



A Business Case for Integrating a Hazelnut Orchard into an Existing Arable Farm

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Executive Summary

The New Zealand arable farming industry faces a number of issues as it attempts to remain profitable in a world of increasing public scrutiny and environmental regulation.

This report investigates whether the integration of a hazelnut orchard into an existing Canterbury arable farm could provide:

- A profitable alternative to other common arable crops;
- A lower nitrate-N leaching profile than other common arable crops thereby bringing down the overall leaching profile of a farm; and,
- An opportunity to sequester carbon on-farm in order to offset the charges associated with agricultural greenhouse gas emissions that will be in place from 2025 onwards.

The New Zealand hazelnut industry is small but has an enthusiastic grower base. Approximately 400ha of hazelnuts are planted across New Zealand. Production and profitability from these orchards has been low when compared to international production and when compared to New Zealand trial data. Low production and profitability are likely due to the choice of the high quality but low yielding cultivar 'Whiteheart' in the majority of New Zealand hazelnut orchards.

Internationally, gross margin returns from well-managed hazelnut orchards can be in excess of \$5,000/ha. New cultivars that have been bred internationally such as 'Jefferson' show significant promise in terms of high yield and nut quality. If international production can be replicated in New Zealand then hazelnuts offer a significantly higher gross margin than most common arable crops. Modelling has shown that income from a hazelnut orchard is highly sensitive to both price and yields, however a gross margin of \$4,375/ha can be achieved after 12 years. The NPV and IRR of a hazelnut orchard are calculated to be \$10,987/ha and 10% respectively.

There is a widely held view by the public and Central Government that excessive nitrate-N leaching and the subsequent pollution of freshwater are no longer acceptable. Hazelnuts use low quantities of nitrogen fertiliser when compared to most common arable crops. The average Canterbury arable farm leaches approximately 50kgN/ha/yr. Modelling in Overseer shows a hazelnut orchard may leach approximately 7kgN/ha/yr. This makes hazelnuts an appealing option especially in catchments where nitrate-N leaching is capped or where reductions have been mandated by regional councils.

The He Waka Eke Noa climate agreement which was established in 2019 will introduce a pricing mechanism for agricultural greenhouse gas emissions by 2025. This mechanism will likely allow for emissions to be offset by on-farm carbon sequestration and planting of orchards may be an allowable component of this agreement. Using ETS pricing as a proxy tool, this report calculated the approximate income (in the form of a cost offset) that a hazelnut orchard could provide to an arable farmer. The result being that the carbon income from a hazelnut orchard would be negligible (\$5-\$50/ha/yr) and therefore the offsetting of greenhouse gas emissions would not be a reason for planting a hazelnut orchard.

Planting an orchard is a significant commitment, particularly in terms of opportunity cost, as the success of the orchard will not be able to be determined until at least 10 years after establishment. For this reason, farmers need robust data to ensure they are making a well-informed decision. Therefore, it is recommended that further research is conducted in the following areas:

- Optimum fertiliser quantities and timings;
- Actual yields that are currently being achieved in New Zealand; and,
- How higher yielding international varieties perform at scale in New Zealand soils and in the New Zealand climate.

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George Lilley – March 2021

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List of Acronyms

ASHS	American Society for Horticultural Science
Cv.	Cultivar
DFM	Drainage Fluxmeter
ECan	Environment Canterbury
EBIT	Earnings Before Interest and Tax
ETS	(New Zealand) Emissions Trading Scheme
FAR	New Zealand Foundation for Arable Research
Ha	Hectare
HGANZ	Hazelnut Growers Association of New Zealand
HWEN	He Waka Eke Noa – A Climate Change agreement between industry and government
ICCC	(New Zealand) Interim Climate Change Committee
IRR	Internal Rate of Return
MPI	Ministry for Primary Industries
N	Nitrogen
NDC	Nationally Determined Contribution
NES	National Environmental Standard
NPV	Net Present Value
NZU	New Zealand Unit (In the Emissions Trading Scheme)
WACC	Weighted Average Cost of Capital

1 Introduction

Arable crops are produced on 180,000 hectares of land around New Zealand with the bulk of production centred in the Canterbury, Southland, Manawatu, Hawke's Bay, Wairarapa and Waikato regions. The industry accounts for \$260m in export sales each year, whilst underpinning New Zealand's \$20 billion livestock industry by providing seed for pasture, grain and silage for supplementary animal feed, and land for winter grazing and finishing. In total, the arable industry accounts for \$2.1b of direct and indirect spending in New Zealand (FAR, 2020).

Arable farms are typically owner-operated and in 2012 had an average size of 269ha (Statistics New Zealand, 2012). These farms produce a range of grains and seeds, and often graze lambs, beef cattle or dairy cattle. Although every farm is different and a number of significant challenges face the industry there are three issues common to all arable farmers that will increasingly affect them in the near future;

- The ability to generate strong cash income and keep costs low to maintain profitability in the absence of large capital gains on land;
- Public and regulatory pressure on the use of nitrogen fertilisers losses due to their impact on the environment; and,
- The pending introduction of a pricing mechanism to charge for greenhouse gas emissions.

The aim of this report is to investigate the business case for planting a permanent hazelnut orchard on an existing arable farm so as to insulate the business against these issues. It will test the hypothesis that a nut crop, such as hazelnuts, could be profitable when compared against other arable crops, reduce the overall nitrogen leaching profile of a farm and sequester carbon on-farm in order to offset against emissions from other crops. The business case is set in a Canterbury arable farming context using typical Canterbury figures for profitability, nitrogen leaching and greenhouse gas emissions.

While this report will focus on hazelnuts, the intention is that it will also provide a framework for analysing any new permanent tree crop for integration into an existing arable farm.

Excluded from the scope of this investigation are the following:

- The potential for further processing of hazelnuts, as it is assumed they will be produced as an in-shell product and delivered to a local processor.
- A market study. This investigation assumes a price of \$4/kg for in-shell nuts that can be realised over the short-medium term.

2 The New Zealand Arable Industry

Agriculture is a significant contributor to the New Zealand economy and arable production is a major part of this contribution. Arable production refers to everything that is grown and harvested as a crop. This includes all grains, seeds and other plants, such as cereals and maize for silage and seeds of other crops such as fodder crops (Robertson & Hurren, 2018).

The value of total direct sales of arable production in 2018 was \$781 million. When indirect expenditure by suppliers to the industry and induced expenditure by employees of producers and suppliers is taken into consideration arable production supported \$2.1 billion of expenditure (Robertson & Hurren, 2018).

New Zealand arable production is centred on the Canterbury region although significant production also occurs in the Manawatu-Wanganui, Hawke's Bay, Gisborne, Bay of Plenty and Waikato regions. In 2011, 88% and 65% of the total wheat and barley areas, respectively, were planted in Canterbury. Dominance of Canterbury in the herbage and vegetable seed industry is even greater; about 90% of production is based in this region (Millner & Roskrige, 2012).

Historically, research in the arable industry has been focussed on increasing profits primarily by increasing crop yields through improved cultivar breeding and advances in agrichemical and fertiliser products. In recent years research has evolved to focus not just on yield but on profitability without negative environmental consequences:

"FAR's focus has changed over time, reflecting the needs of growers, industry and New Zealand as a whole. While initial research was aimed at identifying and fine-tuning tools and methods for increasing yields of key crops, today it is recognised that more isn't necessarily better...that often growing more costs more, financially and environmentally. The focus has shifted towards efficiency, profitability and environmental responsibility. Rather than looking for ways to increase yields, researchers are now seeking tools and methods which will allow our growers to keep being the best in the world and maintain business profitability, without compromising their soils or the wider environment". – Anna Heslop (FAR, 2020).

3 Suitability of Hazelnut Trees for Commercial Production in Canterbury

3.1 Introduction

The aim of this section is to establish whether Canterbury has suitable soils and a suitable climate for the growth of a commercial hazelnut orchard.

3.2 Hazelnut Growing in New Zealand

Hazelnuts have been grown commercially in New Zealand since the 1980s, and currently, orchards are present in regions from Waikato to Southland (Redpath, Introduction to Growing Hazelnuts in New Zealand, 2016).

The Hazelnut Growers Association of New Zealand (HGANZ) is an industry group created by growers and enthusiasts that enables the sharing of knowledge and experience, in addition to fostering the growth of the New Zealand hazelnut industry.

HGANZ have produced a series of detailed documents pertaining to commercial hazelnut growing in New Zealand:

- Bulletin 1: Introduction To Growing Hazelnuts in New Zealand
- Bulletin 2: Hazelnut Varieties
- Bulletin 3: Flowering and Pollination
- Bulletin 4: Nut Development and Quality
- Bulletin 5: Establishment
- Bulletin 6: Orchard Management
- Bulletin 7: Harvesting

These are recommended reading in order to quickly and easily understand all aspects of establishing and operating a hazelnut orchard in New Zealand. These reports summarise that hazelnuts can be grown commercially in New Zealand if orchards are established and managed well.

3.3 Climate and Soils

In a small feasibility study on growing nut trees in North Canterbury, MacDonald (2009) provides a brief summary of the climatic and agronomic requirements for hazelnut trees:

Hazelnuts are generally frost-hardy to around -14°C, although the flowers and catkins can be vulnerable to frosts of -8°C or lower for a short period in early winter. The trees can also suffer from overheating and sunburn in hot summer weather, so shelter is required. Dry autumn weather makes harvesting easier and harvest date more flexible.

Hazelnuts tolerate a wide range of soils, but for optimal production a relatively fertile soil which holds moisture but does not become waterlogged is required. At least 30 cm of topsoil (ideally 60 cm) which is rich in organic matter is desirable. Hazelnuts require plentiful water during hot months, so stony or sandy soils present a challenge in maintaining an adequate soil moisture level in summer if irrigation is not present. Soil nutrient tests are required to determine any nutrient deficiencies and soil should be neutral to slightly acidic (pH 6).

3.4 Shelter

Hazelnuts are easily damaged by strong winds, so good shelter is essential especially in windy areas such as Canterbury. Shelter can be planted before the orchard trees and allowed to become well established before planting the hazelnuts two or three years later. If hazelnut trees are not suitably sheltered strong winds may cause trees to be: 1) weaker overall; 2) more vulnerable to pests and diseases; and, 3) branches may break and

make pruning more difficult later. Poplars and Alders make good shelterbelts as they are fast growing deciduous species that will grow to 15~30 meters tall.

3.5 Pest and Diseases

Hazelnut trees are known to be impacted by the Big Bud Mite - a mite that reduces the amount of productive growth on a tree and hence crop yields from that tree. Some cultivars show more resistance to Big Bud Mite than others. Small infestations can be controlled by removing affecting buds and destroying these.

Rabbits and Hares can damage trees during establishment and need to be controlled.

