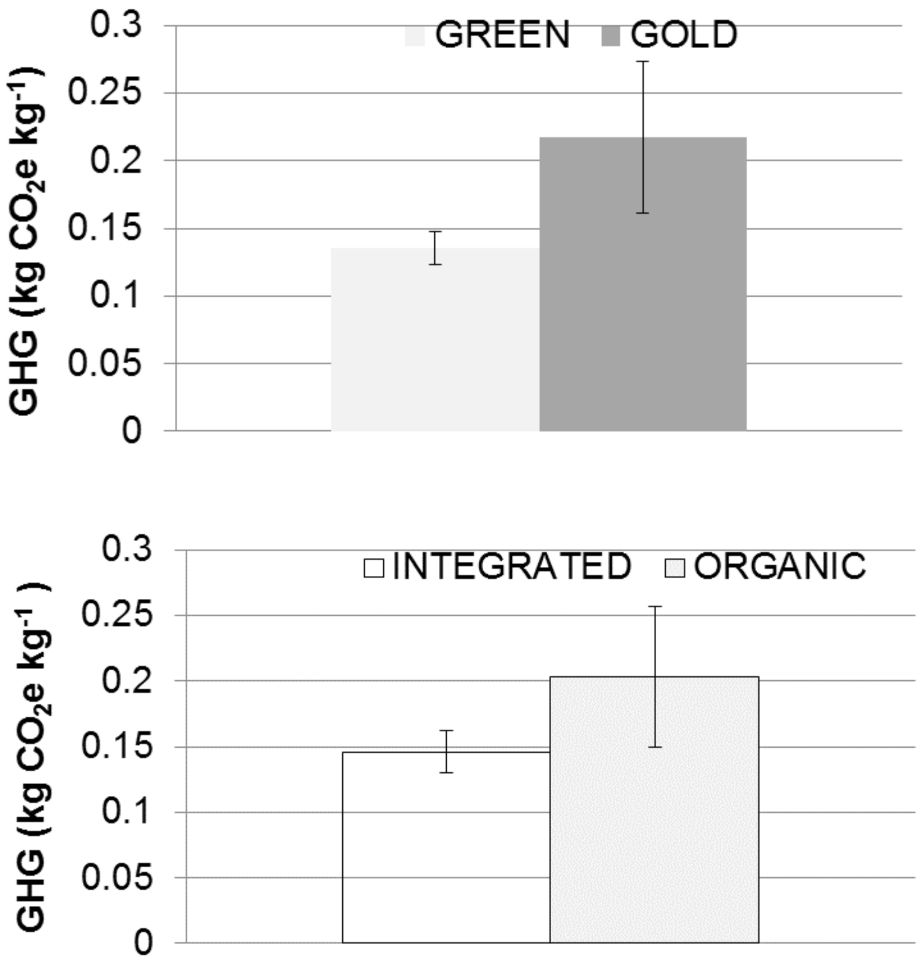
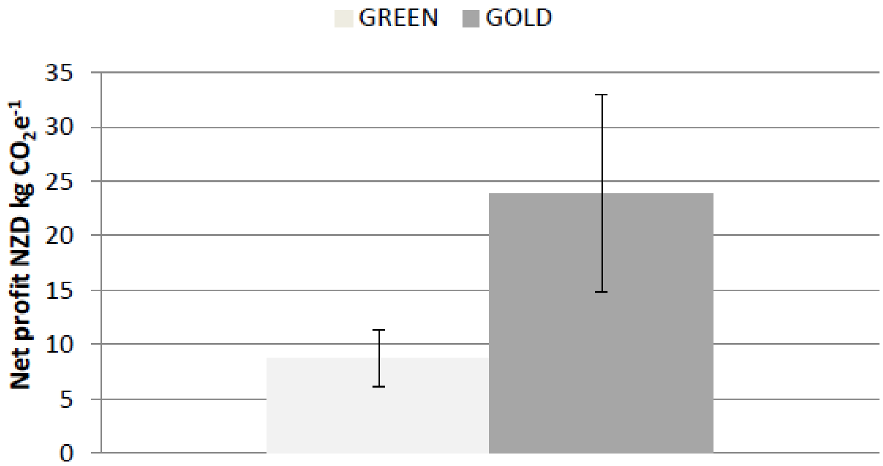



**Figure 6. (a) Average total greenhouse gas (GHG) emissions per kg kiwifruit in the orchard phase for the two cultivars (*Actinidia chinensis* var. *deliciosa* 'Hayward' (Green) and *A. chinensis* var. *chinensis* 'Hort16A' (Gold)). (b) Average total GHG emissions per kg kiwifruit for the management practices in integrated and organic kiwifruit production systems. The bars denote the standard errors of the means.**

Müller et al. (2016) defined eco-efficiency as the net profit per hectare divided by the TGE in kg $CO_{2\text{-}e}$ $ha^{-1}$.



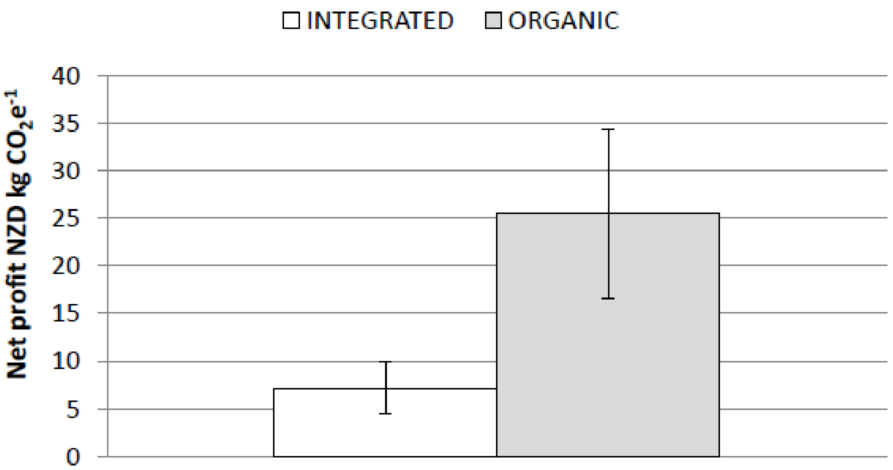




**Figure 7. (a) Average NZD profit/ha per kg of total greenhouse gas emissions ($CO_2$e) for *Actinidia chinensis* var. *deliciosa* 'Hayward' (Green) and *A. chinensis* var *chinensis* 'Hort16A' (Gold) production. (b) Average NZD profit/ha per kg of total greenhouse gas emissions ($CO_2$e) for kiwifruit grown under organic and integrated management systems. The bars denote the standard errors of the means.**

Taking into account the profitability of the orchards, the eco-efficiency of the average organic orchard was significantly higher than that of the average integrated orchard (Figure 7).

## 1.3 Wine grapes

### 1.3.1 Total emissions

In late 2008, the PAS 2050 GHG protocol of the British Standards Institute was published. Greenhalgh et al. (2008) carried a total GHG footprinting analysis following the PAS 2050 using the functional unit as a 750 ml bottle of wine (BW), and the system boundary from vineyard establishment through to consumption of the wine.

As with the earlier kiwifruit GHG assessment, no economic information was provided on the costs and profitability benefit of reducing TGE inside the vineyard gate. However they did provide an economic assessment of reduction options in the winery, but that is beyond the scope of this report.

If the vineyard establishment is ignored (although we will discuss this later), then the TGE of a bottle of Wairau River Sauvignon blanc was found to sum to 1293 g $CO_{2\text{-}e}$ $BW^{-1}$. The breakdown of the emissions were presented by Deurer et al. (2008) and this is reproduced below (Figure 8).

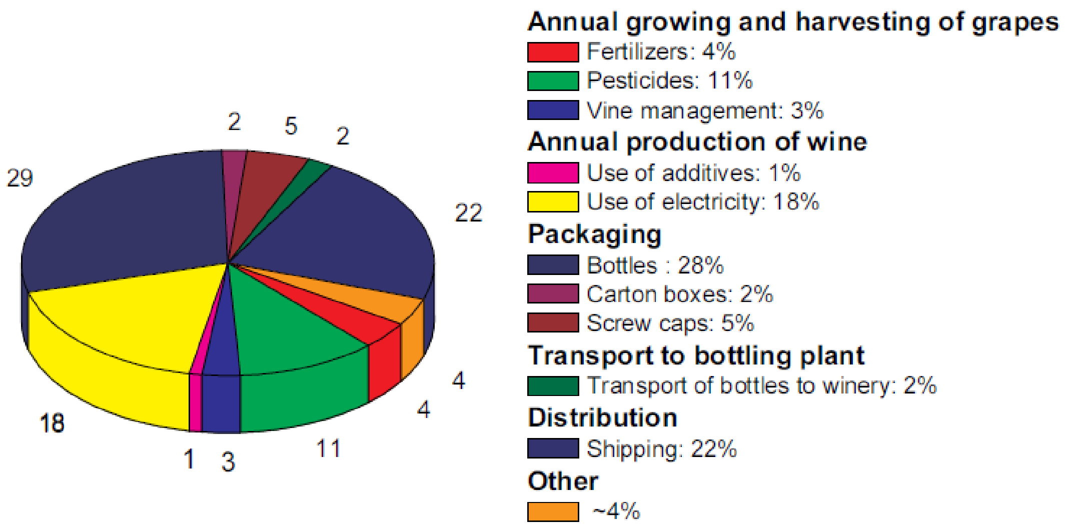



**Figure 8. Percent of the total GHG emissions emitted during the different production stages of a bottle of Wairau River Sauvignon blanc wine taken from Greenhalgh et al. (2008) [from Deurer et al. 2008].**

To convert this total GHG footprint from a bottle of wine to a vineyard area, we will assume here the average yield of grapes at 10 T $ha^{-1}$, and an 85% extraction of juice in the winery. This would mean a yield of 11,333 BW $ha^{-1}$, so that the areal emissions from a vineyard due to the whole life cycle of a bottle wine would be 14.7 T $CO_{2\text{-}e}$ $ha^{-1}$. In their Appendix F2, Greenhalgh et al. (2008) provided a more detailed breakdown of the vineyard TGE than that shown above in Table 5. Part of Appendix F2 is presented here as Figure 5 which shows that 20.4% of the full life-cycle emissions per BW comes from within the vineyard gate. So the vineyard emissions would, on an areal basis, be 2.9 T $CO_{2\text{-}e}$ $ha^{-1}$.

The TGE from a vineyard (3 T $CO_{2\text{-}e}$ $ha^{-1}$) are somewhat less than the total GHG emissions from a kiwifruit orchard (5–6 T $CO_{2\text{-}e}$ $ha^{-1}$).

**Table 5. A summary of the TGE sources within the vineyard for a bottle of Wairau River Sauvignon blanc (from Greenhalgh et al. 2008).**

| | | Total GHG emissions (kg CO2-e) | GHG emissions/ bottle (g CO2-e) | GHG emissions/ bottle (g CO2-e) | Percent |
|---|---|---|---|---|---|
| **Vineyard Total** | | | | 253 | 20.4 |
| Fertiliser | | 16,835 | 52.3 | | |
| Sprays | | 42,440 | 131.9 | | |
| Irrigation | | 3,897 | 12.1 | | |
| Bird Mgt | | 22 | 0.1 | | |
| Vine Mgt | | 11,727 | 36.4 | | |
| Frost Mgt | | 2,376 | 7.4 | | |
| Harvesting | | 3,677 | 11.4 | | |
| Waste | | 578 | 1.8 | | |

### 1.3.2 Biological GHG emissions

We again use the IPCC-based approach to estimate the BGE for viticulture. In a recent study we carried out simulations using SPASMO (Soil Plant Atmosphere System Model) of the nitrogen dynamics in vineyards across 31 soils in the Marlborough region. The simulations were carried out using a 44-year weather record. It was considered that just 5 kg N $ha^{-1}$ $y^{-1}$ was applied as fertiliser, and 30 kg N $ha^{-1}$ $y^{-1}$ as leaf-fall and prunings.

For this viticultural system, the IPCC prediction of BGE is 0.17 T $CO_{2\text{-}e}$ $ha^{-1}$ $y^{-1}$. This BGE is 6% of TGE, if we consider the average viticultural TGE to be 3 T $CO_{2\text{-}e}$ $ha^{-1}$ $y^{-1}$.

### 1.3.3 TGE reduction options

Deurer et al. (2008) considered a range of TGE reduction options for vineyard practices, and beyond the vineyard gate. These are listed below.

Firstly, Deurer et al (2008) considered the carbon emissions of direct land-use change from pasture to a vineyard in relation to the management of the vineyard floor. Reductions of up to 200 g CO2-e BW-1 are possible if the vineyard floor is fully grassed, relative to a 1 m wide herbicide strip (Table 6). This was considered due to the modelled sequestration of carbon in the soil.

**Table 6. Vineyard reduction options and their corresponding reduction in total GHG emissions assuming conversion from pasture (from Deurer et al. 2008).**

| Current Management Practice | Reduction Option | Estimated GHG Reductions (g $CO_2$-e $BW^{-1}$) |
|---|---|---|
| Entire vineyard floor is bare | Grass or crop in the inter-row; 1-m wide strip is regularly treated with herbicides | ~300 |
| Entire vineyard floor is bare | Entire vineyard floor is covered by grass or a crop | ~500 |
| 1-m wide strip is regularly treated with herbicide | Entire vineyard floor is covered by grass or a crop | ~200 |

Next, Deurer et al. (2008) considered how a change in vineyard practices could lead to reduced TGE. These included using less fuel by reduced trafficking, switching to biodiesel and using biochar on prunings. The magnitude of these reductions are showing in Table 7.

**Table 7. Estimated reduction in total greenhouse gas emissions in the "annual growing and harvesting of grapes" phase in the life cycle of a bottle of wine (BW).**

| Reduction options | Time horizon | Estimated GHG reductions (g $CO_2$-e $BW^{-1}$) |
|---|---|---|
| R2 (using less fuel) | Short-medium term | ~5-65 |
| R3 (switching to biodiesel) | Short term | ~12 |
| R4 (biochar) | Medium term | ~18-36 |

In relation to the biochar reduction (R4), Deurer et al. (2008) compared the biochar options in relation to current practices (Table 8).

**Table 8. Biochar reduction options and their corresponding reductions in total GHG emissions.**

| Current Management Practice | Reduction Option | Estimated GHG Reductions (g $CO_2$-e $BW^{-1}$) |
|---|---|---|
| Prunings and leaves are left in the vine-rows | Biocharing of prunings and leaves | ~18 |
| Grape marc is applied to soil as compost | Grape marc is biochared | ~18 |
| Prunings and leaves are left in the vine-rows and grape marc is applied to soil as compost | Prunings, leaves and grape marc is biochared | ~36 |

In summary, Deurer et al. (2008) presented the top 10 reduction options for the life-cycle of a bottle of wine (Table 9). These are presented below. It can be seen that the most significant emissions, and the greatest reduction options related to the packaging and bottling of the bottle of wine.

**Table 9. The top 10 short- and medium-term total GHG emission reduction options for a bottle of wine (BW) from Deurer et al. (2008). The baseline emissions are based on case studies, or taken from the literature.**

| Option | Baseline GHG emission (g $CO_2$-e $BW^{-1}$) | Estimated GHG reduction (g $CO_2$-e $BW^{-1}$) | New GHG emissions (g $CO_2$-e $BW^{-1}$) |
|---|---|---|---|
| Tetra pack | 650[1] | ~540 | ~110 |
| PET bottle | 650[1] | ~340 | ~310 |
| Light glass bottle | 650[1] | ~320 | ~330 |
| Recycled glass bottle | 650[1] | ~240 | ~310 |
| Cover crop | ~0 – (-200)[2] | ~200 – 500 | ~(-500) – (-300) |
| Bulk shipping of wine | ~145 – 310[3] | ~55 - 118 | ~90 – 192 |
| Reduce electricity consumption | 220 | ~22 - 33 | ~187 – 198 |
| Increase fuel efficiency in shipping operations | ~121 – 242[4] | ~24 - 48 | ~96 – 194 |
| Multi-row equipment & optimised orchard operations | ~140 | ~5 - 65 | ~75 – 135 |
| 80/20 diesel/biodiesel mixture | ~140 | ~–12 | ~126 |

The role of the cover crop, and the impact of soil carbon sequestration is one of the larger reduction options. Deurer et al. (2008) examined this further.

