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Implications of global price and supply of supplementary feeds on the New Zealand agricultural sector

Prepared for Our Land and Water Contestable Fund

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Prepared by:	Raewyn Densley Agribusiness Consultant Jeremy Hunt Environmental Consultant Lauren McEldowney Agribusiness Consultant Phil Journeaux Agricultural Economist Julian Reti Kaukau Consultant and Te Ao Māori Lead Whenua Tahi Ltd	
Approved for release:	James Allen Managing Director	

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1.0 EXECUTIVE SUMMARY

A series of recent global events resulted in record prices for internationally produced feed (IPF) and highlighted the dependence of New Zealand's livestock industries on imported grain and feed.

This report discusses factors impacting the price and supply of IPF, quantifies the New Zealand livestock sectors which feed it and examines the consequences of global supply shortages. It quantifies the current arable industry and investigates opportunities to grow more grain or alternative livestock feeds locally. It also looks at the economic and environmental (nitrogen (N) leaching and greenhouse gas (GHG)) implications of New Zealand dairy farms reducing stocking rates and growing more home-grown feed.

Each year the world produces around 2.7-2.9 billion tonnes of grain, but only 17% is traded. Global grain stocks are surprisingly low with stocks-to-use (S/U) ratios around 30-35% for wheat and 20-25% for maize. In 2022/23, China held 70% of global maize grain stocks, 32% of soybean, and 54% of wheat. Human food, livestock feed and biofuel production are all competing for a relatively small pool of surplus grain, and supply and demand are impacted by a wide range of climatic and geopolitical factors. In 2022 grain prices reached an all-time high and this could be attributed to the COVID pandemic, droughts in Europe and parts of the USA, growing Chinese demand and stockpiling and the Russian-Ukraine war.

The New Zealand arable industry is small, producing around 900,000 tonnes of grain off 107,000 ha. The majority (67%) of arable cropping occurs in Canterbury although there are small areas in most regions. While yields are high so are production costs and inter-Island freight rates. This means that it is often cheaper to buy in grain from overseas than it is to source it from local producers especially if it has to be moved between the North and South Island. Returns from arable cropping are comparable to, or better than sheep and beef but below those of dairying. A key advantage of arable systems is their low GHG output when compared to livestock systems.

New Zealand is a net importer of grain and concentrates with imports rising to a record level of 3.7 million tonnes in 2022. The dairy industry is the largest consumer of IPF consuming 75% of all feed imports with poultry consuming 12% and other livestock 4%. Palm kernel extract (PKE), sourced from Malaysia and Indonesia is the highest volume feed supplement and it is predominately fed to dairy cows. Dairy farm feed demand for supplements including IPF has increased over time due to increased cow numbers, higher stocking rates and greater milk solids production per cow. Poultry is the second largest user, and this is likely to continue as the large, integrated companies which control the meat chicken industry use least-cost ration software to drive grain purchase decisions.

The poultry and pig sectors largely rely on grain and protein concentrates (e.g soymeal). Grain of varying types is produced around the globe which means there are multiple harvest events each year. Australia is a large producer exporting more than 40 times the annual NZ demand for imported grain. In contrast, PKE is mainly exported by Malaysia and Indonesia. Changes in consumer preferences away from palm oil could slowly reduce the supply of PKE. Extreme weather events, pests and diseases, labour shortages, geopolitical instability or changes in government policy could have a larger and more rapid impact on New Zealand's ability to source PKE.

Currently we import enough PKE to meet the total feed requirement of around 8% of the nation's dairy cows. A shortage could impact production and cow condition score. Ultimately farmers would need to destock but there could be challenges with culling of surplus animals especially if the shortage coincided with a local adverse weather event which impacted pasture growth or at a time of the year when meat processing facilities were already working to capacity.

While pig and poultry demand for grain is likely to remain stable, dairy demand for supplements and IPF is predicted to increase as farmers attempt to drive higher per cow performance and seasonal pasture growth rates, and possibly quality are impacted by climate change. New Zealand can decrease its demand for IPF by growing more grain, decreasing dairy demand for bought in supplements, or a combination of both.

While local grain yields are high, there is a significant gap between top and average producers. Further work is needed in the arable sector to identify key on-farm limitations to yield and increase them. It is likely that growers could increase yields by fine tuning their management practices and adopting precision farming techniques which allow farmers to identify and address yield limiting factors within a crop management zone.

There are opportunities to grow more grain on whenua Māori, lifestyle blocks and those sheep and beef farms which have suitable contour and soils. Smaller less economic dairy farms or those which are on the cusp of requiring additional labour or wishing to avoid the need for an infrastructure upgrade (e.g. a larger farm dairy or effluent system) also represent an area for potential growth. Of these whenua Māori holds the biggest opportunity.

There is around 1.47 million hectares of Māori freehold land in New Zealand. Many blocks are small and lack infrastructure. Sixty-one percent of blocks do not have a management structure and typically these blocks are leased out to individuals or entities who can farm them, usually for a nominal fee. The main challenge lies in finding a sustainable economic model which can transform these small land parcels into profitable enterprises.

Growing grain presents a transformative opportunity for underutilised whenua particularly if it is coupled with a vertically integrated animal feed business. It aligns deeply with core values of Te Ao Māori – the Māori worldview through key principles such as Kaitiakitanga, Manaakitanga, Whanaungatanga, Whakapapa, Mauri, and Mana, reinforcing the interconnectedness of people, land and all living things.

To help evaluate the potential economic benefits of growing grain, we surveyed shareholders from four Māori land blocks based in the Waikato/King Country regions. Details of current land lease costs, rates and management feeds were used to determine current net return per effective hectare. This was compared to the likely current returns for growing maize grain. Growing maize increased net profit by 67 – 212%.

Māori landowners were interested in the concept of growing grain which would allow them to be more actively involved in the management of and derive higher returns from their whenua.

The largest opportunity to decrease demand for IPF is within the dairy sector. Dairy cows consume the highest volume of IPF, but they are ruminant animals which are able to perform well on a wide range of diets. A potential way for dairy farmers to decrease their demand for IPF is to reduce stocking rates and grow more feed on farm. The ability of crops to increase farm drymatter yield above that of pasture-only systems is well established and previous modelling studies have shown that reducing stocking rate and cropping on-farm has significant N-leaching and GHG reduction benefits with a small reduction in profitability.

To further assess the implications of on-farm cropping vs buying in supplementary feed, five regional whole farm models were created using Farmax farm monitoring software and OverseerFM. The models represented an "average" farm and were using a mix of bought in (including IPF) and homegrown supplements. Scenario 1 modelled removing all crops (excluding home grown pasture silage) and replacing them with imported feed. Scenario 2 modelled removing all imported feed and replacing it with home grown crops/feed.

When compared to the Base scenarios, growing all feed on farm resulted in 5-14% lower milk production but on average, profit was slightly higher. Relying on homegrown feed was generally the most profitable option particularly at lower payouts and when the concentrate price was over $500/tDM delivered, however there were some regional differences.

When compared to the regional Base scenarios, Scenario 2 (all homegrown feed) decreased N loss to water in three regions but increased it slightly in two regions.

Reducing stocking rate and using all homegrown feed (Scenario 2) decreased biological GHG losses by 6 - 13% across all regions or 108 - 326 t CO_2e per farm. This will represent a significant cost saving once farmers have to pay for their GHG emissions.

Growing more grain locally and reducing dairy farm stocking rates and growing supplementary feed requirements on farm are practical and implementable solutions for New Zealand to reduce its reliance on IPF. New Zealand has enough arable land and infrastructure to grow and process more grain and it is likely that arable expansion would occur slowly enabling infrastructure requirements to keep up with growth. A key will be to identify suitable growing areas and promote the economic and environmental advantage of growing grain to target landowners.

The dairy industry has suitable land for on-farm cropping, all that is needed is a change in the way dairy farm systems operate. Fonterra have already recognised destocking and on-farm cropping as a means of reducing on-farm GHG emissions. It would also decrease dairy farm demand for IPF.

In conclusion, this report outlines some of the complexities of the global grain and PKE markets and the associated risks with being very reliant on IPF. It demonstrates that it is possible for New Zealand to decrease its demand for IPF by lifting grain yields, growing more grain (especially on whenua Māori) and returning to dairy farm systems which are less reliant on imported feed. It also highlights how growing grain and cropping on dairy farms can help Aotearoa achieve its environmental aspirations whilst maintaining or lifting farmer profitability.

2.0 INTRODUCTION

New Zealand is a net importer of grain and concentrates, with import volumes rising to a record level of 3.7 million tonnes in 2022. National grain and feed demand continues to outstrip domestic supply by nearly double, with New Zealand producing 2.1 million tonnes in 2022, but consuming an estimated 5.8 million tonnes (USDA, 2023).

In New Zealand, dairy farming is the largest consumer of internationally produced feed (IPF), accounting for about 75 percent. Poultry is the second largest consumer of IPF accounting for around 12 percent of imports, other animals (including pigs) comprise 4 per cent of imports and the remaining 9 per cent is for human consumption (USDA, 2023).

The New Zealand dairy industry has expanded from 2.1 million cows farmed on 1.0 million hectares in the 1985-86 season to 4.9 million cows farmed on 1.7 million hectares in the 2020-21 season. While dairy farm systems are pasture based, farmers are feeding an increasing amount of supplement which is sourced off farm. This includes locally grown harvested crops such as maize silage, cereal silage and lifted fodder beet and grain (maize, wheat and barley) as well as IPF. Palm kernel extract (PKE) is the largest imported dairy feed supplement with 1.97 million tonnes imported in 2022 (NZFMA, 2023).