Bacterial Blight can affect young trees while establishment and appears to be worse if trees are under stress from wind or lack of water. Blight can normally be controlled by spraying with copper in the spring and autumn. The Eastern Filbert Blight has destroyed many orchards in the USA.

New hazelnut varieties, such as the Jefferson which was recently released in Oregon, are resistant to Eastern Filbert Blight in addition to showing good resistance to Big Bud Mite (MacDonald, 2009).

3.6 Summary

The Canterbury Plains have soils and climate suitable for the establishment of a commercial hazelnut orchard provided there is suitable soil depth and the soil is not prone to waterlogging. Any soil nutrient deficiencies should be remedied before planting the orchard. There are currently several small-scale hazelnut orchards operating across the Canterbury plains.

4 The Hazelnut Industry

The objective of this section is to provide a brief summary of the international and domestic hazelnut industries.

The commercial hazelnut industry is based on selections of *Corylus avellana*, a species of wind pollinated shrubs or small trees native to temperate areas of Europe and Asia Minor. The genus *Corylus* (family Betulaceae) consists of about 9 deciduous species naturally occurring in temperate forest areas across Europe, the Middle East, Asia, and North America (Redpath, Introduction to Growing Hazelnuts in New Zealand, 2016).

International hazelnut production between 2005 and 2007 was 831,653t (Fideghelli & De Salvador, 2009). The global market for hazelnuts was estimated at US\$6.5 Billion in the year 2020 and is projected to reach US\$8.2 billion by 2027, representing a compounding annual growth rate of 3.4% over this period (GlobeNewsWire, 2021).

Globally, New Zealand is an insignificant producer. In 2007, New Zealand produced approximately 100 tonnes of hazelnuts from 400ha of trees. This represents approximately 0.012% of global production. This is forecast to increase as younger trees mature and reach full production (Redpath, Introduction to Growing Hazelnuts in New Zealand, 2016). According to the Food and Agriculture Organisation of the United Nations global hazelnut production is dominated by Mediterranean countries with Turkey producing 70% of global nuts followed by Italy with 20% (United Nations FAO, 2021).

4.1 Summary

The international hazelnut industry is significant and is experiencing year-on-year growth. The New Zealand hazelnut industry is minor on a global scale, however research shows strong yields and good nut quality can be produced in New Zealand.

5 Canterbury Arable Farming Profitability

5.1 Introduction

The purpose of this section is to understand the typical profitability of a Canterbury arable farm. Further in this report (Section 10) is a discussion of profitability of hazelnut orchards for comparison.

The typical Canterbury arable farm produces a range of grains and seeds and usually grazes a combination of lambs and/or cattle. Every arable farming business has a combination of different soils, climate, crop types grown, crop rotation patterns, pest and disease issues, grazing practices and management practices, as well as different ownership structures and shareholder risk appetites. This makes it difficult to compare the financial performance of even two adjacent farms which appear to be broadly similar.

This section discusses the literature available for an arable farming business to compare the profitability of different crops. Further in this report a financial model will be created for the planting of a hazelnut orchard on an existing farm and its profitability will be referenced back to this data to see how the orchard compares to the profitability of commonly grown crops.

5.2 Gross Margin

A measure of profitability for different crops is gross margin which is calculated as follows:

$$\text{Gross Margin} = \text{gross revenue for a crop} - \text{gross expenses directly attributed to that crop}$$

Provided gross margin is calculated consistently this is an excellent measure for comparing the profitability of different crops in the same operation. There are significant limitations when comparing gross margins between two different businesses as gross margin does not take into account a number of factors including fixed overheads and business debt levels. Further, the choice of a crop in a rotation is not purely based on gross margin as there are other factors that must be considered such as forage quality, disease, weed and timing issues.

5.2.1 Farm Consultant Report

A reputable Canterbury farm consultant produced a comprehensive report detailing gross margins for 6 commonly grown crops in Canterbury:

Crop	Gross Margin (\$/ha), Average – High Yields
Feed Barley	\$1,089-\$1,997
Ryegrass Seed (common variety)	\$2,204-\$3,458
Garden Peas	\$942-\$1,213
Open Pollinated Radish	\$1,547-\$2,272
Winter Milling Wheat	\$1,414-\$2,405
White Clover (common variety)	\$1,292-\$2,871

If these values are averaged the range of gross margin achieved is **\$1,415-\$2,036**. It must be stressed that this is not a statistically valid analysis however is broadly accurate for comparison purposes.

5.2.2 Personal Experience

The authors personal experience recording gross margins for several different crops broadly agrees with the figures above.

5.3 Summary

There is limited accurate and comparable arable farming profitability data publicly available, likely due to the bespoke nature of every farming operation. The two data sources discussed give a broad gross margin range of **\$1,415-\$2,036/ha**.

6 Climate Change Commitments in New Zealand

This objective of this section is to understand the potential impacts and costs on arable farms due to greenhouse gas emissions.

6.1 Introduction

Since 1992 New Zealand has made climate change commitments under the United Nations Framework Convention on Climate Change, the Paris Agreement, and the Kyoto Protocol.

As a country New Zealand has several greenhouse gas emissions reduction targets (MfE, 2021):

New Zealand's international targets are:

- 5 per cent reduction below 1990 gross emissions for the period 2013-2020;
- 30 per cent reduction below 2005 (or 11 per cent below 1990) gross emissions for the period 2021-2030.

New Zealand's domestic targets are:

- Net zero emissions of all greenhouse gases other than biogenic methane by 2050. This is known as the Climate Change Response (Zero Carbon) Amendment Act;
- 24 to 47 per cent reduction below 2017 biogenic methane emissions by 2050, including 10 per cent reduction below 2017 biogenic methane emissions by 2030.

6.2 New Zealand Emissions Trading Scheme (ETS)

The New Zealand Emissions Trading Scheme (NZ ETS) is the Government's main tool for meeting domestic and international climate change targets. The scheme aims to encourage people to reduce greenhouse gas emissions. The NZ ETS puts a price on greenhouse gas emissions and creates a financial incentive for:

- Businesses to reduce their emissions;
- Landowners to earn money by planting forests that absorb carbon dioxide as the trees grow.

One emission unit, the New Zealand Unit, represents one metric tonne of carbon dioxide or carbon dioxide equivalent (i.e, the amount of another greenhouse gas that does as much damage as one tonne of carbon dioxide) (MfE, 2021).

The ETS works by forcing polluters to pay a price for their emissions, whilst paying a credit to owners of "carbon sinks" like forests (Coughlan, 2019).

The NZ ETS covers the following industries:

- forestry (a net sink);
- energy (42% of total 2012 emissions);
- industry (7% of total 2012 emissions); and,
- waste (5% of total 2012 emissions).

Importantly, the scheme excludes pastoral agriculture (46% of 2012 total emissions) (MfE, 2014).

6.3 The Agricultural Industry and Climate Change Commitments

6.3.1 Exclusion of Agriculture from the ETS

In 2008 no country had previously attempted to include agriculture in an emissions trading system (Kerr & Sweet, Inclusion of Agriculture in a Domestic Emissions Trading Scheme: New Zealand's Experience to Date, 2008) and as of 2020 New Zealand is currently the only country actively considering a compulsory emissions price on biological greenhouse gas emissions from agriculture (MfE, 2020). New Zealand is still wrestling with how to price agricultural emissions given their large contribution to New Zealand's overall emissions - 48% of New Zealand's gross greenhouse gas emissions in 2018, (Figure 1) (MfE, 2021) 92 per cent of which are methane and nitrous oxide emissions from livestock and approximately 6 per cent from nitrogen fertiliser (MfE, 2019). Agriculture has previously avoided inclusion in the ETS for the following reasons:

- The difficulties in measuring and monitoring agricultural emissions. The New Zealand Agricultural Greenhouse Gas Research Centre has produced a comprehensive report detailing the methods and associated challenges of measuring agricultural emissions (NZAGRC, 2015);
- The limited technologies available for reducing emissions in the sector; and,
- The risk of leakage (if emissions were to increase overseas due to New Zealand implementing policies to reduce its domestic emissions). New Zealand is an efficient producer of high-emission agricultural products and because New Zealand is among the most efficient producers in the world, any movement of production is likely to lead to higher emissions intensity elsewhere in the world (Kerr, Agricultural Emissions Mitigation in New Zealand: Answers to Questions from the PCE, 2016).

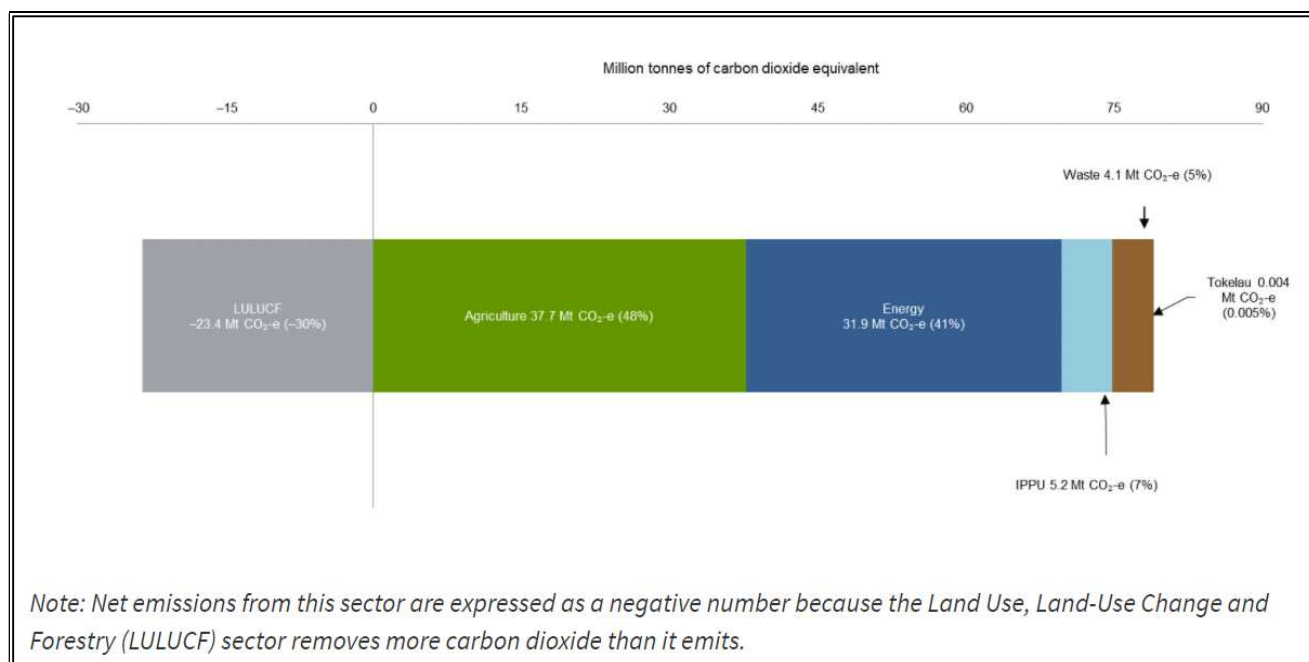


Figure 1 - New Zealand's Emissions Profile in 2018 (MfE, 2021)

6.3.2 He Waka Eke Noa (HWEN)

In 2018 the Government asked the Interim Climate Change Committee (ICCC) to look into options to reduce agricultural emissions. Recommendations from the ICCC's work along with conversations with leaders in the agriculture sector led to the creation of the Action on Agricultural Emissions Discussion Document. Consultation on this document closed in August 2019.