## 1.3.4 Soil carbon sequestration

Stony soils and soils that are low in carbon are favoured for growing wine grapes. For if the soils are too fertile, then vegetative vigour poses a problem for vine management to ensure quality grapes berries for premium wines. Deurer et al. (2008) examined a chronosequence of two blocks of different ages and plotted the soil carbon content in the top 15 m (Figure 9).

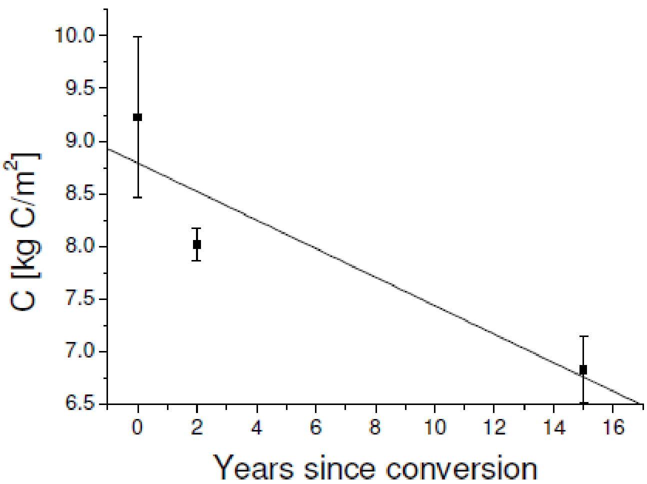



**Figure 9. Average carbon stocks in the top 15 cm of the row and their estimated change in one integrated vineyard in Marlborough (from Deurer et al. 2008). The alley and headland were permanently covered in grass and served as the reference (Year 0).**

Over the 15 years, the row of this vineyard lost about 2.4 ± 1 kg C $m^{-2}$ in the top 15 cm. Assuming that half of the total area of the vineyard is managed as a row, and the alley is permanent pasture, means a decline in carbon stocks of 12 ± 5 T C $ha^{-1}$ in the top 0.15 m. This is a little higher, but not different from the 9 ± 7 T C $ha^{-1}$ reported by Tate et al. (2005). If there were no grass or cover crop, then these values would need to be multiplied by 2.

This soil carbon loss in the vineyard is just for the top 0.15 m, and it is likely that grape vines growing on deep soils, even though they might be stony, would be sequestering carbon at depth, as we have found for kiwifruit. So the loss rate shown in Figure 9 would not be representative for the complete vineyard system.

And it is possible to ameliorate carbon losses in the topsoil through the use of mulches along the vineyard row, as shown in Figure 10 below (Deurer et al. 2008).

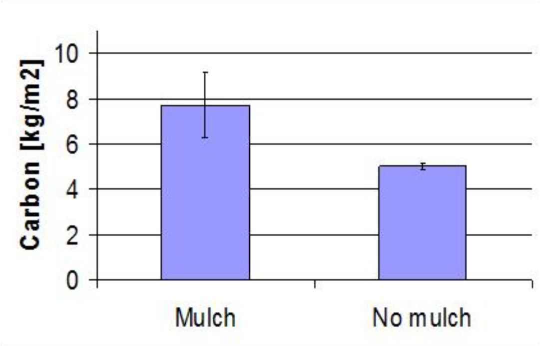



**Figure 10. The application of composted marc and prunings to the vineyard row (right) can lift the level of soil carbon in the surface layer of soil.**

Vineyard practices in relation to floor management practices and the management of prunings and marc can reduce on-vineyard greenhouse gas emissions. Although, for the full life-cycle emissions of a bottle wine, the greatest TGE are from the bottle and packing, plus shipping.

## 1.4 Apple GHG footprint

### 1.4.1 Total emissions

The PAS 2050 total GHG Footprint protocol was used by Hume et al. (2009) to assess the GHG footprint of apple production. The functional unit was taken as a kilogram of export apples, and the system boundary was from the orchard phase through to consumption by a United Kingdom consumer. Deurer et al. (2009) considered the TGE reduction options.

In this study, an economic assessment was provided of the costs and benefits of total GHG reduction options, and it is likely that these numbers would also apply to orchard practices in vineyards and kiwifruit orchards.

Hume et al. (2009) provided a full life-cycle assessment of the GHG emissions of export apples, and the breakdown of the life-cycle phases is shown in Figure 11.

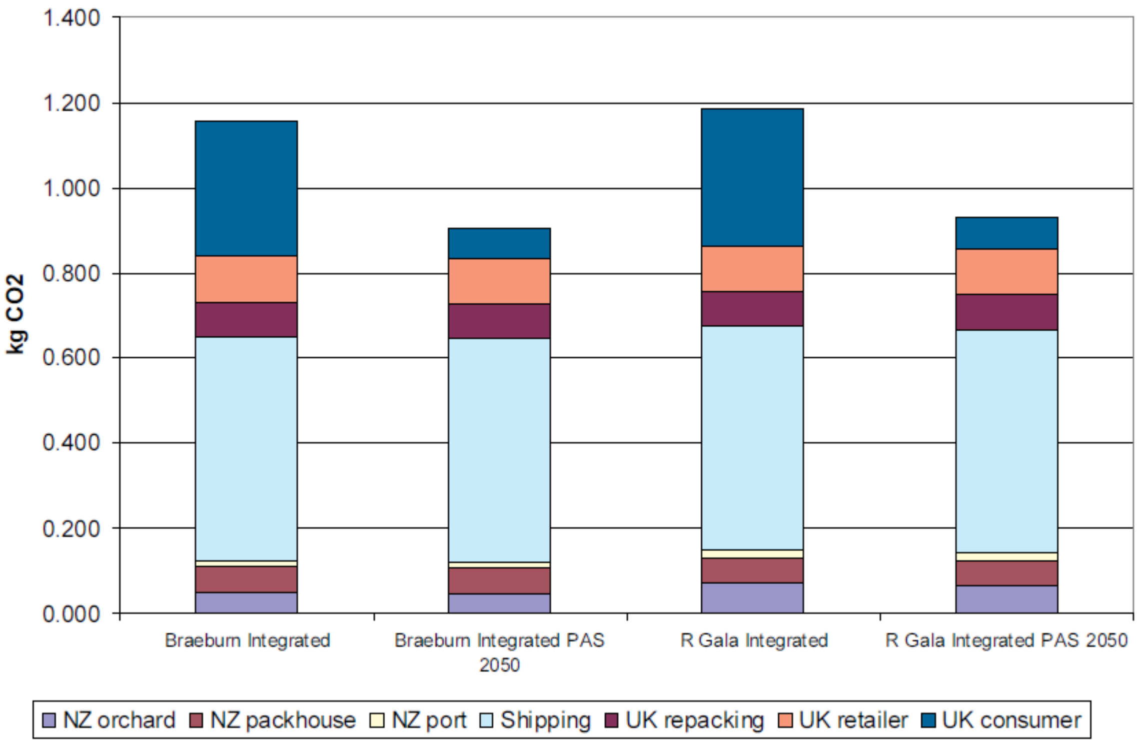



**Figure 11. Total GHG emissions for 1 kg of apples ('Braeburn' and 'Royal Gala') exported and consumed in the United Kingdom as calculated by the ISO 14040 LCA standard (left) and the PAS 2050 method.**

For the individual stages of the supply chain for 'Braeburn' using the PAS 2050 protocol the percentage emissions are: orchard operations 10%, packhouse operations 7%, port 2%, shipping 54%, repackaging in the UK 8%, retailer 11% and consumer 7%. The equivalent percentages for 'Royal Gala' are: orchard operations 7%, packhouse operations 6%, port 2%, shipping 57%, repackaging in the UK 12%, retailer 12% and consumer 8%.

As with kiwifruit and wine, it can be seen that for apples, on-orchard TGE are a small fraction of the full life-cycle emissions of the functional unit.

From Figure 11 it can be seen that TGE per kg of apples range of 0.9 to 1.2 kg $CO_{2\text{-}e}$. If we assume this to be, on average, 1 kg $CO_{2\text{-}e}$ $kg^{-1}$, and consider an average apple yield of 65 T $ha^{-1}$, then the areal GHG emissions for the whole life cycle of apples would be 65 T $CO_{2\text{-}e}$ $ha^{-1}$. The orchard phase contributes between 7–10% of the emissions, so that the orchard-based GHG emissions from apple orcharding would be 4.5 to 6.5 T $CO_{2\text{-}e}$ $ha^{-1}$.

The TGE from an apple orchard (4–6 T $CO_{2\text{-}e}$ $ha^{-1}$) are similar to the GHG emissions from a kiwifruit orchard (5–6 T $CO_{2\text{-}e}$ $ha^{-1}$), and both are a little higher than those from a vineyard (3 T $CO_{2\text{-}e}$ $ha^{-1}$).

### 1.4.2 Biological GHG emissions

We again use the same IPCC-based approach here to estimate now the BGE for apple production. In a recent study of the water footprint of apple production we carried our simulations using SPASMO of the nitrogen dynamics in apple orchards across 13 soils in the Hawke's Bay region. The simulations were carried out using a 40-year weather record. It was considered that 40 kg N $ha^{-1}$ $y^{-1}$ was applied as fertiliser. The incorporation of 105 kg N $ha^{-1}$ $y^{-1}$of prunings and leaf-fall was accounted for.

The IPCC calculations of biological emissions for these apple orchards suggests a BGE 0.71 T $CO_{2\text{-}e}$ $ha^{-1}$ $y^{-1}$. This BGE is just 14 % of TGE, if we take the average TGE to be 5.0 T $CO_{2\text{-}e}$ $ha^{1}$ $y^{-1}$.

### 1.4.3 TGE reduction options

Reduction options for TGE in the orchard phase were assessed by Deurer et al. (2009). First they considered the breakdown of the emission sources within the orchard, and these are shown in Figure 12 for both 'Braeburn' and 'Royal Gala' grown under integrated practices and organic management protocols.

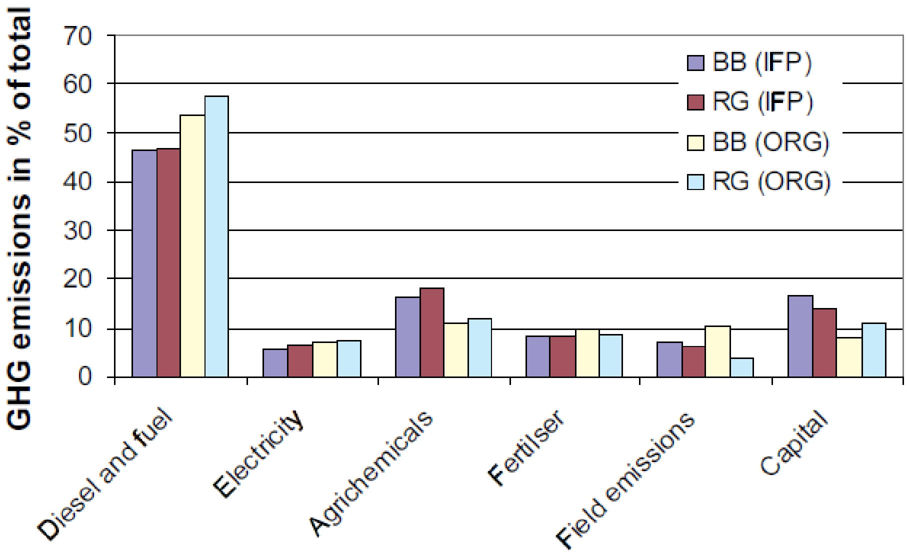



**Figure 12. The contribution of individual processes to the total GHG emissions in the orchard phase of the production of 1 kg of apples exported and consumed in the United Kingdom (from Deurer et al. 2009).**

The five best options for reducing TGE, that would reduce emissions by 3–8 g $CO_{2\text{-}e}$ $kg^{-1}$ apples, or 0.3-0.9% of total life cycle emissions, were:

1. Using multi-row spraying systems
2. Introducing black-spot resistant apple varieties
3. Introducing dwarf trees to avoid the use of Hydraladas®
4. Reducing the height of existing trees to reduce the use of Hydraladas®
5. Improving spraying management through multi-tasking, where possible.

New research is presently being carried out by Plant & Food Research in a programme called FOPS (Future Orchard Production Systems) led by Dr Stuart Tustin. These systems have ultra-high plantings of dwarf trees and the yield (per hectare) is expected to be much higher than that being achieved presently. These FOPS are very likely to have much reduced total GHG emissions.

Cost savings were estimated for 20 reduction options in the orchard phase by Deurer et al. (2009). The best of these are listed below in Table 10.

**Table 10. Estimated cost savings for the most practically feasible GHG emissions reduction options for apple production and the packhouse/coolstore phase (from Deurer et al. 2009).**

| Options[a] | Estimated cost savings |
|---|---|
| | *Min-Max (all systems)* |
| **Orchard production stage** | Per ha |
| R1 Increase tractor use efficiency | NZ$20–57 |
| R4 Better spraying management | NZ$41–79 |
| R5 Participate in Apple Futures | NZ$143–146 |
| R9 Sheep grazing in winter | NZ$12–42 |
| R10 Avoid cosmetic mowing | NZ$15–50 |
| R12 Reduce height of trees | NZ$48–73 |
| R15 Increase irrigation uniformity | NZ$34–95 |
| R16 Implement irrigation strategy | NZ$28–79 |
| R17 Improve maintenance of irrigation | NZ$11–32 |
| **Coolstore/packhouse stage** | Per pallet and during one week of storage |
| R22 Introduce floating head pressure | NZ$0.4–8.1[b] |
| R24 Use Robert Barnes's strategy | NZ$0.6–4.9[b] |

[a] Note the options may not be additive.
[b] The additional costs involved with the implementation of the option (e.g. capital investment) were not considered.

Deurer et al. (2009) found that the top five most feasible options to reduce costs from between $28–146 per ha were:

1. Participating in the Apple Futures programme
2. Increasing irrigation uniformity
3. Improving spray management
4. Reducing the height of tree to reduce the use of Hydraladas®
5. Introducing soil moisture monitoring for irrigation scheduling and adopting an irrigation strategy to minimise water use

More information about the Apple Futures Programme can be found at:

http://www.pipfruitnz.co.nz/Library/Pipfruit_Production/Apple_Futures
The specific objective of the Apple Futures programme is focussed on establishing a combination of management techniques and 'soft' products that target specific pests and diseases where they occur. Products are selected that ensure good quality fruit are produced and that will return 'nil detectable' residue profiles.

This study by Deurer et al. (2009) showed that selecting options to reduce GHG emissions can actually help orchard EBIT. Why these options are not implemented is not clear, and it would suggest that the focus of the growers is elsewhere in their drive for efficiency.

### 1.4.4 Soil carbon sequestration

In his doctoral study, Perié (2015) found no change in soil carbon over the top 1 metre during a 12-year orchard redevelopment sequence (Figure 13). However, as with kiwifruit (above) there might be some deep C-sequestration below 1 m, over time, but this is unknown.

In this New Zealand apple orchard chronosequence located in Hawke's Bay on a silty clay loam soil, there was no net change in SCS to 1 m depth between the 1-, 6-, and 12-year-old orchard blocks. The mean SCS to 1 m depth for the Hawkes Bay orchard blocks was 132 t C ha$^{-1}$ (Gentile et al. 2016).

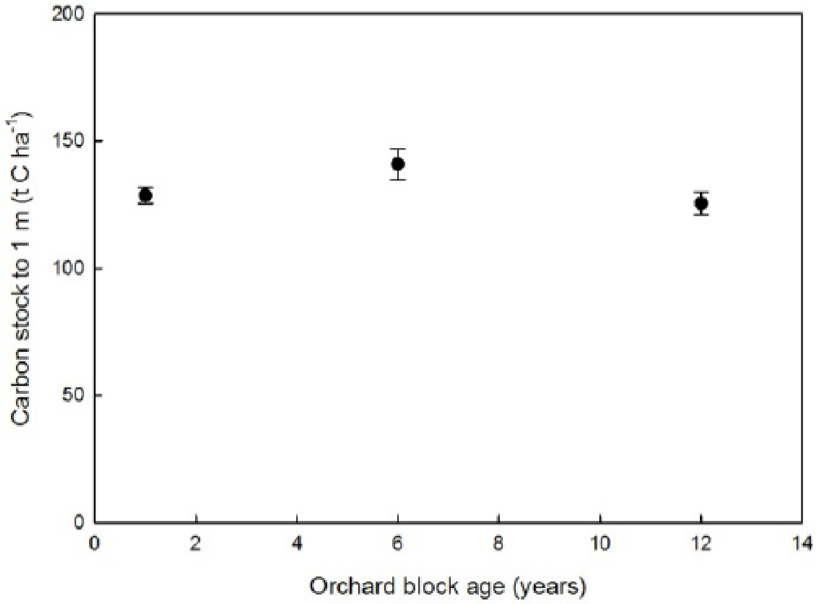



**Figure 13. Soil carbon stocks to 1 m depth in three apple orchard blocks in Hawke's Bay, showing the standard error.**

This finding about soil carbon storage contrasts with some of the findings from the surface soil of two adjacent apple orchards blocks (13 years old) on silt loam soils also located in Hawke's Bay. Generally, it was found that more C was sequestered in the alley than in the tree rows (*P* = 0.05) (Deurer et al. 2008).