Each year the world produces around 2.7-2.9 billion tonnes of grain, but only 17% is traded. A wide range of climatic and geopolitical factors impact world grain supply, demand and pricing. In contrast, the New Zealand arable industry is insignificant by global standards with a total annual grain harvest of around 900,000 tonnes.

Cropping area in New Zealand peaked in the 1970's to 1980's, and has subsequently declined due to a range of factors including the conversion of arable land to horticulture and dairy farming. The contribution of dairying to New Zealand's net importation of grain and concentrates should not be understated in that it has both increased demand for feed supplements and decreased the supply of locally grown grain.

World grain prices peaked in 2022 and this placed upward pressure on the price of by-products (e.g. PKE) which could be used as alternative feeds in livestock rations. The combination of high point of origin and shipping prices for grains and concentrates created significant price rises at farmer level in New Zealand. This has highlighted the risk of New Zealand agriculture being reliant on IPF and the need to explore ways for local agriculture to become more sustainable and self-sufficient.

Moving to more sustainable animal feeding practices incorporates Kaupapa Māori at a base level for those landowners currently in primary production. Kaupapa Māori are philosophical principles that are unique to Māori people. Principles such as Manaakitanga, Whanaungatanga, Whakapapa, Mauri, and Mana are key themes that distinguish the significance of Kaitiakitanga, and the roles and responsibilities Kaitiaki have with their people, land and assets. The interconnectedness of these principles provides a base understanding for landowners to embed long-term sustainable practices on their lands. From these perspectives, the central challenge for Māori landowners in primary production becomes reducing dependence on internationally produced feed (IPF), particularly given constraints like limited arable land for additional grain or feed production.

In this report the authors:

(a) Investigate factors impacting the global supply, demand and price of grain and concentrates.

(b) Quantify the use of IPF in New Zealand agriculture and the willingness of feed importers and pig and poultry end uses to consider locally produced alternatives.

(c) Outline the current size and economics of the arable industry.

(d) Discuss the risks involved in the pastoral sector if a local adverse event (e.g. drought) occurs concurrently with a IPF supply issue.

(e) Investigate opportunities to grow more grain or alternative livestock feeds locally, with a particular emphasis on the opportunity for Māori landowners to improve returns from their whenua.

(f) Discuss the risks of the dairy industry being reliant on IPF, and investigate the opportunities to reduce their reliance on imported feed.

3.0 GLOBAL GRAIN PRODUCTION

While estimates vary, the world produces around 2.8-2.9 billion metric tonnes of grain (including wheat, coarse grains (maize, barley, sorghum, oats and rye) and rice) each year (The Economist, 2022). The four top grains by tonnage harvested are maize (43%), wheat (29%), rice (19%) and barley (6%) (USDA, 2023).

Of the total production around 57% is used for human consumption and around 43% is burned as biofuel or used to feed animals (The Economist, 2022). There are significant differences in the end use of varying grain crops with the majority of rice and wheat destined for human consumption whilst animal feed and biofuel production is mainly from coarse grains including maize (Figure 1).

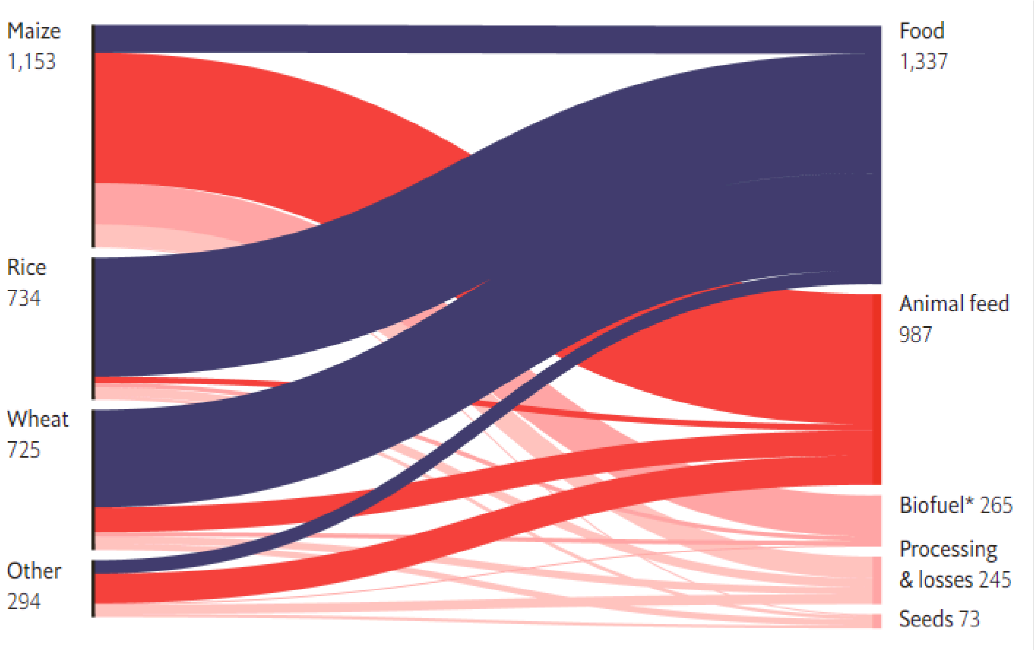


Figure 1: Worldwide grain production, 2019 (The Economist, 2022)

3.1 Imports and exports

While the majority of grain is consumed in the country of production, around 17% of cereal production is traded internationally, with single commodities proportions ranging from 9% for rice to 25% for wheat (OECD-FAO, 2021).

On a continent basis, Europe and North America are the main net exporters, while Africa and Asia are net importers (OECD-FAO, 2021). In 2021 the value of exported grain rose to $159 billion USD and the top five export countries were the United States (19.4%), Ukraine (8.2%), Argentina (8.1%), India (8.0%) and Russia (6.8%)

China is the largest importer of cereals accounting for 11.3% of global trade on a value basis. It is followed by Egypt (4.3%), Mexico (4.3%), Japan (4.1%) and Vietnam (2.9%) (Figure 2, OEC World, n.d).

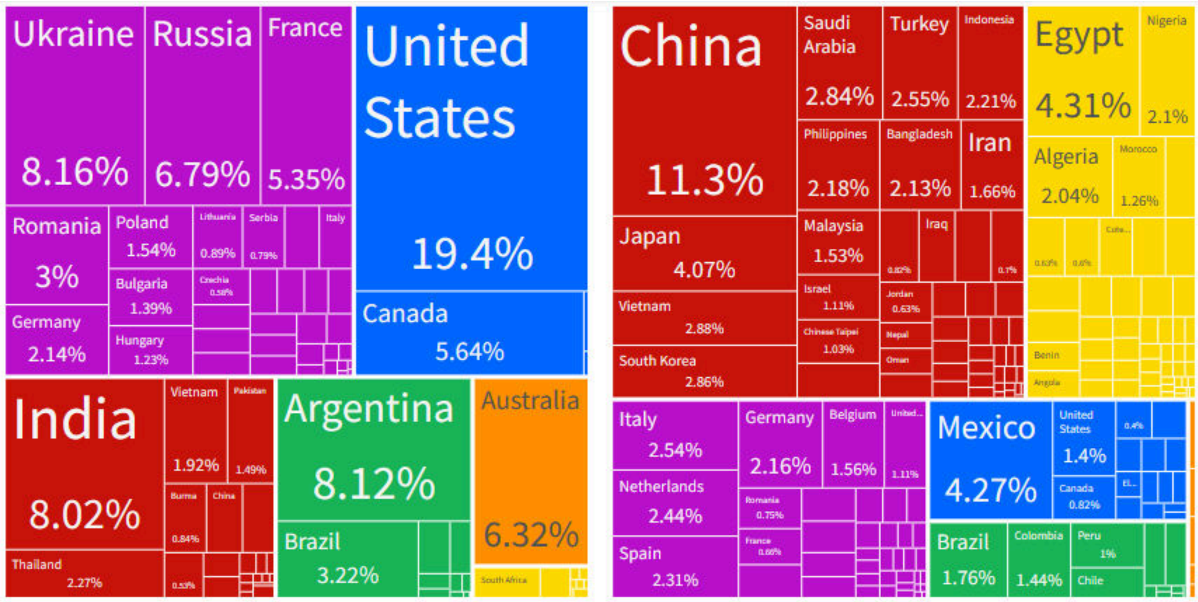


Figure 2: 2021 world cereal exports (left) and imports (right) by country (% export value)

3.2 Grain stocks

The stocks-to-use (S/U) ratio indicates the level of carryover stock for any given commodity as a percentage of the total global use of that commodity. Higher stock-to-use ratios mean more supply is available while lower ratios suggest a tighter supply situation. Stocks-to-use ratios vary for different types of grain but are typically around 30-35% for wheat and 20-25% for maize (OECD-FAO 2021). To put this into perspective, a 27% S/U ratio means we have enough grain to feed the world for 100 days if no more crops were harvested.

In 2022/23, China held 70% of global maize stocks, 32% of soybean, and 54% of wheat. China isn't an exporter of these commodities and removing Chinese stocks provides a more accurate picture of how much grain is available for global trade. In recent years, the stocks for all three crops have trended lower. Current corn stocks are only slightly ahead of the 2012/13 lows. For wheat, stocks are at the lowest levels since 2007/08 (Figure 3, AEI, 2023).

