Sustainable Impact Investing into New Zealand's Horticultural Sector

Is there an Opportunity and Can We Capitalise on It?

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Executive Summary

The global perspective on investment is changing from traditional financial metrics to the relatively recent idea of "impact investing". This is where investments are made with the objectives of creating a positive impact on environmental and social matters as well as receiving financial returns. The growth in this movement has raised questions on whether there is potential within New Zealand's horticultural industry to market its perceived sustainability and therefore access this pool of capital. With this theory in mind, this report looks to quantify the sustainability of the sector as well as analysing the ability of the investment sector in New Zealand to take advantage of impact investing theory.

To achieve this aim, this study uses an analytical framework to measure the carbon footprint of orchards and vineyards as a proxy for environmental sustainability. The model uses a case study of six different orchards and vineyards, owned by Craigmore Sustainables, to get an understanding of the variability within the sector. In addition to the carbon footprint modelling, four informal interviews of leading New Zealand primary industry investment managers and large-scale corporate farmers and foresters were performed to get an understanding of the extent to which the primary industry and its investors are concerned and report on sustainability.

Using the purpose-built carbon model, the producing orchards and vineyards were shown to have a net positive impact on the environment through large sequestration by the plants and compost. The two developing apple and kiwifruit orchards were shown to have comparatively high net emissions in their early years. It was shown that there is significant variation in the sequestration potential of different crop types (apples have the greatest potential sequestration per ha). In addition, the impact of organics was tested across the kiwifruit orchards with organic management producing less emissions overall than a conventional orchard.

Across the multiple interviews and literature reviewed, it was shown that there is significant variation in the positioning of investment funds and corporate farmers on the idea of impact investing. In general, foreign, and younger investors appeared to be further advanced in the understanding of impact investment and its opportunities. However, for the New Zealand market to fully appreciate and take advantage of impact investment opportunities that will arise in the primary industry space, there needs to be changes to the consistency and transparency of sustainability reporting and fund raising.

Although this study provides a baseline understanding of the potential sustainability of the horticultural industry, there are several recommendations that need to be considered in either further research or by leading organisations within the sector. These are:

- Where possible, the increase in establishment and use of other quantifiable sustainability metrics in addition to carbon footprinting.

- Provide actual on-orchard data to test the strength and applicability of the carbon footprint modelling.

- Further research into the environmental sustainability of orchards in an intensity-based approach such as kg CO2-eq per tray produced or per $ return.

In addition, there are also recommendations for the industry's investment sector to capture the possibilities of the impact investment movement:

- To increase the measurement and reporting of the sustainability of the industry and therefore utilise the existing foreign impact investment interest as well as being prepared for when the domestic New Zealand investor base ultimately increase their focus on impact investment.

- For the industry to either create a universal accredited standard of reporting and measurement for sustainability of a business or to align itself to current global reporting standards and initiatives.

These recommendations will help to increase investor confidence in the industry and therefore increase the potential uptake of the opportunity for impact investment.

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Glossary of Terms & Abbreviations

Canopy Hectare	Common measurement of an orchard or vineyard; the area that is under canopy or covered in the permanent crop
Carbon Emissions	The release of carbon into the atmosphere
Carbon Footprint	Total greenhouse gas emissions caused by an individual, event, organization, service, or product, expressed as carbon dioxide equivalent
CO2-eq	Carbon dioxide equivalent, is a metric measure used to compare the emissions from various greenhouse gases on the basis of their global-warming potential, by converting amounts of other gases to the equivalent amount of carbon dioxide with the same global warming potential
ESG	Environmental, Social, Governance; a type of reporting that measures the impact of a business on sustainability
GHG	Greenhouse Gas; gases that trap heat in the atmosphere
GWP	Global Warming Potential; average warming effect of greenhouse gases over 100 years after their emission using carbon dioxide as a reference
Impact Investing	Investing with the intention of generating a measurable and beneficial societal and/or environmental impact alongside a financial return
LCA	Life Cycle Analysis; a tool that provides a systematic way to consider the impact of a material or component over its full life – from extraction to processing/manufacturing to construction/installation to use to eventual disposal
N2O Emissions	Nitrous Oxide emissions, N2O is a gas commonly released from agricultural processes and practices that has a GWP of 310 times more than CO2
Scope 1 Emissions	Direct emissions; occur from sources that are owned or controlled by the company, for example emissions from the vehicle fleet
Scope 2 Emissions	Electricity indirect emissions; emissions that are related to the generation of electricity purchased by the company
Scope 3 Emissions	Other indirect emissions; emissions that are a consequence of the activities of the company, but occur from sources not owned or controlled by the company
Sequestration	A natural or artificial process by which carbon dioxide is removed from the atmosphere and held in solid or liquid form
Sustainability	Meeting the needs of the present without compromising the ability of future generations to meet their needs. Commonly referred to as having three pillars: economic, environmental and social

Chapter 1
Introduction

In the last decade, a growing number of investors have changed their focus away from purely financial returns. Where originally their primary, and often only, objective was financial returns, they have recently become increasingly concerned about the impact that their investments are having on the environment and society. This phenomenon has led to the theory of "impact investing" where investors require their investments to generate a measurable societal, environmental and financial return. This style of investing has until recently been focused on the larger European and US markets with $30tn of global sustainable investment assets under management in 2018 (KPMG, 2019).

While this change in the financial sector has been occurring, New Zealand's primary sector has also been going through significant growth. This growth has been especially prominent in the horticultural sector with on and off-farm investment in the industry increasing from $6.5 bn in 2000 to $57.3 bn in 2019 (New Zealand Institute for Plant and Food Research Ltd, 2020; The Horticulture & Food Research Institute of New Zealand Ltd, 2000). Although sector growth has largely been due to is profitability, there has also been an image created of a sustainable industry that is producing a quality product without damaging our waterways or climate. Therefore, there lies a potential opportunity for the growth in the impact investing sector and the horticultural industry to combine and for New Zealand horticultural-based investments to be marketed as providing a positive impact to the environment and society as well as providing financial returns. In other words, the sector could be an *impact investment*.

This potential opportunity has already started to arise for Craigmore Sustainables; a farm, orchard, and forest investment manager with more than 15,000 hectares under management in New Zealand. As Craigmore has continued to grow, it has come to realise the increasing international focus on sustainable or impact investing and the opportunities for an asset manager that produces returns while managing the land sustainably.

However, there is little quantitative evidence of whether the horticultural industry is actually having a positive or negative effect on the environment and society. Because of this lack of knowledge, this research has the following aims:

1. To provide an understanding of the environmental impact of the horticultural industry through the creation of a carbon footprint model as a proxy measure of sustainability

2. To provide an insight into the potential opportunities for impact investment and whether the current reporting and fund-raising systems coming out of New Zealand's primary sector are "mature" enough to capitalise on this opportunity

To reach these aims this research has the following questions:

1. What is the potential carbon footprint of the horticultural industry? This question provides understanding into the following three complexities of the sector:

    a. How different crop types compare in their carbon emissions with a comparison between a selection of kiwifruit and apple orchards and a wine grape vineyard?

    b. How different production methods compare in their carbon emissions with a comparison between conventional orchards and an organic kiwifruit orchard?

    c. How different plant ages compare in their carbon emissions with a comparison between orchards under development and mature producing orchards?

2. What are the changes, if any, that the New Zealand primary industry investment sector needs to make to take advantage of any impact investment opportunities that may arise in the next decade?

Chapter 2

Literature Review

2.1 Primary Industry Sustainability

The term, “sustainability”, is used regularly in literature and is a common phrase used in public and private policy and marketing. However, there are no universal definitions to the meaning of the phrase. A commonly referred to definition was proposed by the World Commission on Environment and Development, popularly called the Brundtland Report. This describes sustainable development as “the development that meets the needs of the present without compromising the ability of future generations to meet their needs” (WCED, 1987). However, there have been a number of issues raised with this phrase, most notably that the “needs” of the present and future are not clearly articulated. Alternative definitions have been proposed, but none have been universally accepted (Custance & Hillier, 1998; Tellegen, 2006). Although there is no universal definition, it is commonly accepted that the “needs” referred to in the WCED report are broken into three areas: economic, social and environmental. This report only focuses on the environmental aspect of these three viewpoints.

When referring to environmental sustainability in a global sense, a common problem referred to is global warming and the impact of greenhouse gases on changing climatic cycles. Although not the only environmental concern, this is the most universal globally and arguably the most commonly referenced. There have been several global agreements that have focused on reducing GHG with targets to address climate change. The first of these was the Kyoto protocol that was created in 1997 to lower global greenhouse gas production, with targets for all developed nations. Following this early treaty, the Paris Agreement was signed by all countries (developed and developing) in 2015. A major directive of the agreement calls for steps to be taken to limit the increase in the earth’s temperature to 1.5 degrees. In order to meet these targets in New Zealand, the Climate Change Response (Zero Carbon) Amendment Act was passed in 2019 (Ministry for the Environment, 2019a).

In New Zealand, agriculture produces 48% of the greenhouse gas emissions, while in most other developed countries it is between 10 and 12% (Pinares-Patino, Waghorn, Hegarty and Hoskin, 2009). This has led to increased scrutiny on agricultural practices and their sustainability. Although to date this has largely been focused on the dairy and sheep & beef industries, as the horticultural industry has expanded there has been increasing pressure to understand its environmental credentials. However, this scrutiny and regulation is not necessarily a detriment to the industry. As well as potentially changing consumer preferences and marketing, there are significant risks to the farming industry with the impact of changing climates. It is estimated that with an increase of 1.5 degrees of warming, 4% of all land will undergo a transformation from one ecosystem to another, with 13% transforming at 2 degrees (The Aotearoa Circle, 2020). Therefore, it is in the interests of all farmers, growers and producers that the impact of climate change and sustainability are taken seriously.

2.2 Analytical Assessment for Sustainability

2.2.1 Carbon Modelling Methodology

The commonly used tool for carbon modelling and environmental management is the life cycle assessment or analysis (LCA). LCA assesses the environmental impact of a product throughout its life cycle, from extraction of raw materials through to end of life disposal. It is widely recognised as one of the most sophisticated and comprehensive analytical assessments available (Sharma, 2002).

As well as the ambiguity in defining the term "sustainability" there are also different methods to calculate the life cycle of a product or process. As a result of the pressure from governments, the public and consumers, protocols have been created to measure the carbon footprints of goods and services. The first to be created was the UK's *Publicly Available Selection for GHG Emission Measurement of Goods and Services* (PAS 2050). This was published in 2008 and became widely used as a publishing standard for GHG emissions. Since then there have been a range of other approaches created such as the International Standards Organisation's ISO 14040 and 14044. McLaren et al. (2009) undertook a study to measure the variance between the PAS 2050 protocols and the ISO standards on the life cycle of an apple grown in New Zealand all the way to consumption in the UK. This found that the more comprehensive ISO LCA approach produced a result that was 22% higher in emissions that the PAS 2050 approach. The majority of this difference was related to the inclusion of the travel of the consumer between the home and the retailer.

2.2.2 Carbon Modelling on Horticultural Systems

Kiwifruit

Although there have been several studies into the carbon emissions of kiwifruit orchards, particularly in New Zealand, there is limited comparability across the research due to the different methodologies used and the inputs included in the research. The table below summarises the different assumptions used in four of the studies on kiwifruit carbon emissions. As can be seen from these results, there is a high degree of variation amongst the inputs and resulting outputs of the studies. Nabavi-Pelesarai et al (2016) is not relevant for comparison as it is based on kiwifruit production in Iran and therefore has limited climatic and system comparability to New Zealand grown kiwifruit. Mithraratne, Barber & McLaren (2010) and Muller et al. (2015) are both New Zealand based studies, but they do not include the emissions related to soil decomposition and therefore have less functionality. For this research, the Page et al. (2011) study was deemed to be the most comparable as it includes the soil emissions related to decomposition. However, this study is only focused on organic orchards and therefore is expected to have marginally less emissions than a conventional orchard. For comparison, when the soil emissions are excluded from the Page et al. (2011) study, the modelled orchard would be expected to emit 2.75 tCO2-eq per ha.

Table 1: Kiwifruit carbon emissions from research

Source	Includes	Notable Exclusions	Orchard Carbon Emissions As Per Study	Conversion	Carbon Emissions Per Ha
Mithraratne, Barber & McLaren (2010)	Orchard capital, agrichemicals, fertiliser, fuel and electricity and seasonal workers	Soil emissions (e.g. decomposition)	0.58 kgCO2eqv per tray	10,000 trays per ha	5.75 tCO2eqv per ha
Page, Kelly, Minor & Cameron (2011)	Orchard capital, agrichemicals, fertiliser, fuel, electricity, and soil emissions	Only studies organic orchards, excludes inorganic fertiliser and agrichemicals	16.91 tCO2eqv per ha	n/a	16.91 tCO2eqv per ha
Muller, Holmes, Deurer & Clothier (2015)	Agrichemicals, fertiliser and fuel and electricity	Soil emissions (e.g. decomposition), orchard capital	5,379 kg CO2eqv per ha 3,948 kg CO2eqv per ha 4,927 kg CO2eqv per ha 4,400 kg CO2eqv per ha	Gold Kiwifruit Green Kiwifruit Integrated Mgmt. Orga nic Mgmt.	5.38 tCO2eqv per ha 3.95 tCO2eqv per ha 4.93 tCO2eqv per ha 4.40 tCO2eqv per ha
Nabavi-Pelesaraei, Rafiee, Hosseinzadeh-Bandbafha & Shamshirband (2016)	Agrichemicals, fertiliser and fuel and electricity	Soil emissions (e.g. decomposition), orchard capital	1,310 kg CO2eqv per ha	n/a	1.31 tCO2eqv per ha

There are very few studies that also include the carbon sequestration of the kiwifruit vines. Page et al. (2011) estimates the carbon sequestration per orchard to be 19.6 tCO2-eq per ha annually. This is based on sequestration in the biomass of the vines (photosynthesis minus respiration) of 13.7 tCO2-eq per ha with 5.9 tCO2-eq per ha temporarily stored in the applied compost. The temporary nature of this storage is due to the decomposition of the organic matter which is accounted for in the expected emissions as documented in the table above. The Page et al. (2011) study is the considered the most comparable research due to its relatively recent publication and PAS 2050 calculation methodology.

Overall, the Page et al. (2011) study found that the net carbon sequestration for an organic kiwifruit orchard in New Zealand was 2.4 t CO2-eq per ha.

Apples

Carbon footprint studies on apple orchards are predominantly focused on the whole supply chain, from the orchard to consumption in market (usually the United Kingdom). McLaren et al. (2009) and Saunders, Barber & Taylor (2006) are examples of these supply chain footprint studies. The orchard production part of these footprint studies, as well as the Page et al (2011) study, are shown in the table below. The supply chain studies are represented on a production basis (i.e. per tonne or kg of apples produced) and when converted are between 3.0-4.5 tCO2-eq per ha, assuming that production is 50 t of apples per ha. Page et al (2011) provides an estimate of emissions per ha, including soil emission, for different intensities of orchard (semi-intensive of intensive). When the soil-related emissions are excluded, the orchards are expected to emit 3.8-4.8 tCO2-eq per ha. As this range is similar to that represented in the other two studies, it is concluded that the Page et al (2011) study is an accurate representation of an apple orchard's carbon emissions.