In this study, two management systems were compared as options to improve soil carbon stocks in the top soil of apple orchards. Deurer et al. (2008) found:

- For the organic system, the difference was significant only in the top 0.1 m. No statistically significant difference between tree row and grass alley was observed for the average %C of 1 metre profiles, and the carbon contents averaged 1.34 %C (SE=0.012, n=5) in the tree row versus 1.30 %C (SE=0.032, n=5) in the grass alley.
- However, for the conventionally managed orchard, all three depths under the tree row had significantly less C than under the alley (Figure 14).

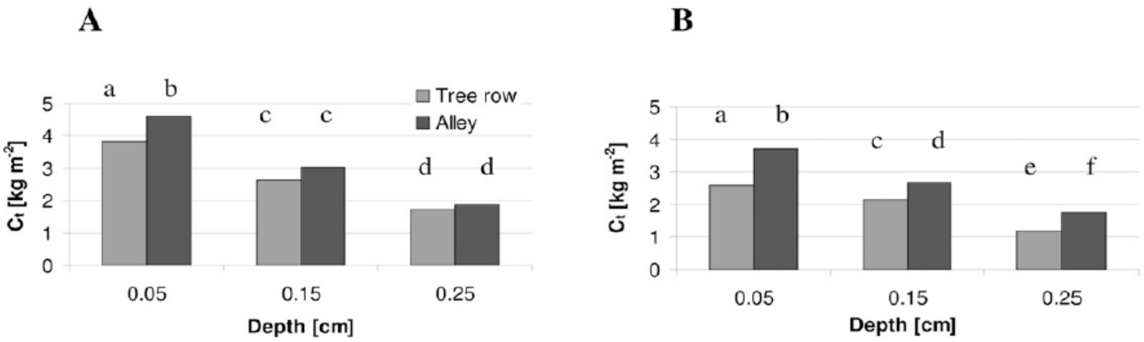



**Figure 14. Average (N=6) total carbon contents of the top 0.3 m of the soils under the tree row and the alley of the apple orchards. (A) Organic system. The LSD between the row and the alley is 0.48 kg C m$^{-2}$. (B) Integrated system. The LSD between the tree row and alley is 0.25 kg m$^{-2}$. The contents refer to 0.1 m thick layers that are centred at 0.05, 0.15 and 0.25 m.**

This shows that management can affect SOC in the top-soils of orchards. In this paired study of an organically and conventionally managed apple orchard by Deurer et al. (2009), SOC (0–0.1 m) of the organic orchard was 3.8 kg C $m^{-2}$ compared with 2.6 kg C $m^{-2}$ in the conventionally managed orchard. In addition, the organic orchard had greater and more inter-connected macro-porosity, which would enhance soil gaseous exchange and potentially lower soil $N_2O$ emissions, providing an additional measure of climate change mitigation.

Surface soil properties and SOC are also affected by wheel trafficking. In the organically managed apple orchard mentioned above, SOC under the wheel track were higher than under the row as the moderate compaction by trafficking provided a physical protection mechanism for SOC (Deurer et al. 2012).

These studies highlight the value of including soil carbon in GHG assessments, but they also demonstrate the great difficulties in quantifying the changes in soil carbon as a result of land management practices.

### 1.4.5 Standing biomass carbon

Perié (2015) also considered the benefits of biomass accumulation by apple trees in relation to GHG emissions. His table is presented below shows that 'Royal Gala' apple trees can accumulate up to 17 T DM per hectare, about half of which is carbon (Table 11).

**Table 11. Literature estimates of woody biomass. All trees were grown on 'M9' rootstock (from Périé 2015).**

| Location | variety | Tree age (years) | spacing * (m); planting density (tree/ha) | Number of trees measured | Calculated woody biomass (t DM /ha) | source |
|---|---|---|---|---|---|---|
| New Zealand | Royal Gala | 8 | 3.5 x 1.3; 2198 | 8 | 17 | Palmer et al. (2002); (Palmer 2011)[2] |
| England | Crispin | 5 | 1.5 x 0.75; 8889 | nc# | 15 | |
| West Virginia, USA | Golden Delicious | 5 | 3 x 3; 1111 | 15 | 8.6 | Stutte et al. (1994) |
| Italy | Pink Lady | 3 | 3.5 x 0.7; 4082 | 16 | 3.8 | Lo Bianco et al. (2003) |
| Italy | Pink Lady | 6 | 3.5 x 1; 2857 | nc# | 3.4 | Lo Bianco et al. (2012) |

* between rows x between trees, # not communicated

With the continuous development of new apple cultivars, there is a regular process of orchard redevelopment, and this cycle is generally about 15 years long. So what happens to this standing biomass during redevelopment is critical.

Even with top-grafting, there is the issue of what to do with the standing biomass of the tree that has been removed. Périé (2015) therefore assessed the end-of-life options for the biogenic biomass of the standing tree. These results are shown below in Table 12 for two GHG emissions protocols and 3 GHG reduction scenarios.

**Table 12. Potential relative contributions of tree woody biomass as a percentage of the New Zealand-based carbon footprint of 1 kg of New Zealand apples exported to the UK as a function of the calculation method and the timeframe chosen. The potential relative contribution of the woody biomass as a percentage of the whole carbon footprint is shown in brackets.**

| Method | IPCC (IPCC, 2006) | | Dynamic LCA (Levasseur et al. 2010) | |
|---|---|---|---|---|
| Timeframe | 20 years | 100 years | 20 years | 100 years |
| Scenario 1: burning | 0% | 0% | 0.82% (0.12%) | 0.52% (0.08%) |
| Scenario 2: Firewood | 0% | 0% | 1.16% (0.17%) | 0.72% (0.11%) |
| Scenario 3: Biochar | 7.8% (1.16%) | 7.8% (1.16%) | 1.47% (0.22%) | 4.6% (0.69%) |

Depending upon the method, and time-scale selected, there are differences. However, in terms of the overall reduction in full life-cycle GHG emissions, these changes are somewhat small relative to the total footprint.

Thus, in summary, the areal emissions for pipfruit are quite low, and meanwhile there are many options that are economically beneficial that can be used to further reduce these emissions. The consequences for these are discussed later on.

## 1.5 Summary: horticultural emissions (TGE and BGE) and reduction options

The TGE from an apple orchards (4-6 T $CO_{2\text{-}e}$ $ha^{-1}$) are similar to the GHG emissions from a kiwifruit orchards (5–6 T $CO_{2\text{-}e}$ $ha^{-1}$), and both are a little higher than those from a vineyard (3 T $CO_{2\text{-}e}$ $ha^{-1}$).

The IPCC calculations for the annual BGE are variable across these three horticultural sectors, ranging from 0.17 T $CO_{2\text{-}e}$ $ha^{-1}$ for grapes, through 0.71 T $CO_{2\text{-}e}$ $ha^{-1}$ for apples, to 1.03 T $CO_{2\text{-}e}$ $ha^{-1}$ for kiwifruit. The IPCC average for these horticultural sectors is 13% of TGE.

Both these emissions appear reasonably low, relative to other land-uses.

Furthermore, the TGE from the orchard or vineyard phases of horticultural comprise only about 10–20% of the total life-cycle GHG footprint of apples, wine and kiwifruit consumed in Europe. So the BGE of the full LCA-GHG footprint is just 1.5–2.5% of the total emissions.

Options do exist to reduce the orchard and vineyard phases of both the TGE and BGE footprints through better management of orchard practices, although in terms of orchard phase GHG reductions, the savings in TGE are quite modest, well less than 10% in general. However, many of these reduction options increase profitability through reduced costs, primarily through lower energy consumption and reduced trafficking.

Horticulture uses nitrogen parsimoniously, since excessive vegetative vigour is deleterious to the production of premium fruit, and fruit products. Although enhancement of nitrogen management is still possible, the value of the mitigation options on BGE would seem to be quite modest, relative to other GHG emissions.

Our observations of soil-carbon sequestration following the establishment of a kiwifruit orchard from pasture showed that deep soil C-sequestration by the vines over 30 years would account for over 40% of the full life cycle GHG footprint of kiwifruit consumed in the UK. This would mean the kiwifruit FOB in Tauranga would be 'carbon neutral'. We do not have such deep soil carbon measurements for apples and grapes. But we have shown that better management of residues and herbicides could enhance soil carbon storage. Biogenic carbon storage in the trees and vines also would reduce the orchard-phase GHG emissions, and this could be enhanced by improved management of prunings, and careful orchard redevelopment through 'top-grafting' rather than removal of the trees.

## 1.6 Arable land area

For arable crops we consider not only arable crops (harvested by a combine), but also maize for silage, forage brassicas and seed crops.

Wheat has been a traditional arable crop, and its planted area has fluctuated considerably over the last century, in response to fluctuating market conditions (Figure 15).

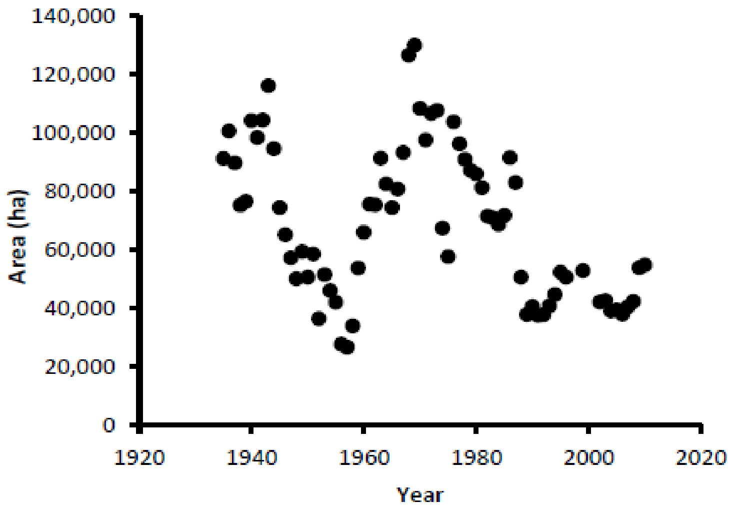



**Figure 15. New Zealand wheat production area since 1935 (from Barber et al. 2011).**

Over the last two years the area in grain crops has risen slightly, as can be seen in Figure 15.

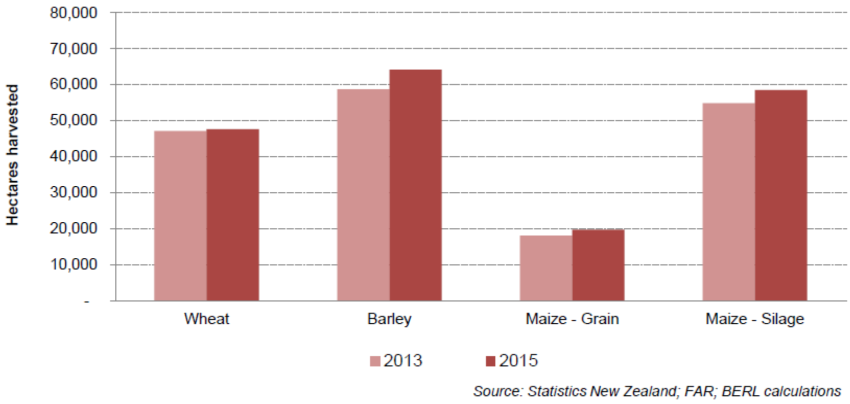



**Figure 16. The change in land area planted in grain and maize silage crops between 2013 and 2015.**

The change in the area of crops planted for seed is shown in Figure 17 and this can be seen to stable over recent years.

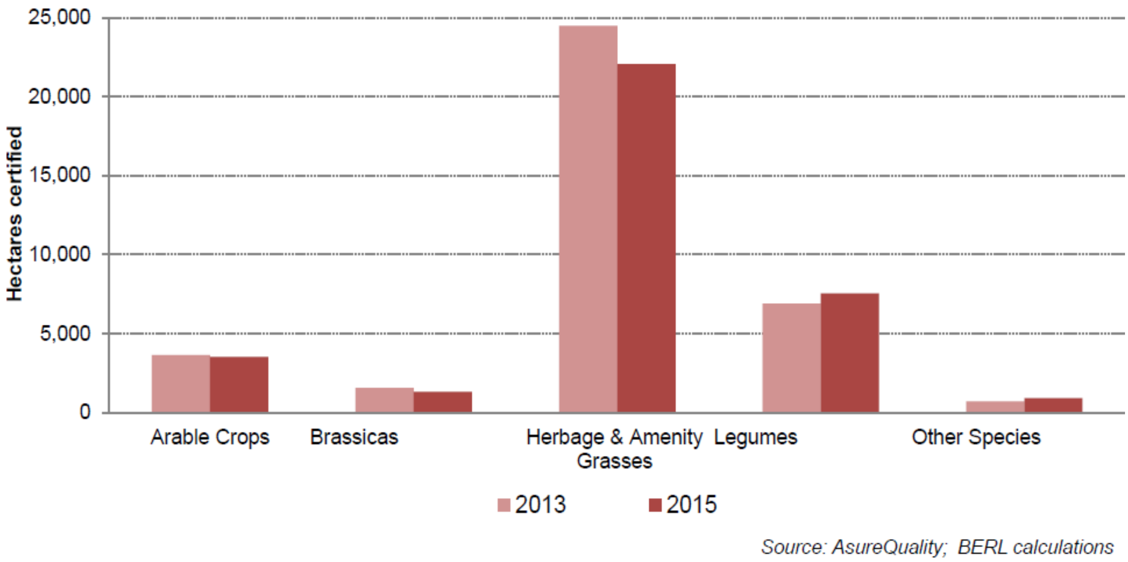



**Figure 17. The change in the planted area for certified seed crops between 2013 and 2015.**

Meanwhile there has been a substantial rise in the planted area of forage brassicas over the last two decades, as shown in Figure 18.

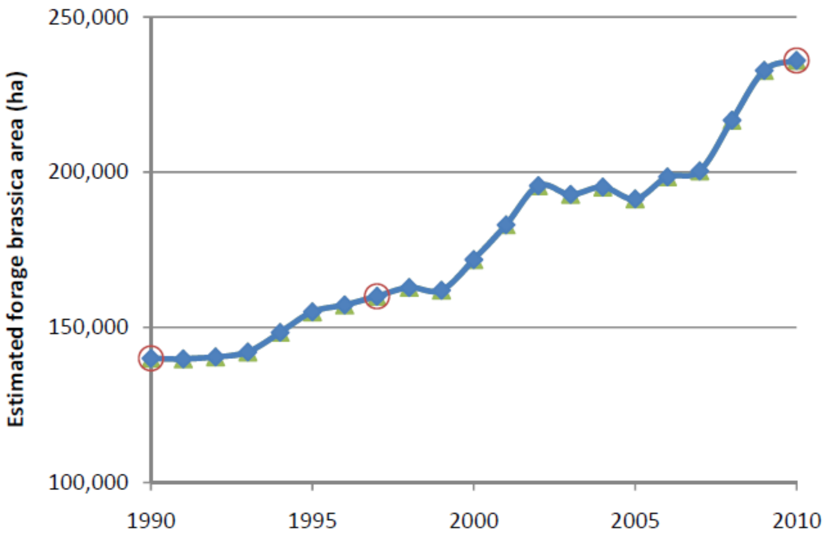



**Figure 18. The estimated area of forage brassicas between 1990 and 2010. The red circles represent the forage area from White et al. (1999) and a Statistics NZ survey (from Thomas et al. 2011).**

The driver for this rise in the area of forage brassicas can be seen in link between planted area and dairy cow numbers (Figure 19).