These reports and the submissions made on them led to the government to decide to put a price on agricultural emissions from 2025. Pricing will be at farm level for livestock and at processor level for fertiliser (MfE, 2021). What these pricing mechanisms will exactly look like is unclear and it is the role of the He Waka Eke Noa steering group to establish this.

There are 11 key agriculture sector organisations working together under He Waka Eke Noa. These include Māori agribusiness interests and two government departments. A Steering Group has been appointed by the Government and the Food and Fibre Leaders Forum to provide oversight and ensure delivery for farmers and growers.

If the government is not satisfied with the sector's progress there is a backstop option to bring the agricultural sector back into the ETS. Under the backstop option, fertiliser emissions (charged at a processor level) and livestock emissions (charged at a farm level) would be brought back under the ETS (Devine & Dent, 2019). Emitters would receive a 95% discount, or 'free allocation of emissions units' so the initial cost would be minor but the discount would likely reduce over time increasing the cost to farmers.

6.3.3 'Netting off' of Carbon Emissions in He Waka Eke Noa

One of the concepts under discussion as part of HWEN is to allow farmers to reduce their greenhouse gas liability is 'Netting Off' their greenhouse gas liability. This means carbon sequestration sinks such as soil and shelterbelts could be offset against their greenhouse gas emissions liability if or when farmers are charged for their emissions. Netting off is of interest to farmers because it allows them to take a holistic approach for all their emissions and think about their farm as a single unit (Burrows, et al., 2018).

6.4 Conclusion

Although largely avoiding costs associated with greenhouse gas emissions up until 2021, arable farmers and the agricultural industry in general will almost soon face financial disincentives for emitting greenhouse gases. The form this will take is not clear, however farmers will need to begin to look at methods for reducing their net on-farm emissions.

"The agriculture sector will have a key role as New Zealand transitions to a low-emissions economy. Biological emissions from agriculture contribute almost half of New Zealand's total greenhouse gas emissions, so we cannot get there without addressing these" – James Shaw, Climate Change Minister (MfE, 2019).

7 Carbon Income from Hazelnut Orchards

Given the high probability that farmers will be charged for their emissions in the near future (see Section 6 - Climate Change Commitments in New Zealand), there is value in understanding possible methods of offsetting carbon emissions or storing carbon on-farm. The purpose of this section is to investigate the quantum of the carbon that hazelnut trees sequester and the potential for a hazelnut orchard to provide a grower additional income via payment (or a reduced liability) for the carbon they sequester.

7.1 Carbon Sequestration by Trees in the NZ ETS

As trees grow, they absorb carbon dioxide from the atmosphere and store it in their trunks, branches, leaves and roots (above ground and below ground biomass). When trees are harvested, carbon that is stored is released back into the atmosphere as the wood decays (MPI, Forestry In The Emissions Trading Scheme, 2021).

The ETS has a specific definition for what a forest is to differentiate between land managed as a forest and other trees in the landscape – this is known as the ‘forest land definition’. Under this definition a forest:

- is at least 1 hectare in size;
- is mainly made up of tree species that can reach 5 metres in height in that location at maturity (**does not include trees grown primarily for fruit or nuts**, gorse, broom or native shrubs);
- has the potential to reach 30% tree canopy cover in each hectare at maturity; and,
- has the potential to reach an average tree canopy cover width of 30 metres at maturity (MPI, Introduction To The ETS For Forestry, 2021).

7.1.1 Exclusion of Fruit and Nut Trees from the NZ ETS

Nut trees, along with fruit trees and shelterbelts are classified as ‘perennial cropland’ that are primarily grown for fruit or nuts, are not considered forests under the ETS or in the GHG inventory (Burrows, et al., 2018). New Zealand adopted the GHG accounting rules of the Kyoto Protocol for its 2020 target and if New Zealand was to retrospectively include fruit and nut trees it would alter New Zealand’s carbon baseline and therefore the targets in terms of reducing emissions.

New Zealand’s first Nationally Determined Contribution (NDC) under the Paris Agreement makes it clear that any change in accounting rules would be matched by a change in its target, so that the overall level of effort to reduce emissions would not be diminished. Therefore, from a national perspective, changing accounting rules to capture a wider range of sequestration actions wouldn’t make meeting the target easier (Burrows, et al., 2018).

The only trees receiving units through the NZ ETS are those that count towards our targets (MfE, 2020). Therefore, carbon sequestration that can count toward New Zealand’s 2020 target is only sequestration from native and exotic forests planted after 1989 that meet the criteria discussed in Section 7.1 above.

It is unclear why fruit and nut trees are excluded under these international carbon accounting rules and therefore from the New Zealand ETS but what is important to farmers is that they are excluded. Interestingly, the acceptance of nut trees into the ETS in the future is not completely off the table. According to (Burrows, et al., 2018), if changing the accounting for the 2030 target made the target easier to meet, the overall ambition of that target will need to be revisited. This does not mean we should or could not change our forest accounting rule with respect of small blocks of trees and vegetation but it does mean that overall New Zealand should not benefit from any change unless we can increase the carbon stored beyond business as usual. New Zealand has reserved the right to adjust its accounting method for the 2030 target on the proviso that any adjustment does not reduce the ambition of the target (Burrows, et al., 2018).

7.2 ETS Income if Nut Trees Were Included in the ETS

Although nut trees are currently and specifically excluded from the ETS, this section seeks to investigate the potential income that a grower could receive (via offsetting against their on-farm emissions) if hazelnut trees were fully included in the ETS or another carbon accounting system in the future.

Several types of fruit and nut trees including hazelnuts, if grown in an orchard of a suitable size, meet all of the dimensional criteria of the ETS (i.e. over 1ha area, 30% canopy cover, over 30m wide and over 5m high). Several varieties have been successfully grown to heights of over 8m in New Zealand (Redpath, Wairata Forest Farm Profile, 2019). It is important to note that trees of this height may not be optimum for nut production. Hazelnuts planted in NZ orchards easily reach 30% canopy cover and the dimensional metrics of 1ha and 30m wide are easily achieved.

For ETS eligible forests, an emissions return must be completed in order to receive income. To complete an emissions return, the age, area and rate of sequestration of the vegetation is required. If the participant has less than 100 hectares of eligible forest land, emissions returns must be calculated using default look-up tables that set out estimated rates of sequestration. These tables do not currently exist, except for five categories of trees:

- Pinus radiata if the predominant forest species on the land is Pinus radiata;
- Douglas-fir if the predominant forest species on the land is Douglas-fir;
- Exotic softwoods if the predominant forest species on the land is exotic softwood;
- Exotic hardwoods if the predominant forest species on the land is exotic hardwood; and,
- Indigenous forest if the predominant forest species on the land is indigenous.

It costs a participant around \$500 to register in the NZ ETS and around \$100 to have an emissions return processed. That does not include participant time to compile the information required for registration and the emissions return, including the costs of any advice sought to assist with the process. (MfE, 2020)

Pricing in the ETS is based around 'emission units'. Figure 2 demonstrates how emissions units (NZUs), colloquially known as carbon credits, are traded.

One emission unit, the New Zealand Unit (NZU), represents one metric tonne of carbon dioxide or carbon dioxide equivalent (ie, the amount of another greenhouse gas that does as much damage as one tonne of carbon dioxide).

The Government gives eligible foresters units for carbon dioxide that is absorbed by their trees. The foresters can sell these units on the NZ ETS market. Businesses with surrender obligations (legal obligations to hand over units) must purchase enough units to cover their emissions. These units are then surrendered to the Government.

For example, a business emitting 2,000 tonnes of greenhouse gases would need to purchase 2,000 emission units on the NZ ETS market. If the emitter reduced their emissions by 500 tonnes of greenhouse gases they would only need to purchase and surrender 1,500 units.

Figure 2 - How the New Zealand ETS Works (MfE, 2021)

7.2.1 'Netting off' of Carbon Emissions

Any income to a farmer would likely not be in the form of an actual cash payment, rather a reduction in the greenhouse gas liability if or when farmers are charged for their emissions (assuming they are still a net emitter – i.e. emissions are greater than sequestration). This concept is known as 'Netting off'.

7.2.2 Literature on Carbon Sequestration by Hazelnut Trees

Carbon sequestration is the process by which carbon dioxide is absorbed during photosynthesis, and is stored as carbon in biomass (trunks, branches, foliage, and roots). Gains in forest carbon stocks through growth and sequestration will reach a maximum level over time, and are eventually offset by carbon losses through harvesting, thinning, and natural decay. (NZFOA, 2021).

There is no literature on carbon sequestration by hazelnut trees in New Zealand. International literature is sparse, inconsistent, and is difficult to compare sequestration rates. There is plentiful data on sequestration rates of Pinus Radiata trees so in order to get an approximate measure of the sequestration the author has assumed a hazelnut tree has a similar relative growth rate as a Pinus Radiata, however in any given year is 5% of the size therefore has sequestered 5% of the carbon of Pinus Radiata.

7.2.3 Carbon income using Pinus Radiata as a Proxy

As of 2023 a new concept for accounting for carbon in Pinus Radiata forests known as Averaging will be compulsory. 'Averaging' can be defined as a carbon accounting method in which an ETS participant receives carbon credits that are equivalent to the long-term average level of carbon storage in the forest across multiple rotations. It is expected that Pinus radiata forests that are harvested within a normal age bracket will receive carbon credits equivalent to 17 years' worth of carbon sequestration (Interpine Innovation, 2020).

Simply put, a forest owner will receive carbon credits in line with the carbon sequestered in a pine forest up to the age of 17 years. From this point as long as the forest is continually cropped across multiple rotations the owner will not receive any additional credits from the age of 17 years until harvest however will not have any liability to pay back credits when the forest is harvested. This is demonstrated in Figure 3 below.