Table 2: Apple carbon emissions from research

Source	Includes	Notable Exclusions	Orchard Carbon Emissions As Per Study		Carbon Emissions Per Ha
Page, Kelly, Minor & Cameron (2011)	Orchard capital, agrichemicals, fertiliser, fuel, electricity, and soil emissions	Only studies organic orchards, excludes inorganic fertiliser and agrichemicals	18.88 tCO2eqv per ha	Semi-intensive (800 trees per ha)	18.88 tCO2eqv per ha
			21.35 tCO2eqv per ha	Intensive (1250 trees per ha)	21.35 tCO2eqv per ha
Saunders, Barber & Taylor (2006)	Orchard capital, agrichemicals, fertiliser, fuel and electricity	Soil emissions (e.g. decomposition)	60.10 kgCO2eqv per t apples	Yield 50 t of apples per ha	3.01 tCO2eqv per ha
McLaren et al (2009)	Not stated	Not stated	0.06 kgCO2eqv per kg apples	Integrated Gala - Assumed 50 t of apples per ha	3.15 tCO2eqv per ha
			0.09 kgCO2eqv per kg apples	Orga nic Gala - Assumed 50 t of apples per ha	4.50 tCO2eqv per ha

Like kiwifruit, there is limited research into the carbon sequestration of apple trees. Although there was some work done in the Hawkes Bay, the only reliable source of information found was the study done by Page et al (2011). This estimates total carbon sequestration in the tree biomass as 23.6 tCO2-eq per ha for semi intensive apple orchards and 26.3 tCO2-eq per ha for intensive apple orchards.

Overall, the Page et al. (2011) study found that the net carbon sequestration for an organic semi-intensive apple orchard in New Zealand was 4.7 t CO2-eq per ha while an intensive organic apple orchard is expected to be 5.0 t CO2-eq per ha.

Grapes

Emissions from wine grape vineyards are typically slightly less than apples and kiwifruit due to their less intensive management. The research shown in the table below shows that emissions related to the vineyard range from approximately 0.6 to 2.7 tCO2-eq per ha. Barry (2011) estimates the emissions based on a 750ml bottle of Sauvignon Blanc wine. When this is calculated to "t CO2-eq per ha" the emissions range from 2.0 to 2.7 tCO2-eq per ha depending on the area where the grapes are grown. This study is considered more reliable than the Australian study by Goward & Whitty (2014). Goward & Whitty (2014) uses actual measurements from a vineyard (rather than modelled statistics); however, it only calculates a few of the relative inputs and lacks key details such as canopy area of the vineyard and the intensity of the vineyard (i.e. the number of vines per canopy ha).

Table 3: Grape carbon emissions from research

Source	Includes	Notable Exclusions	Vineyard Carbon Emissions As Per Study		Carbon Emissions Per Ha
Barry (2011)	Agrichemicals, fertiliser, fuel, electricity, and replacement orchard capital	Soil emissions (e.g. decomposition), starting orchard capital	0.15 kgCO2eqv per bottle	North Is land - 14 t per ha (960 bottles per t)	2.02 tCO2eqv per ha
			0.20 kgCO2eqv per bottle	South Is land - 14 t per ha (960 bottles per t)	2.69 tCO2eqv per ha
Goward & Whitty (2014)	Fertiliser, fuel and electricity	Agrichemicals, soil emissions (e.g. decomposition), orchard capital	48.41 t of C per vineyard	300 ha vineyard (3.67 convert to CO2)	0.59 tCO2eqv per ha

Research into the potential carbon sequestration of vines is limited with the majority of the available research based in either Europe or the United States. This is because it is commonly accepted that in supply chain studies, the amount of carbon sequestrated in the vines is approximately the same as the carbon released during fermentation of the wine and therefore both are excluded from analysis. The Australian study by Goward & Whitty (2014) provides estimates of the carbon sequestration in the vines for different varieties. When calculated to CO2 sequestration, the varieties range from 4 to 16 kgCO2-eq per vine.

2.3 Impact Investing

The term *impact investing* was created in 2007, when the Rockefeller Foundation funded a summit aimed at building a global industry for investments with a positive social and environmental impact (Hochstadter & Scheck, 2014). Since then the term has become increasingly common place in financial literature, financial institutions, and government policies. However, there remains a lack of a universal definition. Generally, impact investing involves the provision of financial resources for a financial return as well as a positive social and environmental impact. In this way it combines traditional philanthropic ideals with mainstream financial decision making (Hochstadter & Scheck, 2014).

Despite the growth of the impact investing sector in the last decade, there remain a number of misconceptions around its practicality. The most common of these is that to embrace environmental and social objectives one must forsake (at least partially) financial returns. A survey done in the US in

2017 by the Morgan Stanley Institute for Sustainable Investing found that the majority of investors (53%) still believe that investing sustainably requires a financial trade off (Morgan Stanley Institute for Sustainable Investing, 2017). However, this idea has been proven to be incorrect. Eccles, Ioannou & Serafeim (2014) found that *high sustainability* companies, those that voluntarily adopted sustainability policies in 1993, significantly outperformed *low sustainability*, those that adopted no sustainability policies, in the period between 1993 and 2010. Based on traditional financial metrics, investing $1 in a portfolio of *high sustainability* companies in 1993 would have grown to $7.10 by 2010. While similarly investing $1 in a portfolio of *low sustainability* companies would have grown to $4.40. This growth in interest and potential returns has led to a large number of traditional and new global financial firms taking up impact investing.

Chapter 3

Methodology

3.1 Research Approach

This research primarily uses an analytical framework through a purpose-built Excel "carbon footprint" model. The model is based on assumptions sourced from relevant literature. This model then has a sample of six different orchards modelled for their net carbon movement in the 2019-20 season. These sample orchards have been selected from Craigmore Sustainables' permanent crop portfolio based on their variability for crop type, production method and age (i.e. stage of maturity).

In addition to the carbon footprint modelling, four informal interviews of leading New Zealand primary industry investment managers and large-scale corporate farmers and foresters were performed. This was then compared to international and New Zealand based literature on sustainability and sustainability reporting for an understanding of the extent to which the primary industry and its investors are concerned and report on sustainability.

3.2 Carbon Footprint Model

To provide comparability in analytical modelling, all inputs and outputs need to be compared on the same "functional unt". For the sake of this study and report, the functional unit has been represented as a canopy hectare. This refers to the area of an orchard that is under canopy or covered in the permanent crop. This varies from the total area as all orchards require some additional area (outside of the "canopy") for headlands, tracks and other spare land.

Another important consideration for carbon footprinting is the setting of system boundaries for modelling. The model created largely uses Scope 1, 2 & 3 based emissions (depending on the definition) while focusing on the cradle to gate system boundary. Ministry for the Environment (2019b) describes Scope 1 emissions as those directly related to sources owned or controlled by the company, Scope 2 as the emissions from the generation of purchased energy (largely electricity) and Scope 3 as the indirect emission occurred because of the activities of the organisation but generated from sources out of their control. Cradle to gate in a horticultural context refers to the emissions (both direct and indirect) that have occurred in the processes of the orchard (such as from the materials it purchases and the production of the fruit) but the calculations stop at the orchard gate. Therefore, emissions arising from the transport and processing of the product to market are not included.

As far as possible this model aims to follow the PAS 2050 protocols. However, there may some instances where in the interest of time and simplicity some of the assumptions and parameters used will fall outside the PAS 2050 protocols.

There are a number of areas that this model either assumes or doesn't include for simplicity. These are:

- The impact of different soil types on the soil carbon sequestration or emissions
- The impact of different climates within New Zealand on the carbon sequestration or emissions
- The carbon currently stored in the soil at varying depths
- The termination or removal of the orchard. This would theoretically result in the removal of stored carbon and therefore emissions. However, as the lifespan of orchards can be multiple decades and this model is only on an annual basis, this has been discounted
- The impact of the land use change from either pasture or annual cropping into permanent crop has not been included. Although this may have a positive or negative impact on the carbon footprint of some orchards, as this model was designed on an annual basis, this has been discounted

The carbon footprint model is prepared using the most applicable assumptions available from the studies available at the time of writing of this report. The "carbon cycle" represented in the model is shown on the following page. As previously represented, this is aimed to follow the "cradle to gate" principles and therefore doesn't include any fruit produced in the analysis.

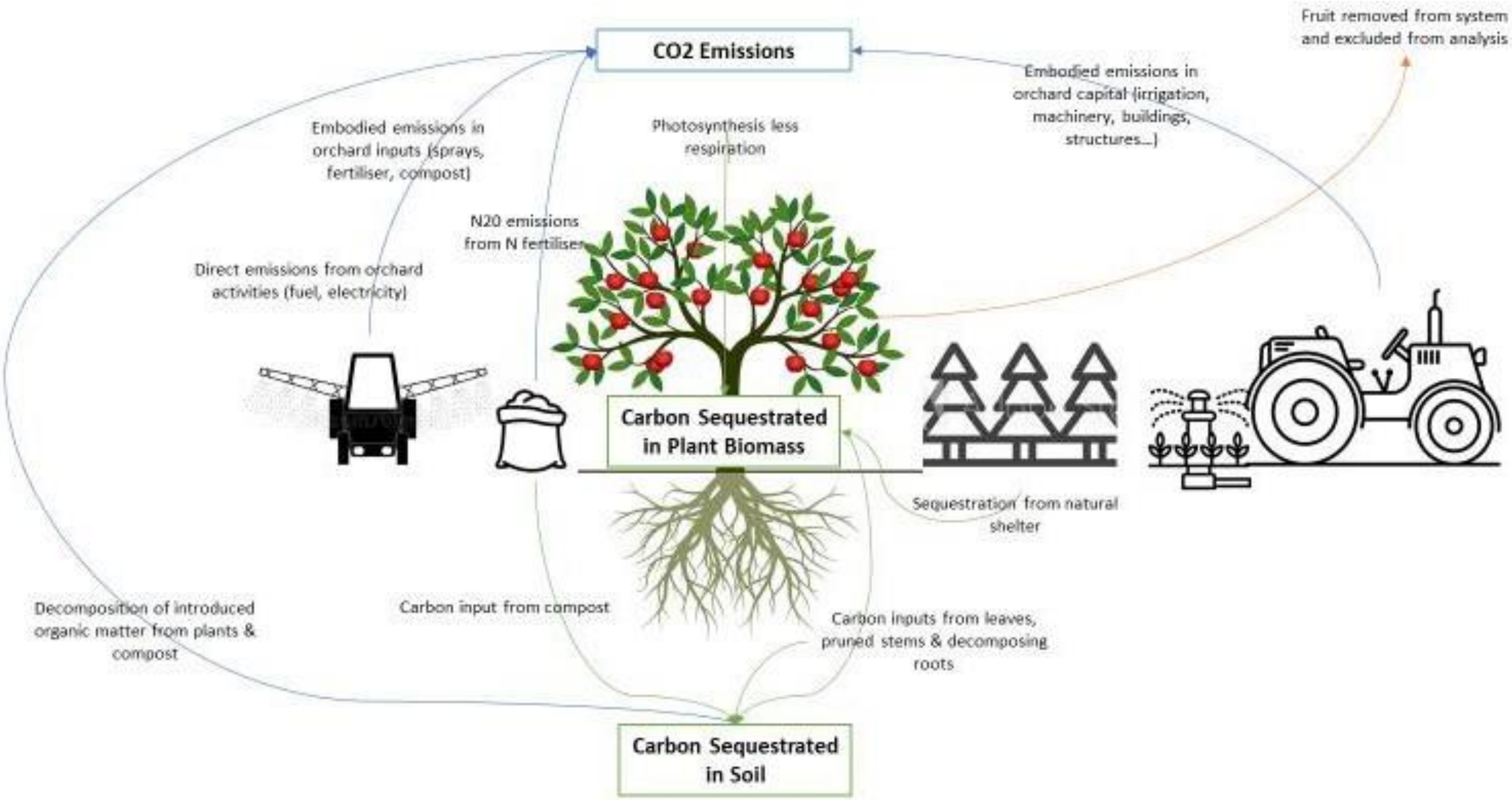

Figure 1: Visual representation of carbon footprint model

3.2.1 Carbon Emissions Assumptions

Fuel Use

Fuel consumption on orchard is assumed to have an emission of 3.75 kgCO2-eq per L (Wells, 2001). The use of fuel on orchard is calculated using two different methodologies. The first is a direct measurement of the fuel purchased by Craigmore for use on orchard. However, as most of the orchard activities are done by contract managers or subcontractors, the amount of fuel consumed by their activities needs to be considered. For this, an estimation of the fuel used per hour and the work rate (hours per hectare) is used to calculate the fuel consumed per activity. This is then added to the Craigmore purchased fuel for an assumption of fuel-based emissions. The fuel consumption of common kiwifruit orchard activities taken from Page (2009) are shown below.

Table 4: Fuel use on a kiwifruit orchard (Page, 2009)

Operation	Fuel Use (L per hr)	Work Rate (hr per ha)	Fuel Use (L per ha per pass)
Spraying	9.45	0.75	7.09
Mowing	9.45	0.92	8.69
Mulching	9.45	1.50	14.18
Fertiliser Spreading	9.45	0.50	4.73
Hedge Trimming	21.00	0.50	10.50
Harvest Tractor	9.45	2.00	18.90
Compost Application	8.00	0.50	4.00

Electricity Use

Electricity use on orchard is estimated to have carbon emissions of 0.45 kgCO2-eq per kWh used (Wells, 2001).

Property and Orchard Capital

The physical structures, machinery and buildings that are used on an orchard have been included in this study based off assumptions on their embodied energy and CO2 ratio. A detailed list of these calculations and assumptions is shown in the appendices. The table below shows the summarised inputs used for the model.

Table 5: Property and orchard capital embodied emissions

Input	Embodied Emission	Source
Buildings	59.00 kgCO2eqv per m2	Wells (2001)
Vehicles	12.80 kgCO2eqv per kg	Wells (2001)
Other Machinery	6.40 kgCO2eqv per kg	Wells (2001)
Irrigation Pumps	12.80 kgCO2eqv per kg	Saunders et al. (2006)
Irrigation Wells	32.00 kgCO2eqv per m drill	Saunders et al. (2006)
Irrigation Mainlines	6.24 kgCO2eqv per m	Saunders et al. (2006)
Irrigation Laterals & Dripline	5.12 kgCO2eqv per m	Saunders et al. (2006)
Posts	1.44 kgCO2eqv per post	Barber & Scarrow (2001)
Wire	0.10 kgCO2eqv per m	Barber & Scarrow (2001)
Agbeam	4.48 kgCO2eqv per m	Mithraratne et al. (2010)
String	0.96 kgCO2eqv per m	Own assumption (appendices)
Stringing Poles	0.40 kgCO2eqv per pole	Own assumption (appendices)
6m Shelter Posts	8.00 kgCO2eqv per post	Own assumption (appendices)
6m Shelter Cloth	2.18 kgCO2eqv per m2	Own assumption (appendices)
Undervine Shelter Cloth	2.05 kgCO2eqv per m2	Own assumption (appendices)
Hailnet Cloth	0.83 kgCO2eqv per m2	Own assumption (appendices)
Hailnet Posts	8.00 kgCO2eqv per post	Own assumption (appendices)
Frost Fans	12,800.00 kgCO2eqv per fan	Page (2009)

Fertiliser Inputs

The embodied emissions in fertiliser include the emissions associated with the raw materials and fossil fuels required for its manufacture as well as the packaging and transport of the materials to the farmer or grower. The emissions of the different fertilisers used on the orchards have been estimated either on their nutrient components or as an organic fertiliser. The table below summarises the assumptions used for the model.