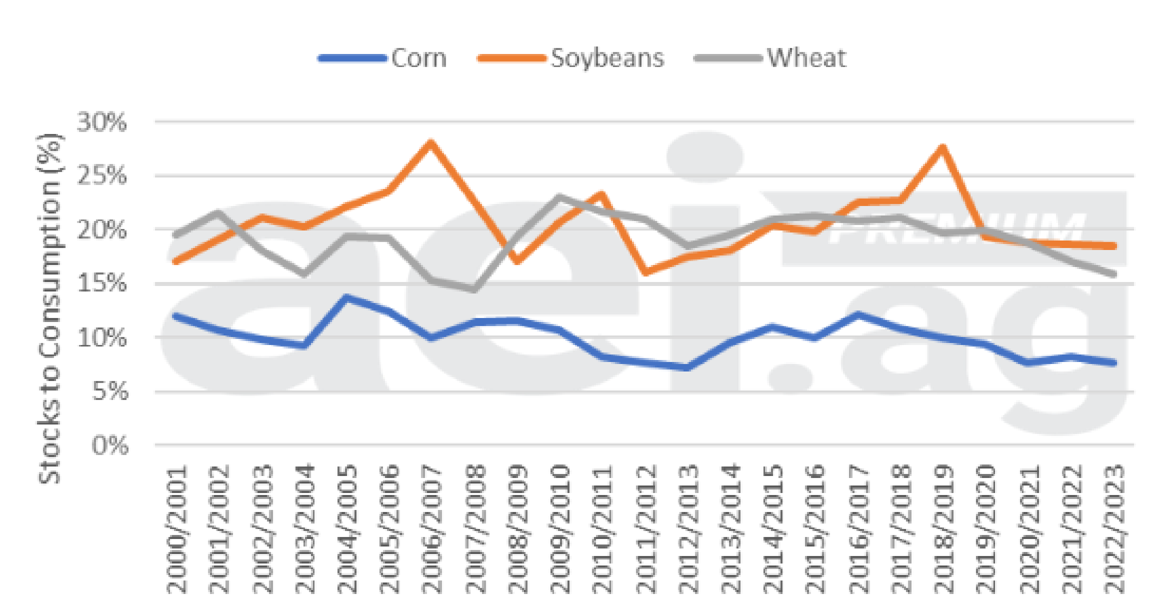


Figure 3: Stocks-to-use ratios for corn, soybeans and wheat less China's stocks (AEI,2023)

3.3 Ethanol production from grain

In the past two decades annual global ethanol production has risen six-fold (Figure 4) with the USA and Brazil producing 55% and 27% of total production respectively (Renewable Fuels, 2023). Grain is a major feedstock for ethanol production with currently 60% of ethanol being produced is generated from maize, 25% from sugar cane, 3% from wheat, 2% from molasses, and the rest from other grains, cassava and sugar beets (Hoang, 2021).

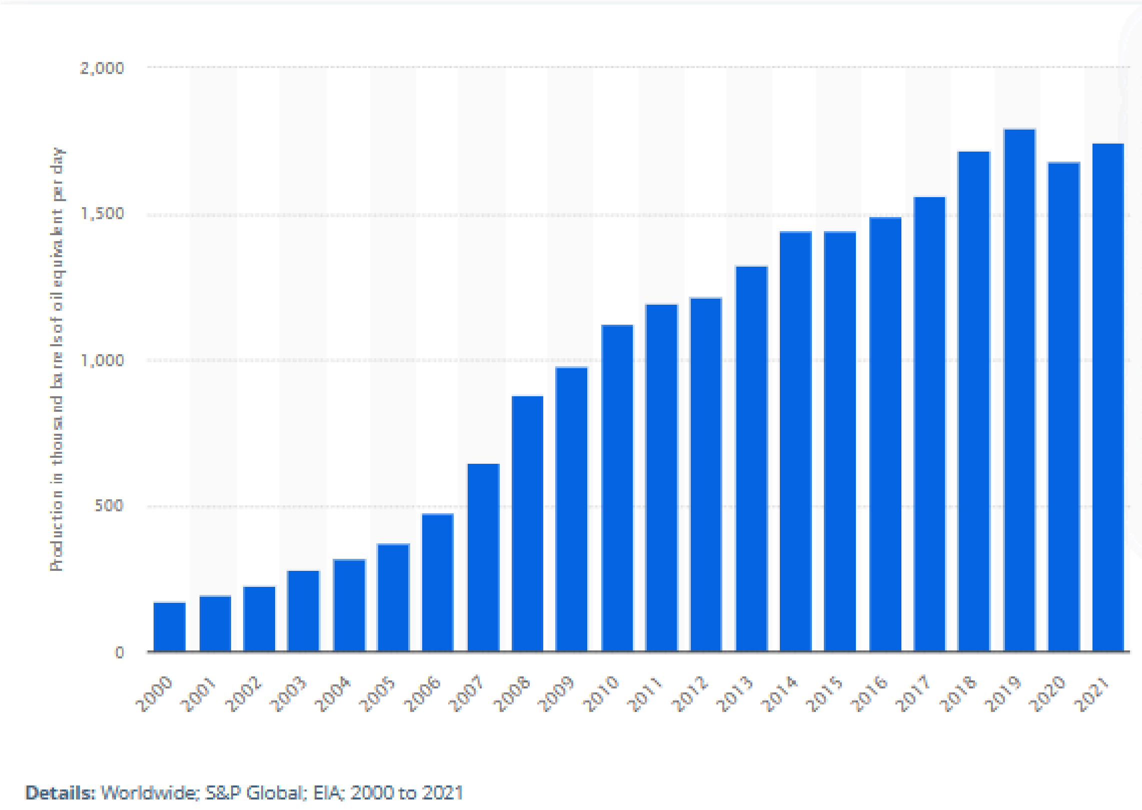


Figure 4: Global biofuel production in 1,000 barrels of oil equivalent per day (Graph is © Statista)

In the USA, ethanol production (mainly from maize) has been driven by the Renewable Fuel Standards programme. Introduced in 2005, this federal initiative requires all transportation fuel to contain a rising minimum level of renewable fuels. The diversion of grain (especially maize) into ethanol production has seen maize in the United States increase from a government-mandated low of 60.2 million planted acres in 1983 to close to or exceeding 90 million since 2018. Ethanol production now accounts for nearly 45% of total maize use (USDA, 2023a; Figure 5).

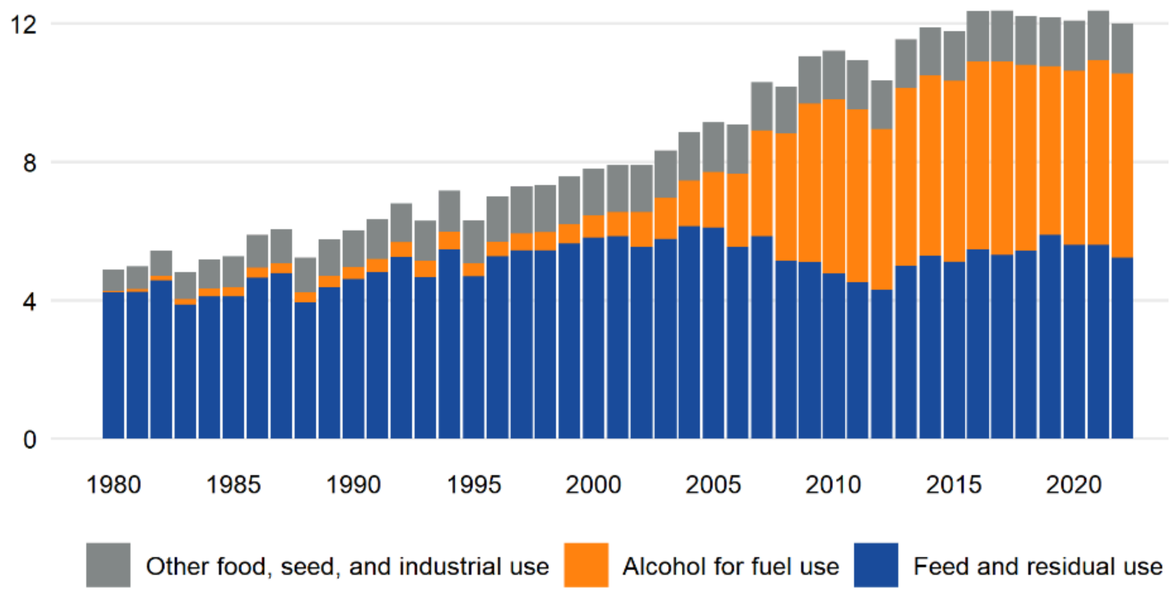


Figure 5: USA domestic maize use (billion bushels)

Economic models show that biofuel use has resulted in higher maize prices although there are large variations in the magnitude of the projected increase (Zang et al., 2013).

3.4 Factors impacting global grain prices in 2022

The world wheat price reached an all-time high of USD $12.09/bushel (bu) in February 2022 and maize peaked at USD $8.14/bu in April of the same year. While the Russia-Ukraine conflict was seen as the main driver of prices, the reality was there were a number of climatic and geopolitical factors which led to peak grain and feed prices. These included:

3.4.1 Global COVID pandemic

The COVID pandemic changed consumer demand patterns and disrupted supply chains. A surge in demand as consumers purchased food for quarantine led to a temporary emptying of grocery store shelves around the world and created concerns about the availability of food (Falkendal et al., 2021). A number of countries including significant grain exporters (Russia, Ukraine, India and Vietnam), placed temporary sanctions on the export of grains to protect domestic food supplies. The International Grains Council's wheat, rice and maize commodity price index increased 12%, 15% and 26%, respectively, from January to October 2020.

The Baltic Dry Index, a benchmark for the price of moving the major raw materials by sea, surged to record heights in late 2021 (Trading Economics, 2023, Figure 6) largely due to increased shipping demand and Chinese port congestion as a consequence of COVID lockdowns and the China/Australia coal ban (Hellinic Shipping News, 2021).