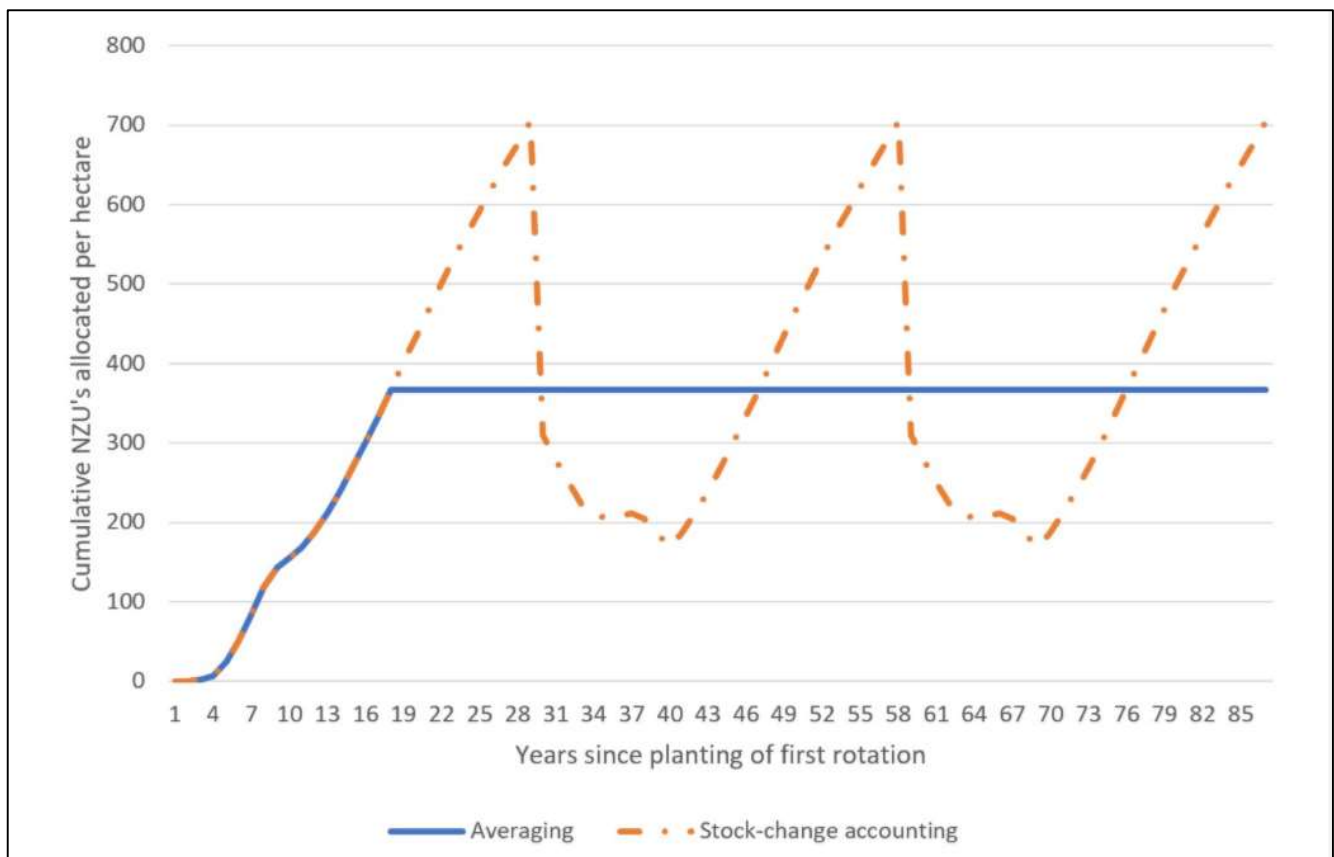


Figure 3 - Comparison of averaging and stock-change accounting in Pinus Radiata Forest (Interpine Innovation, 2020)

Using the data in the chart above and the following assumptions:

- a hazelnut tree is 5% the size of a Pinus Radiata tree and is planted at the same density;
- a hazelnut tree has a similar growth curve to a Pinus Radiata tree;
- the orchard will be continuously cropped (i.e. once the trees reach the end of the commercial life they are replanted); and,
- At 17 years a pinus radiata orchard has sequestered 370 t CO₂e.

It is possible to develop a picture of the potential carbon income from a hazelnut orchard (Table 1):

Table 1 - Possible Carbon Income from a Hazelnut Orchard at Different Carbon Prices

Carbon Price (\$/NZU)*	Value in Pinus Radiata Forest (after 17 years)	Value in Hazelnut Forest (after 17 years)	Value in Hazelnut Forest if 95% of carbon credits refunded
\$20	\$7,400	\$370	\$18.50
\$30	\$11,100	\$555	\$27.80
\$40	\$14,800	\$740	\$37.00
\$50	\$18,500	\$925	\$46.25

*At the time of writing (Feb 2021) the NZU price was approximately \$40/unit.

7.2.4 Summary

Fruit and nut trees are currently not included in the ETS. There is limited research on carbon sequestration rates of hazelnut trees, however some proxy modelling using *Pinus Radiata* has determined that if hazelnut trees were included in the ETS, carbon returns from an orchard would be extremely low and for a 10ha orchard would not offset the costs of registering for the scheme.

8 Nitrogen Use in Arable Farming

The purpose of this section is to:

1. Understand how nitrate leaching issues and subsequent nitrate leaching restrictions will restrict land-use in Canterbury arable farms into the future; and,
2. Give typical nitrate-N leaching values for a Canterbury arable farm. Nitrate leaching is expressed as kgN/ha/yr lost to the environment.

8.1 Nitrogen Leaching in Canterbury

8.1.1 What is Nitrate Leaching?

According to (ECan, 2020):

- Nitrate is a chemical made of nitrogen and oxygen (NO_3^-). It occurs naturally in soil, where it is a major source of nitrogen for plants, helping them grow.
- When the soil contains more nitrate than plants can use, the excess can be washed through the soil by rainwater and carried into the underlying groundwater. This is known as nitrate leaching.
- If groundwater feeds springs that flow into streams or lakes, the nitrate can cause excess weed growth, algal blooms, and toxicity for fish and invertebrates.
- If groundwater is used as a source of drinking water, the nitrate can pose a health risk to some people.

The two key factors which determine the magnitude of leaching loss are the amount of drainage that occurs through the soil and the concentration of nitrate-N in the soil solution (Norris, et al., 2020).

Nutrients like nitrate feed periphyton growth which consumes the oxygen in a waterbody and effectively suffocates any aquatic life within it. (Harris, 2018).

Between 1994 and 2016, freshwater quality in many New Zealand catchments has declined. Levels of contaminants indicative of diffuse discharges generally increased, while levels of contaminants indicative of point source discharges, such as industrial or sewerage discharges, were generally found to decrease. Nitrogen, phosphorus and sediments from agricultural land can be lost to surface waterways through run-off, where contaminants, such as fertiliser or animal waste on the paddock, are transported by rainfall or irrigation into waterways on the property. (Harris, 2018).

8.1.2 Government Response to Nitrate Leaching Issues

In 2014, the New Zealand government issued a National Policy Statement for Freshwater Quality (NPSFW), requiring all regional authorities to implement changes which “maintain or improve” overall water quality as well as encourage “the adoption of best practicable option to prevent or minimise any actual or potential adverse effect on the environment of any discharge of a contaminant into freshwater or onto or into land in circumstances that may result in that (or, as a result of any natural processes from the discharge of that contaminant, or any other contaminant) entering freshwater” (MfE, 2014).

Although individual regional councils had previously capped nitrogen usage, the new provisions under the NPSFW were the first time these types of provisions have been applied on a national scale (Harris, 2018).

More recently, on 3 September 2020, the National Policy Statement for Freshwater Management 2020 came into force where local authorities are required to give effect to the NPSFW along with three additional documents (MfE, 2020) :

- National Environmental Standards for Freshwater (NES);

- Stock exclusion regulations; and,
- Water measurement and reporting regulations.

These documents contain additional, stricter standards than the 2014 NPSFW that farmers and regional councils must meet with respect to water quality and continue a pattern of government legislation which aims to improve freshwater health and increases monitoring requirements.

8.1.3 Canterbury Response to Nitrate Leaching Issues

According to Environment Canterbury (ECan, 2020), over the past 10 years the Canterbury Water Management Strategy, Canterbury Land and Water Regional Plan and sub-regional updates have started to address the problems caused by land-use intensification. Some of the impacts of these new rules are only starting to take effect with respect to improving water quality and there is still significant work to be done by farmers, industry and Environment Canterbury in coming years. In the meantime, nitrate concentrations will continue to cause problems in spring-fed streams and lakes for some years yet (ECan, 2020).

Figure 4 details a number of actions have been taken by ECan in Canterbury to stop nitrate increase and improve water quality.

1. We put controls on land-use activities that could threaten water quality. For example, we control land use to the west of Christchurch (where most of the Christchurch groundwater recharge rainfall lands) to protect the city's drinking water supply. Much of this area is used for very low intensity stock grazing and recreational parks.
2. We have introduced some of the strictest farming rules in the country to help address water quality issues and, over time, deliver the improvements needed to protect our water.
3. This includes requiring farmers to operate within strict nitrogen leaching limits and adhere to industry agreed good management practices.
4. Higher-risk farming types are now required to measure and manage nitrogen leaching via a consent to farm. They are also required to have a Farm Environment Plan and their performance against this plan is graded by independent auditors as part of Environment Canterbury's compliance programme.
5. Farmers are required to work hard to reduce their impact on the environment, including fencing off waterways and planting along stream margins.
6. Very few dairy conversions have been allowed in Canterbury in recent years. For farmers outside irrigation schemes, all the conversions and herd size changes have been made within allowable nitrogen loss rates, meaning the farmer has made environmental improvements to mitigate any additional nitrogen loss.

Figure 4 - ECan Actions to Improve Water Quality (ECan, 2020)

8.1.4 Summary

There is significant data detailing the link between excessive nitrogen in agricultural soil and degradation of freshwater in adjacent lakes, rivers and groundwater. At central and regional governance levels there are, and will be, further expectations that all farmers reduce their nitrate-N losses to the environment. What exactly this will look like depends on a number of factors including water quality in a given catchment, soil type, and land use, however there is a notable trend towards regulators applying pressure to encourage farmers to: a) apply less nitrogenous fertiliser; and, b) emit less pollutants, particularly nitrate, to the environment.

8.2 Typical N Losses for Canterbury Arable Farms

8.2.1 Introduction

Every arable enterprise in Canterbury, although broadly similar, will have different N loss characteristics. This is due to the range of crops grown, types and numbers of animals grazed, variation in management practices and variation in soil and climate. This makes it difficult to determine 'typical' figures of N loss for individual arable farms, however a range of methods are used and these are discussed below.

8.2.2 Literature

Few data sets exist in NZ that describe mineral-N losses from arable systems over multiple seasons and across multiple crop sequences. Even fewer exist where losses have been quantified using measurements of both drainage and N concentration (Norris, et al., 2020).