Table 6: Fertiliser embodied emissions

Input	Embodied Emission	Source
N Fertiliser	3.25 kgCO2eqv per kgN	Wells (2001)
P Fertiliser	0.90 kgCO2eqv per kgP	Wells (2001)
K Fertiliser	0.60 kgCO2eqv per kgK	Wells (2001)
S Fertiliser	0.30 kgCO2eqv per kgS	Wells (2001)
Organic Fertiliser	0.40 kgCO2eqv per kgFert	Page (2009)
Lime	0.43 kgCO2eqv per kgLime	Wells (2001)

Agrichemical Spray Inputs

The agrichemicals used on the orchards have been broken down into different categories based on the information available. The table below summarises the assumptions used for the model.

Table 7: Agrichemical embodied emissions

Input	Embodied Emission	Source
Herbicide (Glyphosate)	33.00 kgCO2eqv per kg	Saunders et al. (2006)
Herbicide (General)	18.60 kgCO2eqv per kg	Saunders et al. (2006)
Insecticide	18.90 kgCO2eqv per kg	Saunders et al. (2006)
Fungicide	12.60 kgCO2eqv per kg	Saunders et al. (2006)
Plant Growth Regulator	10.50 kgCO2eqv per kg	Saunders et al. (2006)
Mineral Oil	7.20 kgCO2eqv per kg	Saunders et al. (2006)
Copper Spray	8.92 kgCO2eqv per kg	Wells (2001)
Sulphur Spray	8.92 kgCO2eqv per kg	Wells (2001)
Biostimulant	0.40 kgCO2eqv per kg	Page (2009)
Other	7.20 kgCO2eqv per kg	Saunders et al. (2006)

Embodied Emissions in Compost Preparation

The preparation of compost has had an assumed embodied emission of 0.04 kgCO2-eq per kg applied.

3.2.2 Carbon Sequestration Assumptions

Kiwifruit Carbon Sequestration

The net carbon sequestration of a plant is a based on the photosynthesis accumulated during the growing season minus the plant respiration. This can then be converted to carbon dioxide sequestration my multiplying by the weight of carbon by 3.67 (due to the molecular weight ratio of carbon in CO_2). For mature kiwifruit vines the CO_2 sequestration has been assumed at 40.99 kg CO_2 per vine per year (Page, 2009). There is limited information on the CO_2 sequestration in younger plants. An assumption has therefore been made on the size of the plant relative to the mature state. This is then applied to the mature CO_2 sequestration value to get an assumption for sequestration during establishment. See below for this assumption.

Table 8: CO2 sequestration per plant relative to age

Years since planting	1	2	3	4	5	6	7	8
CO2 Sequestration per plant relative to mature state	5%	15%	40%	65%	85%	90%	95%	100%

As CO_2 sequestrated in the fruit is released back to the atmosphere, the fruit portion of the plant's sequestration has been discounted. The breakdown of the plant's sequestration by the leaves, fine roots, stems and fruit has been assumed for a mature, fully producing kiwifruit vine as 22:22:23:33 respectively (Kroodsma & Field, 2006). Therefore, the CO_2 sequestrated by a mature kiwifruit vine's leaves, fine roots and stems has been calculated as 27.46 kg CO_2 per vine per year (based on 40.99 x

(1-33%)). In younger plants the production is less. Therefore, an assumption has been made on the production factor relative to maturity or full production. This is shown below.

Table 9: Production relative to maturity for kiwifruit and apples

Years since planting/grafting	1	2	3	4	5	6	7
Production relative to maturity / full production	0%	33%	50%	67%	80%	95%	100%
Kiwifruit Fruit Portion of Sequestration	0%	11%	17%	22%	26%	31%	33%
Kiwifruit Leaves, Roots & Stems Portion of Sequestration	100%	89%	84%	78%	74%	69%	67%

Therefore, the equation to calculate carbon sequestration per ha (kgCO2qv per ha) is:

$$Plants\ per\ ha \times Mature\ Sequestration\ per\ Plant \times Discount\ for\ Age\ of\ Plant \times (1 - Fruit\ Portion\ Relative\ to\ Age)$$

Apples Carbon Sequestration

Similar principles apply to apple carbon sequestration. However, an additional assumption has been made based on the rootstock used.

A traditional mature apple tree has been assumed to sequestrate 62.85 kg CO2 per year (Page, 2009). However, if M9 dwarf rootstock is used the plant has been assumed to be 35% of the traditional tree, meaning mature sequestration per tree is 22.00 kg CO2 per year. If M106 rootstock is used in an intensive orchard, the plant has been assumed to be 50% of the traditional tree, meaning mature sequestration per tree is 31.43 kg CO2 per year. If M106 rootstock is used in a semi-intensive orchard, the plant has been assumed to be 70% of the traditional tree, meaning mature sequestration per tree is 44.00 kg CO2 per year (Page, 2009).

Assumed CO2 sequestration per plant relative to age and production relative to maturity is the same as kiwifruit.

Therefore, the equation to calculate carbon sequestration per ha (kgCO2qv per ha) is:

$$Plants\ per\ ha \times Mature\ Sequestration\ Relative\ to\ Rootstock \times Discount\ for\ Age\ of\ Plant \times (1 - Fruit\ Portion\ Relative\ to\ Age)$$

Wine Grapes Carbon Sequestration

CO2 sequestration in wine grapes has been estimated based on the variety. Goward & Whitty (2014) provided estimates of the carbon sequestrated in the roots and stems. This was then converted to all of the vine, based on the assumption that 30% of the carbon is sequestrated in the leaves and fruit. This can then be converted to carbon dioxide sequestration my multiplying by the weight of carbon by 3.67. The same methodology for younger vines, as per kiwifruit and apples, was used for grapes. See below for a summary of the CO2 sequestration of different varieties.

Table 10: CO2 Sequestration of Different Grape Varieties

Variety	Carbon Stored in the Roots & Stems	Carbon Stored in the Leaves, Roots, Stems & Fruit	CO2 Sequestrated per Vine
Chardonnay	2.04 kg per vine	2.91 kg per vine	10.70 kg per vine
Sauvignon Blanc	1.92 kg per vine	2.74 kg per vine	10.07 kg per vine
Riesling	1.44 kg per vine	2.06 kg per vine	7.55 kg per vine
Pinot Gris	0.78 kg per vine	1.11 kg per vine	4.09 kg per vine
Shiraz	2.52 kg per vine	3.60 kg per vine	13.21 kg per vine
Cabernet Sauvignon	3.11 kg per vine	4.44 kg per vine	16.31 kg per vine
Merlot	1.90 kg per vine	2.71 kg per vine	9.96 kg per vine
Pinot Noir	1.27 kg per vine	1.81 kg per vine	6.66 kg per vine

The fruit portion of the carbon sequestration in the grape vines has been estimated based on information from Goward & Whitty (2014). This is shown below.

Table 11: Production relative to maturity for grapes

Years since planting/grafting	1	2	3	4	5	6	7
Production relative to maturity / full production	0%	27%	53%	80%	100%	100%	100%
Grape Fruit Portion of Sequestration	0%	4%	8%	12%	15%	15%	15%
Grape Leaves, Roots & Stems Portion of Sequestration	100%	96%	92%	88%	85%	85%	85%

Therefore, the equation to calculate carbon sequestration per ha (kgCO2-eq per ha) is:

$$Plants\ per\ ha \times Mature\ Sequestration\ per\ Grape\ Variety \times Discount\ for\ Age\ of\ Plant \times (1 - Fruit\ Portion\ Relative\ to\ Age)$$

Natural Shelter Carbon Sequestration

The carbon sequestration potential in natural shelterbelts was calculated using Ministry for Primary Industries (2018) data. This proposed that there is approximately 0.67 t C accumulated per year in a hectare of orchard, assuming that there is 400 m of shelterbelt per hectare of orchard. The shelterbelt is assumed to have reached maturity at 30 years old. Therefore, natural shelter, that is younger than 30 years, is assumed to sequestrate 6.15 kgCO2-eq per m planted annually.

3.2.3 Soil Carbon Assumptions

Changes in soil carbon levels are a trade-off between carbon inputs from the addition of compost and plant material (prunings, leaves and decomposing roots), and carbon loss from the decomposition of organic material in the soil.

Soil Carbon Inputs from the Plant

As described in the sections above, the carbon that is sequestrated by a plant is stored in the plant's leaves, stems, fruit and roots. Carbon in the fruit is removed from the system, therefore the remaining carbon is stored in the leaves, stems and roots. As a deciduous plant, the leaves are returned to the soil annually. In addition to the leaves, it is a standard horticultural practice to prune a portion of the plant's stems and return them to the soil as mulch. Therefore, carbon inputs to the soil annually are a sum of the leaf material, pruned and mulched stems, and the decomposing roots. The calculation below has been used to estimate the soil carbon inputs from the plant in the model (kgCO2-eq per ha).

$$
\begin{aligned}
Plants\ per\ ha \times \sum(&CO2\ in\ Leaf\ Material\ (kgCO2eqv\ per\ plant) \\
&+ CO2\ in\ Root\ Material\ (kgCO2eqv\ per\ plant) \\
&+ (CO2\ in\ Stem\ Material\ (kgCO2eqv\ per\ plant) \times Percent\ of\ Stems\ Pruned \\
&\times Percent\ of\ Pruned\ Material\ Returned\ to\ Soil))
\end{aligned}
$$

The below table summarises the inputs for a mature kiwifruit, apple and grape orchard/vineyard.

Table 12: Soil carbon inputs from the plant (Page, 2009)

Plant	Soil CO2 Input from the Leaves		Soil CO2 Input from the Roots		CO2 Contentof the Stems		Percent of Stems Pruned	Pruned Material Returned to Soil	Soil CO2 Input from the Stems		Soil CO2 Input from the Plant	
Kiwifruit	9.02	kgCO2eq	9.02	kgCO2eq	9.43	kgCO2eq	50%	100%	4.72	kgCO2eq	22.76	kgCO2eq
Apples (M9 Rootstock)	4.84	per	4.84	per	5.06	per	30%	100%	1.52	per	11.20	per
Grapes (Sauvignon Blanc)	1.51	plant	2.11	plant	4.93	plant	50%	100%	2.47	plant	6.09	plant

Soil Carbon Inputs from Compost

Carbon is estimated to be 40% of compost dry matter (Page, 2009). Therefore, soil carbon inputs from compost is derived from kg of compost applied multiplied by 50% to get dry matter and multiplied by 40% to get carbon. This is then converted to CO2 (multiplied by 3.67).

Soil Carbon Decomposition

The majority of the carbon that is added to the soil, through plant material and compost, returns to the atmosphere though the decomposition of organic matter. In this model, this has been assumed as 82% of all carbon inputs (i.e. only 18% remains in the soil) (Page, 2009).

N20 Emissions

The application of Nitrogen fertiliser causes an increase in nitrification and denitrification rates that leads to increased production of N2O. This has been broken into three groups of emissions: direct emissions from the application of Nitrogen fertiliser, indirect emissions from the leaching of Nitrogen fertiliser, and indirect emissions from atmospheric deposition in which soils emit ammonia and oxides of nitrogen that react to form nitrous oxide in the atmosphere (Mithraratne, Barber & McLaren, 2010). The calculations involved with these are shown in the appendices and are summarised below.

Table 13: N2O emissions

Input	Emission Factor	Source
Direct N2O Emmisions	4.19 kgCO2eqv per kgN	Mithraratne et al. (2010)
Indirect Leaching N2O Emmisions	0.73 kgCO2eqv per kgN	Mithraratne et al. (2010)
Indirect Atmospheric N2O Emmisions	0.47 kgCO2eqv per kgN	Mithraratne et al. (2010)

3.3 Description of Case Study Orchards

A selection of Craigmore's horticultural properties were used as a case study for emissions for the industry. The six sample orchards were chosen based on their variability and relativity to the research questions. The table below provides a summary of the orchards chosen with further descriptions provided in the following subsections.

Table 14: Sample orchards summary

Detail	Glenpark Orchard	Springhill Orchard	Wiroa Orchard	Angus Orchard	Gold Crest Orchard	Maha West Orchard
Total Area (ha)*	59.2	163.0	137.3	3.7	4.5	5.0
Location	Gisborne	Hawkes Bay	Northland	Bay of Plenty	Northland	Northland
Crop	Grapes	Apples	Kiwifruit	Kiwifruit	Kiwifruit	Kiwifruit
Production Method	Conventional	Conventional	Conventional	Organic	Conventional	Conventional
Canopy Area (ha)*	8.7	13.9	28.0	3.3	2.4	4.4
Production Stage	Producing	Development	Development	Producing	Producing	Conversion**
Age of Plants	6 years (~95% mature)	1 year (~5% mature)	1 year (~5% mature)	6 years (~90% mature)	6 years (~90% mature)	2 years (~15% mature)

* as per model

** converted in the winter of 2019 from a different variety to Gold3

Wiroa Orchard

Wiroa Orchard is a 137 ha former dairy farm that was purchased in May 2019. The orchard is two years into a large scale Gold3 conventional kiwifruit development. The orchard had 27.9 canopy hectares of vines planted in winter of 2019 with a further 32 canopy hectares planted in the late winter/spring of 2020. For the sake of this report, only the 2019 planted orchard has been modelled in this study.

The orchard is planted in an intensive manner with approximately 936 vines per hectare. The vines are supported by a trellis system composed of wooden posts, wire and steel agbeam. There are three forms of artificial shelter throughout the orchard: 1.6m undervine shelter throughout the orchard, 6m artificial shelter above the vines throughout the orchard, and 6m artificial shelter around the perimeter of blocks that require extra shelter. Water is supplied through the Kerikeri Irrigation Scheme and reticulated around the orchard through a network of mainlines and submains. As a former dairy farm, there are a number of sheds around the property as well as one small dwelling.

Craigmore manages the development and operations of the orchard with a third party. The majority of the machinery and activities are supplied by the third party apart from an orchard tractor and several implements.

Angus Orchard

Angus Orchard is a 4 ha organic kiwifruit orchard that was purchased in June 2017. The orchard is expected to be certified in organics (BioGro certification) in 2021. This is a three-year process that was started in 2018. The orchard has 3.3 canopy hectares of Gold3 kiwifruit vines that are approaching maturity.