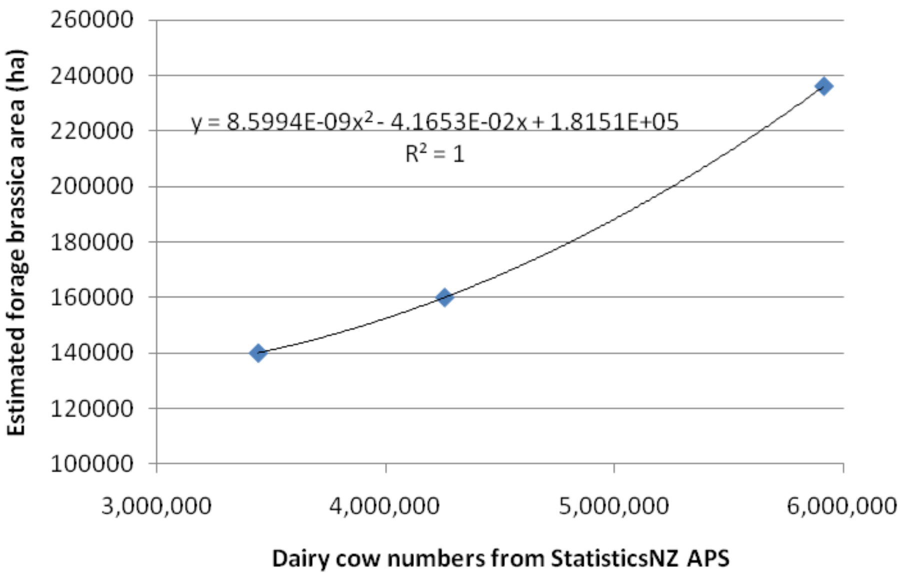



**Figure 19. Relationship between increasing dairy cow numbers and estimates of the forage brassica area from White et al. (1999) and from the 2010 Statistics NZ survey. (from Thomas et al. 2011).**

Thus, in sum for the arable sector, the planted area in crops has grown substantially, primarily due to the growth in the area of forage brassicas. Otherwise, there has been a modest growth in the planted area of other arable crops.

In total, we estimate the area planted in arable crops to be about 500,000 ha.

## 1.7 Arable GHG footprint

As part of the suite of footprinting studies sponsored by the (then) MAF a pilot LCA study of the arable industry was carried under the project "The Carbon Footprint of New Zealand Arable Production – Wheat, Maize Silage, Maize Grain and Ryegrass Seed" This was reported by Barber et al. (2011). The system boundary is shown in Figure 20.

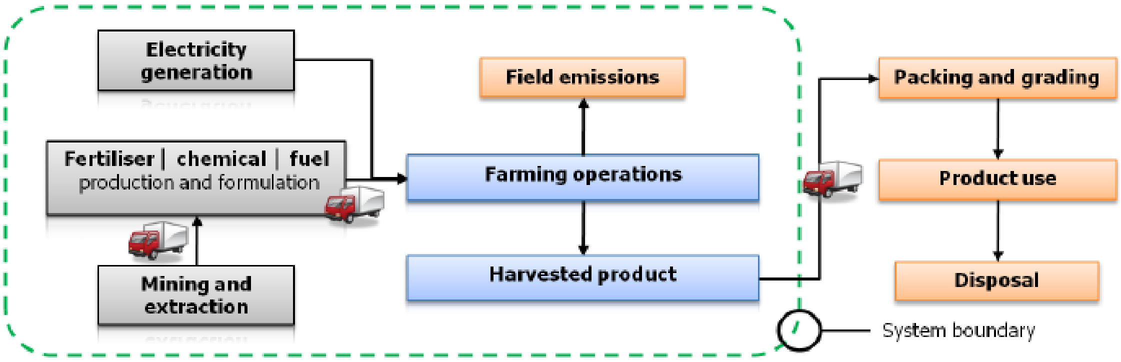



**Figure 20. Processes and inputs/outputs with the system boundary (Barber et al. 2011).**

The system boundary here was the farm gate, and the LCA analysis considered not only field emissions from the foreground system, but also background emissions into the farm.

### 1.7.1 Total emissions

The full LCA within the farm gate emissions are shown in Table 13 below.

**Table 13. The total LCA within farm gate GHG emissions and the direct emissions (foreground system) from four arable farm types. Soil carbon changes were excluded (Barber et al. 2011).**

| Total On-Farm LCA Emissions in kg CO2-e | Wheat | Maize silage | Maize grain | Ryegrass seed | Average |
|---|---|---|---|---|---|
| per tonne | 340 | 125 | 190 | 1325 | **495** |
| per ha | 2820 | 2190 | 2380 | 2190 | **2395** |
| | | | | | |
| **% Contribution of direct field emissions to total GHG exc. Soil C** | **47** | **35** | **38** | **37** | |
| | | | | | |
| **Direct Field Emisions in kgCO2-e** | **Wheat** | **Maize silage** | **Maize grain** | **Ryegrass seed** | **Average** |
| per tonne | 159.8 | 43.75 | 72.2 | 490.25 | **191.5** |
| per ha | 1325.4 | 766.5 | 904.4 | 810.3 | **951.65** |

Two functional units were considered by Barber et al. (2011): a tonne of grain harvested, and the planted area in crops. Four arable farm types were considered: wheat, maize silage, maize grain and ryegrass seed.

Here, for our heuristic purposes, we later consider emissions on a per unit area basis. On average the full within farm-gate TGE are 2.4 T $CO_{2\text{-e}}$ $ha^{-1}$. This is just lower than that estimated for wine grapes (3), and lower than that of both apples and kiwifruit (4–6).

### 1.7.2 Biological GHG emissions

The direct farm BGE were calculated by Barber et al. (2011) using IPCC protocols. These BGE emissions are less than half (40%) of the total emissions (Table 13), being 0.95 T $CO_{2\text{-e}}$ $ha^{-1}$.

The arable sectors have modest total and biological GHG emissions. And because of the intensity of these farming operations, many reduction options in both TGE and BGE are possible.

### 1.7.3 Total GHG reduction options

The reduction options for mitigating GHG emissions from arable systems have only been examined indirectly through seeking to improve fertiliser management, trafficking impacts and irrigation management. We list these below. Most are related to nitrogen management.

**Matching N fertiliser to plant requirements**

High rates of nitrogen usage in arable farming (Thomas et al. 2008) can lead to GHG emissions through leaching and $N_2O$ emissions. Better accounting for soil N at the time of planting and the mineralisation of N in the soil will enable better matching of crop demand to supply. This would reduce GHG emissions through reduced leaching and gaseous emissions.

**Reducing soil compaction by trafficking**

Thomas et al. (2008) showed that compacted soil led to substantially increased $N_2O$ emissions from a potato crop. The mitigation options are reduced trafficking, avoiding trafficking during wet conditions, and the use of minimum tillage practices.

**Reducing losses through management of crop residues**

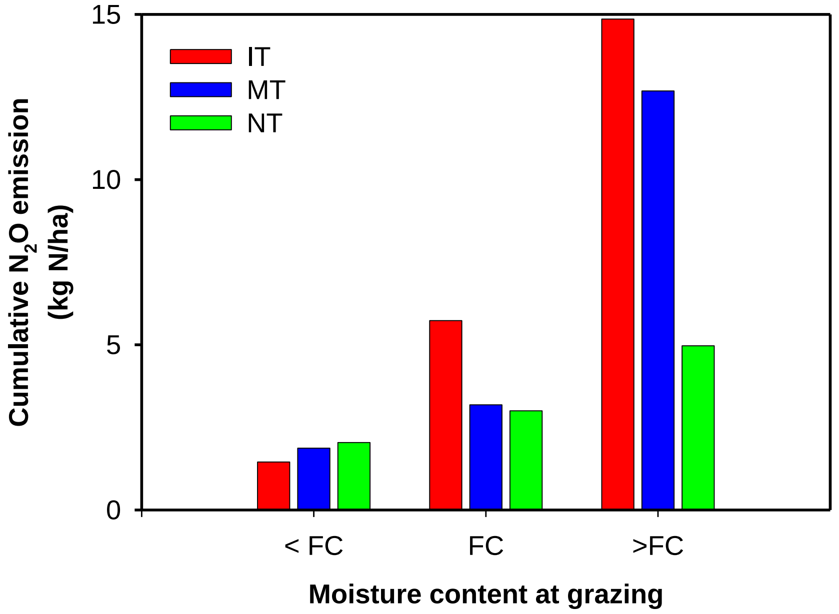
In the study by van der Weerden et al. (2000), three contrasting onion production systems were compared in Canterbury over 8.5 months. These were conventionally grown onions following a clover crop, and two crops established after ploughing or rotovating an organically grown ley crop. $N_2O$ emissions over the crop period ranged from 1.6 to 3.8 kg N $ha^{-1}$. The greatest emissions occurred from conventionally grown onions established after the clover crop had been ploughed in. No fertiliser N had been applied to any of the plots. The magnitude of emissions followed the order ploughed clover > rotovated ley > ploughed ley. When the previous crops were included in calculating an annual $N_2O$ emission, the emissions from the ploughed clover treatment increased to 8.0 kg $N_2O$-N $ha^{-1}$, which was significantly greater than the other cultivated and non-cultivated treatments.

Large amounts of N released from cultivating leguminous pastures. Therefore the timing of ploughing is important, as is the planting of cover crops. By sowing cereals as early as possible in autumn it is possible to mop up mineral N (Francis et al. 1995) and avoid GHG emissions through leaching and gaseous losses.

**Reduced emissions from grazing forage crops**

Large $N_2O$ emissions occur from winter grazed crops, especially when the soils are wet and when they were established using conventional tillage methods. High N loads over a relatively short period of time can occur when soils are wet. The soil is more easily damaged under these conditions, and this results in conditions conducive for denitrification (Thomas et al. 2008). This can be seen in Figure 21 below.




FC = Field Capacity

**Figure 21. The impact the moisture content at grazing on nitrous oxide emissions in relation to integrated tillage (IT), minimum tillage (MT) and no tillage (NT) (from Thomas et al. 2008).**

### Reducing leaching losses through improved fertiliser and irrigation management

Francis et al. (2007) examined the nitrate leaching losses from potatoes as a function of applied fertiliser and irrigation management. Their results are shown in Figure 22 below. The irrigation treatment W1 is optimal, whereas W2 is excess irrigation which led to greater nitrate losses, and therefore GHG emissions.

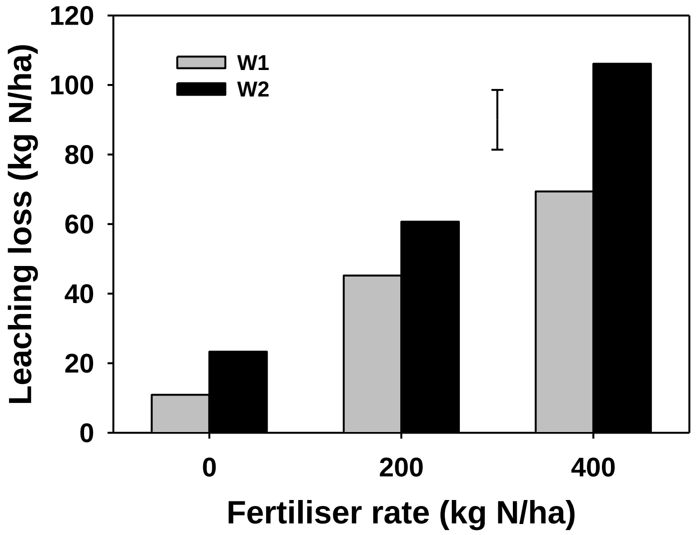



**Figure 22. Nitrate leaching losses during the potato crop in 2004-05. Irrigation treatment W1 is optimal and W2 is excessive (from Francis et al. 2007).**

**Reduction summary**

The most significant GHG reduction options are related to fertiliser management:

- Matching N supply with demand to reduce the often large residual mineral N in the soil post-harvest
- Limit winter grazing of crops to reduce large N inputs on wet or damaged ground
- Autumn soil mineral-N management through the use of cover crops and by the timing of autumn-sown cereals.

It is considered that these reduction options would have a moderate impact on GHG emissions, as direct on-farm emissions comprise about 40% of total farm emissions (Table 12). Furthermore, better management of nitrogen fertiliser to match supply with demand will, at the same time, enhance farm profitability.

### 1.7.4 Soil carbon sequestration

Soil carbon sequestration in arable systems could be managed through better soil tillage practices and timing, and via enhanced residue management options. Work is currently underway on this in New Zealand. International research suggests there are a range of options.

## 1.8 Total and biological emissions: summary

A summary table of the TGE and BGE for the four farming systems are shown in Table 14.

**Table 14. The average annual total greenhouse gas emissions (TGE, T $CO_{2\text{-}e}$ $ha^{-1}$) for various crop systems, and the biological greenhouse gas emissions (BGE, T $CO_{2\text{-}e}$ $ha^{-1}$) and the percentage of the total emissions that are biological in origin. The calculations are by standard IPCC procedures for applied nitrogen and prunings and leaf-fall.**

| Crop System | Average Total Greenhouse Gas Emissions (TGE) T $CO_{2\text{-}e}$ $ha^{-1}$ | IPCC Biological Greenhouse Gas Emissions (BGE) T $CO_{2\text{-}e}$ $ha^{-1}$ | Average Percentage of TGE as BGE % |
|---|---|---|---|
| Kiwifruit | 5.5 | 1.03 | 19 |
| Wine grapes | 3.0 | 0.17 | 6 |
| Apples | 5.0 | 0.71 | 14 |
| Arable [!] | 2.4 | 0.95 | 40 |

[!] From Barber et al. (2011).

There is quite a range in the absolute values of BGE from the various sectors; ranging from just 0.17 T CO2-e ha-1 y-1 for grapes, through to 1.03 T CO2-e ha-1 y-1 for kiwifruit. This difference reflects the difference in the total nitrogen inputs into the various systems. For kiwifruit there is fertiliser, plus prunings and leaf fall, a total input of fertiliser and prunings of 200 kg N ha-1 y-1. In contrast, there is only a total input of 35 kg N ha-1 y-1 into vineyards. The annual average BGE for the three horticultural sectors is 0.64 T CO2-e ha-1 y-1, and the annual average fraction of BGE to TGE is 13% for these three sectors. The BGE fraction presented by Barber et al. (2011) is 40% of TGE.

# 2 PART 2: PRODUCTIVITY, PROFITABILITY AND LAND AREA

## 2.1 Performance of horticulture

In 2015 horticultural exports increased 9.5% in value from 2014 to $4.3 billion, with productivity, new cultivars, strong branding and marketing all helping capture premiums in world markets (Fresh Facts 2015).

The growth in export revenues is shown in Figure 23 (Fresh Facts 2015).

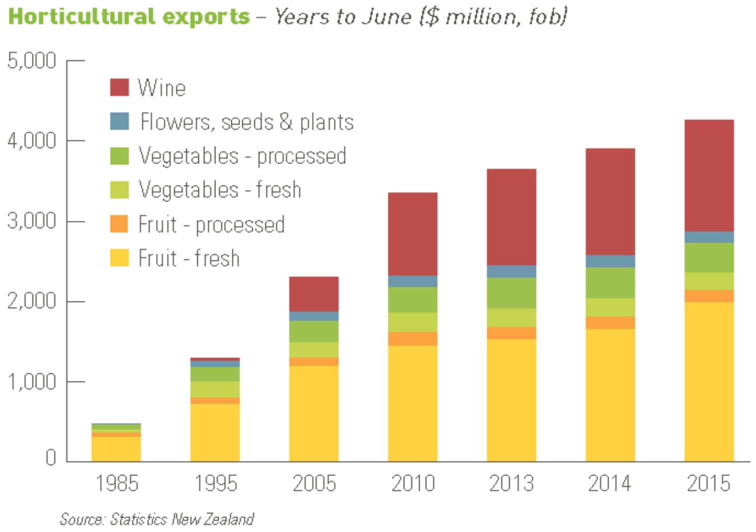



**Figure 23. The growth in the value of horticultural export revenues since 1985 (Fresh Facts 2015).**

The breakdown by commodity of these export figures is shown in Figure 24 (Fresh Facts 2015).