(Thomas, Francis, & Ledgard, 2005) provide some modelled estimates of N leaching losses from "typical" cropping rotations in Canterbury. Over the whole rotation, the average N leaching loss estimated by the Overseer model was c. 48 kg N ha⁻¹ year⁻¹. This report further breaks down the N leaching losses from 6 different crops and this is displayed in Figure 5. Note the IPCC bars in Figure 5 show the N leaching losses using an alternative calculation from the Intergovernmental Panel on Climate Change (IPCC) calculations. Overseer is the accepted model for calculating N leaching losses in New Zealand and this is discussed further in Section 8.2.3. The difference between the models is beyond the scope of this report and will not be discussed here.

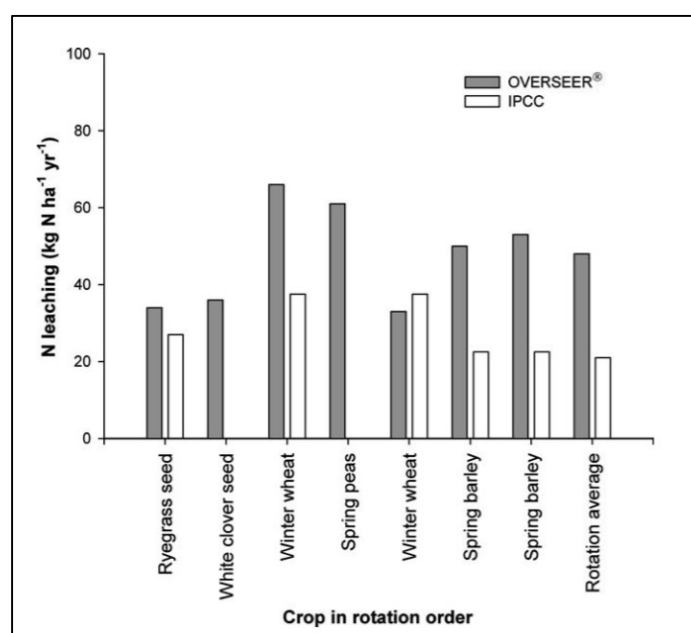


Figure 5 - Comparison of average annual N leaching estimates for a 'typical' arable cropping rotation system using the OVERSEER

(Norris, et al., 2020) summarises a number of previous studies and gives values of 14 to 110 kg N/ha/year of mineral-N losses in drainage from NZ mixed cropping or arable systems. This report further details the difficulty in accurately measuring N losses in arable systems noting that:

"the range in observed losses reflect the different factors which drive drainage and soil N fertility, including weather conditions (especially rainfall), soil physical and chemical properties, site attributes (e.g. slope and surface hydrologic conditions), grower

management practices (e.g. fertiliser use, irrigation, cover crops, cultivation techniques, crop sequences) and crop uptake demands”.

8.2.3 Overseer Modelling

Since the implementation of the NPSFM in 2014, many regional councils have chosen to use Overseer to set limits for nutrient losses to groundwater and surface water and to improve the efficiency of fertiliser use (Harris, 2018). Overseer has been accepted by the Environment Court for use by councils in regional plans to manage nitrogen losses (Upton, 2018).

Overseer was developed in New Zealand by AgResearch and incorporates 30 years of science model development. It produces nutrient budgets and helps farmers understand how nutrients are cycled on different parts of their farm. The software combines data on farm management, topography, soil, and climate to determine nutrient losses and greenhouse gas emissions (MPI, 2020).

Overseer can be used to assess nutrient losses for dairy, sheep and beef, dairy goats, deer, outdoor pigs, kiwifruit, viticulture, and a range of vegetables and arable crops. It can assess a mixed farm system that includes any of these different enterprises. It is owned by the Ministry for Primary Industries, the Fertiliser Association of New Zealand, and AgResearch Limited and is licenced to Overseer Limited who deliver the OverseerFM service (MPI, 2020).

Overseer is a largely empirical model, which has mechanistic components that have been fitted to match data that has been collected in the field. This means it relies on calibration – a process that fine-tunes its parameters using experimental data (Upton, 2018). Pastoral blocks within Overseer are the most calibrated. In comparison, crop blocks in Overseer are based on a limited body of research and not all crops grown by horticultural and arable enterprises are currently represented in the model (Upton, 2018). Table 2 shows the lack of calibration of the Overseer model for several management blocks including arable land use.

Table 2 - Calibration Extent of Overseer (Upton, 2018)

Management block	Nitrogen calibration	Phosphorus calibration
Pastoral	Calibration (undertaken in 2012) used nutrient loss measurements from farmlet studies at eight locations. These were: Edendale, Southland (intensive beef); Tussock Creek, Southland (dairy); Kelso, Otago (dairy); Lincoln University Dairy Farm, Canterbury (dairy); Massey University Dairy Farm, Manawatu-Whanganui (dairy); Ruakura, Waikato (dairy); Scott Farm, Waikato (dairy); and Wharenui, Bay of Plenty (dairy). A recalibration exercise is currently underway.	Calibration (undertaken in 2005) used data from 23 sites: Canterbury (2), Otago (3), Southland (2), Manawatu (5), Northland (2), Waikato (4), West Coast (2), Wellington (1), Hawkes Bay (2).
Crop	Arable crops – very limited calibration (one Lincoln site).	Arable crops – none due to a lack of experimental sites. Forage crops – limited to 2 sites in Otago and 1 in Southland.
Fruit crop	None due to a lack of experimental sites.	None due to a lack of experimental sites.
Trees and scrub	None due to a lack of experimental sites.	None due to a lack of experimental sites.
Wetlands and riparian	Very limited calibration based on published studies.	Very limited calibration based on published studies.
House	Very limited calibration (based on one international study).	None.

8.2.4 Fluxmeter Research

According to (Norris, et al., 2020) the most accurate means of quantifying nitrate losses is to capture drainage from below the crop rootzone. One option for doing this is with the use of drainage fluxmeters (DFMs).

Research by (Norris, et al., 2020) involved the installation of a network of DFMs between August 2014 and June 2016 on twelve commercial cropping farms around New Zealand.

From this research it was determined that annual nitrate-N losses (the predominant form of mineral N) averaged 79 kg/ha/yr for mixed cropping (n=2) and 54 kg/ha/yr for mixed cropping with livestock grazing (n=8) however across individual sites in the trial results varied widely – by 17–163 kg-N/ha/yr (Norris, et al., 2020).

8.2.5 Personal Experience

Under irrigation schemes in Canterbury nutrient budgets must be produced periodically (usually every 1-3 years) and presented to the scheme. This is required as part of their consent with ECan. From the authors personal communications with arable farmers in the Mid-Canterbury region the following anonymous data has been collected (Table 3).

Table 3 - Overseer N Leaching Rates for Mid-Canterbury Arable Farmers

Farm	N Leaching (kgN/ha/yr)
Farm A	71
Farm B	61
Farm C	83
Farm D	35

8.2.6 Summary

Calculation of nitrate N leaching losses from arable farms is difficult due to the bespoke nature of each operation. Overseer is poorly calibrated as a tool for calculating nitrate N leaching losses on arable farms and large numbers of arable crops are not modelled in Overseer. Despite this, it is likely to be the default tool used moving forward and will improve as more data is gathered. Nitrate N leaching data from several sources broadly agrees that a typical arable farm over the long-term leaches approximately 50kgN/ha/yr and this value will be used for comparisons in this report.

9 Nitrogen usage in Hazelnut Orchards

9.1 Introduction

The purpose of this section is to understand typical nitrogen usage and subsequent nitrate-N leaching in hazelnut orchards in order to obtain optimal yields. This will then be compared with the data discussed in Section 8.2 (Typical N Losses for Canterbury Arable Farms) to establish if hazelnuts offer an attractive option for reducing nitrate-N leaching on an arable property.

No (scientific) research has been undertaken on nitrogen requirements for Hazel Orchards in NZ (Redpath, Personal Communication, 2021) however data from international studies and anecdotal data on nitrogen usage from New Zealand growers can be used in order to understand the N required to grow successful crops in New Zealand.

9.1.1 Lake Taupo Report

In 2003 water quality deterioration in Lake Taupo led the Waikato District Council to place a nitrogen leaching cap on individual properties and the conversion of land to uses with lower N potential (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012).

In 2012 a report was produced for the Lake Taupo Protection Trust and the Waikato Branch of the Tree Crops association of NZ to investigate whether commercial hazelnut production could offer an alternative economical land use in the Lake Taupo Catchment while producing low levels of leached nitrogen (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012).

The water quality in Lake Taupo and the actions taken by the Waikato Regional Council during this period can be seen as a pre-cursor to what has happened across other parts of New Zealand including the Canterbury Plains during the 2010s with respect to water quality and nitrogen use restrictions. It is likely other councils including ECan will be requesting landowners to transition to lower N-intensity farming as the rules in the recent 2019 NPSFW and NES are implemented.

The report by Redpath cites several examples of nitrogen usage in international hazelnut orchards and this is summarised in Table 4 below.

Table 4 - A summary of Nitrogen Use in Hazelnut Orchards from (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012)

Location / Source	N Usage
Oregon Orchards	183-245kg/ha/yr
Tous et al, Oregon	150-200kg/ha/yr
Ferrero Orchards in (the Country) Georgia	40-70kgN/ha/yr
Wairata Forest Farm	46kgN/ha/yr

9.1.2 Ravensdown Data

A technical note from Ravensdown in 2011 recommends that hazelnuts receive an annual application of NPK and boron fertiliser. With respect to nitrogen, it is recommended that mature trees receive 240g of ammonium sulphate each annually (Ravensdown, 2011). Ammonium Sulphate has a nitrogen content of 20% (Ravensdown, 2021) and assuming a planting density of 450 trees / ha this gives a N use of 21.6kgN/ha/yr.

9.1.3 Comparison to Other Common Arable Crops

The New Zealand Fertiliser Manufacturers' Research Association (NZFMRA) in 2012 released Managing Soil Fertility on Cropping Farms. This document details the recommended fertiliser, including nitrogen, use for common arable crops. A selection of these are summarised in Table 5 below (Nicholls, van der Weerden, Morton, Metherell, & Sneath, 2012):

Table 5 - N Requirements of a Selection of Arable Crops

Crop	N requirement (applied + background soil N)
12.5T Autumn Sown Feed Wheat Crop	330 kgN/ha
10.0T Autumn Sown Feed Barley Crop	238 kgN/ha
Perennial Ryegrass (seed yield approx. 2000kg/ha)	200k gN/ha

9.1.4 Leaching from Hazelnut Orchards

No studies into leaching from Hazelnut orchards has been found (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012).

As Overseer is the accepted model for calculating N leaching losses in New Zealand, the author has created an Overseer model to establish indicative figures for nitrate-N leaching losses from a hypothetical irrigated hazelnut orchard in Canterbury. These are displayed in Table 6 below.