The orchard is planted in a semi-intensive manner with approximately 600 vines per hectare. The vines are supported by a trellis system composed of wooden posts, wire and steel agbeam. The majority of the orchard is covered in hail cloth of moderate quality. Approximately 10% of the orchard is not covered due to powerlines running through the orchard and because of damage to the nets. Natural shelter surrounds the orchard. Water is supplied through a 138 m deep bore and reticulated around the orchard through a network of mainlines and submains. The only other infrastructure on the property is a small irrigation and chemical shed.

The orchard is managed by a third party with all of the machinery and orchard activities supplied by the third party.

Gold Crest Orchard

Gold Crest Orchard is a 5 ha conventional kiwifruit orchard that was purchased in November 2018. The orchard has 2.4 canopy hectares of Gold3 kiwifruit vines that are approaching maturity.

The orchard is planted in a mix of planting densities. The vines are supported by a trellis system composed of wooden posts, wire and steel agbeam. Natural shelter surrounds and is throughout the orchard, separating it into several smaller blocks. Water is supplied through the Kerikeri Irrigation Scheme and reticulated around the orchard through a network of mainlines and submains.

The orchard is managed by a third party with all of the machinery and orchard activities supplied by the third party.

Maha West Orchard

Maha West Orchard is a 5 ha conventional kiwifruit orchard that was purchased in July 2019. The orchard has 4.4 canopy hectares of immature Gold3 kiwifruit vines that were grafted in the winter of 2019.

The orchard is planted in an intensive manner with approximately 936 vines per hectare. The vines are supported by a trellis system composed of wooden posts, wire and steel agbeam. Natural shelter surrounds and is throughout the orchard, separating it into several smaller blocks. Water is supplied through the Kerikeri Irrigation Scheme and reticulated around the orchard through a network of mainlines and submains.

The orchard is managed by a third party with all of the machinery and orchard activities supplied by the third party.

Springhill Orchard

Springhill Orchard is a 479 ha property in Central Hawkes Bay that is in the process of being developed from an arable farm into an intensive apple orchard and wine grape vineyard. For this report, only the area around the apple orchard has been modelled. This orchard had 13.9 canopy hectares of apples planted in the winter of 2019 and a further 54.0 canopy hectares of apples planted in the winter of 2020. For simplicity only the 2019 planted area has been modelled.

The orchard is planted in an intensive manner with approximately 3906 trees per hectare. The trees are supported by a trellis system composed of wooden posts and wire. The orchard is covered by new hail netting and has fans throughout the area to protect against frost. Water is supplied through two large bores and is partially stored in two large reservoirs on site. The water is reticulated around the orchard through a network of mainlines and submains that also provide fertigation to the trees. The property has a large house on site as well as numerous other buildings.

The orchard is being developed by Craigmore and therefore owns and operates the majority of the machinery. The orchard has been set up in a modern design to provide the option for robotics and other technology in the future. Three-row sprayers are currently used on orchard. These have arms from the sprayer that enter the rows each side of the where the machine is running and therefore theoretically reduce running costs. This is expected to also have a positive impact on emissions from less fuel use as the orchard develops.

Glenpark Vineyard

Glenpark is a 59 hectare property near Gisborne that has an 8.7 canopy hectare Sauvignon Blanc vineyard with the remaining land used for cropping. The vineyard is close to maturity with the vines planted in 2013. For the purpose of this report, only the emissions related to the vineyard are calculated.

The vineyard is of a high quality with the vines planted on a post and wire trellis. Water is supplied to the property though a surface take from the Waipaoa River and reticulated around the vineyard through a network of mainlines and submains. The property has a small woolshed and moderate implement shed on site as well as a number of smaller buildings.

The orchard is managed by a third party with all of the machinery and orchard activities supplied by the third party.

Chapter 4

Carbon Footprint Results

4.1 Orchard Net Carbon Footprint

The total orchard carbon footprint for the 2019-20 season is shown in the table below. This shows the carbon dioxide sequestrated in the orchard (this includes by the plant, compost and natural shelter) as well as the split between the emissions based on scope.

All of the producing and conversion orchards were net sequestrators of carbon while both of the development orchards had significant emissions of carbon dioxide equivalents. Glenpark vineyard had the greatest total net carbon sequestration or footprint while the Gold Crest kiwifruit orchard had the greatest carbon sequestration or footprint per ha.

The below table is an example of the kind of reporting that could be provided for a collection of orchards to understand the total footprint of an organisation. For Craigmore Permanent Crop Limited Partnership (one of Craigmore's investment funds), the below selection of orchards are only a sample of the total orchards owned. The other orchards would need to be modelled in a similar process to understand the total carbon footprint of the organisation.

Table 15: Carbon footprint per orchard for the 2019-20 season

Category	Glenpark Grape Vineyard	Springhill Apple Orchard	Wiroa Kiwifruit Orchard	Angus Kiwifruit Orchard	Gold Crest Kiwifruit Orchard	Maha West Kiwifruit Orchard	Total Emissions
Carbon Sequestration (t CO2-eq)	**141.4**	**59.6**	**248.6**	**98.5**	**81.3**	**90.4**	**719.8**
Carbon Emissions (t CO2-eq)	**117.3**	**187.0**	**351.4**	**89.1**	**70.4**	**83.7**	**898.9**
Scope 1 - Fuel	8.3	55.7	44.0	3.4	2.2	2.8	116.4
Scope 2 - Electricity	0.1	5.2	6.4	2.3	1.6	3.0	18.6
Scope 3 - Orchard Capital	3.4	57.9	42.2	6.5	2.7	4.9	117.5
Scope 3 - Fert, Spray, Compost & Lime	18.3	33.0	71.5	7.5	9.7	7.2	147.2
Additional Scope - Soil Emissions	87.2	35.2	187.3	69.4	54.2	65.9	499.1
Net Carbon Footprint (t CO2-eq)	**24.2**	**-127.3**	**-102.8**	**9.4**	**10.8**	**6.7**	**-179.1**
per ha (t CO2-eq per ha)	2.8	-9.2	-3.7	2.8	4.5	1.5	-3.0

The charts on the following page provide understanding of the split between the different emission scopes for each orchard

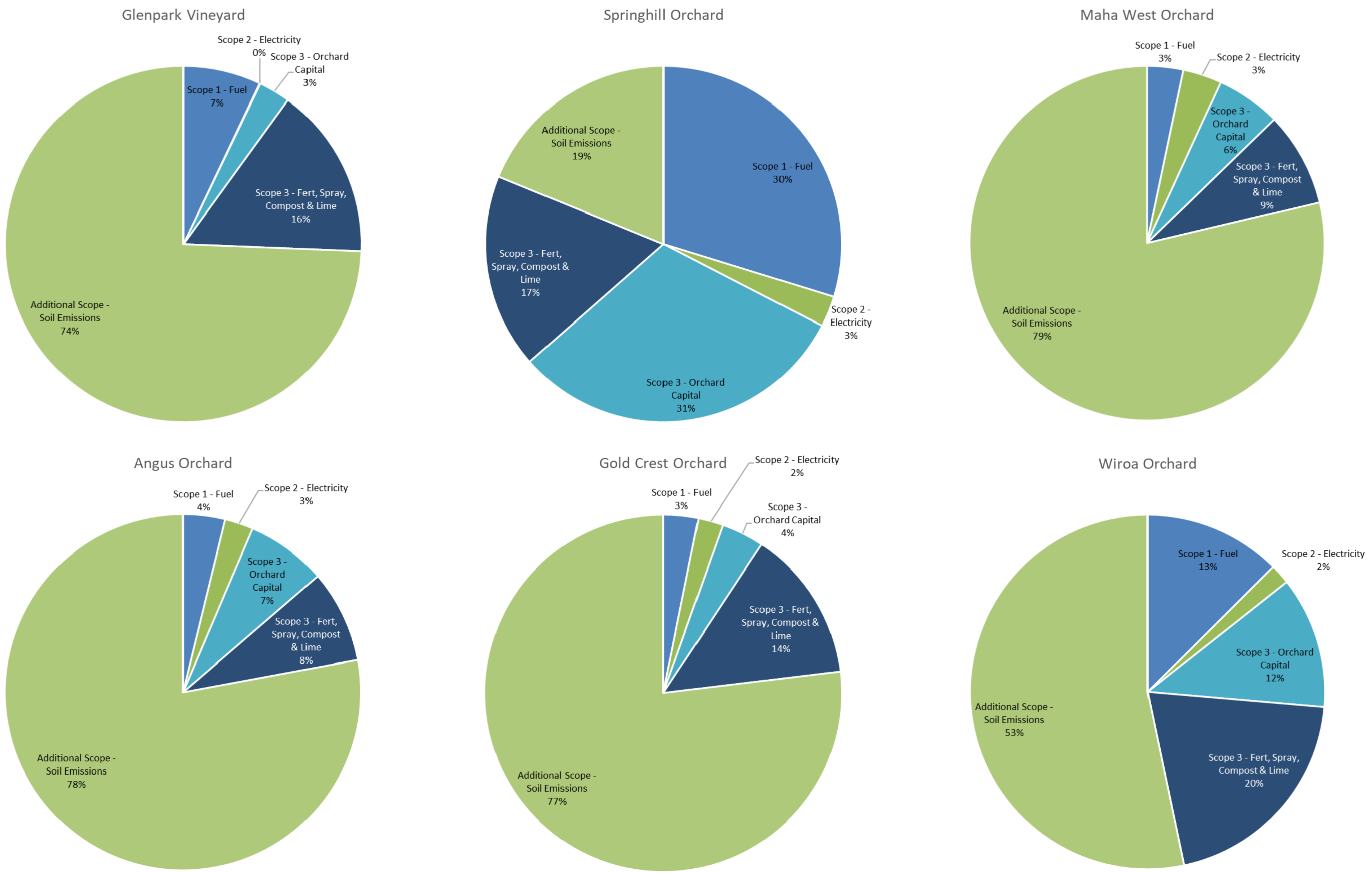

Figure 2: Carbon Emissions Per Scope

4.1.1 Comparison Across Different Crop Types

The primary difference between crop types arises from the carbon sequestration potential of the plants. The inputs required to operate the orchard do not vary greatly between the different crop types. The graph below shows the carbon sequestration potential of the different orchards modelled, as well as an assumption for if the Springhill and Wiroa orchard developments were complete. The brown bar represents the permanent soil CO2 inputs from the plant after decomposition losses, the green bar represents the CO2 that is permanently stored in the plant biomass (i.e. what remains after the soil inputs) and the light blue bar represents the CO2 that is added to the soil but is then lost to decomposition. Excluded from this analysis is the sequestration related to the natural shelter and the compost to make a relative comparison. Therefore, the sum of all three bars is the total CO2 sequestration potential of the different orchards and crop types.

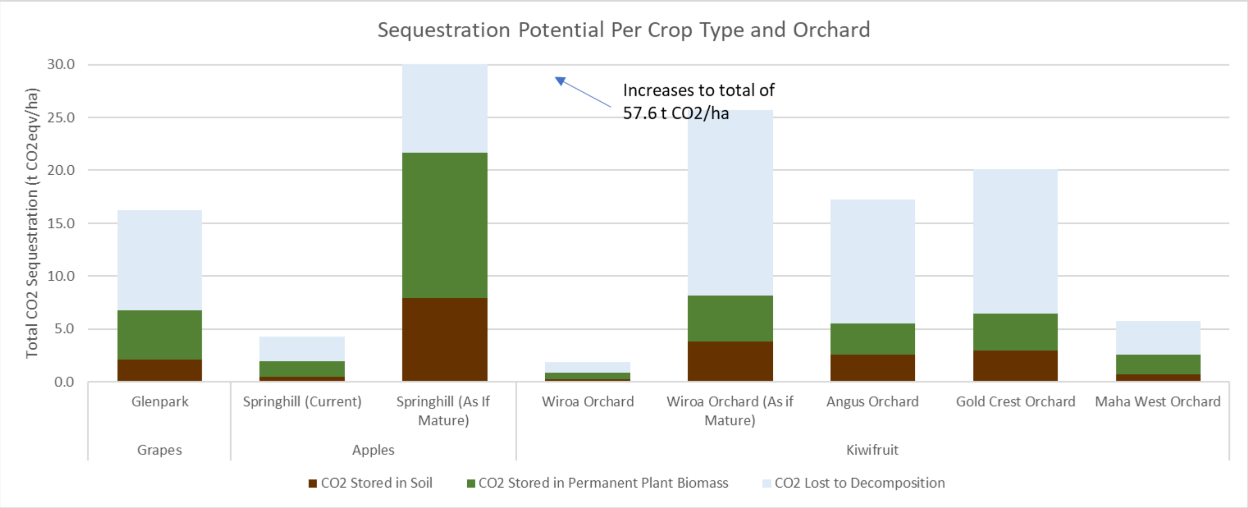

Figure 3: Sequestration potential of the different crop types

4.1.2 Comparison Across Different Production Methodologies

The organic Angus Orchard and the conventionally managed Gold Crest Orchard have been chosen to compare the different production methodologies of orchards. Both are kiwifruit orchards of a similar age and stage of production.

The orchards have the following differences that *are not* related to their production methodology:

- The amount of natural shelter. Angus has approximately 200 m per ha (~660 m in total) while Gold Crest has approximately 610 m per ha (~1,800 m in total).

- Gold Crest is a mix of strip male and opposing female planting design and has been assumed at approx. 700 vines per ha (i.e. a mix of planting densities) while Angus is purely a strip male orchard and therefore has less vines per ha (assumed at approx. 600 per ha)

- Angus orchard is partially covered by hail netting (approx. 90% covered) while Gold Crest has no overhead shelter

- Angus Orchard sources water from a well on the property while Gold Crest has water reticulated to the property through the Kerikeri Irrigation Scheme

- Gold Crest applied 2,000 kg per ha of lime-based products while Angus applied 1,000 kg per ha (for this model, gypsum has been assumed to have the same carbon emissions as lime)

The orchards have the following differences that *are* related to their production methodology:

- Fertiliser inputs

  - Gold Crest has several different fertiliser compounds applied (both foliar and solid fertiliser) with an NPKS ratio (kg applied per ha) of 126:29:360:150 respectively. In addition, there was approx. 100 kg per ha applied of Calmag (calculated in the model using the organic fertiliser assumptions). A capital allocation of 14 tonnes per ha of compost was also applied.

  - Angus had two applications of organic fertiliser mixes as well as 300 kg per ha of fishmeal applied. The organic fertiliser applications provided an NPKS ratio (kg applied per ha) of 24:377:288. in addition, 15.5 tonnes per ha of compost was applied.

- Spray inputs

  - While organic orchards still apply sprays, Gold Crest applied 65 more kg of spray per ha (214 kg per ha vs. 149 kg per ha). The chemicals used by a conventional orchard are also considered to be higher emitters than the predominant copper sprays, mineral oils and bio-stimulants used on the Angus orchard.