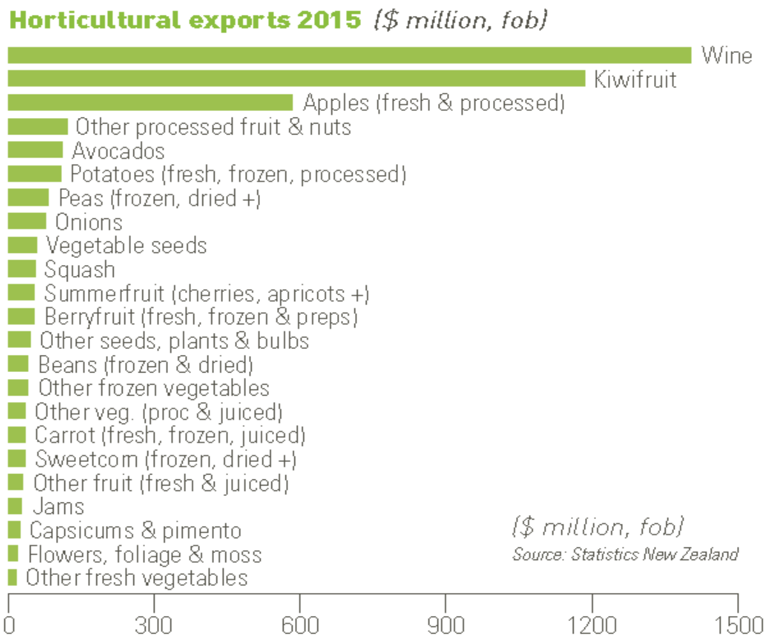



**Figure 24. The breakdown of export revenues for horticultural commodities in 2015 (Fresh Facts 2015).**

It can be seen that there is a 'big three' horticultural products: wine, kiwifruit and apples.

## 2.2 Current performance and horticultural outlook

A recent 2016 report on the website Stuff on 5 December 2016 was headlined that "Rising star horticulture helped by falling tariffs" (Stuff, 2016).

Horticulture is on track to become New Zealand's most valuable primary sector industry, trade envoy Mike Petersen says.

*In total, the value of horticulture could reach $10b by 2020, a target the industry has set itself.*

*"It's only a matter of time before horticulture exceeds other sectors, and that's because you can generate so much from a small amount of land," Petersen said.*

*Dairy exports are worth $13.2b, although the Ministry for Primary Industries forecasts they will rise by 4 per cent in 2017 and 20 per cent the following year to reach $17.7b in 2020.*

*Horticulture exports have had 40 per cent growth since 2014, according to a new report New Zealand Horticulture - Barriers to Our Export Trade, with tariffs on exported produce down by 22 per cent since 2012.*

### 2.2.1 Kiwifruit

The latest Zespri Annual Report provides information of the performance of the kiwifruit sector. The Zespri media release on 31 August 2016 stated (Zespri, 2016):

> *Zespri's Annual Meeting today recapped the strong 2015/16 season for the kiwifruit industry – record sales and highest-ever total grower returns – as well as charting the industry's future as the government approves amendments to the Kiwifruit Regulations.*
>
> ***2015/16 season recap***
> *Zespri Chairman Peter McBride explains total sales revenue for the season grew to hit a record high of $1.9 billion, up 22 percent from the previous season. The total fruit and service payment to growers for New Zealand-grown fruit also grew 22 percent on the previous year to $1.143 billion, with average return per hectare reaching a record $60,758.*
>
> *"Sales volumes were up 21 percent from the previous season, with sales of 131.6 million trays in the 2015/16 season. This included sales of 117 million trays of New Zealand-grown kiwifruit– nearly 22 million trays more than the previous year – and 14.5 million trays of non-New Zealand kiwifruit," says Mr McBride.*
>
> *Zespri's corporate net profit after tax in 2015/16 was also strong, increasing by $1.2 million to $35.8 million, with a final full-year dividend of 24 cents per share. This was partly attributable to the release of a $13 million provision for matters relating to Zespri's subsidiary in China, ZMCC, which are now resolved and income from licence fees. The normalised profit after tax is $27.8 million (compared to normalised profit of $21.5 million last year).*
>
> **Highlights of the 2015/16 season**
> Other highlights of the season covered at the Annual Meeting were:

*The record volume of SunGold of 27.5 million trays (from total New Zealand gold volume of 32.6 million trays) sold in excellent time with positive customer and consumer feedback, earning an average return for the gold pool of $8.21 per tray.*

*The record per hectare Green return of $56,673 (up from $53,884 last year) driven by a reduced per-tray return of $5.13 (down from $6.01 last year) and very strong average orchard yields of 11,048 trays a hectare, up from 8,972 trays per hectare in 2014/15.*

*Continued investment in Zespri's Northern Hemisphere production to grow SunGold supply alongside the growth in NZ volumes. Volumes of 2.3 million trays of SunGold were sold from a total gold Zespri Global Supply (ZGS) volume of 3.6 million trays, with gold volume set to nearly double next season.*

***Looking ahead***
*Zespri Chief Executive Lain Jager reflects on a satisfactory result for 2015/16. "Each season brings its own challenges and opportunities and we remain focused on consistently delivering our strategy over time and staying on track to provide the world's best portfolio of kiwifruit 12 months a year.*

*"For the 2016 season and beyond, Zespri will focus on growing demand ahead of supply as our volumes grow strongly and growing our share of the market with a premium price positioning.*

*"After a late start to the 2016 season with delayed maturity, we're pleased to report that weekly sales run rates have now surpassed last year's sales and we're on track to sell 82 million trays of Zespri Green and 47 million trays of Zespri SunGold of NZ-grown kiwifruit. The strong positive response from customers and consumers around the world is very encouraging as we seek to further establish SunGold in new and developed markets," says Mr Jager.*

### 2.2.2 Wine grapes

The media release from New Zealand Winegrowers on 19 August 2016 noted that wine exports this year were up 10%.

It noted that …

*New Zealand's wine industry is well on track to reach its target of $2 billion of exports by 2020, according to Chair of New Zealand Winegrowers, Steve Green.*

http://www.nzwine.com/assets/sm/upload/lk/ay/it/gw/19%20Aug.%20New%20Zealand%20wine%20exports%20up%2010%25%20-%20NZ%20Winegrowers%20Annual%20Report%202016.pdf

*New Zealand Winegrowers' Annual Report shows exports have risen 10% in the last year, to just under $1.6 billion. This is the 21st consecutive year the industry has experienced significant export growth.*

*"The on-going progress towards the $2 billion goal is founded on our reputation as a wine exporter of the first rank, known for crafting and marketing distinctively New Zealand, high quality, high value wines," said Mr Green.*

*"This continued strong performance is testament to underlying market and consumer demand for our wines in key markets."*

*With demand strong the improved supply from Vintage 2016 is expected to lift export volumes by a further 10% over the next 12 months.*

The 2016 Annual Report can be accessed here and is available at: http://www.nzwine.com/media-centre-1/statistics-information/

### 2.2.3 Apples

Pipfruit New Zealand released a media report on 17 November concerning the performance of the pipfruit sector is at:

http://www.pipfruitnz.co.nz/News_and_Events?cms_584_param_detail=5656
The release comments that …

> *New Zealand is set to grow its largest ever export apple crop of 21.5 million cartons worth a record $800 million, the industry's leader announced today.*
>
> *Pipfruit New Zealand chief executive Alan Pollard said the success of New Zealand's apple industry was breaking all records.*
>
> *"We are the first of New Zealand's larger primary sectors to meet the Government's challenge of doubling exports by 2025, and are well ahead of our own target of becoming a billion dollar industry by 2022.*
>
> *The 2017 season was an 'on year' crop, which along with the first of another million new fruit trees coming into production would produce the largest tonnage of fruit ever harvested in New Zealand, Mr Pollard said.*
>
> *"In just four years New Zealand's apple industry went from producing 16 million cartons in 2012 to 19.5 million cartons in 2016 and an expected 21.5 million cartons in 2017.*

## 2.3 Profitability for Various Land Uses in New Zealand

In 2013, the ANZ Bank released a report on the returns per hectare of various land-uses in New Zealand. The information can be found at https://www.anz.co.nz/resources/2/b/2b7af074-59dc-4a4f-be18-13177d165f7a/ANZ-AgriFocus-20131004.pdf?MOD=AJPERES.

Given the recent changes to production and commodity prices, these 2013 figures (Table 15) are somewhat out of date, especially given the recovery from the disease Psa in kiwifruit and the recent rise in wine prices and apple returns. Nonetheless, these 2013 figures highlight the higher per hectare returns from horticulture, relative to broad-acre farming.

**Table 15. Returns from different land uses (ANZ 2013).**

| SUMMARY OF RETURNS OF DIFFERENT LAND USES UNDER IRRIGATION | | |
|---|---|---|
| **Dairy** | Average | $2,380/ha |
| | Range | $2,000-$6,000/ha |
| **Sheep, Beef & Dairy Support** | Average | $700-$900/ha |
| | Range | $100-1,000/ha |
| **Arable and Processed Crops** | Average | $2,000/ha |
| | Range | $1,000-$2,500/ha |
| **Viticulture** | Average | Depends on region & variety. |
| | Range | $4,000-$10,000/ha |
| **Kiwifruit** | Average | Depends on variety split but $900/ha |
| | Range | Wide range |
| **Pipfruit** | Average | $4,400/ha |
| | Range | Depends on variety split. |

We discuss more recent and updated figures, as many market aspects and growing conditions have changed since 2013, especially so for horticulture.

## 2.4 Recent information on returns from horticulture

### Kiwifruit

The ANZ updated their information on kiwifruit returns in 2015. This can be found at https://www.anz.co.nz/resources/6/d/6d8836cb-019d-404e-93e6-5114fd03b83c/ANZ-AgriFocus-20150609.pdf?MOD=AJPERES. The feature article was entitled *Kiwifruit Revival*. An excerpt of the net orchard-gate return per hectare information is presented below.

JUNE 2015

INSIDE



CONTRIBUTORS

**Cameron Bagrie**

# SWEET & SOUR MIX

**FEATURE ARTICLE: KIWIFRUIT REVIVAL**

The New Zealand kiwifruit sector typifies many aspects of true 'value-add' leading the way in producing and selling a premium offering. Despite the challenges posed by Psa, the industry is in good heart appearing to have navigated the worst of its impacts. Confidence in the industry is reflected in current orchard prices and returns. Grower support for the single point of entry industry structure is also at historic highs. Green orchard prices have averaged $300,000-$350,000 per canopy hectare recently. With medium-term orchard-gate returns expected to be close to the $15,000-$18,000/ha mark this implies a rate of return close to 5-6.5%. The real potential is with the new Gold3 variety. Current Gold orchard prices have averaged $425,000-$500,000 per canopy hectare recently. Medium-term orchard gate returns are expected to be around $53,800/ha, which implies a rate of return of between 11.5-13.5%.

This shows that for green kiwifruit the medium-term orchard gate return is around $15–18,000 per hectare, with a rate of return (ROI) of 5–6.5%. The orchard gate returns and ROI for the new gold variety commonly known as Gold3 (*A. chinensis* var. *chinensis* 'Zesy002') are even higher.

### Pipfruit

Pipfruit NZ provided us through the latest MPI Farm Monitoring report key parameters, financial results and budgets for pipfruit and the key information is provided in the table below (Table 15).

**Table 15. Key parameters, financial results and budgets for the pipfruit orchard models.**

| Year ended 31 December | 2013 | 2014 | 2015 | 2016 Budget |
|---|---|---|---|---|
| **Hawke's Bay model** | | | | |
| Total planted area (ha) | 40.0 | 40.0 | 40.0 | 40.0 |
| Owned planted area (ha) | 24.0 | 24.0 | 24.0 | 24.0 |
| Leased planted area (ha) | 16.0 | 16.0 | 16.0 | 16.0 |
| Total TCE[1] | 145 925 | 127 390 | 135 500 | 129 870 |
| Export TCE | 96 615 | 92 200 | 91 085 | 98 225 |
| Weighted average return at FAS ($/export TCE)[2] | 25.45 | 26.80 | 28.75 | 30.10 |
| Net cash income ($)[3] | 1 585 300 | 1 602 900 | 1 844 500 | 1 979 400 |
| Earnings before interest and tax ($) | 514 900 | 538 000 | 687 200 | 790 400 |
| On-orchard working expenses[4] / Net cash income | 65% | 63% | 60% | 57% |
| Earnings before interest and tax / Net cash income | 33% | 34% | 37% | 40% |
| Return on assets = Earnings before interest and tax less lease expenses / Total owned orchard assets | 16.6% | 15.9% | 19.9% | 21.3% |
| **Nelson model** | | | | |
| Total planted area (ha) | 40.0 | 40.0 | 40.0 | 40.0 |
| Owned planted area (ha) | 32.0 | 32.0 | 32.0 | 32.0 |
| Leased planted area (ha) | 8.0 | 8.0 | 8.0 | 8.0 |
| Total TCE | 129 340 | 123 135 | 123 325 | 121 310 |
| Export TCE | 97 565 | 96 350 | 89 035 | 89 300 |
| Weighted average return at FAS ($/export TCE) | 25.50 | 25.65 | 28.10 | 29.25 |
| Net cash income ($) | 1 545 400 | 1 572 500 | 1 751 400 | 1 856 100 |
| Earnings before interest and tax ($) | 425 400 | 379 800 | 498 600 | 621 500 |
| On-orchard working expenses / Net cash income | 69% | 72% | 68% | 63% |
| Earnings before interest and tax / Net cash income | 28% | 24% | 29% | 34% |
| Return on assets = Earnings before interest and tax less lease expenses / Total owned orchard assets | 11.1% | 8.7% | 11.5% | 14.2% |

Key results from the Ministry for Primary Industries 2016 Pipfruit Monitoring Programme indicate that the Hawke's Bay EBIT is $19,760 per ha with an ROI 21.3%, and in Nelson the EBIT is $15,540 per ha with an ROI 14.2%.

The monitoring report did highlight these three concerns listed below:

- Concerns: Growth constraints identified include (i) having an adequate supply of suitably skilled seasonal and full-time staff, (ii) available land and (iii) the lead time in obtaining trees on desired rootstocks. Long-term security of water supply in the main growing regions was also noted as a concern.
- These concerns around human capacity, and natural capital stocks of land and water, plus issues around infrastructure and breeding material, where also mentioned for other primary sectors in general, and horticulture in particular.

#### Viticulture

New Zealand Winegrowers provided us with the 2015 Viticulture Monitoring Report for Marlborough and Hawke's Bay. Tables of this information are provided below

#### Marlborough

| Year ended 30 June | 2005-14 | 2010-14 | 2014 | 2015[3] |
|---|---|---|---|---|
| | 10 year average | 5 year average | | |
| **Producing area (ha)** | 30 | 30 | 30 | 30 |
| **Total production[1] (t)** | 329 | 348 | 439 | 324 |
| **Average production (t/ha)** | 11.0 | 11.6 | 14.6 | 10.8 |
| **Average return ($/t)** | 1 865 | 1 535 | 1 730 | 1 810 |
| **Sauvignon Blanc ($/t)** | 1 815 | 1 420 | 1 640 | 1 710 |
| **Net cash income ($)** | 619 300 | 541 100 | 763 100 | 587 300 |
| **Vineyard working expenses ($)** | 262 600 | 248 800 | 289 300 | 291 600 |
| **Vineyard profit before tax ($)** | 230 600 | 196 500 | 368 800 | 183 200 |
| **Vineyard surplus for reinvestment[2] ($)** | 165 000 | 133 100 | 189 100 | 36 600 |
| **EBIT/Total Capital (%)** | 4.8% | 5.1% | 8.7% | 4.9% |

The 10-year average EBIT for a Marlborough vineyard is $7,686/ha with an ROI of 4.8%.

#### Hawke's Bay

| Year ended 30 June 2015 | Sauvignon Blanc | Chardonnay | Merlot |
|---|---|---|---|
| **Total production[1] (t/ha)** | 9.3 | 6.6 | 9.1 |
| **Average return ($/t)** | 1 500 | 1 915 | 1 925 |
| **Grape income ($/ha)** | 13 945 | 12 685 | 16 870 |
| **Vineyard direct expenses ($/ha)** | 7 305 | 7 325 | 7 260 |
| **Gross Margin ($/ha)** | 6 640 | 5 360 | 9 610 |
| **Gross Margin ($/tonne)** | 715 | 815 | 1 060 |

Depending on grape variety the EBIT for Hawke's Bay vineyards range from $5400 to $9610 per ha.