Table 6 – Results Overseer Modelling of a Hazelnut Orchard

N Applications	Total N Applied (kg)	Nitrate-N Leaching/ha
Nov – 25kg, Dec - 25kg	50	5
Nov – 51kg, Dec- 51kg	102	8
Nov – 101kg, Dec – 101kg	202	47

It is important to note that the timing of nitrogen applications is an important factor when determining leaching from Overseer models. Hazelnuts nitrogen uptake is greatest when they are actively growing in the spring and early summer (November-December in New Zealand) (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012). In Overseer this generally results in less leaching than applications over winter months that: a) are wetter; and, b) have less plant growth.

Hazelnuts are one of many crops that are not modelled in Overseer therefore apples were used as a proxy crop. A full list of assumptions is listed in 37Appendix 1 – List of Assumptions in Overseer Model.

It must be noted that this data is indicative (at best) as the hazelnut crop was modelled as a completely different species (apple) and the author is not qualified in the use of Overseer. The information was, however, prepared with the assistance of a Certified Nutrient Management Advisor.

9.1.5 Summary and Discussion

There is a lack of research on: a) the optimum nitrogen requirements for hazelnut crops in New Zealand; and, b) Nitrate-N leaching from hazelnut orchards both globally and in New Zealand.

The limited data analysed suggests there is a strong case for the use of hazelnuts as a low N-use crop that only requires N during active growing months. The N use of hazelnuts appears to compare favourably to other

arable crops, thus, a block of hazelnut trees on an arable farm may bring down the overall nitrate-N leaching profile of an arable farm.

10 Profitability of Hazelnut Orchards

The purpose of this section is to summarise the literature on the profitability of hazelnuts in New Zealand and around the world.

10.1 International Data

Redpath (2012) summarises gross margin data for international hazelnut orchards. This is presented in Table 7 below.

Table 7 - Gross Margins for International Hazelnut Orchards (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012)

Source	Location	Gross Margin	Gross Margin (NZD)
Baldwin (2010)	Australia	AUD\$4,400/ha	\$4,734
USDA FAS (2011)	Italy	EUR 2,500-3,000/ha	\$4,193-5,031
Julian et al (2009)	Oregon, USA	USD\$3,325	\$4,598

Similar data is repeated by Redpath in a HGANZ document (Redpath, Bulletin 1: An introduction to growing hazelnuts, 2016) which suggests gross margins for well managed hazelnut orchards in Australia, Oregon (USA) and Italy are commonly in the range \$4,000 to \$7,000/ha.

A South Australian report estimates established orchards should be capable of providing a gross margin of AUD\$3-5,000 (NZ\$3,230-5,380) per hectare, depending on yield and price received (Baldwin, 2010).

10.2 New Zealand Gross Margin Data

No published data exists for actual yields in New Zealand orchards, however HGANZ provide some guidance on expected returns. According to the HGANZ growers should plan to harvest 1 tonne/ha by year 6 and 2.5 tonnes/ha by year 10. HGANZ purports that these yields have been achieved by New Zealand growers with good management in suitable environments (Redpath, Bulletin 1: An introduction to growing hazelnuts, 2016). At \$4/kg in shell this results in a gross profit of \$10,000/ha.

Redpath (2010) has performed a gross margin analysis for a theoretical orchard in the Lake Taupo Catchment and this is displayed in Figure 6 below (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012). Redpath also suggests orchards in this area could earn a gross margin of \$2,500-8,500 depending on several factors, including scale.

<u>Income (per hectare)</u>		
2500kg @ \$3/kg	\$7500	
Gross income		\$7500
<u>Expenditure (per hectare)</u>		
Fertilizer (including lime)	\$185	
Mowing	\$680	
Weed control	\$51	
Sucker control	\$114	
Pruning	\$653	
Pest control	\$28	
Pre-harvest grass spray	\$50	
Harvest costs	\$300	
Washing and drying	\$250	
Freight	\$125	
Shelter trimming	\$250	
Total direct costs		\$2686
Gross margin per hectare		\$4814

Figure 6 - Estimate of the Gross Margin per hectare for an unirrigated mature hazelnut orchard in the Lake Taupo Catchment

10.3 Yield Data

Yield is a major contributing factor in the determination of income and therefore gross margin. It should be noted that approx. 10% of the trees in an orchard need to be polliniser trees which are required to pollinate the primary crop tree. The type, placement and ratio of pollinisers required will depend on the cultivar to be pollinated and local conditions (including wind and rainfall during the flowering period). The pollinisers usually produce a nut of different size and quality and this should be taken account when calculating yields.

10.3.1 International Yields

10.3.1.1 American Society for Horticultural Science (ASHS)

Table 8 summarises the results of yield trials on a number of cultivars planted in 2002. Some of these cultivars show exceptionally good yields. Cv. Jefferson, for example, can produce over 20kg/tree after 8 years. Many of these higher yielding trees are larger trees and are usually planted at a lower density or thinned to a lower density as they mature. Using the yield data in Table 8 and a 6x3m planting density (assuming 500 trees/ha), cv. Jefferson could yield over 3500kg/ha in Year 8.

Table 8 - Nut yield, tree size, and yield efficiency of 'Jefferson' and other hazelnut cultivars and selections in two hazelnut trials planted in 2002

Selection	No. of trees	Nut yield (kg·tree ⁻¹)						TCA ^z (cm ²)	Yield efficiency ^y (kg·cm ⁻²)
		2004	2005	2006	2007	2008	Total		
First trial									
OSU 688.010	8	0.23	1.06	4.43	4.14	5.02	14.89	79.0	0.190
Barcelona	8	0.38	1.35	5.63	5.16	4.42	16.94	115.9	0.147
Clark	8	0.24	2.21	3.90	3.76	5.80	15.91	64.1	0.248
Jefferson	8	0.46	2.18	5.58	5.14	7.02	20.38	78.2	0.261
Lewis	8	0.42	2.84	4.35	6.40	6.28	20.29	84.4	0.242
LSD (0.05)		0.18	0.55	0.81	0.84	1.03	2.37	10.8	0.024
Second trial									
OSU 684.104	4	0.09	1.12	6.15	4.64	5.71	17.70	116.5	0.153
OSU 688.012	4	0.26	2.15	4.85	3.84	6.50	17.60	103.0	0.172
OSU 688.013	4	0.07	0.85	3.71	3.53	5.79	13.95	78.4	0.179
OSU 713.068	4	0.35	2.20	3.33	3.29	5.10	14.28	75.3	0.189
Barcelona	4	0.47	1.56	4.60	4.26	3.95	14.84	100.6	0.149
Clark	4	0.17	2.61	3.77	3.27	6.60	16.42	64.4	0.255
Jefferson	4	0.26	0.24	5.30	3.91	7.06	18.89	63.3	0.299
Lewis	4	0.31	2.79	4.30	5.86	6.31	19.56	72.9	0.268
Zeta	4	0.17	0.59	2.29	2.64	3.86	9.55	108.5	0.088
LSD (0.05)		0.20	0.54	0.95	1.16	1.58	3.0	15.3	0.038

^zTCA = trunk cross-sectional area (cm²).
^yYield efficiency = total yield (2004–08)/TCA.
LSD = least significant difference.

Redpath (2012) in Appendix 1 cites 2,500kg/ha as a long-term production figure based on Oregon growing systems and this is achieved in approximately Year 10 of the orchard.

10.3.2 Yields in New Zealand

The HGANZ gives some indicative yields in their introductory bulletin and this table is repeated below as Table 9. In 2014 almost 100% of production was from the hazelnut cultivar Whiteheart (Redpath, 2014).

Table 9 - Indicative Hazelnut Yields Over Time (Redpath, Bulletin 1: An introduction to growing hazelnuts, 2016)

Year	5	6	7	8	9	10	11	12
kg/tree	0.1	0.25	0.6	1.2	2.0	2.8	2.9	3.0
kg/ha	60	150	360	720	1200	1680	1740	1800
Return @ \$3.50/kg	210	525	1260	2520	4200	5880	6090	6300

A trial planted at the Appleby Research Orchard in Nelson was assessed for yield from 1970 to 1975 and one cultivar (incorrectly labelled as Barcelona but later renamed "Appleby") yielded an average of 10.3 kg per tree per year over that period. This equated to a crop of over 4 tonnes per hectare based on the spacing used in that trial (Redpath, Bulletin 1: An introduction to growing hazelnuts, 2016).

In the report about the suitability for growing hazelnuts in the Lake Taupo Catchment, Redpath details some results in from the Wairata Forest Farm Variety Collection. Whiteheart trees averaged 2.2kg/tree or 1408kg/ha (sample size 8 trees). Barcelona trees average 7.18kg/tree or 2,296kg/ha (sample size 4 trees) (Redpath, Hazelnut Production: Potential for Lake Taupo Catchment, 2012).

Figure 7 is extracted from a presentation about the potential for commercial hazelnut production in the Rotorua Region (Repdath, 2014). This chart demonstrates that yields in excess of 5T/ha are possible from cultivars Ennis and Barcelona. The higher quality Whiteheart begins to yield moderately well around Year 13.