Figure 6: Baltic dry index January 2018 – February 2023 (Trading Economics, 2023).

3.4.2 Climatic factors

Extreme heat and drought in major maize growing regions of Europe and the USA created a difficult growing season for crops.

In Europe, widespread drought during pollination and tasselling significantly diminished maize yields in Spain, Southern France, Italy, and the Balkans. Total 2022-23 maize yields were 18% lower than the 5-year average (USDA, 2023b).

In the USA, drought across parts of the western Corn Belt and Great Plains resulted in increased abandoned (unharvested) areas in 2022 with Nebraska, Kansas and Colorado showing significant declines in both yield and harvested area (Futrell, 2023). The USDA estimated that total maize production in 2022 was 9% lower than for 2021.

Low water levels in the Lower Mississippi River affected the potential of US maize export due to the record high barge freight cost amid barge transit restrictions (Singh et al., 2022). Shipping operators were forced to reduce the weight of cargo per barge and the number of barges per tow because of draft (the distance between the waterline and the deepest point of the boat) restrictions. This resulted in significant increases in maize freight prices (Figure 7).

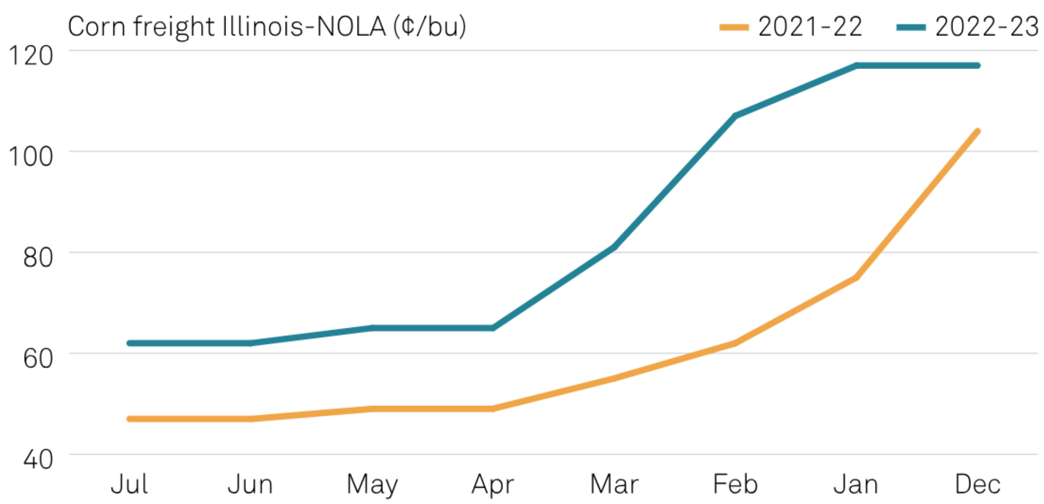


Figure 7: Maize freight rates (c/bu) from Illinois to New Orleans.

3.4.3 *Chinese demand and stocks*

China has become a major grain importer (Figure 8) as it tries to feed 22% of the world's population with only 7% of its arable land. In the last three years import volumes have reached an all-time high as weather impacted domestic production and demand increased as the pig industry rebuilt following an African swine fever outbreak. China has also been accused of expanding share of global grain stocks, intended for food security. In 2022/23, China held 70% of global maize stocks, 32% of soybean, and 54% of wheat (AEI, 2023).

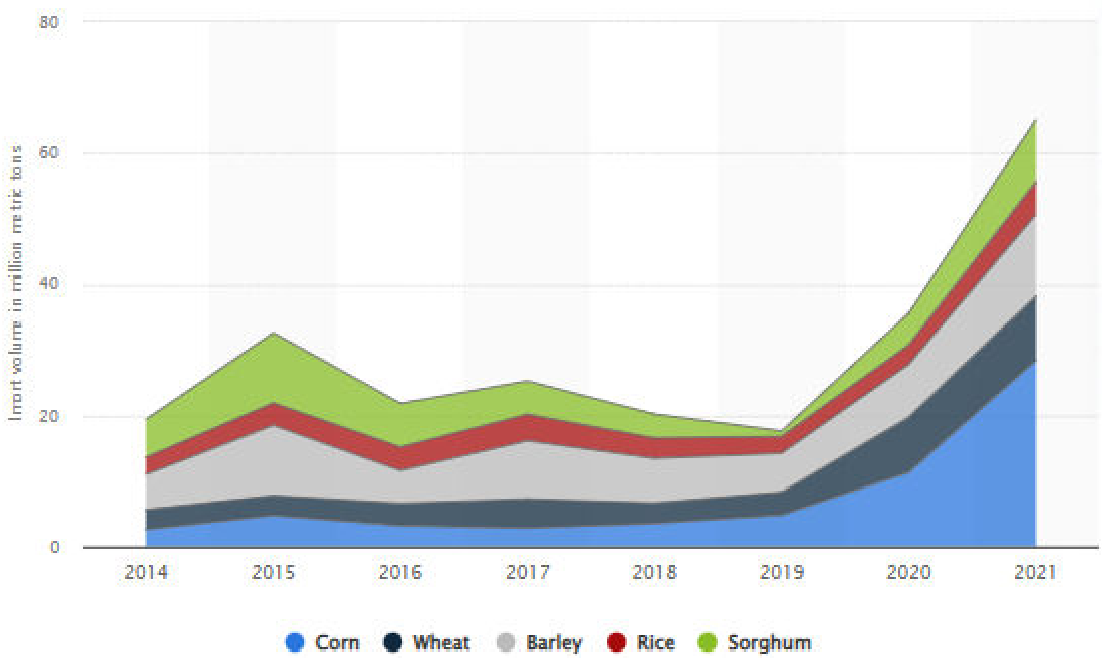


Figure 8: Chinese grain import volume (millions of metric tonnes (Source Chinese Customs © Statista)

3.4.4 *Russian-Ukraine war*

On 24 February 2022, Russia invaded and occupied parts of Ukraine in a major escalation of the Russian-Ukrainian War. Both countries are net exporters of grain and Russia is the world's top exporter of nitrogen fertilisers, the second leading supplier of potassic fertilisers and the third largest exporter of phosphorous fertilisers. (FAO, 2022).

The conflict affected grain production, drying and transportation within and out of the Ukraine. While the Black Sea Grain Initiative (initially signed in July 2022) allowed for grain and fertiliser (including ammonia) exports from three key Ukrainian ports in the Black Sea, export volumes were reduced and the outlook for future sea shipments remains uncertain.

In a bid to protect the domestic market and ensure food security, Russia announced restrictions on grain exports. Global sanctions against Russia impacted its exports particularly of oil and fertiliser and the severing of the Nord Stream gas pipeline impacted the cost and production of agrochemicals and nitrogenous fertilisers in Europe. As a consequence, crop establishment costs rose globally.

3.5 Plant protein production

Around 350 million metric tonnes of plant-based protein meals are produced each year (USDA, 2023c) and the majority are the co-product of plant oil extraction processes.