- Fuel use

  - Gold Crest is expected to use approximately 252 L of fuel per ha per year while Angus is expected to use 276 L of fuel per ha per year. This is primarily because of more mowing runs in the Angus orchard. This variance only creates a minimal difference to the carbon footprint model

The table below compares the different carbon footprints, on a per canopy hectare basis, of the organic Angus Orchard and the conventionally managed Gold Crest Orchard. The grey cells have been discounted to get an accurate comparison when excluding the orchard differences that are not related to production methodology.

Table 16: Carbon footprint of organic Angus and conventional Gold Crest orchards

	Units	Angus Orchard Organic	Gold Crest Orchard Conventional	Difference
Carbon Sequestration				
CO2 Sequestrated in Permanent Plant Biomass	*t CO2-eq per ha*	3.0	3.5	-0.5
CO2 Sequestrated in Natural Shelter	*t CO2-eq per ha*	1.2	3.8	-2.5
CO2 Sequestrated in Soil (Plant)	*t CO2-eq per ha*	14.3	16.7	-2.4
CO2 Sequestrated in Soil (Compost)	*t CO2-eq per ha*	11.4	10.3	1.1
Total Carbon Sequestration	***t CO2-eq per ha***	**29.8**	**34.1**	**-4.3**
Carbon Emissions				
Direct Carbon Emissions (Scope 1 & 2)				
Fuel	*t CO2-eq per ha*	1.0	0.9	0.1
Electricity	*t CO2-eq per ha*	0.7	0.7	0.0
Total	*t CO2-eq per ha*	1.7	1.6	0.1
Embodied Carbon Emissions (Scope 3)				
Orchard Capital	*t CO2-eq per ha*	2.0	1.1	0.8
Fertiliser Inputs	*t CO2-eq per ha*	0.5	0.7	-0.3
Spray Inputs	*t CO2-eq per ha*	0.7	1.9	-1.2
Compost Preparation	*t CO2-eq per ha*	0.7	0.6	0.1
Lime Inputs	*t CO2-eq per ha*	0.4	0.9	-0.4
Total	*t CO2-eq per ha*	4.2	5.2	-1.0
Soil Carbon Emissions (Additional Scope)				
Decomposition of Plant Matter	*t CO2-eq per ha*	11.7	13.7	-2.0
Decomposition of Compost	*t CO2-eq per ha*	9.3	8.4	0.9
N2O Emissions	*t CO2-eq per ha*	0.0	0.7	-0.7
Total	*t CO2-eq per ha*	21.0	22.8	-1.7
Total Carbon Emissions	***t CO2-eq per ha***	**27.0**	**29.6**	**-2.6**
Net Carbon Footprint (Actual)	***t CO2-eq per ha***	**2.8**	**4.5**	**-1.7**
Difference with equal shelter, capital, plant density	**t CO2-eq per ha**	**2.8**	**0.7**	**2.1**

4.1.3 Comparison Across Different Plant Ages

Of the kiwifruit and apple orchards chosen for this case study, two were in the first year development stage (Springhill apples and Wiroa kiwifruit), one was in the year following grafting/conversion to a different variety (Maha West kiwifruit), and two were approximately 90% mature (Angus and Gold Crest kiwifruit). To compare the relative carbon footprint of orchards from development to maturity, the data collected from these orchards has been amalgamated.

For a kiwifruit orchard's carbon footprint from development, the following assumptions were made:

- An intensive planting density (936 plants per ha) with mature production reached in Year 8 following planting.
- Assumes no natural shelter
- Compost applied as per the Wiroa orchard for Year 1, Maha West for Year 2 until Year 6, and Gold Crest from Year 6 until Year 8
- Pruning of growth starts at 0% for Year 1 and Year 2 and then increases to 50% by Year 6 (Page, 2009)
- Soil decomposition emissions based on the plant sequestration and pruning regime.
- All other emissions based on the Wiroa orchard for Year 1, Maha West for Year 2 until Year 6, and Gold Crest from Year 6 until Year 8

In the figure below, the drop off in sequestration after Year 5 is primarily due to the decrease in compost applied between the two years as well as the increasing production offsetting the close to mature sequestration per plant. Therefore, a higher proportion of the total carbon sequestrated is removed from the system and calculation as fruit.

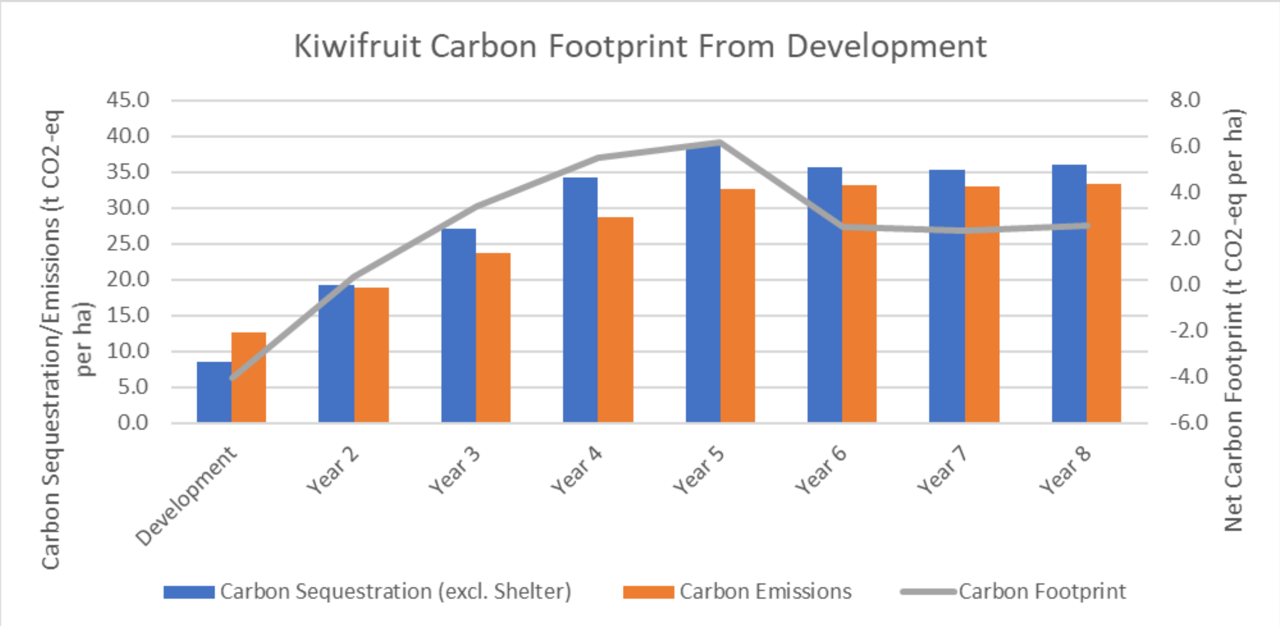

Figure 4: Kiwifruit carbon footprint from development

For an apple orchard's carbon footprint from development, the following assumptions were made:

- An intensive planting density (3,906 plants per ha) with mature production reached in Year 7 following planting.
- Assumes no natural shelter and no compost applied
- Pruning of growth starts at 0% for Year 1 and Year 2 and then increases to 30% by Year 4 (Page, 2009)
- Soil decomposition emissions based on the plant sequestration and pruning regime.
- All other emissions based on the Springhill orchard for Year 1 (11.2 tCO_2-eq per ha), increasing to a mature emissions of 17 t CO_2-eq per ha by Year 5

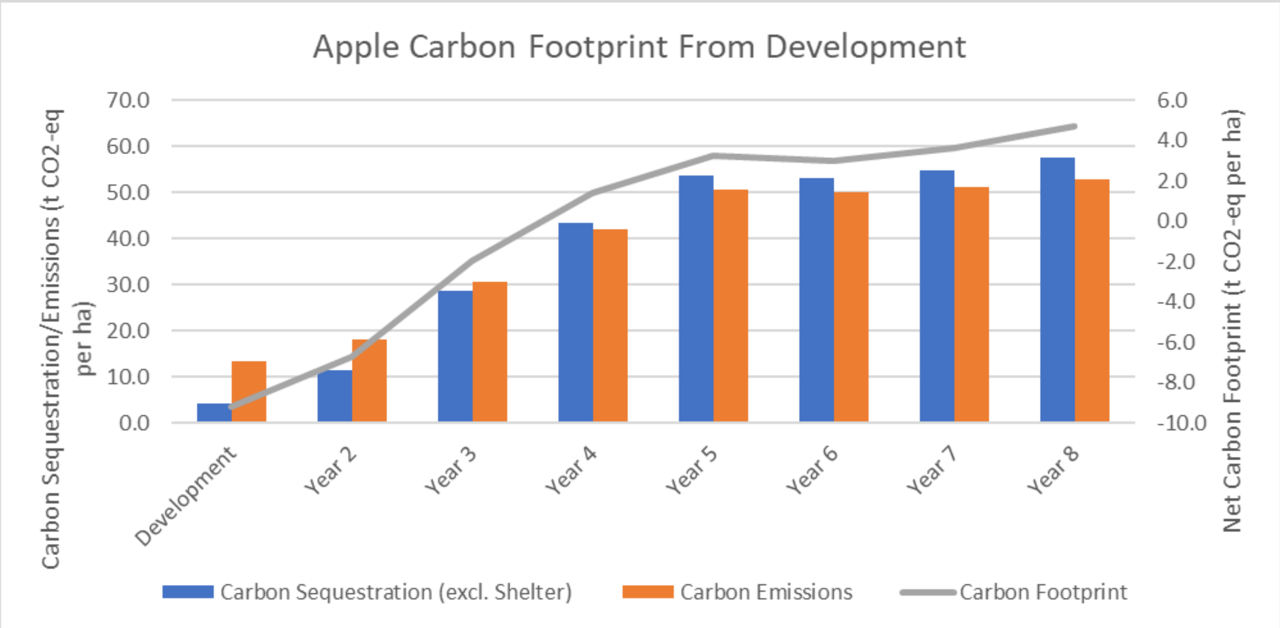

Figure 5: Apple carbon footprint from development

Chapter 5

Discussion

5.1 Is the Industry Sustainable?

5.1.1 Horticulture's Carbon Footprint

New Zealand's horticultural sector has undergone considerable investment growth in the last 20 years. Both domestic and international investors have been drawn by the prospect of asset growth and promising future returns with on and off-farm investment in the industry increasing from $6.5 bn in 2000 to $57.3 bn in 2019 (New Zealand Institute for Plant and Food Research Ltd, 2020; The Horticulture & Food Research Institute of New Zealand Ltd, 2000). This growth has until recently been largely driven by financial returns. However, there is a growing interest in the industry as a sustainable option for food production that both provides a nutritional, healthy product as well as acting as a carbon sink for the atmosphere.

This study has strived to measure the assumption that the industry has a net positive impact on the environment. In this study, an analytical carbon model was used as a proxy to get an understanding of the general sustainability of the horticultural industry. Using this generalisation, the results have shown that the horticultural sector can be considered to have a positive impact on the environment. The Glenpark vineyard had a net carbon sequestration of 24.2 t CO2-eq while both the producing kiwifruit orchards (Gold Crest and Angus) and the recently converted Maha West kiwifruit orchard had a net positive impact of sequestrating 10.8, 9.4 and 6.7 t CO2-eq, respectively. Both the development orchards were the only ones to have a net carbon emission or footprint with the Springhill apple development having net emissions of 127.3 t CO2-eq and the Wiroa kiwifruit development having net emissions of 102.8 t CO2-eq.

5.1.2 Different Crop Types

The analyses across the different crop types was focused on their respective sequestration potential. This was because the carbon emissions (Scopes 1, 2 & 3) were largely relative to the orchard's management rather than the crop type. As was expected, both the vineyard at Glenpark and the close to mature kiwifruit orchards had a similar sequestration potential. This was because both are similar plants, being perennial deciduous vines that require structural support. In comparison the apple orchard at Springhill has the potential for considerably larger sequestration as a larger tree. This was shown with the comparison between the "as if mature" Springhill, Wiroa and the Glenpark vineyard. The Springhill orchard has the potential to sequester 2.2x the mature Wiroa kiwifruit orchard and 3.5x the Glenpark vineyard.

One of the input factors that does differ between crop types is the application of compost. Both the vineyard and the apple orchard didn't apply any compost whereas all of the kiwifruit orchards applied at least 9 tonnes of compost per hectare. This impacts the sequestration and emissions of the orchards through soil carbon inputs and decomposition as well as the Scope 3 embodied emissions relative to the creation and preparation of the compost.

5.1.3 Organic or Conventional?

To compare the difference between organic and conventionally managed orchards, the conventional Gold Crest and the organic Angus orchard were analysed. The results showed that across the whole orchard system, the Gold Crest orchard had a greater net sequestration than the organic Angus orchard. However, a large proportion of this result was influenced by factors other than the production methodology. Therefore, when the different plant densities, amount of natural shelter and orchard capital, and the amount of lime applied had been removed the organic system was proven to be more "sustainable" by sequestrating an extra 2.1 t CO2-eq per hectare.

This variation between the organic and conventional management is primarily from the amount of compost applied and the agrichemicals used. The higher compost application with the organics is as a replacement for the inorganic nitrogen applied in the conventional system. However, as the amount of compost impacts both the sequestration potential of the orchard and the emissions (both embodied and from decomposition) the net impact of applying more compost is actually only minimal (only contributes 0.1 t CO2-eq to the variation between both systems). The significantly higher agrichemical spray related emissions for the Gold Crest orchard provide the main difference between the emissions. Although the Gold Crest orchard does apply more sprays, part of the difference is potentially due to the different orchard locations (Gold Crest is in Northland and Angus is in Bay of Plenty) requiring different spray programmes.

Muller, Holmes, Deurer & Clothier (2015) modelled the difference in emissions between organic and conventionally grown kiwifruit. Their study was based on the emissions of the use of agrichemicals, fertilisers, fuel and electricity. They found that there was an insignificant difference between conventional ("integrated") and organically managed orchards. The conventional orchards emitted 4.93 t CO2-eq per ha while the organic orchards emitted 4.40 t CO2-eq per ha. In comparison, this research found that the organic Angus orchard emitted 4.0 t CO2-eq per ha compared to the conventional Gold Crest orchard emissions of 5.7 t CO2-eq per ha. A potential fault of this model is that only the inorganic N is included in the N2O emissions. In reality, the organic N applied (from fishmeal and compost) would also impact these emissions. This would potentially reduce the greater variation between the organic and conventional systems shown in this research versus the Muller, Holmes, Deurer & Clothier (2015) study.

Overall, both the study and this research showed benefits in environmental sustainability, for having organic management. Further research could analyse the intensity of this result by comparing the footprint on a production basis (i.e. per tray of kiwifruit produced) or on a returns basis (i.e. per $ income per hectare).

5.1.4 Footprint from Development

The age of the orchard and the plants within it impacts both the sequestration potential and the emissions, particularly the soil organic matter decomposition. To provide an understanding of the changes that occur as an orchard matures, a comparison was made between kiwifruit and apple orchards as they develop.