## 2.5 Future profitability and potential carbon costs: a heuristic assessment

### 2.5.1 Horticulture

Here we examine what might be the implications on horticultural profitability should there be a realistic cost assigned to carbon emissions. This exercise is simply a heuristic assessment based on the best information we could, at short notice, assemble. With further economic assessment, we could refine these predictions.

From above, we have vineyard surplus information for viticulture, orchard-gate returns for kiwifruit, and EBIT data for apples. In the absence of any other information, we will assume that these orchard-gate returns, gross margins, and EBIT are identical, and we will for simplicity refer to these as EBIT. From the GHG assessments above, we now consider the implications of these results below.

### 2.5.2 EBIT

**Kiwifruit**

The medium term assessments for orchard-gate returns from green kiwifruit are predicted to be $15–18,000 $ha^{-1}$ with a return on investment (ROI) of 11–13%. The EBIT for 'Zesy002' Gold3 is expected to be higher.

**Grapes**

The reported EBIT for Sauvignon blanc grapes in Marlborough is given as $7686 $ha^{-1}$ and between $5360 (Chardonnay) and $9,610 (Merlot) in the Hawke's Bay. The ROI is between 5–9%.

**Apples**

In Hawke's Bay, the reported EBIT for apples is $19,760 $ha^{-1}$ with an ROI of 21.3%, whereas in Nelson the EBIT is $15,540 $ha^{-1}$ and an ROI of 14%.

### 2.5.3 Summary

From these results, for our preliminary heuristic exercise we will take a simple average EBIT for horticulture to be **$10,000 $ha^{-1}$**, reflecting the range from $5360 to $53,800 $ha^{-1}$ for these big-three horticultural crops. This use of an average value, especially given the wide range, is purely for heuristic purposes to explore the impact of any future price of carbon on profitability.

## 2.6 GHG emissions and mitigations

We have assessed the GHG emissions for these three crops and we have considered the implications of short-term mitigations that can reduce emissions, and how a changed carbon costing might affect the profitability of these industries.

We have earlier assessed GHG emissions from these perennial crops to be between 3 and 6 T $CO_{2-e}$ $ha^{-1}$. From our LCA-assessments of on-farm emissions of GHGs, we will for heuristic purposes consider horticultural emissions to be **5 T $CO_{2-e}$ $ha^{-1}$.**

Furthermore, we will consider that 15% of these emissions can be mitigated without reductions to EBIT/ha. These could be achieved without improvements to EBIT as assumed, or even they might generate enhancements to profitability. These mitigations could even be further realised with reductions to GHG emissions by considering biogenic carbon accumulations and soil-C sequestration.

Thus, for our heuristic assessment we will consider the mitigated net TGE to be **4.25 T $CO_{2-e}$ $ha^{-1}$**.

We have used the IPCC method for calculating BGE. For the three horticultural sectors we find the annual average BGE to be **0.64 T $CO_{2-e}$ $ha^{-1}$**. The IPCC annual value for a 15% mitigated BGE could be taken to be **0.54 T $CO_{2-e}$ $ha^{-1}$**.

### 2.6.1 Net Impact of carbon prices

For our simple assessment we take EBIT profitability of horticulture to be **$10,000 $ha^{-1}$**.

For the emissions from horticulture we have calculated earlier, we take on-farm mitigated TGE to be **4.25 T $CO_{2\text{-}e}$ $ha^{-1}$.**

It is therefore possible to examine the impact of carbon pricing on orchard profitability. For heuristic purposes we could assume a future carbon price of **$50 T $CO_{2\text{-}e}$ $^{-1}$**.

This would then add to on-orchard costs of **$212.50 $ha^{-1}$**.

So the net impact on orchard EBIT would drop from $10,000/ha down to an EBIT **$9788.00/ha**, or a drop of just **2.1%**.

If the carbon price were to apply only to the mitigated IPCC BGE this would then add to on-orchard costs of **$27 $ha^{-1}$**.

So the net impact for the IPCC calculation of BGE on the orchard EBIT would be to drop the EBIT of **$10,000/ha** down to an EBIT **$9973/ha**, or a drop of just **0.3%**.

The variability these horticultural industries and regions make this heuristic assessment quite simplistic. But these considerations do highlight that the impact of any increase in carbon pricing might have somewhat minimal impacts on the broad-acre horticultural industries, primarily because of their low GHG emissions per unit area, and their high profitability per unit area. Our results do not, of course, apply to covered horticultural enterprises where production practices are much more intensive.

## 2.7 Performance of the arable industry

Barber et al. (2011) commented that "…the arable industry is a vibrant and successful sector within the New Zealand economy, covering small and large grain crops and crops grown for seed production. Maize represents 30% of the arable industry; wheat 20% and grass seed 20%. New Zealand exports over $70 million of wheat based products around the world. Seed production has developed to a $115 million export industry."

BERL reported in 2015 *that "…arable production is a significant contributor to the New Zealand economy. Production from the arable industry is a substantial input to the livestock industries, especially the more-intensive dairy production, and poultry and pig production.*

*When these industries experience strong markets and embark on strong growth, they require increased output from the arable industry for their feed.*

*The opposite is also the case when these livestock industries experience reduced market strength for their products, as has been the case with New Zealand's dairy industry in the recent seasons. This has caused some reduction of demand for arable industry output, as has shown in this current estimate of arable production in 2015."*

*The numbers for arable production in 2015 are that this production added nearly $750 million in total to GDP in 2015. The direct sales value from arable production was $683 million. When the indirect impacts to suppliers of arable producers are added, the direct and 'upstream' value of sales was over $1.8 billion.*

*Employment of almost 10,000 FTEs in total in the arable industry is similar to the employment in fruit-growing, including kiwifruit, apples and pears. It is not much less than the number directly employed in the dairy farming industry."*

In a report to the Foundation for Arable Research (FAR), the research agency BERL presented a table of the economic impacts of the arable industry and this is reproduced below (Table 16) [courtesy of FAR].

**Table 16. A summary of the economic impacts of arable production in 2015.**

| | 2015 | | | | 2013 |
|---|---|---|---|---|---|
| | Tonnes | Total Value ($Millions) | With Indirect Impacts ($Million) | With total impacts ($million) | With total impacts ($million) |
| **Gross output ($M)** | | | | | |
| Grain production | 2,025,553 | $479.2 | $1,013.7 | $1,282.4 | $1,815.9 |
| Seeds | 92,765 | $187.6 | $396.9 | $502.1 | $653.2 |
| **Total** | **2,118,318** | **$666.9** | **$1,410.6** | **$1,784.5** | **$2,469.1** |
| **GDP ($M)** | | | | | |
| Grain production | | $168.8 | $397.0 | $529.6 | $750.0 |
| Seeds | | $66.1 | $155.4 | $207.4 | $269.8 |
| **Total** | | **$234.9** | **$552.4** | **$737.0** | **$1,019.7** |
| **Employment (FTEs)** | | | | | |
| Grain production | | 2,927 | 5,671 | 6,945 | 9,834 |
| Seeds | | 1,146 | 2,220 | 2,719 | 3,537 |
| **Total** | | **4,072** | **7,892** | **9,664** | **13,372** |

### 2.7.1 Total GHG emissions and mitigations

In Table 13 above we presented the total LCA-assessed GHG emissions from within the farm-gate of four types of arable farms (Barber et al. 2011). The average TGE is 2.4 T $CO_{2\text{-}e}$ $ha^{-1}$. Some 40% of these emissions were found to be direct on-farm emissions. We consider that there are a moderate number of options to reduce these emissions with affecting farm EBIT, primarily through better nitrogen management. These reductions we assess would be able to reduce GHG emissions by 15–20%, so we can consider that sustainable arable farming would have mitigated TGE of **2 T $CO_{2\text{-}e}$ $ha^{-1}$**. The mitigated BGE is just 40% of this, or **0.80 T $CO_{2\text{-}e}$ $ha^{-1}$**.

### 2.7.2 EBIT

The ANZ farm profitability in 2013 assessed arable farm EBIT to be on average **$2000 $ha^{-1}$**. In the absence of further information, we presently use this EBIT number for heuristic purposes to assess the impact of a putative carbon price.

### 2.7.3 Net Impact of carbon prices on arable farming

If the price of carbon were to rise to **\$50 T $CO_{2\text{-}e}$** then if an arable farmer needed to pay for all the farm's TGE this would be a cost **\$100 $ha^{-1}$**. Given an EBIT of \$2000 $ha^{-1}$, this additional cost would reduce arable farm profitability by **5%**.

Since BGE comprise 40% of the average annual arable TGE (Table 13), if this price of carbon were only applied to biological emissions, this would mean a cost of **\$40 $ha^{-1}$**, and a reduction of **2%** in the profitability of arable farms.

## 2.8 Summary: horticulture and arable

Our simple heuristic exercise based on TGE and the impact of a putative carbon price of **\$50 T $CO_{2\text{-}e}$** suggests that there would be a **0.3–5%** drop in farm profitability for horticulture and arable farming, respectively.

Because mitigated BGE for horticulture, in general, is on annual average 13% of TGE, the impact of this carbon price would only reduce EBIT by **0.3%**. For arable farming, BGE is considered to be about 40% of TGE, and the impact of a \$50 T $CO_{2\text{-}e}$ price on just BGE would reduce farm EBIT by **2%**.

These costs are quite modest, especially if further GHG mitigation options were adopted. Furthermore, many of these mitigations would likely reduce on-farm costs.

## 2.9 Land area changes—Horticulture

With the surging growth in export revenues and high EBIT, the kiwifruit, grape and apple horticultural sectors are slated to undergo a growth in planted areas.

### 2.9.1 Kiwifruit

David Armour of Zespri has provided an assessment of changes in the land area planted in kiwifruit, for the traditional green 'Hayward', and the new gold cultivar 'Zesy002' Gold3.

There is planned some 400 ha of new 'Hayward' planting, on top of a base of 7600 ha currently. And how much of the new plantings remains as 'Hayward', and how much is slated to be grafted over to a new variety, is hard to ascertain.

There has been 400 ha of new 'Zesy002' licenses released, with some 175 ha being for new KPIN orchards. David Armour comments that there will be therefore somewhere between 150 and 400 new hectares of new 'Zesy002' plantings. Current is 4,000ha of G3 licensed plantings.

Thus, in the near future, the growth in the planted area of kiwifruit is predicted to be less than 1000 ha.

### 2.9.2 Grapes

Projected land area information for viticulture was received from NZ Winegrowers. These data are shown below (Table 17).

**Table 17. Projected land area changes over the next four years for viticulture.**

| Region | 2016 | 2017 | 2018 | 2019 |
|---|---|---|---|---|
| Auckland | 323.03 | 324.62 | 323.12 | 322.75 |
| Canterbury | 167.92 | 167.97 | 167.97 | 167.97 |
| Gisborne | 1,350.40 | 1,371.13 | 1,402.69 | 1,417.52 |
| Hawkes Bay | 4,640.63 | 4,693.93 | 4,785.57 | 4,804.72 |
| Marlborough | 24,324.10 | 25,109.87 | 25,739.73 | 25,918.22 |
| Nelson | 1,134.93 | 1,154.95 | 1,176.27 | 1,191.27 |
| Northland | 64.01 | 66.74 | 66.76 | 66.76 |
| Otago | 1,921.35 | 1,937.64 | 1,955.70 | 1,965.65 |
| Waikato / Bay of Plenty | 3.17 | 3.17 | 3.17 | 3.17 |
| Waipara | 1,251.79 | 1,257.32 | 1,257.52 | 1,258.96 |
| Wgtn / Wairarapa | 1,004.63 | 1,017.46 | 1,027.80 | 1,028.37 |
| **Totals:** | **36,185.96** | **37,104.80** | **37,906.30** | **38,145.36** |

There is predicted to be a modest increase in the area of viticulture of 1960 ha, or 5%, over the next 3 years.

### 2.9.3 Apples

Long-term crop estimates for apples were received (in confidence) from Pipfruit NZ. These data are shown below (Table 18).

**Table 18. The projected land area change in apple orcharding over the next six years.**

| Main Region | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|
| Hawkes Bay | 5,921 | 6,177 | 6,469 | 6,856 | 7,274 | 7,560 |
| Nelson | 2,512 | 2,553 | 2,539 | 2,539 | 2,554 | 2,564 |
| Otago | 430 | 431 | 430 | 443 | 443 | 443 |
| Other | 444 | 461 | 450 | 440 | 430 | 428 |
| **Grand Total** | **9,308** | **9,621** | **9,887** | **10,277** | **10,700** | **10,995** |

* Planted area in January of each year

Although the area increase by 2020 is predicted to be just 1,687 ha, this is a 17.5% increase in the area under pipfruit.

> Ross Wilson from AgFirst commented that *"…the pipfruit industry is currently in the longest run of profitability for some time. This year 2016 will be the 4th profitable year in a row. Consequently there is investment interest in new plantings. This is primarily due to increasing demand from the economies in the Asian region.*
>
> *Most of the new pipfruit developments are occurring in the Hawkes Bay. There are also developments occurring in Nelson, and Poverty Bay. As with kiwifruit and grapes, microclimate is critical to be able to grow pipfruit well. Recently Nelson has experienced large losses to canker, hence growth there is slower than in the drier HB region. The need for industry infrastructure, e.g. supplies, packing, cool storage and port facilities also means growth is more likely to occur in the established regions."*
>
> Peter Beaven, Pipfruit NZ Board member and ex-CEO of Pipfruit NZ has commented in a personal email, that in terms of land suitability …
>
> *"On the Heretaunga Plains there are around 20,000 hectares of suitable land of which only 6000-7000 are planted in pipfruit. There is almost no pipfruit grown around Wairoa but around 10,000 hectares suitable. Gisborne has some apples but would also have 10,000 hectares capable. There is some renewed interest and some new plantings happening currently. In the Waikato around Cambridge the opportunity is limitless. In South Canterbury around Timaru they have found it the best place in NZ to grow Honeycrisp on the Heretaunga Plains. There are thousands of hectares there that could be converted. These are the main opportunities but Central Otago and Nelson can also expand each by 2000 hectares. Water availability might be the limiting factor in Nelson.*
>
> *The pipfruit industry could easily quadruple in size in NZ."*

We now examine what potential the natural capital assets of New Zealand might provide for future expansion of horticulture. Might a quadrupling of the land area in horticulture be possible – in relation to our biophysical resources?

## 2.10 Potential land area for horticulture

Given the good future prospects for horticulture, its high profitability per hectare, and its high export revenue returns per hectare, what is the natural capital asset-base in New Zealand that could support horticulture? We examine this to assess what the natural-capital potential might be for future expansion, and we do this without consideration of any economic or sociological assessment.

Currently there is, as noted, 55,000 ha of land growing kiwifruit, grapes and apples. When other horticultural land is added in, there is some 121,000 ha of land growing fruit and vegetable crops. What might be the potential for all, or any these crops to expand on to land currently not under horticulture?

We first consider the LUC (land use capability) classes that could sustain horticulture. We take these as being LUC classes 1, 2 and 3, plus we have added in classes 4s–7s. This latter addition is to account for the preference for viticulture for stony, yet deep, soils, such as the Gimblett Gravels (LUC 7). The potential for LUC 4–7 applies only to viticulture, as we wished to include the 'stony, less fertile soils' that are favoured for grape growing.

A map of all these LUC areas is shown in Figure 25 (left). In total this sums to a large land area of 5730 kha.

We next considered the climate criterion that the growing degree days, base 10°C, must exceed 800 (GDD10), for this we consider the 'warmth' that is needed to enable fruit to reach maturity. A map of the land areas fulfilling this criterion is shown in Figure 25 (right).