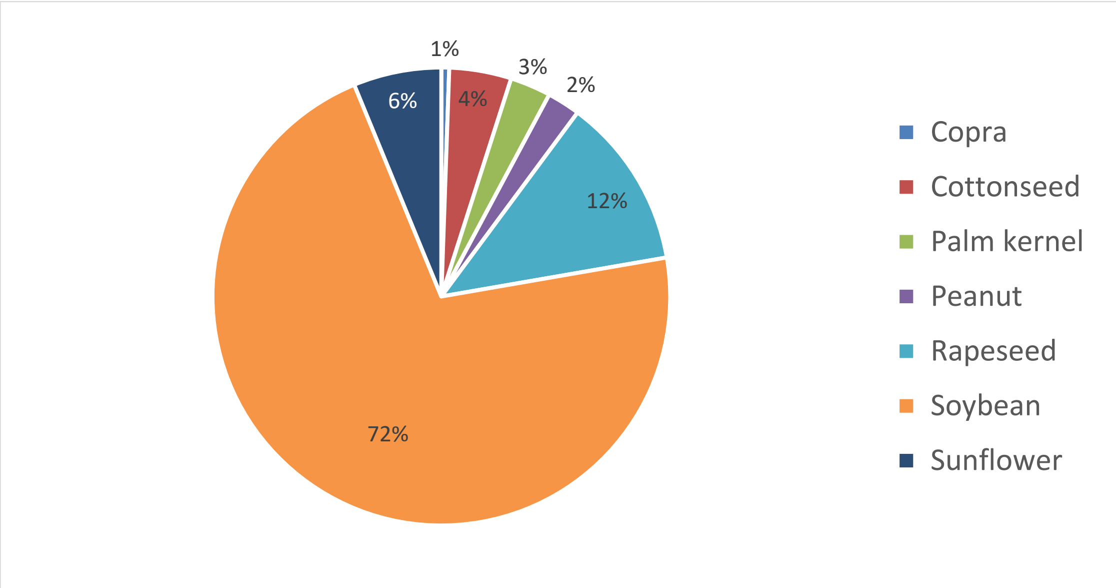


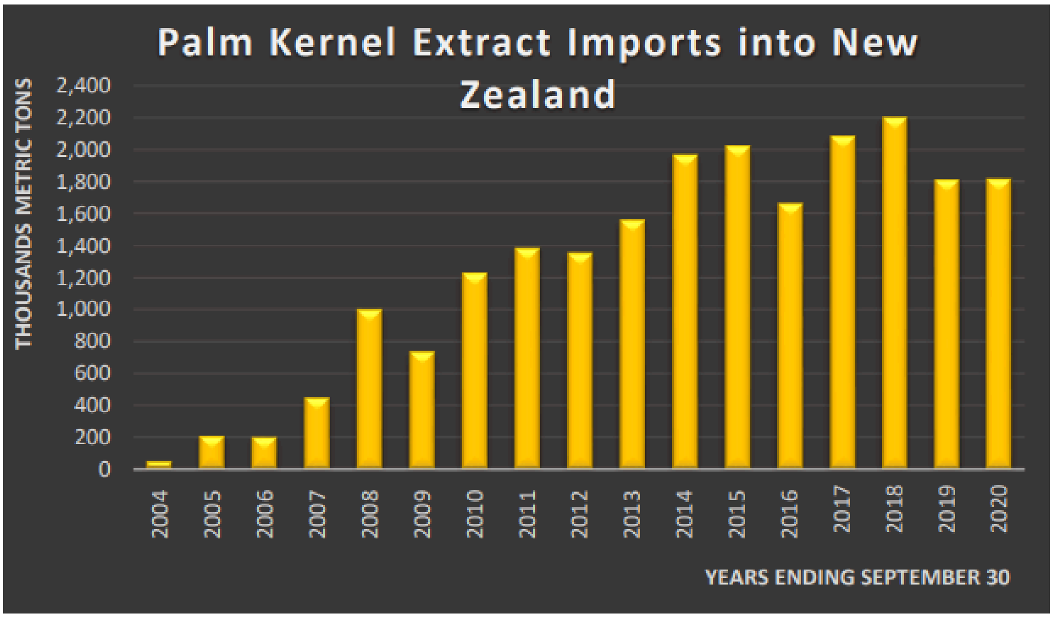
Figure 9: Worldwide plant protein feed production by type in 2021/22 (USDA, 2023)

Total soybean meal production is around 258 million tonnes a year and the largest producers are China (29%), USA (19%), Brazil (16%) and Argentina (12%). Most soymeal is used in the country of production but around 70 million tonnes is traded each year. The largest exporters of soymeal in 2021-22 were Argentina (39%), Brazil (28%) and the USA (18%) while the largest importers are the EU (26%), Indonesia (9%) and Vietnam (8%).

3.5.1 Palm Kernel Extract (PKE)

Palm kernel extract (PKE) is one of a number of by-products of the palm oil industry. It is used globally for stock feed, petfood and the production of biofuel. Indonesia and Malaysia produce more than 80% of the worlds palm oil and export 93% of palm nut or kernel oil residues (OECD, n.d). Global palm oil production has remained relatively stable at 70-75 million metric tonnes per annum since 2017-18 (USDA, 2023c).

In 2021, the top importers of palm oil production residues (including PKE) were New Zealand (USD $332M), Netherlands (USD $250M), South Korea (USD $177M), China (USD $156M), and Vietnam (USD $99.4M) (OECD World, n.d). Since PKE can be used to replace grains and/or protein meals in livestock feeds, the price tends to follow global grain prices.



Source: trade data monitor

Figure 10: Palm kernel imports to NZ (USDA, 2022)

Palm kernel extract imports to New Zealand were modest until the 2008 drought when the quantity imported jumped rapidly (Figure 10). Imports peaked in 2017 and 2018 which corresponded with the peak in cow numbers. In 2022, New Zealand imported 1,973,749 tonnes of PKE, representing around 54% of total grain and feed imports. It is mainly used in New Zealand dairy farm systems with around 300 kg of PKE/cow being fed on an annual basis. This compromises around 36% of total supplements and 6% of total feed (including pasture) eaten (DairyNZ, 2019).

3.6 Conclusions

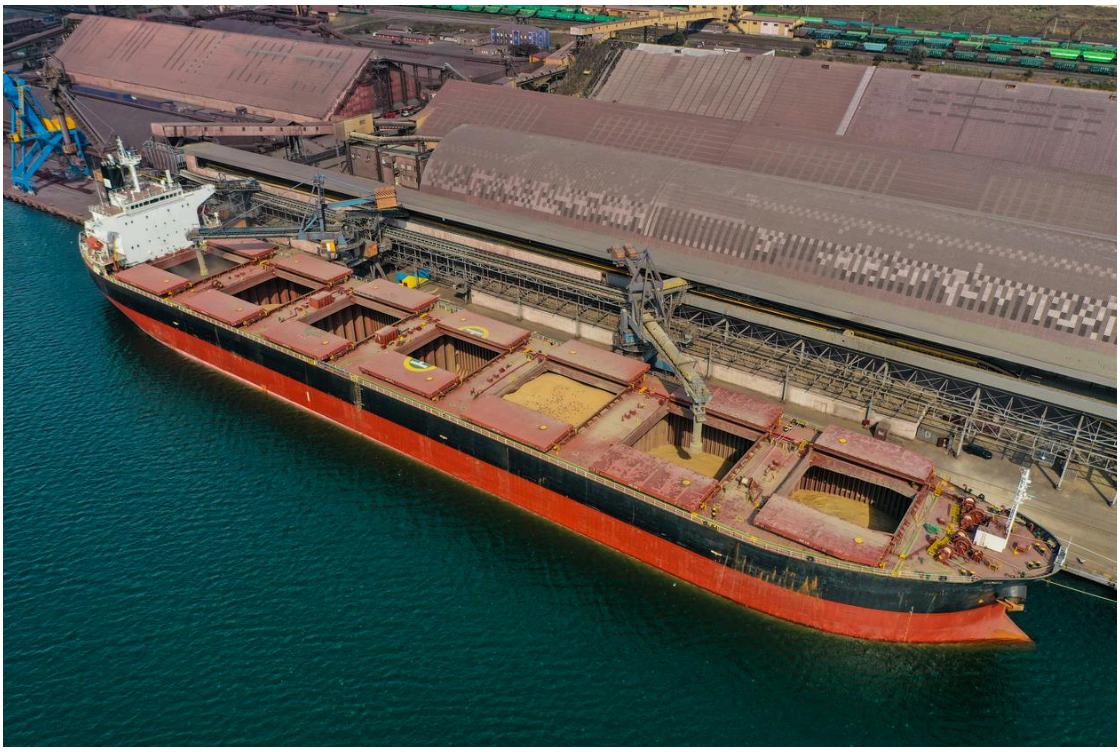
While world grain production is large, most is consumed domestically with only 17% of total production traded. The top five exporting countries (USA, Russia, Ukraine, Argentina and India) make up around 47% of exports. China is the largest importer of cereals accounting for 11.3% of global trade on a value basis.

Global grain stocks are typically around 30-35% for wheat and 20-25% for maize. In 2022-23 China held 70% of global maize and 54% of wheat stocks.

A wide number of factors impact grain supply, demand and pricing. The increasing diversion of grain into bioethanol production has impacted global grain stocks and pricing over the past two decades.

In 2022 grain prices reached a record height as a consequence of the COVID pandemic, climatic factors, changes in Chinese stock levels and the impact of the Russia-Ukraine conflict on grain trading as well as crop input prices. While this “perfect storm” of events is unlikely to occur again, this analysis highlights the many factors which can impact the supply and price of the IPF we rely on for livestock production in New Zealand.

Palm kernel extract is the main imported feed used in dairy cow rations in NZ. Its price tends to follow global grain prices.



4.0 NEW ZEALAND GRAIN AND FEED PRODUCTION

It is estimated that around 2% of the total area of New Zealand is arable or horticultural land. This is a much smaller percentage than the majority of the rest of the OECD countries (MfE, 2010).

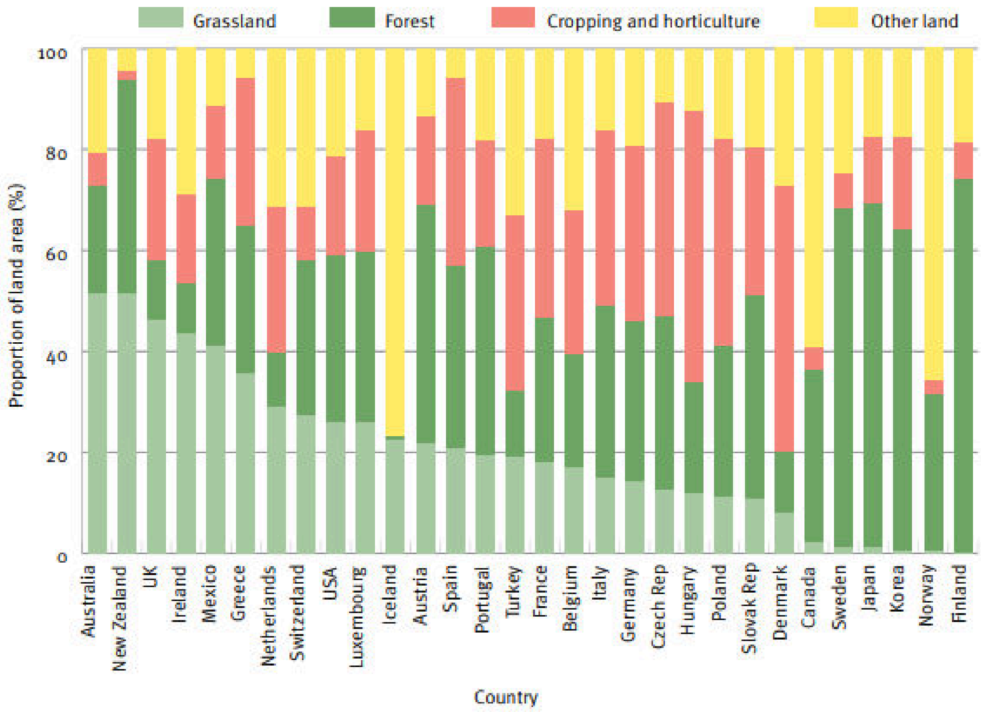


Figure 11: Land uses in OECD countries (MfE, 2010)

In 2022, New Zealand arable farmers produced around 900,000 tonnes of grain off around 107,000 hectares (AIMI, 2022; AIMI, 2023).