The kiwifruit orchard summary showed a steady increase in net footprint until Year 5 where the change in compost assumptions reduced the expected net sequestration to approximately 2.5 t CO2-eq per hectare per year. The modelled orchard started having a net positive footprint (i.e. net sequestration) in Year 2 with a cumulative net positive impact achieved in Year 4.

Overall, the total Scope 1, 2 & 3 emissions (i.e. not including the decomposition) stayed relatively constant with the main variation caused by increases in soil decomposition as the compost and plant matter added to the soil increased. The split within the emissions changed as the orchard developed. In the development year, there is a higher proportion of Scope 1 emissions due to the fuel required for ground preparation and the construction of the orchard while a mature orchard has higher Scope 3 emissions, particularly from fertiliser and spray inputs. This is shown with the fuel portion being 37% of the combined Scope 1, 2 and 3 emissions for Wiroa while this is only 14% for Gold Crest. In contrast the fertiliser and spray inputs comprise 6% of the combined Scope 1, 2 and 3 emissions for Wiroa while this is 38% for Gold Crest.

The apple orchard summary showed a more even increase in net footprint without the impact of changing compost applications. Overall, an apple orchard is shown to have a greater net sequestration at maturity (4.7 t CO2-eq per ha compared to 2.6 t CO2-eq per ha for kiwifruit). However, the orchard also has a greater net negative footprint (net emissions) in the early development years. A positive net footprint is not expected to be reached until Year 4 with a cumulative net positive impact not achieved until Year 9.

As there is no literature that has already researched the emissions of orchards in the development phase, there are no checks that can be used to compare the reliability of this research. However, as the model is believed to be reasonably accurate at a mature level there is no reason why these assumptions may not be in the correct range of emissions for the younger orchards (shown with net kiwifruit footprint of 2.6 t CO2-eq per ha compared to Page (2009) net footprint of 2.4 t CO2-eq per ha).

5.1.5 Additional Key Drivers

In addition to the key drivers of plant age, orchard management and crop type, the orchard layout had a major impact on the properties net carbon footprint. This was particularly relevant to the amount of orchard capital required and the planting density.

The more capital required to operate the orchard (e.g. hail nets or additional buildings) the greater the embodied emissions. This can be seen in comparison between the Gold Crest and Angus orchards. The Gold Crest orchard has natural shelter and limited orchard infrastructure apart from the necessary vine support structures and irrigation. In comparison, the Angus orchard is largely covered by hail netting, has less natural shelter and sources water from a well on the property. These factors mean that the Gold Crest orchard sequestrates an extra 2.5 t CO2-eq per hectare from the natural shelter and has 0.8 t CO2-eq per hectare less embodied emissions in its orchard capital.

The planting density has a large impact on the modelled sequestration and therefore the potential decomposition of soil organic matter. This is demonstrated by increasing the planting density of the Angus orchard to the intensive double planted, opposing female 4m by 6m design (i.e. 936 plants per hectare compared to the actual ~600 per hectare). This would increase the net sequestration of the orchard by a factor of at least 2 (19.6 t CO2-eq per hectare compared to the actual 9.4 t CO2-eq per hectare). However, this could be influenced by the model set up rather than an actual increase. For example, the modelled linear increase in sequestration as the planting density increases may in reality reach a certain equilibrium in that as the density increases the plants get smaller, thereby maintaining a relatively even sequestration per hectare. This issue requires further research for better understanding and is a potential issue with this model.

5.1.6 Model Comparison to Literature

As a measure of the modelling accuracy the results for the mature kiwifruit orchards (Gold Crest and Angus) were compared to the relevant literature. As can be seen in the table below the modelled systems were relatively similar to the literature (after adaptations had been made for the different metrics used). Both modelled orchards had similar emissions to the Mithraratne, Marber & McLaren (2010 study) and the Muller, Holmes, Deurer & Clothier (2015) study. The variance between Muller, Holmes, Deurer & Clothier (2015) and Nabavi-Pelesaraei, Rafiee, Hosseinzadeh-Bandbafha & Shamshirband (2016) is because of the exclusion of compost and lime in the latter research. The difference between the Page, Kelly, Minor & Cameron (2011) study and this research (both had similar model assumptions) is because of the soil emissions. The large variation between these is due to the higher plant density and greater compost application impacting soil inputs and therefore decomposition. The literature modelled a density of 500 plants per hectare compared to 600 and 700 plants per hectare for Angus and Gold Crest respectively. It also modelled a compost application of 8 tonnes per hectare compared to 15.5 and 14 tonnes per hectare for Angus and Gold Crest respectively.

Table 17: Comparison of kiwifruit emissions to literature

Source	Relative Emissions	Result from the Literature	Comparison from Gold Crest Orchard	Comparison from Angus Orchard
Mithraratne, Barber & McLaren (2010)	Orchard capital, agrichemicals, fertiliser, fuel and electricity and seasonal workers	5.8 tCO2-eq per ha	6.2 tCO2-eq per ha	5.3 tCO2-eq per ha
Page, Kelly, Minor & Cameron (2011)	Orchard capital, agrichemicals, fertiliser, fuel, electricity, and soil emissions	16.9 tCO2-eq per ha	29.6 tCO2-eq per ha	27.0 tCO2-eq per ha
Muller, Holmes, Deurer & Clothier (2015)	Agrichemicals, fertiliser and fuel and electricity (gold Kiwifruit)	5.4 tCO2-eq per ha	5.7 tCO2-eq per ha	4.0 tCO2-eq per ha
Nabavi-Pelesaraei, Rafiee, Hosseinzadeh-Bandbafha & Shamshirband (2016)	Agrichemicals, fertiliser and fuel and electricity	1.3 tCO2-eq per ha	4.2 tCO2-eq per ha	2.9 tCO2-eq per ha

The results from the Glenpark vineyard are similar to the Barry (2011) literature, although the more intensive nature of Glenpark means that its relevant emissions are slightly higher (approx. 3.1 t CO2-eq per hectare compared to 2.0-2.7 t CO2-eq per hectare in the research).

As the Springhill example orchard is only in development its emissions are only approximately 63% of the most comparable Page, Kelly, Minor & Cameron (2011) study. As this orchard develops it would be expected to have similar if not greater emissions than the comparable research due to its highly intensive and capital heavy set up.

5.2 Impact Investing Opportunities

5.2.1 Gathering Diverse Opinions on Sustainable Investment and Reporting

The global perspective on investment is changing. The next generation of investment is becoming increasingly focused on shifting to whole system value creation rather than purely financial returns. Even the world's largest investment fund, BlackRock, has recognised this shifting paradigm. Larry Fink, BlackRock's CEO, stated that "To prosper over time, every company must not only deliver financial performance, but also show how it makes a positive contribution to society" (KPMG, 2019). However, this increasing focus on sustainable and impact investment is not universal. Some financial institutions remain towards the beginning of the journey and are still traditionally focused solely on the financial returns. This spectrum from traditional investment, through to impact investment is shown in the figure below.

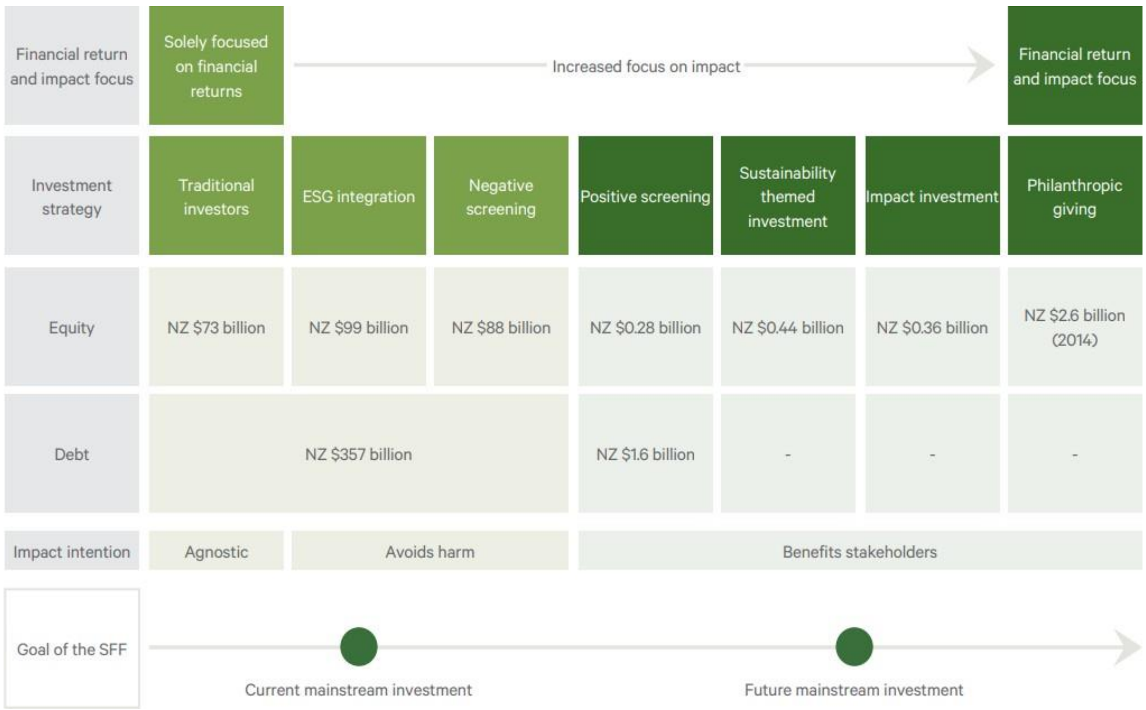

Figure 6: Sustainable Investment Spectrum (The Aotearoa Circle, 2020)

To gauge an understanding of how New Zealand managed primary industry investment groups and corporate scale farmers see themselves on the above spectrum, leaders within four different organisations were interviewed.

The first of these is Craigmore Sustainables ("Craigmore"). Craigmore is a farm and forest investment manager in New Zealand. The majority of their capital comes from overseas high net worth individuals and institutions, particularly from Europe. As asset managers focused on overseas capital, they are exposed to the changing investment opinions and provide an understanding of the interests and opinions of large foreign investors.

The second is Port Blakely. Port Blakely is a tightly controlled, 6th generational family owned global forestry company with a strong presence in the New Zealand forestry sector. As a foreign (US) family owned business, they provide a different perspective to Craigmore while also providing an understanding of the interests of foreign investment into New Zealand.

The third is MyFarm. MyFarm are focused on New Zealand-based investment into the primary sector. As an investment vehicle driven by relatively large numbers of New Zealand investors, they provide a domestic perspective on sustainable investment into the primary sector.

The final interview was of Dairy Holdings Limited ("DHL"). DHL is New Zealand's largest dairy farming company with the majority of ownership with two long term New Zealand farming families and a minority ownership by Sooke Investments, a Canadian public sector pension fund. This example provides an understanding of the perspective of large New Zealand family investment as well as the influence of foreign capital on a business.

5.2.2 Investor Driven Sustainable Investment

The first attribute to moving further down the scale towards impact investment is to understand the drivers of the investors in the sector. This provides background to the changing mindset in the markets and is at the core of the reason why investment vehicles will change their focus and strategy for capital deployment going forward.

Interest from the investors of the four organisations in sustainable investment and reporting was varied. On the scale shown in the previous section, Port Blakely was closely aligned to the impact investment theory. Sustainability, and a positive impact on the environment and social matters, was a key part of their vision and goals. Although not necessarily required, the family investors would go to the extent of taking a reduction in potential short-term financial returns in order to provide a longer-term whole value chain benefit. Craigmore investor's interests were mixed. The majority of investors would like Craigmore to sit further towards the impact investment side but struggled to clearly articulate and put their ambitions and interests into practice. DHL investors, both domestic and foreign, are interested and supportive in the progress that DHL is making in this space, however their primary focus remains on financial returns. In comparison MyFarm's investors are still heavily focused on economic parameters and financial returns. The company itself is making proactive investment decisions based on potential sustainability risks and opportunities (e.g. investment into

Manuka honey); however, this is largely because of the financial benefits of these decisions rather than a target of whole system gain.

The causes of the varied opinions of the four organisations interviewed showed that there is a large variation between the opinion of the different nationalities and types of the investors into New Zealand's primary sector. Investors from different areas and nations around the world are in different spaces on the impact investment spectrum. Craigmore has found that particularly Northern European (i.e. Scandinavian) states are more focused on the sustainability of their investments. In comparison the domestic New Zealand based investors are still largely focused on financial metrics, as seen by the opinions of the MyFarm and the domestic DHL investors. For DHL, the new Canadian investors are further advanced on the sustainable investment journey and are more concerned with their public image and responsibility. This analysis has also been seen in different government stimulus responses to Covid economic downturns. The figure below shows that there is a significant difference in the scale of funds flowing into environmentally intensive sectors and the efforts which steer stimulus towards (green) or away from (brown) pro-environmental recovery. European nations in general are more focused on sustainable investment than particularly the US, China and India. Canada is shown to offer promise but is split between both green and brown stimulus packages.

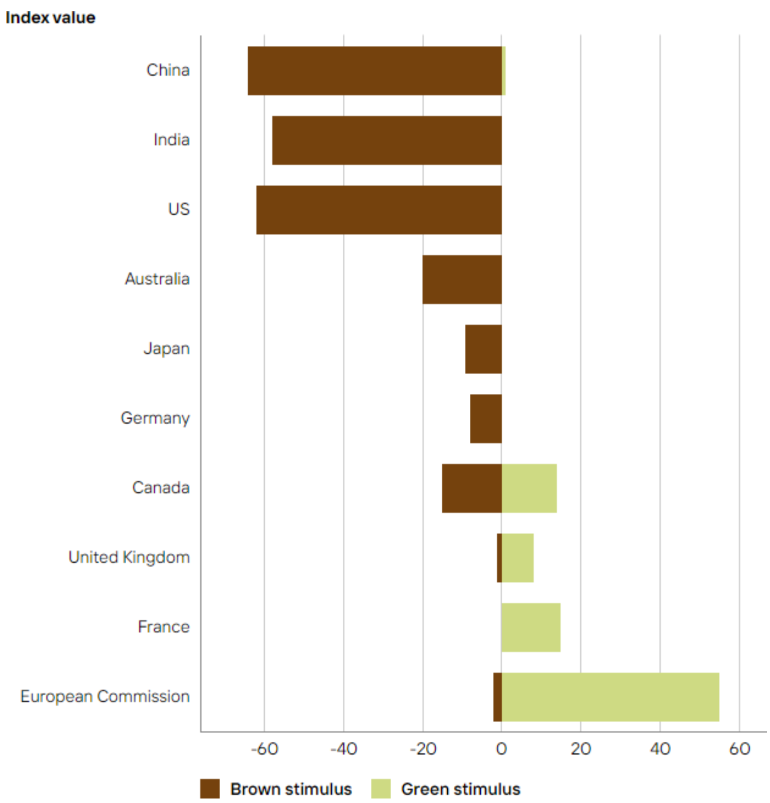

Figure 7: Stimulus packages in response to Covid-19, by type of stimulus (Generation Investment Management, 2020a)

In addition to the location of investors, the analysis showed that there is a significant difference in opinion between with the age and type of investors. MyFarm's investors are largely "baby boomers". This demographic has grown up in and become accustomed to the traditional attitude towards investment (i.e. prioritising financial returns). As this demographic moves further towards the younger generations, primarily "millennials", the opinion of investors towards sustainability and impact is expected to change. This sentiment is also held by investors such as Karam Hinduja who, at 29 years old, is a fourth generation of the Hinduja family, the third richest in India. He sees this new wave of investors as one of the key movements in the 2020s which will bring impact investing into the mainstream; "the more dire our global challenges become, the more this group will mobilise with capital and entrepreneurship" (Chiu, 2020). A study in the US by Morgan Stanley, found that there is a variation in interest in sustainable investing between the general pool of investors (75% interested) and millennials (86% interested) (Morgan Stanley Institute for Sustainable Investing, 2017). As well as the age and generation of investors, the type of investors also plays a key role in the attitude they have to impact investing. For example, Port Blakely's family investors have a holistic opinion to investment where they understand that a sustainable focus will be beneficial for financial returns, as well as the environment and society, in the long term. This view is likely to have arisen because of the multi-generational approach they have taken to investment (6th generation of family ownership) compared to larger financial institutions being more focused on the shorter-term rewards.