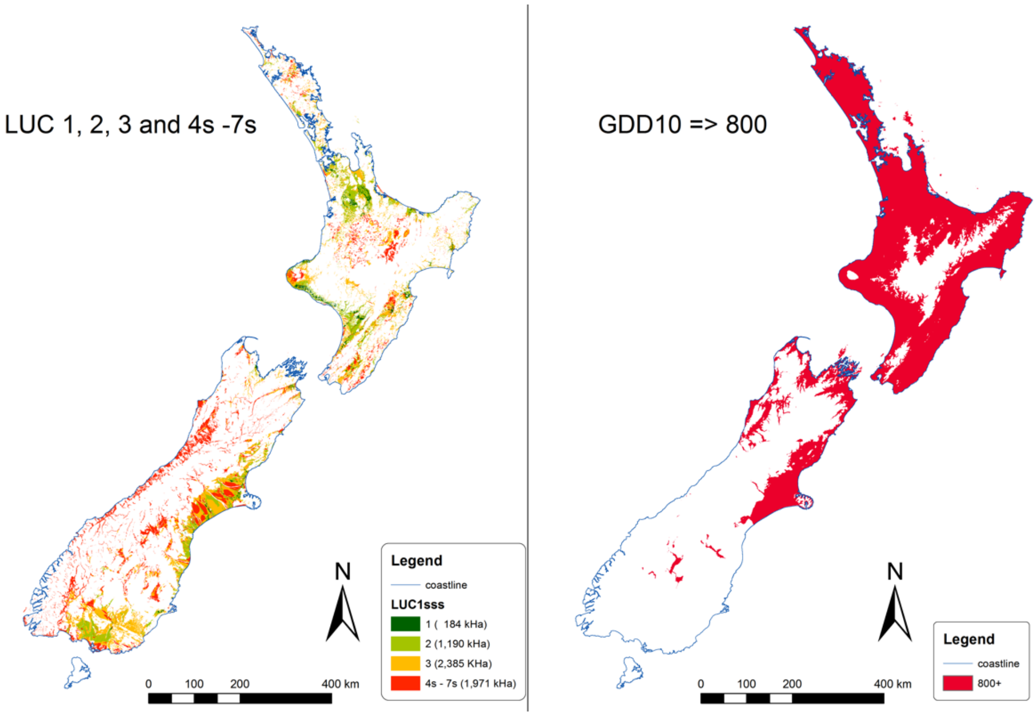



**Figure 25. Left. Land Use Capability classes deemed suitable for horticulture and arable cropping (classes 1 and 2) and potentially suitable for horticulture (class 3 and 4s–7s). (Data reproduced with the permission of Landcare Research New Zealand Limited). Fig 25 Right. Areas where the Growing Degree Day base 10 (20th percentile) meets or exceeds the 800 thresholds commonly applied for apple suitability studies. (Data reproduced with the permission of NIWA).**

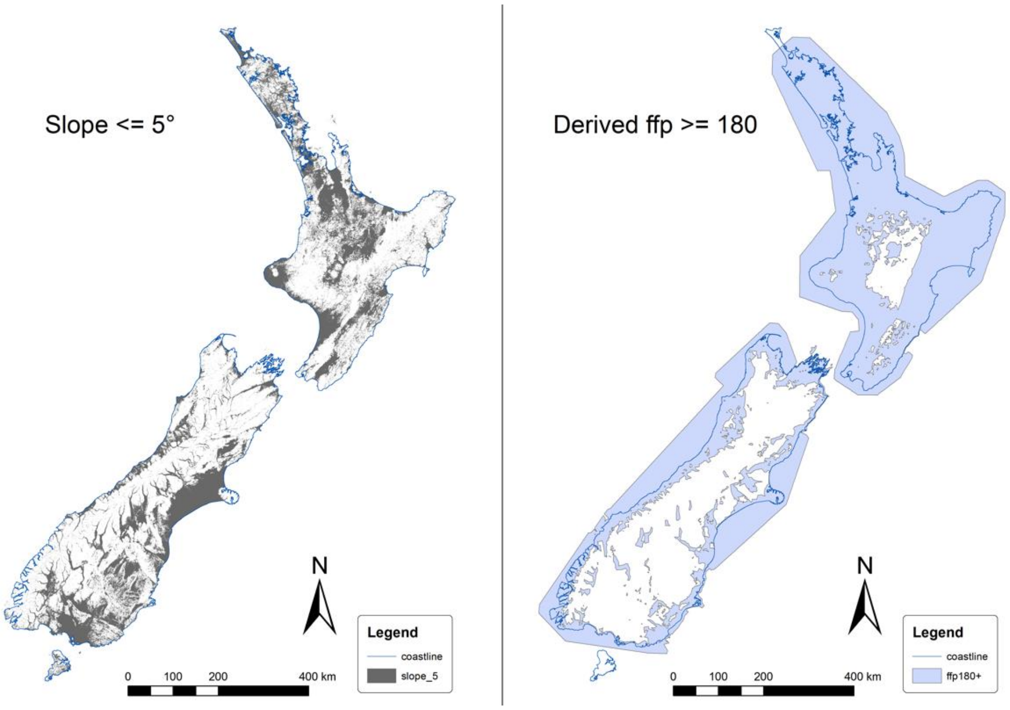



**Figure 26. Left. Areas where the slope does not exceed 5 degrees, therefore easily allowing for horticultural operations and cultivation. (Data reproduced with the permission of Landcare Research New Zealand Limited). Fig 26 Right. Areas where the derived Frost Free Period meets or exceeds 180 days, thus allowing a long enough growing season for fruit crops to ripen. (Data reproduced with the permission of NIWA).**

Next we considered two additional criteria that we consider important for horticulture. First we consider that because of trafficability, the slope of the land should not exceed 5° slope (Figure 26). Next it is important that there be a sufficiently long period free of frosts so that neither flowering nor fruit ripening are affected. We consider a 180 day frost-free period (ffp) is sufficient for horticulture. A map of this ffp is shown in Figure 26.

When all four criteria are overlain, we end up with a map of the potential area for horticulture that is shown in Figure 27. The sum total of this area is 2097 kha (Figure 28).

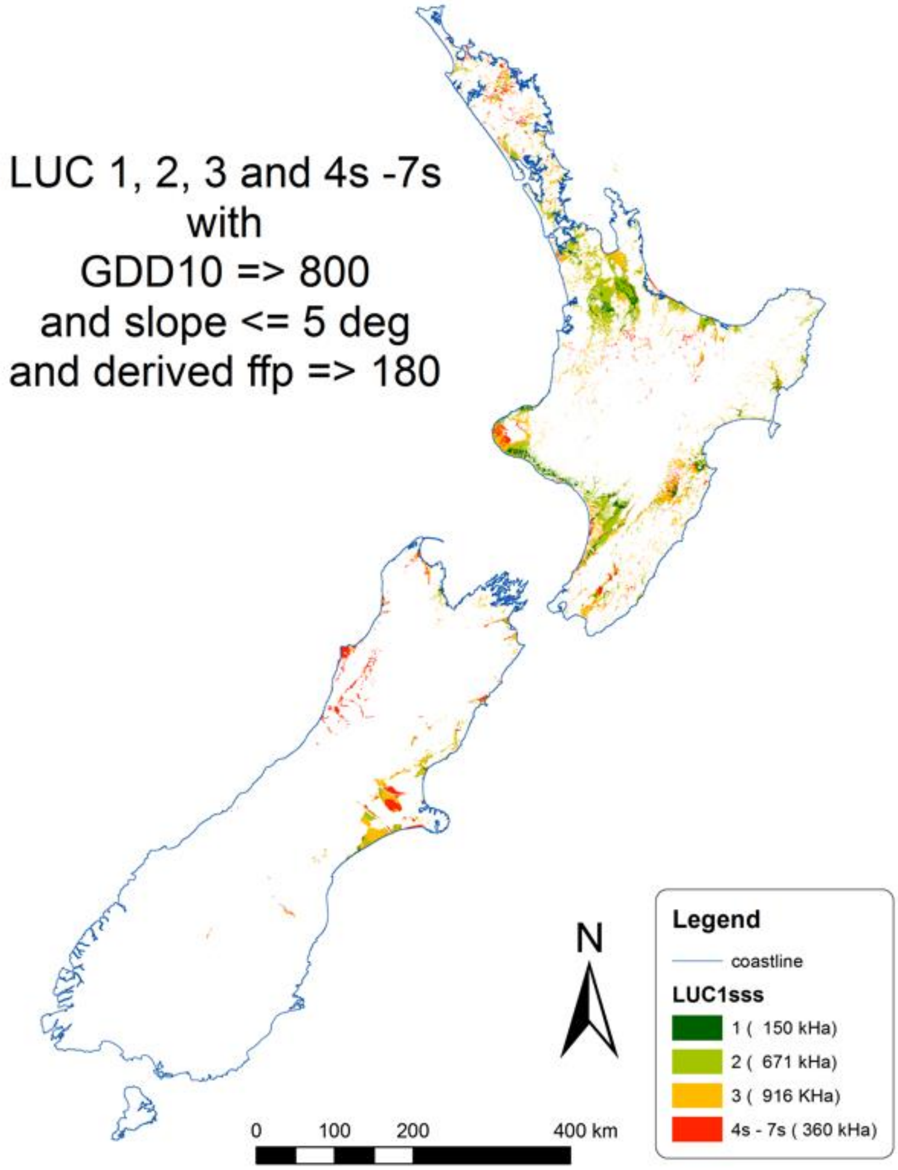



**Figure 27. Land Use Capability classes 1, 2, 3 and 4s–7s where our criteria of Growing Degree Days, Slope and Frost Free Period are met. (Data reproduced with the permission of Landcare Research New Zealand Limited and NIWA)**

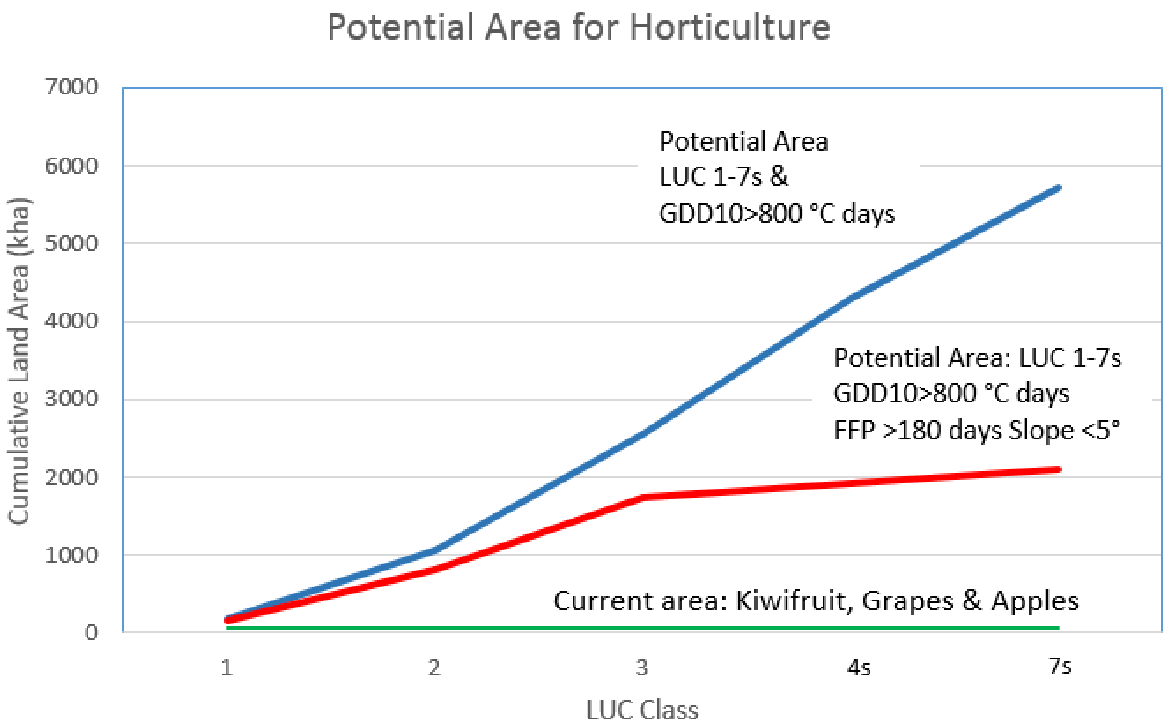



**Figure 28. The cumulative total of land area in New Zealand that is suitable for horticulture, as a function of Land Use Capability (LUC) class. The blue line is simply for LUC and climatic 'warmth' with the growing degree day (base 10) GDD10 being greater than 800°C days. The red line is where the additional criteria of slope < 5° and the frost-free period being longer than 180 days. The current area in kiwifruit, grapes and apples is also shown (green).**

We were also asked to provide an assessment of the potential for these horticultural sectors to replace land-uses that are currently under livestock. In Figure 29 we show a map of those areas with the same horticultural criteria as in Figure 27, and which now are also classed as being high-producing exotic grassland in the Land Cover Data Base (LCDB). This latter LCDB category would predominantly indicate livestock farming. The total area of this intersection of potential horticultural lands and current livestock farming is 1635 kha. So of the land onto which horticulture could potentially expand (2097 kha), some 78% of it (1635 kha) would currently seem to be under livestock farming. Hence potential horticultural expansion onto new, non-horticultural land, would, if it were to happen, likely come at the expense to the areal extent of livestock farming.

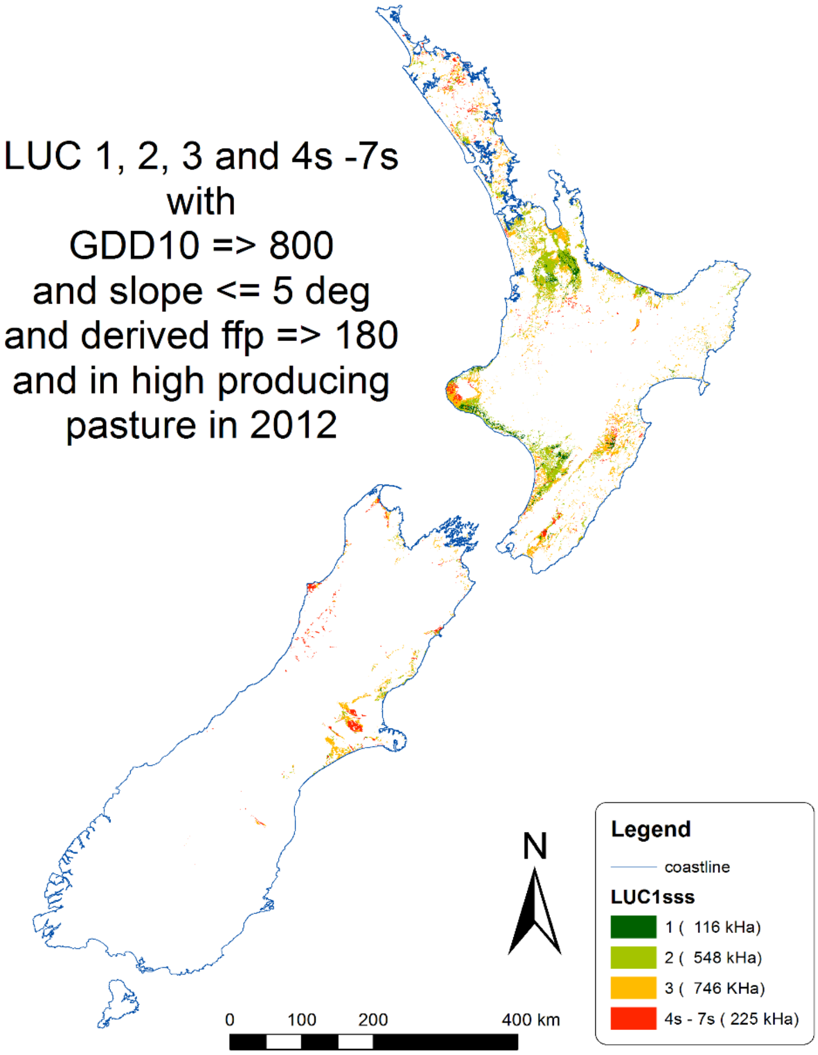



**Figure 29. Land Use Capability classes 1, 2, 3 and 4s–7s where our criteria of Growing Degree Days, Slope and Frost Free Period are met, and which include areas of high-producing exotic grassland. (Data reproduced with the permission of Landcare Research New Zealand Limited and NIWA)**

We add several caveats to these assessments of horticultural expansion (Figures 27, 28 and 29). These land areas will also require protection from wind, and there will also be the need for irrigation water. The first of these limitations can be overcome through the use of appropriate canopy designs and constructed shelter.

The latter is a constraint that will depend on how much of the local water resource is already allocated, and restrictions that might flow from the implementation of the National Policy Statement on Fresh Water Management (NPS-FW). Nonetheless, compared to other land uses, horticulture is a parsimonious user of irrigation. This is due to several factors:

- Horticultural crops are deciduous, thus the period of irrigation is only limited to the period after bud-break through until fruit maturity and harvest.
- Horticultural training systems are designed to enable light penetration into the canopy to enable fruit maturation, and these systems general result in a crop factor of between 0.3

for grapes, apples (0.65) and kiwifruit (0.9). Thus these crops use between 30–90% of the water that would be used by pasture.