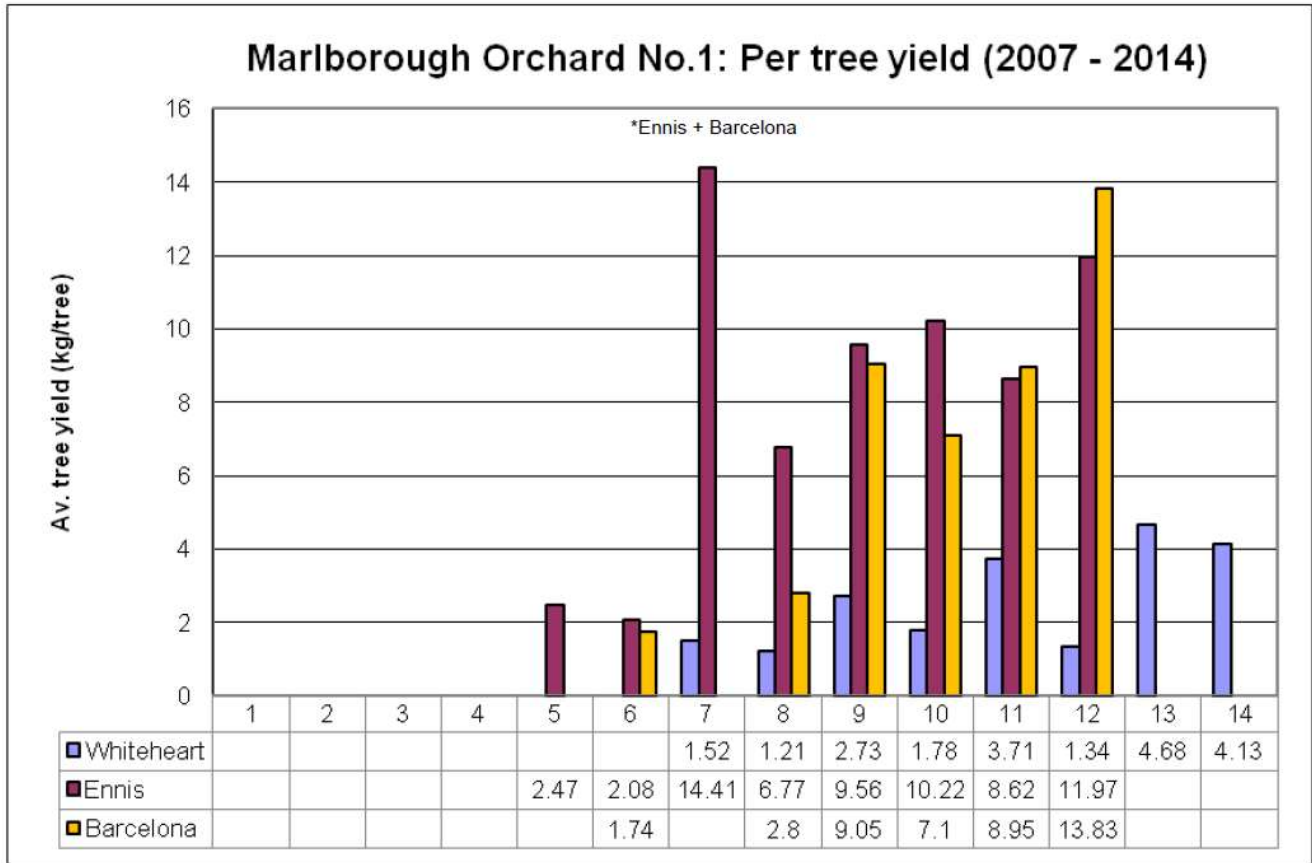


Figure 7 - Marlborough Hazelnut Yields from 3 Varieties over 9 years (Repdath, 2014)

Figure 8 shows Whiteheart yields across six different South Island areas. Assuming planting density of 500 trees/ha, orchards in Canterbury are only producing approximately 750kg/ha in Year 11.

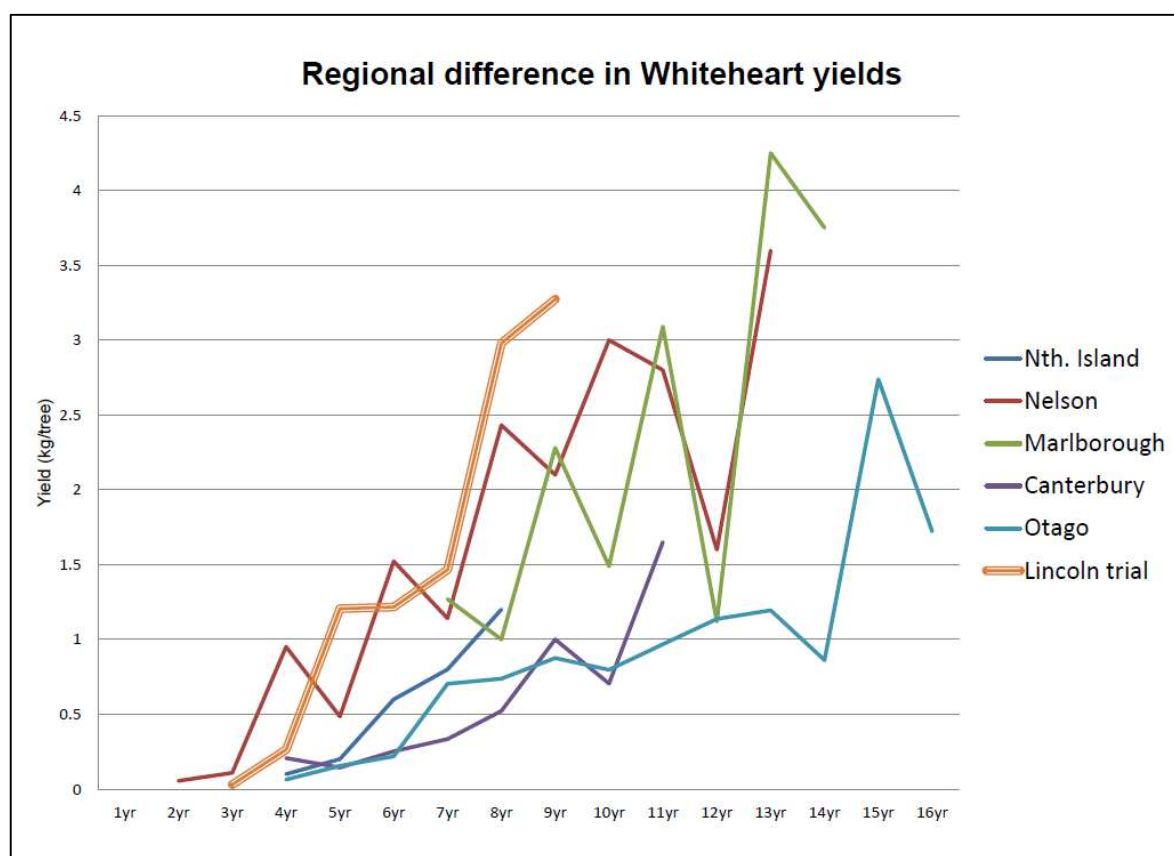


Figure 8 - Difference in Whiteheart Yields Across the South Island (Redpath, 2014)

The author contacted several hazelnut orchardists in the South Island and yields are consistently disappointing, usually between 500-1200kg/ha from mature or almost mature trees. All orchards are producing from the cultivar Whiteheart.

10.3.3 Timing of Production

The timing of production has a significant impact on the economics of an orchard. With good New Zealand conditions and with appropriate management, hazels will start to provide a modest crop after 5-8 years and should reach full production around 12-15 years of age (Redpath, Bulletin 1: An introduction to growing hazelnuts, 2016).

Several orchard growers with the cultivar Whiteheart have indicated that their trees aged 16 years and older still haven't reached full size or full production, with some orchardists anticipating they may not achieve full production until year 25.

10.3.4 Summary

Yields vary significantly between different cultivars. It appears the cultivar Whiteheart, although it produces a nut of a very high quality, is low yielding in New Zealand. There is a significant gap between the yields that literature suggest are possible in New Zealand and what has actually been produced on orchards. Small-scale trials in New Zealand and overseas show higher yields can be achieved from alternative cultivars to Whiteheart but this must be carefully weighed against other qualities like disease resistance and nut quality.

10.4 Cash Flow Model

A cash flow model has been created to represent the revenue and expenses from establishing a hazelnut orchard on an existing arable farm in order to determine if planting a hazelnut orchard would be a positive investment from a profitability point of view. This has been included in Appendix 2 – Cash Flow Model

10.4.1 Major Assumptions

The model contains a number of assumptions and these are detailed in Appendix 2 – Cash Flow Model

Some of the significant assumptions are:

- The land is already owned and is being farmed as part of a larger arable operation.
- Main crop trees are planted in year 1 at 450 trees /ha along with 50 polliniser trees /ha.
- Irrigation water is already owned however the model includes a cost to install drip-line irrigation.
- It is assumed the orchard is established with efficient operation in mind and the labour required to operate the orchard is the same as that required for any other crop.
- Additional machinery costs are not included as it is assumed suitable tractors, mowers and spraying equipment is already owned. It is assumed existing drying floor space can be used for drying nuts. There may be an additional requirement for capital spend after year 5-10 on mechanised harvesting equipment.

10.4.2 Pricing

Along with yield, the price received is a major contributor to revenue. Nuts can be processed locally in Canterbury. Table 10 shows pricing data from 2011. Several local growers have informed the author they have received \$4.0/kg in recent years when processing with local firms, with some growers receiving premiums based on nut quality and as part of forward contracting their harvest.

Table 10 - Hazelnut Processor Pricing in 2011 (HGANZ, 2011)

Processor	Whiteheart	General	Organic premium?
The Hazelnut Company (Christchurch). Phone: (03) 318 1141 Web: www.hazelnut.co.nz	\$3.00~\$6.00/kg		Under consideration
Uncle Joe's Walnuts and Hazelnuts (Marlborough) Phone: (03) 577 9884 Web: www.unclejoes.co.nz	From \$4.00/kg	From \$4.00/kg	Not at present

10.4.3 Gross Margin Sensitivity Analysis

As discussed above in Section 10.310 Yield Data, yield along with price, plays a significant role in gross income. Table 11 shows the importance of achieving a positive gross margin. Yields above 1T/ha at the current market price of \$4/kg compare favourably to gross margins from other arable crops (ref. 5.2 Gross Margin). Note this is a gross margin at full production which is expected between years 10-15.

Table 11 - Sensitivity Analysis of Gross Margin for a Hazelnut Orchard (\$/ha)

Crop Price (\$/kg)	Nut Yield (tonnes/ha, in-shell)				
	0.5	1	1.5	2	3
\$3.00	\$75	\$1,475	\$2,875	\$4,275	\$7,075
\$4.00	\$575	\$2,475	\$4,375	\$6,275	\$10,075
\$5.00	\$1,075	\$3,475	\$5,875	\$8,275	\$13,075

10.4.4 IRR and NPV Sensitivity

Gross margin should not be viewed as the sole measure to determine the suitability of a hazelnut orchard as there are significant establishment costs associated with planting an orchard. Thus, the orchard has been modelled over a 20-year period (Appendix 2 – Cashflow Model) the metrics of Net Present Value (NPV) and Internal Rate of Return (IRR) have been used to identify if the establishment of a nut orchard is a good investment. A Weighted Average Cost of Capital (WACC) value of 5% has been used for calculation of the NPV. The model estimates a capital investment of approximately \$12,000/ha in order to establish the orchard. In real terms this model has a payback period of 12 years after which the orchard will start to turn a profit. This model excludes tax and depreciation considerations.

Table 12 - NPV and IRR for Hypothetical Orchard

	Crop Price (\$/kg)	Nut Yield (tonnes/ha, in-shell)				
		0.5	1	1.5	2	3
IRR (%)	\$4.00	-3%	6%	10%	12%	14%
NPV (\$)		-\$9,448	\$1,808	\$10,987	\$17,826	\$27,951

10.4.5 Opportunities to Improve Income

There are several opportunities to increase income from a hazelnut orchard, although these have not been investigated as part of this report. These opportunities include:

1. The cultivation of truffles on the roots of hazelnut trees;
2. The possibility to receive additional income by growing a crop (e.g. lucerne) between nut tree rows while the trees are young and before the trees begin to produce a harvestable amount of nuts; and,
3. Grazing the orchard instead of mowing (note sheep must be excluded from the orchard several months before harvest due to contamination risk from sheep pellets).