5.2.3 Sustainability Reporting to Investors

For effective sustainable and impact investment there needs to be accurate and comparable data and reporting of environmental and social goals. However, there is generally a lack of consistency and availability amongst companies on their reporting of sustainability or "ESG". Of the organisations interviewed, Craigmore is the most advanced in this space and uses internally built ESG metrics for annual reporting to investors. These use quantitative metrics where possible; however, the majority are narrative based. In comparison, Port Blakely relies more on a trust and narrative based approach to its sustainability reporting. This is because of the smaller, tightly controlled family investors compared to the larger financial institutions with Craigmore. MyFarm have just started the process of looking at ESG metrics and are not actively reporting on them currently. DHL has aligned its reporting to its major product customer, Fonterra. They have manipulated and applied their own quantitative-based metrics to the Cooperative Difference programme. In general, there are several different options available to investment management companies for sustainability reporting. The most widely used example of this is the Global Reporting Initiative (GRI) which is aimed at providing transparent global standards and a common language for reporting a company's impacts. However, these standards are not commonly applied in New Zealand with only 17 of the 50 S&P/NZX 50 Index companies using GRI, despite a large portion of investors wanting ESG reporting (95% of Kiwisaver investors want ESG factors considered when investing) (The Aotearoa Circle, 2020).

This lack of consistency is one of the issues with sustainable investing as it allows for companies to “greenwash” their reports. “Greenwashing” is when products and assets have claimed green credentials that in reality have little positive impact. This is why it is important that the standards are either universal or externally accredited. An example of this is the Forest Stewardship Council (FSC) certification for Port Blakely. Despite their relationship with the investing family being built on trust and an understanding of the vision, it still helps to provide external and universal accreditation and confirmation that their vision and values are being followed. This requirement for external verification is one of the reasons that accreditation organisations such as “Certified B Corporation” are so successful.

Another solution to the lack of consistency is to have a national accounting system alongside standard definitions for “green” and “sustainable” investment. This is emerging in global markets, particularly in Europe. There are now definitions for “green or sustainable” debt investments with the Green Bond Principles and the Climate Bonds Initiative. The EU have also recently created a specific standard and taxonomy for finance in a sustainable economy through the EU Technical Expert Group on Sustainable Finance (HEG) (The Aotearoa Circle, 2020). However, the New Zealand market lacks a specific standard and would potentially not be well aligned to other global standards due to its different climate and productions systems. Groups such as the Aotearoa Circle, a partnership of public and private sector leaders committed to the pursuit of sustainable prosperity of New Zealand’s natural resources, are actively working towards a unified definition that could be used for sustainability accounting.

5.2.4 Fund Raising: Opportunities for Change

Since inception, Craigmore has had to change their fund-raising approaches as their understanding of the investors they are pitching to, has increased and as the interests and drivers of the investor’s decision making have shifted. Originally, they focused purely on the financial and economic aspects of Craigmore’s investment opportunities. In the last few years this changed to being more focused on the competitive advantage of New Zealand as a food producing nation and the economics involved with the food production. However, recently they have seen an increasing relevance of the sustainability metrics and the impact that Craigmore’s farms and orchards have on the environment and society. This shift is particularly obvious in the European investors and is the reason for starting to move the focus of the fund-raising pitches to a more sustainability-based approach. In comparison, MyFarm relies on the economics and financial performance of their investment vehicles in their fund-raising efforts. Sustainability is considered in their investment decisions; however, it does not seem to add any value to their pitches to New Zealand investors. At the current time and to the current investor base, it is not believed that being able to use a statement such being "net carbon zero" would add any value or increase market demand from investors. These differences in opinion again highlight the variation between the New Zealand and foreign (particularly European) investors.

The recent report by The Aotearoa Circle highlighted "mobilising of capital" as one of the three themes that need to occur for New Zealand to move towards a sustainable finance economy (The Aotearoa Circle, 2020). A key pathway of this theme is to scale up the access to impact investing opportunities. Even though the domestic New Zealand investors are only just starting on the journey towards becoming focused on impact investment, the international equity markets are increasingly focused in this space, as highlighted by the difference between MyFarm and Craigmore. This international focus is already being capitalised on by large investment managers around the world. In January 2020, BlackRock made an active decision to make sustainability integral to the way the company operates. This is grounded from the two core convictions created from market research; one that companies who focus on sustainability related issues will be more resilient in the long term, and two that "we are on the front end of a profound, long-term structural shift in global investor preferences toward sustainability that is not fully priced into the market today and may therefore drive outperformance during a long transition period" (BlackRock, 2020). This mentality has already been used for some time by other funds such as Generation Investment Management. Since their founding in 2004, Generation has been focused on the development of sustainable investment and demonstrating the long-term commercial benefits of this decision. This has allowed them to grow to US$ 25.7bn assets under management as of September 2020 (Generation Investment Management, 2020b). Overall, this shifting focus overseas presents an attractive opportunity for primary sector investment managers, and corporate farmers requiring capital, to market themselves as sustainable through transparent metrics and thereby access the growing impact focused investor base.

Chapter 6

Conclusion

This research provides a potential understanding of the environmental sustainability of the horticultural industry by using the carbon footprint of a selection of Craigmore Sustainables' horticultural properties as a proxy. Overall, the producing orchards and vineyards were shown to have a net positive impact on the environment through large sequestration by the plants and compost. The total impact of the six orchards measured was a net emission of 179.1 t CO_2-eq in the 2019-20 season. However, this was heavily weighted towards the two developing orchards that were shown to have comparatively high net emissions in their early years. It was shown that there is significant variation in the sequestration potential of different crop types (apples have the greatest potential sequestration per ha). In addition, the impact of organics was tested across the kiwifruit orchards with organic management producing less emissions overall than a conventional orchard.

By measuring and clarifying the general assumptions on sustainability, this study allows for better understanding into the potential for impact investing into the sector. The ability of orchards and vineyards to be a carbon sink, following development, allows for investors to have confidence that they are not only gaining financial returns but also having a net positive impact on the environment. This quantifiable metric provides the ability for Craigmore, to source additional capital that would otherwise not be available to it, thereby providing an opportunity for the continued growth of the sector.

Across the multiple interviews and literature reviewed, it was shown that there is significant variation in the positioning of investment funds and corporate farmers on the idea of impact investing. Foreign and younger investors and correspondingly their asset managers, appeared to be further advanced in the understanding of impact investment and its opportunities. However, for the New Zealand market to fully appreciate and take advantage of impact investment opportunities that will arise in the primary industry space, there needs to be changes to the consistency and transparency of sustainability reporting and fund raising. These could include universal external accreditation programmes or consistent national accounting standards.

Chapter 7

Recommendations

The recommendations that emerge from this report can be broken down into two separate areas: those for the modelling and measurement of sustainability in the horticultural industry, and those for the industry's investment sector to capture the possibilities of the impact investment movement.

Although this study provides a baseline understanding of the potential sustainability of the horticultural industry, there are several factors that need to be considered in either further research or by leading organisations within the sector. These are:

- Where possible, the increase in establishment and use of other quantifiable sustainability metrics in addition to carbon footprinting. Although the carbon footprint provides a proxy of the environmental sustainability of the industry, other metrics will be key to the practical uptake and continued use of sustainability reporting that is required for effective impact investment

- Provide actual on-orchard data to test the strength and applicability of the carbon footprint modelling. Examples of this could be soil carbon measurements or measurements of plant biomass (this has been trialled in the viticulture industry with relationships between trunk diameter and carbon sequestrations analysed)

- Further research into the environmental sustainability of orchards in an intensity-based approach such as kg CO2-eq per tray produced or per $ return. This would align the focus of the impact reporting more closely to the idea of "whole value chain" benefits rather than compartmentalising the different objectives.

The recommendations for the primary industry investment sector are:

- To increase the measurement and reporting of the sustainability of the industry and therefore utilise the existing foreign impact investment interest as well as being prepared for when the domestic New Zealand investor base ultimately increase their focus on impact investment.

- For the industry to either create a universal accredited standard of reporting and measurement for sustainability of a business or to align itself to current global reporting standards and initiatives. This will increase investor confidence in the industry and therefore increase the potential for impact investment.

Chapter 8
References

Barber, A., & Scarrow, S. (2001). *Kiwifruit energy audit*. Pukekohe and Tauranga: Agriculture New Zealand Ltd.

Barry, M.T. (2011). *Life cycle assessment and the New Zealand wine industry: A tool to support continuous environmental improvement*. (Masters thesis). Massey University, Wellington, New Zealand

BlackRock. (2020). *Helping our clients invest sustainably*. Retrieved from https://www.blackrock.com/au/individual/about-us/sustainability-progress-update

Chiu, B. (2020, January 10). *A next gen investor's prediction on impact investing in 2020s*. Retrieved from https://www.forbes.com/sites/bonniechiu/2020/01/10/a-next-gen-investors-predictions-on-impact-investing-in-2020s/#1258c645646c

Custance, J., & Hillier, H. (1998). Statistical issues in developing indictors of sustainable development. *Journal of Royal Statistical Society, 161*(3), 281-291.

Eccles, R.G., Ioannou, I., & Serafeim. (2014). The Impact of Corporate Sustainability on Organizational Processes and Performance. *Management Science, 60*(11), 2835-2857.

Generation Investment Management. (2020a). *Sustainability Trends Report 2020*. Retrieved from https://str2020.generationim.com/chapters/introduction

Generation Investment Management. (2020b). *Our Story*. Retrieved from https://www.generationim.com/firm-overview/our-story/

Goward, J., & Whitty, M. (2014). Estimating and Predicting Carbon Sequestration in a Vineyard using Precision Viticulture Techniques. *In, Proceedings of the 19th Association of Public Authority Surveyors Conference (APAS2014), Pokolbin, Australia, 31 March – 2 April 2014*.

Hochstadter, A.K., & Scheck, B. (2014). What's in a name: an analysis of impact investing understandings by academics and practitioners. *Journal of Business Ethics, 132*, 449-475. DOI: 10.1007/s10551-014-2327-0

KPMG. (2019). *The numbers that are changing the world: Revealing the growing appetite for responsible investing*. Retrieved from https://assets.kpmg/content/dam/kpmg/ie/pdf/2019/10/ie-numbers-that-are-changing-the-world.pdf

Kroodsma, D.A., & Field, C.B. (2006). Carbon sequestration in California agriculture, 1980-2000. *Ecological Applications, 16*(5), 1975-1985.

McLaren, S., Hume, A., Barber, A., Clothier, B., Deurer, M., East, A., Greenhalgh, S., McDonald, R., Palmer, J., & Sinclair, R. (2009). *Carbon Footprinting for the Apple Supply Chain: Project Summary*. Auckland, New Zealand: Landcare Research.

Ministry for Primary Industries. (2018). *Carbon sequestration potential of non ETS land on farms*. Wellington: Manaaki Whenua – Landcare Research.

Ministry for the Environment. (2019a). *Climate Change Response (Zero Carbon) Amendment Bill: Summary*. Wellington: Ministry for the Environment.

Ministry for the Environment. (2019b). *Measuring Emissions: A guide for organisations. 2019 Detailed Guide*. Wellington: Ministry for the Environment.

Mithraratne, N., Barber, A., & McLaren, S.J. (2010). *Carbon Footprinting for the Kiwifruit Supply Chain – Report on Methodology and Scoping Study.* Auckland, New Zealand: Landcare Research.

Morgan Stanley Institute for Sustainable Investing. (2017). *Sustainable Signals: New Data from the Individual Investor*. Retrieved from https://www.morganstanley.com/pub/content/dam/msdotcom/ideas/sustainable-signals/pdf/Sustainable_Signals_Whitepaper.pdf.

Muller, K., Holmes, A., Deurer, M., & Clothier, B.E. (2015). Eco-efficiency as a sustainability measure for kiwifruit production in New Zealand. *Journal of Cleaner Production, 106*, 333-342. http://dx.doi.org/10.1016/j.jclepro.2014.07.049

Nabavi-Pelesaraei, A., Rafiee, S., Hosseinzadeh-Bandbafha, H., & Shamshirband, S. (2016). Modelling energy consumption and greenhouse gas emissions for kiwifruit production using artificial neural networks. *Journal of Cleaner Production, 133*, 924-931. http://dx.doi.org/10.1016/j.jclepro.2016.05.188

New Zealand Institute for Plant and Food Research Ltd. (2020). *Fresh Facts: New Zealand Horticulture 2019*. Retrieved from https://www.freshfacts.co.nz/files/freshfacts-2019.pdf

Page, G. (2009). *An environmentally-based systems approach to sustainability analyses of organic fruit production systems in New Zealand*. (Doctoral thesis). Massey University, Palmerston North, New Zealand.

Page, G., Kelly, T., Minor, M., & Cameron, E. (2011). Modelling Carbon Footprints of Organic Orchard Production Systems to Address Carbon Trading: An Approach Based on Life Cycle Assessment. *HortScience, 46*(2), 324-327.

Pinares-Patino, C.S., Waghorn, G.C., Hegarty, R.S., & Hoskin, S.O. (2009). Effects of intensified cation of pastoral farming on greenhouse gas emissions in New Zealand. *New Zealand Veterinary Journal, 57*(5), 252-261. DOI: 10.1080/00480169.2009.58618

Saunders, C., Barber, A., & Taylor, G. (2006). *Food Miles – Comparative Energy/Emissions* Performance *of New Zealand's Agriculture Industry*. Lincoln, New Zealand: Agribusiness and Economics Research Unit, Lincoln University.

Sharma, V. (2002). Report on the international conference on EcoBalance and life cycle assessment in India. *The International Journal of Life Cycle Assessment, 7*(3), 179-179.

Tellegen, E. (2006). *Sociology & sustainable development. A literature review.* The Hague: DHO, The Dutch Network for Sustainable Higher Education.