Our favourable climate means that New Zealand's arable growers are some of the most productive in the world, holding the world's second highest yield records for both wheat and barley (Grain Central, 2023) and producing high average maize yields (FAO, 2023). Despite this, cost of production is high mainly due to small scale agricultural production and high input and transport costs.

The average cost of production per hectare (excluding post-harvest costs) and per tonne for New Zealand (FAR, 2022) and Australian (GRDC, 2022) feed wheat in 2022 is shown in Table 1.

Table 1: Average cost of production (per ha and per tonne of grain) for feed wheat in New Zealand and Australia in 2022.

Cost Item	New Zealand	Australia (< 400 mm rainfall)*	Australia (> 400 mm rainfall)*
Average cost of production per ha (using contractor rates, excluding post-harvest costs)	$3,684	$457	$1,140
Average grain yield (t/ha)	12.7	1.8	4.8
Cost of production (NZ$/tonne)	$290	$253	$238

* All costs quoted in NZD and assume an exchange rate of 1.1 NZD/AUD

Lower production costs mean that depending on the season, it is often cheaper to procure wheat and barley from Australia than from local growers. Due to the high freight rates, it is almost always cheaper to buy grain from Australia than freight it from the South Island to the North Island (Figure 12).

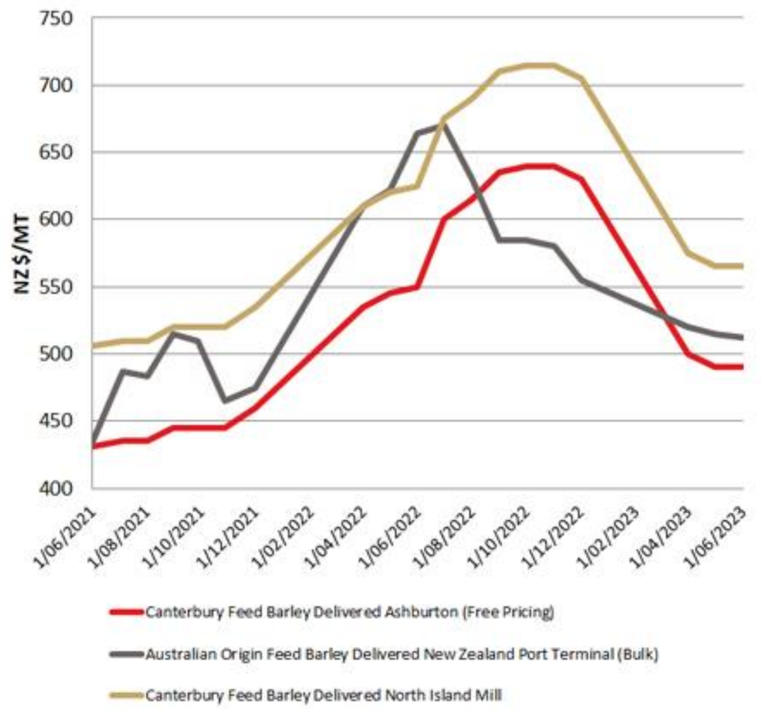


Figure 12: Comparative feed barley prices 2021-23 (Ruralco, 2023)

4.1 Grain production by region

The bulk of small cereal (predominately wheat and barley) production occurs in Canterbury with lesser volumes produced in Southland, Otago and the Manawatu-Wanganui. Due to the build-up of fungal diseases cereals cannot be grown continuously in the same paddock. They are often planted in crop rotations, which include more profitable crop options such as vegetable or grass seed as well as fodder crops which are fed to livestock.

Maize grain production is largely North Island based with significant areas in Gisborne, Hawke's Bay, the Bay of Plenty and Manawatu-Wanganui. Many crops are grown as a monoculture and there are blocks which have been cropped in maize for more than 30 years.

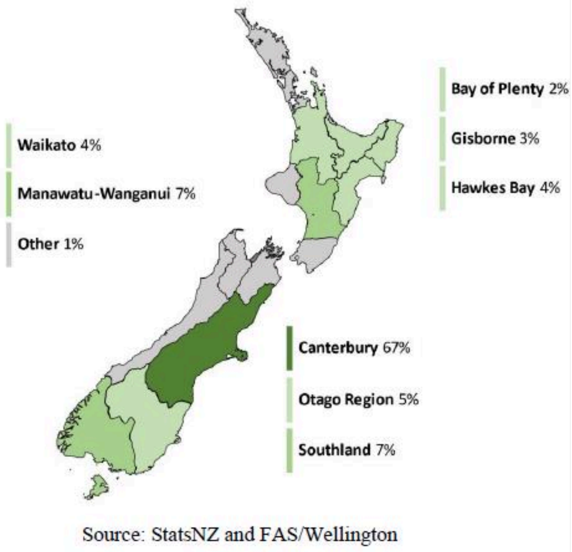


Figure 13: Distribution of arable cropping in NZ (USDA, 2023)

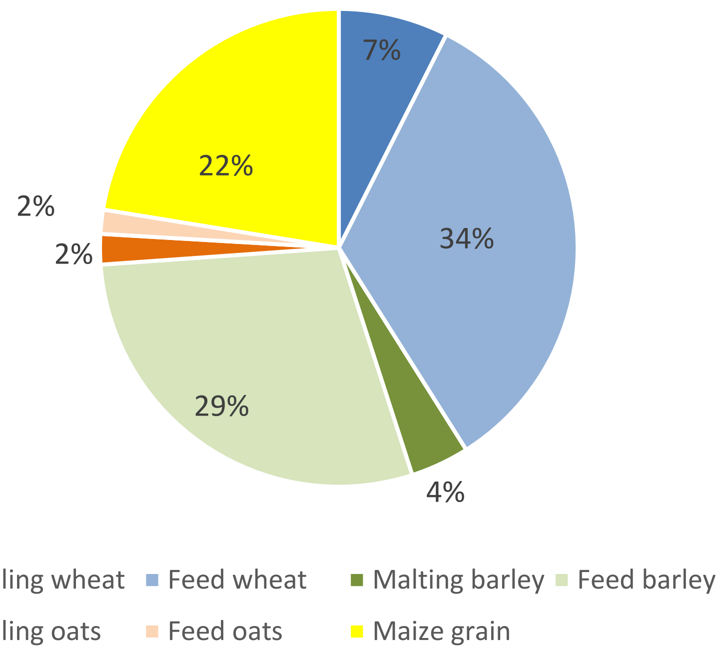


Figure 14: New Zealand grain production 2022 (AIMI, 2022; AIMI 2023)

Wheat and maize area peaked in the 1970's (Millner, 2013, Booker, 2009) and barley in the 1980's (Milner, 2013). The area of all three crops has subsequently declined due to a range of factors including the conversion of arable land to dairy farming and horticulture.

Average crop yields in 2022 are shown in Table 2 (AIMI, 2022; AIMI 2023).

Table 2: Average grain crop yields in NZ in 2022

Grain Crop	Average yield in 2022 (t/ha)
Feed wheat	9.6
Feed barley	6.9
Feed oats	6.0
Maize grain	11.2

4.2 Protein crop or meal production

New Zealand grows a small area of peas and oilseed crops, mainly oilseed rape, linseed and sunflowers in Canterbury. There are several South Island-based small oil extraction plants. Our high cost of production mean it is difficult to compete in the global oil market.

4.3 Maize silage production

Maize silage is a popular forage crop throughout the North Island and upper to mid-South Island. In 2022 an estimated area of 57,266 ha of maize was planted for silage producing an average of 21.1 tDM/ha, with a total of 1,194,914 tDM (AIMI, 2022).

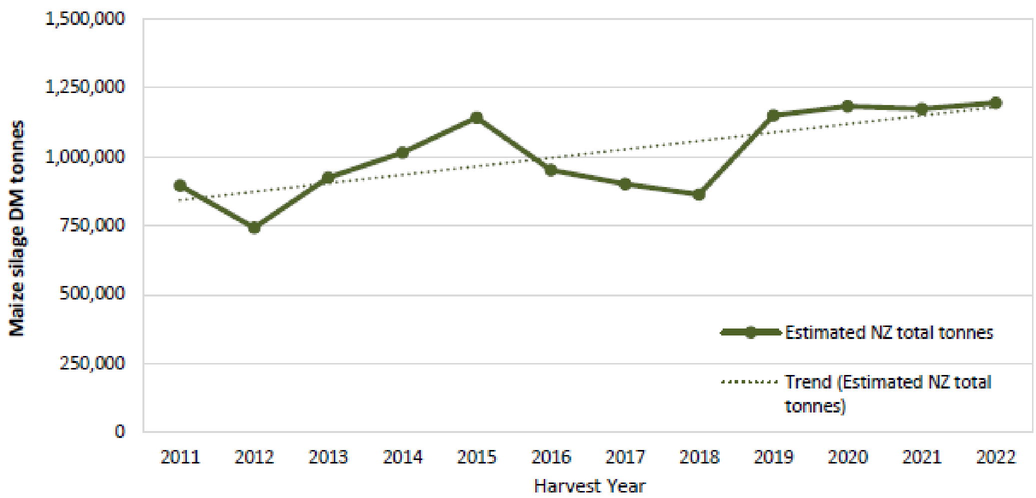


Figure 15: NZ Maize silage harvest tonnages (tDM) estimated in October each year (AIMI, 2022)

More than 98% of the maize silage grown is fed to dairy cows. Around 25% of dairy farmers grow their entire maize silage supply, 25% buy it from contract growers and 50% use a combination of methods (Pioneer® brand seeds, pers. comm).