- During the late stages of fruit maturation, it is counter-productive to irrigate to crop demand, rather deficit irrigation strategies are commonly used to enhance fruit maturation and fruit quality.

Also we note that our overlain criteria do not suggest opportunities for horticulture in Central Otago, yet we note that there are significant plantings of grapes and summerfruit. This is because measures are taken to avoid the impacts of frosts, and also we add that the greater warmth of the summer months will enable fruit maturation well within the ffp of 180 days.

## 2.11 Potential areas for arable farming

We have not carried out a detailed separate analysis of what might be the potential area for we consider that potential areas for cropping would be subsumed in our horticultural analysis for horticulture by considering just LUC classes 1–3. We estimate the current planted area of arable crops to be 500 kha, and in Figure 28 above, we can see that there is 3759 kha on land with LUC ≤ Class 3. Thus there is vast biophysical potential to expand cropping – should there be market drivers to do so.

## 2.12 Mixed farming systems

Some of the suitable area identified in Figure 29 above will be fragmented pockets of land with potential for horticulture. They might not be of sufficient size for a stand-alone horticultural enterprise. However, these high-value tracts of land might be in close proximity, so that there could be sufficient land distributed across a region to sustain a horticultural enterprise. For example, Mr Apple in the Hawke's Bay has some 30 orchards distributed from the Heretaunga Plains through to the Ruataniwha. These distributed orchards are often focussed on one apple variety. Furthermore, there are three distributed packhouse/coolstores to service these orchards. Such distributed orchards under a common enterprise enables sharing of equipment, infrastructure and human resources.

Also there are examples of mixed farming systems that 'cherry pick' distributed pockets of high-value and versatile lands, so that there is a regional industry.

In the Bay of Plenty, a number of kiwifruit growers also have avocado trees on their properties. Junction Winery in the Central Hawke's Bay is based, on valuable frost-free land, at the foot of a sheep and beef farm. In the Whangaehu and Turakina Valleys near Whanganui, there are several sheep and beef farms with kiwifruit orchards on the versatile soils of the lower river flats. Around Timaru, in South Canterbury, there are livestock farms with apple orchards on the versatile flat areas of their land. Lack of off-farm infrastructure would seem to limit further expansion of the apple industry there presently.

This selective use of high-value and versatile lands should enable better use of our natural resources and sustain further growth in horticultural revenues and farm profitability.

Nonetheless, there will be issues and challenges in the development of such mixed farming systems. Ross Wilson of AgFirst has commented that "… *horticultural production has become so technically demanding that the orchards are best run as specialist operations. Many years ago I witnessed many stock farmers plant a small area of orchard on their farms. Most of them* *have since gone. The basic reason is that over time, the technical and compliance requirements have increased 10 fold, making it too hard for most farmers to be good at both stock farming and horticulture.*

*However if a farm has land suitable for horticulture and is prepared to invest in scale sufficient to employ specialist staff then it is possible*."
Mr Wilson concludes that "…*horticultural development should be encouraged where the following attributes are in place;*

1. *Land and microclimate is ideal for the intended crop*
2. *Any intensive land use is located reasonably close to existing infrastructure.*
3. *Labour resources including skilled managers/foreman and seasonal staff are accessible.* "

Our maps and assessments address his first point.

For the arable industry, similar options exist. And for arable farming, crop rotations across farming enterprises enable cycles of farming activities to enhance EBIT and maintain soil carbon stocks.

## 2.13 Potential horticultural land area: a synopsis

We have shown, on the basis of New Zealand's natural capital assets, that horticulture has the potential to be carried out over 2000 kha. Currently kiwifruit, grapes and apples cover just 55 kha. When other horticultural crops and vegetables are added in, horticulture covers some 121 kha. So there is huge biophysical potential for horticultural expansion. We have not considered any economic and sociological constraints that might limit this. Furthermore, there are licensing restrictions on the planting of new cultivars, such as 'Zesy002' Gold 3 kiwifruit, and so the potential for expansion can be limited by industry strategies.

In contrast, we do note that every year some 40 kha of land is 'consumed' by infrastructure and peri-urban expansion (Mackay et al. 2011). Furthermore, a lot of this land that is 'lost' to agriculture is versatile land on the peri-urban fringe. And although regulations can sometimes be used to prevent this (Robinson et al. 2013), there is an inexorable 'march' of urbanisation onto prime agricultural lands.

## 2.14 Summary

The range of EBIT for the three dominant horticultural crops ranges from $5000 per hectare (Chardonnay in Hawke's Bay) up to $54,000 per hectare ('Zesy002' Gold3 kiwifruit in the Bay of Plenty).

This profitability is higher than livestock-based pastoral agriculture and invites the question of why there is not a burgeoning growth in horticultural expansion? In part this is due to infrastructural inertia, conservative investment, and a lack of human capital. However, in the case of viticulture since 1980, there has been a dramatic increase in the area under vineyards. So where opportunities are seen, rapid changes can occur.

Unlike the expansion of viticulture, primarily in Marlborough, Central Otago and Martinborough, the failure of Applefields in Canterbury with pipfruit can be seen as a counterpoint. This failure was due to a host of complex issues, rather than the lack of the biophysical potential for apple growing in Canterbury. Albeit, there were different maturation timings and altered fruit sizing regimes in the climate of Canterbury that did not fit industry 'norms'.

Also, for horticultural products there is an inertia between a business decision, orchard establishment, and full production. Also, rapid expansion can also lead to industry problems, as happened 5 years ago with over-production in the wine industry, and also the rapid expansion and subsequent contraction of the kiwifruit industry into areas such as Whanganui during the 1980–1990s. There is also a requirement for investment into both on-farm infrastructure and supply-chain infrastructure to enable a harmonised expansion of plantings with processing, packaging, storage and despatch of fruit and fruit products.

So whereas it would seem that New Zealand has the biophysical assets for over a 15-fold expansion of horticultural, this is unlikely to be realised because of the fragmentation of the suitable land-areas, a lack of water, the loss of land to urbanisation, industry strategies, the lack of infrastructure and insufficient human capital, and uncertainty about international markets.

Nonetheless, horticulture does have expansion potential based on New Zealand's valuable stocks of natural capital. This expansion, were it to happen, would likely come at the expense of livestock farming.

The economic performance of the big-three horticultural sectors of kiwifruit, grapes and apples has been very good and the future prospects look favourable. The EBIT for these horticultural sectors range from $5–19000 per hectare. Total greenhouse gas emissions from horticulture are reasonably low, at around 5 T $CO_{2\text{-}e}$ $ha^{-1}$. Mitigations of TGE should easily be able to reduce emissions to around 4.25 T $CO_{2\text{-}e}$ $ha^{-1}$. A simple heuristic exercise indicates that if carbon were priced at $50 per T $CO_{2\text{-}e}$ then there would be about a 2.1% drop in EBIT if the carbon price were applied to TGE. If the carbon price were applied to BGE, which comprises 13% of TGE, then there would only be a 0.3% drop in EBIT.

Horticulture results in high returns per hectare, with low per hectare GHG emissions, such that any imposition of a carbon cost should only make a small difference to profitability.

The planted area of these horticultural sectors is predicted to grow by about 1–2000 ha over the next 3–4 years. Without considering the socio-economic potential for further expansion, we show that New Zealand's soil and climate resources could provide potential for even further expansion.

## 2.15 Co-benefits of GHG reductions

### 2.15.1 Freshwater management

In a recent study, Shepherd et al. (2016) estimated the impact of the National Policy Statement for Freshwater Management (NPS-FW) on GHG emissions. They assessed four primary production systems: sheep and beef, dairy, cropping and forestry.

The table below shows the model values assumed (Table 19).

**Table 19. Summary of model values for the range of farms in this study.**

| Sector | N and P loss (kg/ha) | | GHG | Contribution (%) | | | Area |
|---|---|---|---|---|---|---|---|
| | N | P | (kg $CO_2$-e/ha) | $CH_4$ | $N_2O$ | $CO_2$ | (M ha) |
| Sheep & Beef | 11-31 | 0.2-5.3 | 1288-7431 [4861][1] | 34-81 | 15-65 | 1-5 | 7.7 |
| ***Median*** | ***16*** | ***1.0*** | ***4734*** | ***57*** | ***41*** | ***2*** | |
| Dairy | 36-61 | 0.5-2.3 | 9427-18459 | 46-69 | 17-47 | 7-15 | 1.5 |
| ***Median*** | ***44*** | ***1.1*** | ***11769*** | ***66*** | ***22*** | ***12*** | |
| Cropping | 14-240 | 0.1-2.5 | 1326-15000 [5980][2] | 0-14[3] | 17-87 | 13-83 | 0.5 |
| ***Median*** | ***32*** | ***0.4*** | ***3696*** | ***0*** | ***40*** | ***51*** | |
| Forestry[4] | 0.5-6 | 0.2 | (27000)-(48000) | | | | 1.5 |

[1]lower maximum if the two most intensively managed farms are excluded; [2]lower maximum if the Southland vegetable farm is excluded (high $N_2O$ emissions); [3]Three rotations included grazing animals, which caused methane emissions; [4]Literature values

The resulting relationship between reduced nitrate leaching and GHG emissions is shown in Figure 30 for 13 cropping farm systems (Shepherd et al. 2016).

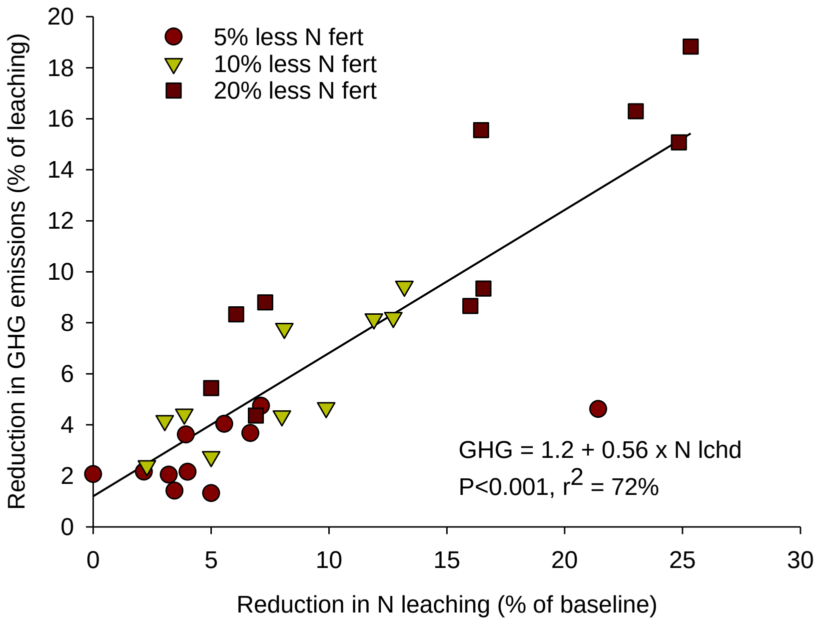



**Figure 30. The relationship between OVERSEER®-modelled reductions in N leached and GHG emissions for an assumed reduction in fertiliser inputs into 13 baseline cropping farms due to improved technologies of 5, 10 or 20% (with no reduction in yield). [From Shepherd et al. (2016)]**

The effect of mitigations across various regions for various crops is shown in Table 20 below.

**Table 20. Effect of mitigations integrated into a range of crop rotations on TGE reductions in N and P loss to water and associated total GHG emissions. Here Gis stands for Gisborne, Wai for Waikato, and Can for Canterbury.**

| Farm and rotation | P run-off (kg/ha) | N leached (kg/ha) | GHG kg $CO_2$-e/ha) |
|---|---|---|---|
| ***Base farms*** | | | |
| Can arable | 0.2 | 33 | 2810 |
| Gis arable | 0.9 | 29 | 1630 |
| Gis arable maize | 0.6 | 15 | 1326 |
| Wai arable | 0.1 | 14 | 1582 |
| Can cereals | 0.1 | 30 | 2547 |
| Wai potatoes | 0.3 | 82 | 3973 |
| *Mean* | *0.4* | *34* | *2311* |
| ***With mitigations*** | | | |
| Can arable | 0.2 | 25 | 2717 |
| Gis arable | 0.8 | 8 | 1464 |
| Gis arable maize | 0.3 | 5 | 1352 |
| Wai arable | 0.1 | 5 | 1363 |
| Can cereals | 0.1 | 26 | 2498 |
| Wai potatoes | 0.3 | 58 | 3687 |
| ***Mean*** | ***0.3*** | ***21*** | ***2180*** |
| *% change from base* | | | |
| Can arable | 0 | 24 | 3 |
| Gis arable | 11 | 72 | 10 |
| Gis arable maize | 50 | 67 | -2 |
| Wai arable | 0 | 64 | 14 |
| Can cereals | 0 | 13 | 2 |
| Wai potatoes | 0 | 29 | 7 |

In relation to cropping the overall conclusions were that there were lower GHG emissions from pastoral. And that:

- Irrigation is a key driver, mainly through energy and nitrous oxide emissions. It is a priority area. They did not include in the baseline because it skewed the results.
- This aside, N fertiliser technologies could yield some benefit – but these benefits have yet to be realised in practice. The science is still under development. Even so, a 10% saving in fertiliser would yield only a 4% decrease in N leaching and a 3% reduction in GHG emissions.
- Limited options are available within a rotation to implement mitigations. Modelling, however, suggests that when implemented they could have a significant effect on N losses – but only a lesser effect on GHG emissions.

- Priorities should be irrigation management and for research to realise some of the potential benefits of more efficient fertiliser use."

In a summary report to MPI, Daigneault et al. (2016) commented that

"*Overall, the analyses found that the impact of the freshwater reforms on greenhouse gases was not large. This is because (a) many of the mitigation options that are likely to be employed to meet freshwater contamination reduction targets have a limited effect on animal production and hence on GHG emission profiles, and (b) the NZ-wide aggregate contaminant reductions to water are relatively small*."

### 2.15.2 Biodiversity

There is currently very little information available on the impact of our primary production systems on biodiversity, and even how GHG mitigations might influence this. However with the orchard-shelter belt system of horticultural production, and especially with the use of composts and residues, it seem logical that the biodiversity of horticultural systems, with their alley systems, shelterbelts and pollination systems, and the mixed land-use farming systems we suggest, would be much higher than other land-use types.

# 3 CRITICAL GAPS

There are critical gaps identified from these analyses. These include; how can soil-carbon sequestration and standing biomass accumulation be better accounted for in GHG emissions schemes; why do growers not adopt climate-smart options even when they would improve farm EBIT; why with the horticultural EBIT high, and export markets strong, are their not more conversions to horticulture and arable? It would be worthwhile to examine the barriers to the adoption of a profitable, climate-smart farming system. Such enquiries are beyond the ambit of this report, as they would need not only the biophysical analyses carried out here, but also socio-economic surveys and interpretations for the enterprising behaviour of individuals, communities and industries.

# 4 CONCLUSIONS

The total GHG footprints of both the horticultural and arable industries are relatively modest, ranging from 2 T $CO_{2\text{-}e}$ $ha^{-1}$ for arable farming, through to 3-6 T $CO_{2\text{-}e}$ $ha^{-1}$ for horticulture. The biological emissions of GHG are an average 13% of TGE for horticulture, with a range from 6 to 19%. The portion of BGE of the arable TGE is 40%.

Because of the intensity of on-farm practices, there are a range of total and biological GHG mitigations that can be adopted, and many of these would improve farm profitability. If soil sequestration of carbon were to be considered, the total GHG footprints of these industries would likely be reduced, especially for deep-rooted trees and vines in horticulture. There are challenges in quantifying and verifying these changes in soil carbon.

If the price of carbon were to be set at $50 T $CO_{2\text{-}e}$, and applied to easily mitigated TGE, then this would like negatively affect farm EBIT by 2% for horticulture and 5% for arable farming. If the price of carbon were applied only to BGE, then the impact on EBIT would be on average 0.3% for horticulture, and 2% for arable farming.

The EBITs of the arable and especially the horticultural industries are high. There is potential for these industries to move onto new lands, as across New Zealand there are many valuable and versatile soils in regions with favourable climates. Commodity prices, water resources, human capacity and infrastructure might pose limits on the expansion of these industries. There is biophysical potential across New Zealand's diverse landscapes to enable expansion of horticulture and arable farming, should entrepreneurs and the market see opportunities to do so.

Mixed farming systems and diverse-crop rotations offer future potential to extract value from New Zealand's natural capital assets, with moderate GHG emissions.

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