10.4.6 Summary

Financial returns for a hazelnut orchard compare favourably to other arable crops if reasonable yields can be achieved. If high yields in excess of 2t/ha can be achieved and prices remain stable at \$4.0/kg then returns from both a gross margin and IRR perspective are positive.

11 Conclusions and Discussion

11.1 The New Zealand Hazelnut Industry

This report aimed to investigate the suitability of hazelnuts as an alternative crop on an arable farm in order to help insulate the business against three major issues facing the industry: 1) profitability; 2) restrictions on nitrate-N leaching; and, 3) the anticipated costs associated with greenhouse gas emissions.

New Zealand has a small but enthusiastic hazelnut industry which has not yet lived up to its potential. The majority of orchards in New Zealand are small (<10ha), standalone, lifestyle blocks and are planted in the high quality, yet low yielding variety Whiteheart. These orchards were mostly planted in the 2000's and have struggled to reach their potential with respect to yield. Most orchards do not appear to be profitable.

This lack of profitability means there are no significant budgets for research. Most research in the New Zealand hazelnut industry is conducted by a small number of enthusiastic volunteers which limits the amount of research that can be undertaken. There does not appear to be any objective data on important parameters such as fertiliser types, timings and quantities. There is significant potential for the New Zealand industry as newer and higher yielding cultivars enter the market.

Canterbury has an ideal climate and soils for growing hazelnuts which is similar to other prolific hazelnut regions such as Oregon in the United States.

11.2 Profitability

The profitability of all commodity crops depends on the yield and the price received. High yields have been achieved in orchards overseas and in trials in New Zealand, however this does not appear to have been successfully scaled on any commercial orchards in New Zealand. If yields of greater than 1.0t/ha can be consistently achieved then hazelnuts compare favourably to other arable crops on a gross margin basis. A sensitivity analysis has demonstrated that if overseas yields in excess of 2.0t/ha can be achieved then a gross margin in excess of \$6,000/ha is possible, being well in excess of almost any arable crop. The gross margins calculated in this investigation are similar to those achieved in orchards in Europe, Oregon and Australia.

11.3 Nitrogen Usage

There is a lack of research into optimum nitrogen requirements for hazelnut crops in New Zealand as well as Nitrate-N leaching from hazelnut orchards both globally and in New Zealand.

The limited data available does suggest there is a strong case for the use of hazelnuts as a low N-use crop that only requires N during active growing months. There is a visible trend towards a requirement for arable farmers in Canterbury to use less nitrogen-based fertiliser and leach less nitrate-N to the environment. The N use of hazelnuts appears to compare favourably to other arable crops, therefore a block of hazelnut trees on an arable farm may bring down the overall nitrate-N leaching profile of an arable farm provided they are as profitable as the crops that are being replaced.

Overseer has become the default tool for local authorities to measure Nitrate-N leaching from agricultural land. Hazelnuts, along with all other tree crops, are not modelled in Overseer which makes it difficult to make an accurate assertion about how they will perform if and when they are modelled.

11.4 Carbon Sequestration

The greenhouse gas emissions profile of New Zealand is dominated by agriculture however the agricultural industry has so far avoided any significant costs associated with these emissions. This will change by 2025 as the He Waka Eke Noa group works towards a mechanism for charging farmers for emissions.

One suggestion by the working group is for farmers to be able to reduce their emissions via the concept of 'netting off' which involves a portion of emissions being offset by on-farm sequestration. Fruit and nut trees are specifically excluded from the ETS at this point however this may change as He Waka Eke Noa investigates on-farm sequestration options.

This report investigated the value of hazelnut trees as a sequestration tool and calculated this value using the ETS as a proxy tool. Due to the lack of data on carbon sequestration rates in hazelnut orchards it was assumed a hazelnut tree grows at 5% the rate of a pinus radiata tree. If farmers do have to enter the ETS in 2025 they will initially receive a 95% rebate. Given these assumptions and a carbon price of NZ\$40, a 10ha hazelnut orchard would sequester carbon valued at less than \$50/ha over the life of the orchard. Thus, the use of a horticultural tree, such a hazelnut, is currently not an economically viable option to reduce the greenhouse gas emissions costs of an arable farm.

11.5 Summary

A hazelnut orchard is a viable alternative to most existing arable crops in terms of profitability and could reduce the overall nitrate-N leaching profile of an existing arable farm in Canterbury. Hazelnuts do not provide any meaningful value as a carbon sequestration tool.

12 Recommendations and Next Steps

It is recommended that further research be conducted into:

- An independent study of the actual yields currently being achieved by New Zealand orchards;
- Orchard-scale research into yields that can be obtained through new cultivars such as 'Jefferson';
- Nitrogen use trials on new and existing orchards in order to obtain objective data on optimum nitrogen usage;
- The potential for growing crops between tree rows for 3-5 years during tree establishment in order to generate some income (such as lucerne);
- The actual man-hour requirements for establishing and operating an orchard, and the costs and benefits of replacing manual labour with machinery (e.g. a tractor mounted harvester);
- Research by Overseer™ into modelling the N-loss profile of nut trees.

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13 Appendices

13.1 Appendix 1 – List of Assumptions in Overseer Model

- 4T/ha produce
- No foliar spray
- No livestock in orchard
- Sward type - full pasture
- 2x application of 110kg Urea (50kgN) - one in Nov one in Dec
- Is Orchard under dripline - Yes
- Soil Moisture Sensors / Tapes used - trigger point and depth applied to achieve target
- Irrigation Months – November to March
- SMap Soil Reference - Mayf_2a.1 (70%), Darn_1a.1 (30%)

13.2 Appendix 2 – Cash Flow Model

Nut trees / ha		450																			
Note	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
	Yield (kg/tree)	0	0	0	0	0.1	0.25	0.6	1.2	2	2.8	2.9	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3	3.3
5	Yield (kg/ha)	0	0	0	0	45	112.5	270	540	900	1260	1305	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0	1500.0
1,4	Sale Price (\$/kg)	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4	\$4
	Total Nut Revenue	\$0	\$0	\$0	\$0	\$180	\$450	\$1,080	\$2,160	\$3,600	\$5,040	\$5,220	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000
	Gross Revenue	\$0	\$0	\$0	\$0	\$180	\$450	\$1,080	\$2,160	\$3,600	\$5,040	\$5,220	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000	\$6,000
	Capital Costs (\$/ha)																				
8	Irrigation Install	\$5,000																			
9	Orchard floor preparation	\$270																			
10	Purchase and plant shelter trees	\$1,500																			
11	Purchase and plant nut trees	\$4,050																			
12	Purchase and plant polliniser trees	\$1,150																			
	Total Capital Costs	\$11,970	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0	\$0
	Operating Costs (\$/ha)																				
13	Fertiliser - Urea	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130	\$130
14	Fertiliser - Other	\$500		\$200		\$200		\$200		\$200		\$200		\$200		\$200		\$200		\$200	
15	Fertiliser - Spreading	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50	\$75	\$50
16	Soil / Plant Tissue Tests	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70	\$70
17	Orchard Mowing					\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100
19	Weed Control - chemical and application	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100
20	Sucker Control - chemical and application	\$150																			
21	Disease Control - chemical and application	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50	\$50
22	Pruning			\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200	\$200
23	Shelter Belt Trimming					\$300		\$300		\$300		\$300		\$300		\$300		\$300		\$300	
24	Harvest Costs					\$9	\$23	\$54	\$108	\$180	\$252	\$261	\$300	\$300	\$300	\$300	\$300	\$300	\$300	\$300	\$300
25	Transport					\$50	\$50	\$50	\$50	\$50	\$50	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100	\$100
	Total Operating Costs	\$1,075	\$400	\$825	\$600	\$1,284	\$773	\$1,329	\$858	\$1,455	\$1,002	\$1,586	\$1,100	\$1,625	\$1,100	\$1,625	\$1,100	\$1,625	\$1,100	\$1,625	\$1,100
	Total Annual Costs (\$/ha)	\$13,045	\$400	\$825	\$600	\$1,284	\$773	\$1,329	\$858	\$1,455	\$1,002	\$1,586	\$1,100	\$1,625	\$1,100	\$1,625	\$1,100	\$1,625	\$1,100	\$1,625	\$1,100
	Annual Cashflow	-\$13,045	-\$400	-\$825	-\$600	-\$1,104	-\$323	-\$249	\$1,302	\$2,145	\$4,038	\$3,634	\$4,900	\$4,375	\$4,900	\$4,375	\$4,900	\$4,375	\$4,900	\$4,375	\$4,900
	Cumulative Cashflows	-\$13,045	-\$13,445	-\$14,270	-\$14,870	-\$15,974	-\$16,297	-\$16,546	-\$15,244	-\$13,099	-\$9,061	-\$5,427	-\$527	\$3,848	\$8,748	\$13,123	\$18,023	\$22,398	\$27,298	\$31,673	\$36,573
	IRR	10%																			
	NPV	\$10,987																			
	Weighted Average Cost of Capital (WACC)	5%																			
	Notes																				
	1 All prices are on an in-shell basis																				
	3 Orchard assumes layout of 6x3m and 450 crop trees / ha																				
	4 Sale price data from http://www.hazelnutnurseries.co.nz/faq.html , also reflected in conversations with other growers																				
	8 Irrigation costs based on individual sprinkler to each tree. Does not include costs of purchasing water and major infrastructure costs e.g. wells, pumps, consents etc																				
	9 Includes costs of spraying out, cultivating and drilling lucerne seed and spraying out planting strips																				
	10 Assumes 300 shelter trees /ha. Cost from Growing Hazelnuts in New Zealand, HGANZ																				
	11 Assuming 500 trees / ha - 90% (450 trees) will be crop trees and the remaining 10% pollinisers. \$9/tree to buy and plant																				
	12 10% of trees are pollinisers. \$23/ tree to buy and plant																				
	13 Urea @ 200kg / year split over 2 applications. Based on price of \$650/t																				
	14 Assumes \$500/ha to remedy any deficiencies for hazels in first year then \$200 every 2nd year to remedy specific deficiencies incl. pH (via lime)																				
	15 Assumes 2 or 3 applications a year @ \$25/application by contractor																				
	16 One plant tissue or soil test / year @ \$70/test																				
	19 For control of weeds around trees / between rows using a herbicide e.g. Glyphosate																				
	20 Sucker control once / year using a dessicant spray																				
	21 2x copper sprays for disease / year																				
	23 Shelter trimming every 2nd year. No trimming for first 4 years																				
	24 Assumes non-mechanical harvester e.g. hand roller type harvester @ a nominal cost of 20c/kg																				
	25 Nominal cost to deliver nuts to processor within 100km of orchard																				