Maize plants develop according to heat unit accumulation. The development of high yielding shorter maturity maize hybrids coupled with a warming climate has seen the expansion of the maize silage growing area into South Canterbury/North Otago and into higher altitude parts of the North Island.

4.4 Cropping gross margins

Cropping gross margins for feed wheat, milling wheat, maize grain and maize silage are shown in Table 3 alongside comparable returns for sheep and beef or dairy. All cropping costs are based on contractor rates. To make a fair comparison, the livestock returns are gross revenue less operating costs excluding administration cost /standing charges (e.g. accountancy, consultancy, rates, insurance and other). It should be noted that livestock returns are on an annual basis while the cropping gross margins are for a single crop. It is sometimes possible to grow more than one crop per year. For example, in the North Island maize silage or grain are often followed by an annual ryegrass crop.

The numbers show cropping returns range from $1,500 to $3,300/ha and compare favourably with current returns from sheep and beef farm systems, but are lower than for dairy (Table 3).

Table 3: Estimated gross margin for feed wheat, milling wheat and maize grain in 2022-23 (FAR, 2022) and gross revenue less operating costs excluding administration cost for sheep and beef or dairying in 2021-22

Crop	Yield	Grain price ($/t) or silage price ($/tDM)	Gross margin ($/ha)
Feed wheat (South Island)	12.7	$540	$2,451
Milling wheat (South Island)	10.6	$620	$2,216
Maize grain (North Island)	12.0	$600	$2,797
Maize silage (South Island)	20.5	$250	$1,487
Maize silage (North Island)	22.0	$300	$3,307
Dairy*(Waikato/BOP)	-	-	$5,251
Sheep and beef** (North Island Intensive Finishing)	-	-	$1,053
Sheep and beef** (North Island Easy Hill Country)	-	-	$660

* Financial Survey 2022 – Waikato/Bay of Plenty Dairy (AgFirst, 2022)
** Beef + Lamb NZ Economic Service – Sheep and Beef Farm Survey 2022

4.5 Environmental footprint of arable production systems

Generally arable crops are grown as part of a rotation which may include a range of different crop species including high value vegetable or vegetable seed crops, as well as forage crops which are grazed by livestock. Nutrient and GHG losses tend to be variable depending on the rotation.

4.5.1 Nitrogen leaching

A number of studies have measured or modelled nitrogen (N) loss under arable cropping systems. Many have included vegetables or vegetable seed as part of the cropping rotations and consequently N inputs and leaching losses have been high.

Norris et al. (2022) used network passive wick drainage fluxmeters to measure nitrate-N loss on nine arable and vegetable cropping farms. Nitrate-N loss was highly variable (13 - 148 kg N/ha/year. Annual losses averaged 52 kg N/ha for mixed cropping systems with livestock grazing (n=6) and 101 kg N/ha/year for mixed cropping systems with a focus on vegetable production (n=3).

Fraser et al. (2013) measured N leaching using soil solution samplers and drainage calculations, over the course of a 7-year arable crop rotation in Lincoln, Canterbury. The crop rotation included wheat, barley and peas as well as forage crops of rape and oats. The average N losses across the 7 years was 21.5 kg N/ha/year (range 8.6 to 70.8 kg N/ha).

Tsimba et al. (2021) used lysimeters and suction cups to measure N loss under a maize silage-ryegrass or maize silage-fallow (control) cropping rotation in Te Awamutu, Waikato. Nitrogen loss under the maize silage-ryegrass rotation was 8.8 and 0.3 kg N/ha in 2018-19 and 2019-20 respectively.

Keys to reducing nitrogen leaching in arable systems include matching fertiliser N applications to crop requirements (rate and timing), minimising the period of time where there is no crop in the ground (fallow period) and moving to reduced tillage systems which slow down the speed of mineralisation of soil organic matter.

National average N leaching loss under dairy and sheep and beef systems have been estimated (using OverseerFM) at 43.8 and 7.1 kg N/ha/year respectively (MPI, 2021).

4.5.2 Greenhouse gas production

Arable systems which include less animals, tend to have lower greenhouse gas (GHG) emissions than livestock systems where there is a significant output of methane.

A 2011 partial lifecycle analysis (LCA) representing a 'cradle to farm-gate' analysis of all resources and processes that contribute to the production of one tonne of wheat, maize silage, maize grain and ryegrass seed and the associated greenhouse gas emissions showed total GHG emissions of 2,820, 2,380 and 2,190 kg/ha of carbon dioxide equivalents (kg CO_2e) for wheat, maize grain and maize silage respectively (MAF, 2011).

Farm data for the 2020-21 growing season were collected for maize grain (n=8) and silage (n=12) systems located in the main growing areas of the country and biological GHG losses were estimated using OverseerFM. Total annual GHG emissions for the maize grain systems ranged from 1,114 to 2,873 kg CO_2e/ha (average 2,036 kg CO_2e/ha). Maize silage systems without livestock (n=3) had on average biological GHG emissions of 1,850 kg CO_2e/ha which was very close to that of maize grain systems without livestock (1,916 kg CO_2e/ha). Maize silage systems which included winter livestock, produced on average biological GHG emissions of between 1,512 to 6,135 kg CO_2e/ha (average 3,543 kg CO_2e/ha, Williams et al., 2022).

McNally et al. (2021) calculated total GHG emissions across five years of an arable rotation. The average annual emission was 1,962 kg CO_2e/ha. The largest emissions were from grazing (29%), residue (26%) and fertiliser associated emissions (19%). Approximately 10% of the total emission was from fuel which is not included in the biological GHG total.

In contrast biological GHG emissions from dairy farm systems average 9,600 kg CO_2e/ha (range 3,100 to 18,800; DairyNZ, 2017) and sheep and beef farm systems average 3,600 kg CO_2e/ha (range 170 to 7,100; AgResearch, 2020).

4.6 Conclusions

Only about 2% of the total area of New Zealand is used for horticultural and arable production. On a global basis our grain production is insignificant comprising around 0.03% of global production. While arable crop yields are very high on a global basis, high input costs mean our grain is expensive to produce.

Grain and maize silage gross margins range from $1,500 to $3,300 per ha and are comparable with sheep and beef but substantially lower than average dairy farm returns.

Modelled N losses from arable systems can be variable depending on the crop rotation and the level of N input. Greenhouse gas losses from arable systems tend to be lower than those of traditional livestock systems.

5.0 NZ GRAIN AND CONCENTRATE IMPORTS

New Zealand is a net importer of grain and concentrates with import volumes rising to a record level of 3.7 million tonnes in 2022. National grain and feed demand continues to outstrip domestic supply by nearly double, with New Zealand producing 2.1 million tonnes in 2022, but consuming an estimated 5.8 million tonnes (USDA, 2023).

Palm kernel extract (PKE) from Indonesia and Malaysia is the highest volume feed supplement imported, accounting for 54 percent of imports and 35 percent of total feed consumed in 2022. Distiller's Dried Grains with Solubles (DDGS) from the United States has seen the biggest growth of feed imports at 10 percent per year, almost doubling since 2017. Some shipments of maize (and a shipment of sorghum in 2020) have also come from the United States, and maize has also been imported from Romania. Wheat has historically been sourced exclusively from Australia every year, with volumes typically consistent. Another major feed imported is soybean meal, which is imported almost entirely from Argentina (Figure 16).

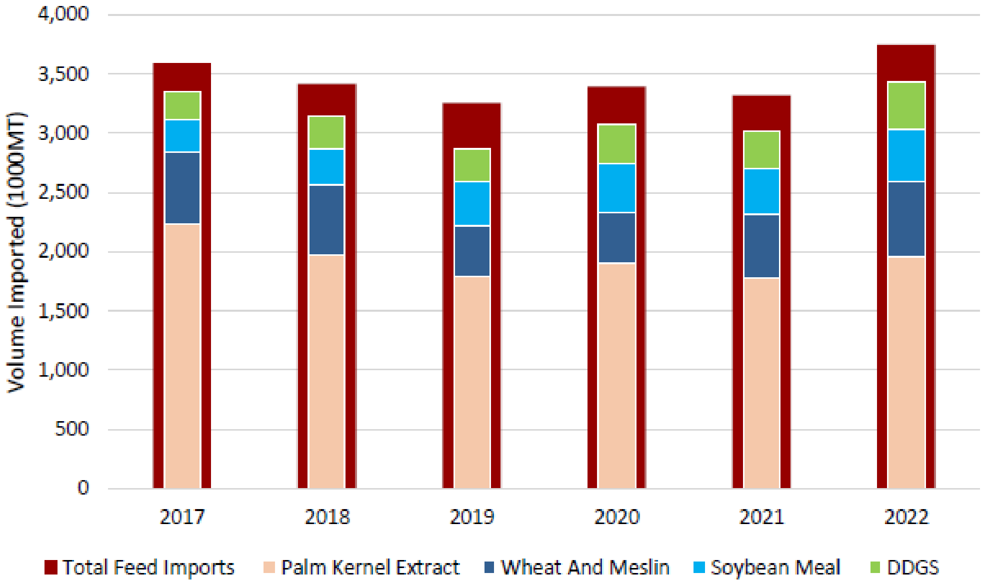


Figure 16: New Zealand Feed Imports (USDA, 2023)

In New Zealand, the dairy industry is consistently the largest consumer of grain and imported feed at approximately 75%. Poultry consume around 12%, humans 9% and other animals 4% (USDA, 2023).