The Aotearoa Circle. (2020). *Sustainable Finance Forum: Interim Report 2019*. New Zealand: The Aotearoa Circle.

The Horticulture & Food Research Institute of New Zealand Ltd. (2000). *Horticulture Facts and Figures 2000*. Retrieved from https://www.freshfacts.co.nz/files/new-zealand-horticulture-facts-and-figures-2000.pdf

WCED. (1987). *Our common future, OUP*. Oxford: Oxford University Press

Wells, C. (2001). *Total* Energy *Indicators of Agricultural Sustainability: Dairy Farming Case Study*. Wellington, New Zealand: Ministry of Agriculture and Forestry.

Chapter 9

Appendices

9.1 Carbon Model Calculations and Assumptions

The direct emission for fuel use (kgCO2-eq per ha) is estimated as:

$$\sum(Fuel\ Use\ from\ Contractor\ Activities + Fuel\ Purchases\ (L\ per\ ha)) \times Energy\ Coefficient\ (MJ\ per\ L) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:

- *46.70 MJ per L (Wells, 2001)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The direct emission for electricity use (kgCO2-eq per ha) is estimated as:

$$Electricty\ Use\ (kWh\ per\ ha) \times Energy\ Coefficient\ (MJ\ per\ kWh) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:

- *7.45 MJ per kWh (Wells, 2001)*
- *0.06 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for a building (kgCO2-eq per building) is estimated as:

$$\frac{Size\ of\ Building\ (m2) \times Energy\ Coefficient\ (MJ\ per\ m2) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Building}$$

Using the following assumptions:

- *590 MJ per m2 (Wells, 2001)*
- *0.10 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for a vehicle (kgCO2-eq per vehicle) is estimated as:

$$\frac{Mass\ of\ Vehicle\ (kg) \times Energy\ Coefficient\ (MJ\ per\ kg) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Vehicle}$$

Using the following assumptions:

- *Mass conversion factor of 40.8 kg per hp + 190 kg (Wells, 2001)*
- *160 MJ per kg (Wells, 2001)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for other machinery (kgCO2-eq per machine) is estimated as:

$$\frac{Mass\ of\ Machine\ (kg) \times Energy\ Coefficient\ (MJ\ per\ kg) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Machine}$$

Using the following assumptions:

- *80 MJ per kg (Wells, 2001)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for irrigation pumps (kgCO2-eq per pump) is estimated as:

$$\frac{Mass\ of\ Pump\ (kg) \times Energy\ Coefficient\ (MJ\ per\ kg) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Pump}$$

Using the following assumptions:

- *160 MJ per kg (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for irrigation wells (kgCO2-eq per well) is estimated as:

$$\frac{Depth\ of\ Well\ (m) \times Energy\ Coefficient\ (MJ\ per\ m) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Well}$$

Using the following assumptions:

- *400 MJ per m (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for irrigation mainlines (kgCO2-eq per property) is estimated as:

$$\frac{Length\ of\ Pipe\ (m) \times Energy\ Coefficient\ (MJ\ per\ m) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Pipe}$$

Using the following assumptions:

- *0.65 kg per m of pipe*
- *120 MJ per kg of pipe (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for irrigation dripline (kgCO2-eq per ha) is estimated as:

$$\frac{Dripline\ per\ ha\ (m) \times Energy\ Coefficient\ (MJ\ per\ m) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Pipe}$$

Using the following assumptions:

- *0.40 kg per m of pipe*
- *160 MJ per kg of pipe (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for posts (kgCO2-eq per ha) is estimated as:

$$\frac{Posts\ per\ ha \times Energy\ Coefficient\ (MJ\ per\ post) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Posts}$$

Using the following assumptions:

- *18 MJ per post (Barber & Scarrow, 2001)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for wire (kgCO2-eq per ha) is estimated as:

$$\frac{Wire\ per\ ha\ (m) \times Energy\ Coefficient\ (MJ\ per\ m) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Wire}$$

Using the following assumptions:

- *1.3 MJ per m (Barber & Scarrow, 2001)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for agbeam (kgCO2-eq per ha) is estimated as:

$$\frac{Agbeam\ per\ ha\ (m) \times Energy\ Coefficient\ (MJ\ per\ m) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Agbeam}$$

Using the following assumptions:

- *56 MJ per m (Mithraratne, 2010)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for string (kgCO2-eq per ha) is estimated as:

$$\frac{String\ per\ ha\ (m) \times Energy\ Coefficient\ (MJ\ per\ m) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ String}$$

Using the following assumptions:

- *7.5 g per m of string*
- *160 MJ per kg of string (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for stringing poles (kgCO2-eq per ha) is estimated as:

$$\frac{Poles\ per\ ha \times Energy\ Coefficient\ (MJ\ per\ pole) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Pole}$$

Using the following assumptions:

- *5 MJ per pole*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for 6m Shelter Posts (kgCO2-eq per ha) is estimated as:

$$\frac{Posts\ per\ ha \times Energy\ Coefficient\ (MJ\ per\ post) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Post}$$

Using the following assumptions:

- *100 MJ per post*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for 6m Shelter Cloth (kgCO2-eq per ha) is estimated as:

$$\frac{Cloth\ per\ ha\ (m2) \times Energy\ Coefficient\ (MJ\ per\ m2) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Cloth}$$

Using the following assumptions:

- *170 g per m2 of cloth*
- *160 MJ per kg of cloth (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Undervine Shelter Cloth (kgCO2-eq per ha) is estimated as:

$$\frac{Cloth\ per\ ha\ (m2) \times Energy\ Coefficient\ (MJ\ per\ m2) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Cloth}$$

Using the following assumptions:

- *160 g per m2 of cloth*
- *160 MJ per kg of cloth (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Hailnet Posts (kgCO2-eq per ha) is estimated as:

$$\frac{Posts\ per\ ha \times Energy\ Coefficient\ (MJ\ per\ post) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Post}$$

Using the following assumptions:

- *100 MJ per post*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Hailnet Cloth (kgCO2-eq per ha) is estimated as:

$$\frac{Cloth\ per\ ha\ (m2) \times Energy\ Coefficient\ (MJ\ per\ m2) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Cloth}$$

Using the following assumptions:

- *65 g per m2 of cloth*
- *160 MJ per kg of cloth (Saunders et al., 2006)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Frost Fans (kgCO2-eq per ha) is estimated as:

$$\frac{Fans\ per\ ha \times Energy\ Coefficient\ (MJ\ per\ fan) \times CO2\ Emission\ Coefficient\ (kgCO2eqv\ per\ MJ)}{Working\ Useful\ Life\ of\ Fan}$$

Using the following assumptions:

- *1 tonne per machine*
- *160 MJ per kg of machine (Page, 2009)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Nitrogen in inorganic fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ Fert\ per\ ha) \times Proportion\ of\ N\ in\ Fert\ (\%) \times Energy\ Coefficient\ (MJ\ per\ kgN) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:

- *65 MJ per kg of N (Welles, 2001)*
- *0.05 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Phosphorus in inorganic fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ Fert\ per\ ha) \times Proportion\ of\ P\ in\ Fert\ (\%) \times Energy\ Coefficient\ (MJ\ per\ kgP) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:
- *15 MJ per kg of P (Welles, 2001)*
- *0.06 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Potassium in inorganic fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ Fert\ per\ ha) \times Proportion\ of\ K\ in\ Fert\ (\%) \times Energy\ Coefficient\ (MJ\ per\ kgK) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:
- *10 MJ per kg of K (Welles, 2001)*
- *0.06 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for Sulphur in inorganic fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ Fert\ per\ ha) \times Proportion\ of\ S\ in\ Fert\ (\%) \times Energy\ Coefficient\ (MJ\ per\ kgS) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:
- *5 MJ per kg of S (Welles, 2001)*
- *0.06 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for organic fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ Fert\ per\ ha) \times Energy\ Coefficient\ (MJ\ per\ kg) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:
- *5 MJ per kg of organic fertiliser (Page, 2009)*
- *0.08 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for lime (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ Lime\ per\ ha) \times Energy\ Coefficient\ (MJ\ per\ kg) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:
- *0.6 MJ per kg of lime (Wells., 2001)*
- *0.72 kgCO2-eq per MJ (Wells, 2001)*

The embodied emission for agrichemical sprays (kgCO2-eq per ha) is estimated as:

$$Number\ of\ Sprays\ per\ Year \times \frac{Spray\ Rate\ (g\ per\ 100L)}{100\ L} \times Water\ Rate\ (L\ per\ Ha) \div 1000\ (to\ convert\ to\ kg) \times Energy\ Coefficient\ (MJ\ per\ kg) \times CO2\ Emission\ Coeffiient\ (kgCO2eqv\ per\ MJ)$$

Using the following assumptions:
- *550 MJ per kg of herbicide (Glyphosate) (Barber, 2004)*
- *310 MJ per kg of herbicide (general) (Barber, 2004)*
- *315 MJ per kg of insecticide (Barber, 2004)*
- *210 MJ per kg of fungicide (Barber, 2004)*
- *175 MJ per kg of plant growth regulator (Barber, 2004)*
- *120 MJ per kg of mineral oil (Barber, 2004)*
- *111.5 MJ per kg of copper spray (Wells, 2001)*
- *111.5 MJ per kg of sulphur spray (Wells, 2001)*
- *5 MJ per kg of bio-stimulant (Page, 2009)*
- *120 MJ per kg of other agrichemical (Barber, 2004)*

- *0.06 kgCO2-eq per MJ of all sprays except copper, sulphur and bio-stimulant (Wells, 2001)*
- *0.08 kgCO2-eq per MJ of copper, sulphur and bio-stimulant sprays (Wells, 2001)*

The embodied emission for direct soil emissions (N2O) from Nitrogen fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ N\ per\ ha) \times (1 - Fraction\ of\ N\ Fert\ Emitted\ as\ NOx\ or\ NH3) \times Emission\ Factor\ for\ Direct\ Emissions \times \frac{44}{28} \times Global\ Warming\ Potential\ of\ N2O$$

Using the following assumptions (Mithraratne, Barber & McLaren, 2010):

- *Fraction of N Fert Emitted as NOx or NH3 as 0.1*
- *Emission Factor for Direct Emissions as 0.01*
- *Global Warming Potential of N2O as 296*

The embodied emission for indirect atmospheric soil emissions (N2O) from Nitrogen fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ N\ per\ ha) \times (Fraction\ of\ N\ Fert\ Emitted\ as\ NOx\ or\ NH3) \times Emission\ Factor\ for\ Indirect\ Atmospheric\ Emissions \times \frac{44}{28} \times Global\ Warming\ Potential\ of\ N2O$$

Using the following assumptions (Mithraratne, Barber & McLaren, 2010):

- *Fraction of N Fert Emitted as NOx or NH3 as 0.1*
- *Emission Factor for Indirect Atmospheric Emissions as 0.01*
- *Global Warming Potential of N2O as 296*

The embodied emission for indirect leaching soil emissions (N2O) from Nitrogen fertiliser (kgCO2-eq per ha) is estimated as:

$$Application\ Rate\ (kg\ N\ per\ ha) \times (1 - Fraction\ of\ N\ Fert\ Emitted\ as\ NOx\ or\ NH3) \times (Fraction\ of\ N\ Fert\ that\ is\ Lost\ to\ Leaching) \times Emission\ Factor\ for\ Indirect\ Leaching\ Emissions \times \frac{44}{28} \times Global\ Warming\ Potential\ of\ N2O$$

Using the following assumptions (Mithraratne, Barber & McLaren, 2010):

- *Fraction of N Fert Emitted as NOx or NH3 as 0.1*
- *Fraction of N Fert Lost to Leaching as 0.07*
- *Emission Factor for Indirect Leaching Emissions as 0.025*
- *Global Warming Potential of N2O as 296*

9.2 Detailed Carbon Footprint Per Orchard

Orchard	Units	Glenpark Vineyard	Springhill Orchard	Wiroa Orchard	Angus Orchard	Gold Crest Orchard	Maha West Orchard	Total Sample Emissions	Emissions per hectare
Crop Area		8.70	13.88	27.95	3.30	2.38	4.43	**60.64**	
Crop		Grapes	Apple	Kiwifruit	Kiwifruit	Kiwifruit	Kiwifruit		
Management		Conventional	Conventional	Conventional	Organic	Conventional	Conventional		
Production Stage		Producing	Development	Development	Producing	Producing	Conversion		
Carbon Sequestration									
CO2 Sequestrated in Permanent Plant Biomass		40.8	20.5	18.4	9.8	8.2	8.5	**106.1**	**1.8**
CO2 Sequestrated in Natural Shelter		0.0	0.0	10.4	4.1	8.9	5.4	**28.8**	**0.5**
CO2 Sequestrated in Soil (Plant and Compost)		100.7	39.2	219.8	84.7	64.1	76.4	**584.9**	**9.6**
Total Carbon Sequestration	t CO2-eq	141.4	59.6	248.6	98.5	81.3	90.4	**719.8**	**11.9**
	per ha	16.3	4.3	8.9	29.8	34.1	20.4	**11.9**	
Carbon Emissions									
Direct Carbon Emissions (Scope 1 & 2)									
Fuel		8.3	55.7	44.0	3.4	2.2	2.8	**116.4**	**1.9**
Electricity		0.1	5.2	6.4	2.3	1.6	3.0	**18.6**	**0.3**
Total	t CO2-eq	8.4	60.9	50.5	5.7	3.8	5.7	**135.0**	**2.2**
Embodied Carbon Emissions (Scope 3)									
Orchard Capital		3.4	57.9	42.2	6.5	2.7	4.9	**117.5**	**1.9**
Fertiliser Inputs		3.8	3.6	4.2	1.5	1.7	2.3	**17.2**	**0.3**
Spray Inputs		14.6	5.5	7.9	2.3	4.4	1.3	**36.0**	**0.6**
Compost Preparation		0.0	0.0	11.1	2.3	1.5	3.6	**18.3**	**0.3**
Lime Inputs		0.0	24.0	48.3	1.4	2.1	0.0	**75.8**	**1.2**
Total	t CO2-eq	21.7	90.9	113.7	14.0	12.4	12.1	**264.8**	**4.4**
Soil Carbon Emissions (Additional Scope)									
Decomposition of Plant Matter		82.5	32.1	28.9	38.6	32.5	13.9	**228.6**	**3.8**
Decomposition of Compost		0.0	0.0	151.4	30.8	20.1	48.8	**251.0**	**4.1**
N2O Emissions		4.7	3.1	7.0	0.0	1.6	3.2	**19.5**	**0.3**
Total	t CO2-eq	87.2	35.2	187.3	69.4	54.2	65.9	**499.1**	**8.2**
Total Carbon Emissions	t CO2-eq	117.3	187.0	351.4	89.1	70.4	83.7	**898.9**	**14.8**
	per ha	13.5	13.5	12.6	27.0	29.6	18.9	**14.8**	
Net Carbon Footprint	t CO2-eq	24.2	-127.3	-102.8	9.4	10.8	6.7	**-179.1**	**-3.0**
	per ha	2.8	-9.2	-3.7	2.8	4.5	1.5	**-3.0**	