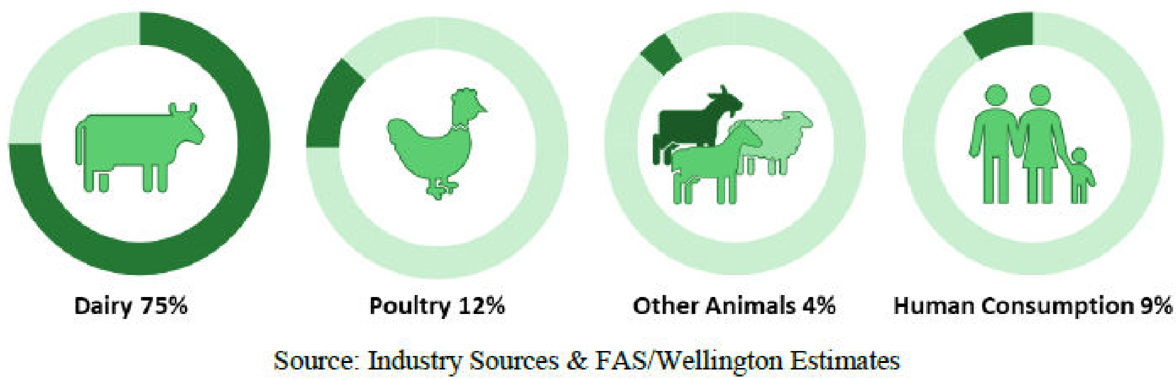


Figure 17: New Zealand grain and feed consumption (USDA, 2023)

The New Zealand Feed Manufacturers Association (NZFMA) records manufactured feed production statistics and the total tonnage of raw materials used in feed production (NZFMA, 2023). It does not report feeds which are fed unmixed or blended. Examples of feeds which are typically not included in compound feed include PKE, DDGS, molasses, soy hull and wheat bran pellets.

For the year ending December 2022, a total of 1,123,018 tonnes of raw material was used in compound feed production. Forty percent of the raw material was domestically produced and 60% was imported, but there were major differences between islands. In the South Island 69% of raw material used in compound feed was domestically produced, but in the North Island only 25% was domestically produced (Figure 18, NZFMA, 2023).

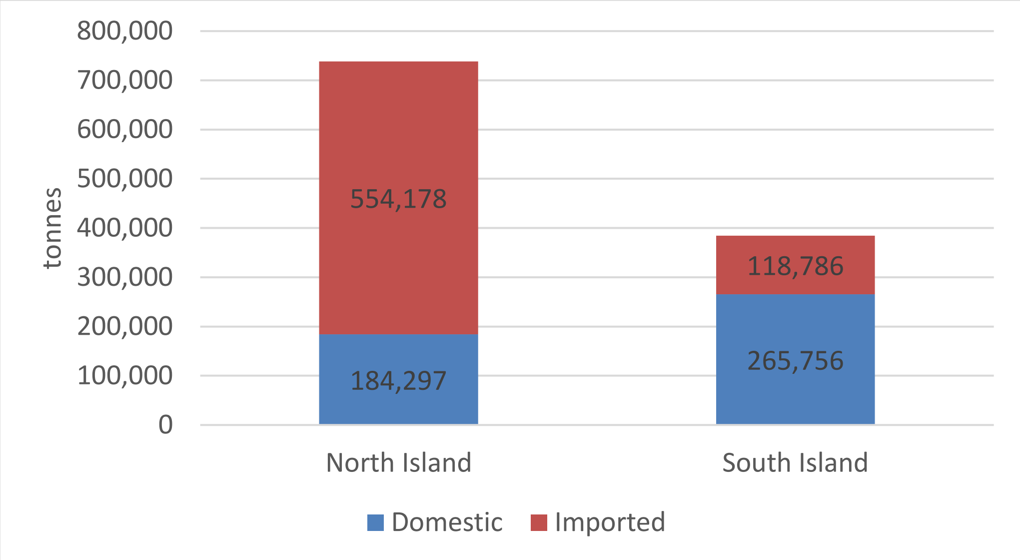


Figure 18: Volume and source of raw materials used in compound feed manufacture in NZ in 2022 (NZFMA, 2023)

New Zealand's main imports for compound feed production were wheat and soyabean meal (Figure 19).

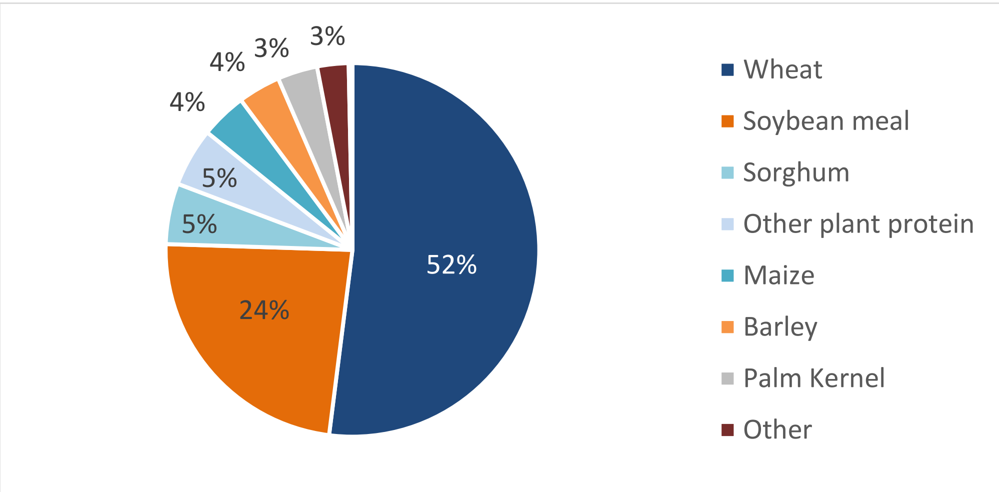


Figure 19: NZ raw material imports for compound feed manufacture (NZFMA, 2023)

The top consumers of NZ manufactured compound feeds were the poultry industry (61%), pigs (14%), dairy cows (12%) and calves (8%).

5.1 Dairy farm feed demand

The New Zealand dairy industry is the largest consumer of internationally produced feed (IPF). Dairy cow numbers increased from around 2.4 million in 1992-93 to a peak of 5.0 million cows in 2017-18. During this time more than 730,000 additional hectares were converted to dairying (Table 4). Over approximately the same period average per cow production has lifted from around 259 kilograms of milk solids (kgMS)/cow to 397 kgMS/cow (53%) and stocking rates have risen 18% from 2.43 to 2.86 cows/ha (LIC, 2022).

Table 4: Summary of national feed demand from 1990-91 to 2017-18 (DairyNZ, 2019)

	Cows Milked (million)	Feed Demand (million t DM)	Feed Demand (t DM/cow)	Pasture eaten (t DM/cow)	Crop eaten (t DM/cow)	Harvested supplement (t DM/cow)	Imported Supplement (t DM/cow)
1990-91	2.40	9.30	3.87	3.72	0.07	0.05	0.04
2000-01	3.49	15.22	4.37	4.09	0.11	0.12	0.04
2010-11	4.53	20.34	4.49	3.80	0.18	0.23	0.28
2017-18	5.00	23.58	4.72	3.84	0.30	0.22	0.37

Hedley et al. (2006) characterised dairy farm systems according to the percentage of home-grown feed used in their system (Table 5). In 2000, 72% of farms grew at least 90% of their feed at home (Greig, 2012) but by the 2021-22 season it was estimated that 73% of their farms imported at least 20% of their total feed requirements (DairyNZ, 2022).

Table 5: NZ dairy farm systems in 2000/01 and 2021/22

Farm System	Description	2000-01[a]	2021-22[b]
		% of NZ dairy farms	
1	» All grass, self-contained, all adult stock on the dairy platform. » No supplement is fed unless harvested off farm. No off farm wintering. » 100% of total feed is home grown.	41	3
2	» Feed imported, includes either supplement or grazing off, fed to dry cows. » 90-99% of total feed is home grown feed.	31	24
3	» Feed imported to extend lactation and for dry cows. » 80-89% of total feed is home grown feed.	17	47
4	» Feed imported and used at both ends of lactation and for dry cows. » 70-79% of total feed is home grown feed.	11	20
5	» Imported feed used all year. » 50-69% of total feed is home grown feed (occasionally less than 50%).	1	6

[a] Greig, 2012 [b] DairyNZ, 2022

Between 1990-91 and 2017-18, the total amount of feed eaten by NZ cows has increased 153%. This increase has occurred primarily (80%) by more cows, which is due to increases in dairy land and stocking rates (in the 1990's and early 2000's). On a per cow basis feed eaten has increased from 3.87 to 4.72 tDM/year. Imported feeds, including PKE, had a compound annual growth rate (CAGR) of 9%, harvested supplements including maize silage and barley increased 5.6% CAGR, while grown crops including fodder beet, kale and swedes also increased 5.6% (DairyNZ, 2019).

Maize silage (North Island and Canterbury) and cereal silage (Lower North Island and South Island) areas grew during the 1990's. In the 2000's the use of PKE began to expand and its uptake was hastened by a widespread drought that impacted most dairy districts in the summer of 2007-08. In the 2010's fodder beet rose due to popularity, especially in the Lower North Island and South Island dairy districts. There were also substantial increases in the use of kale and swedes, mainly in South Island wintering systems (Figure 20).

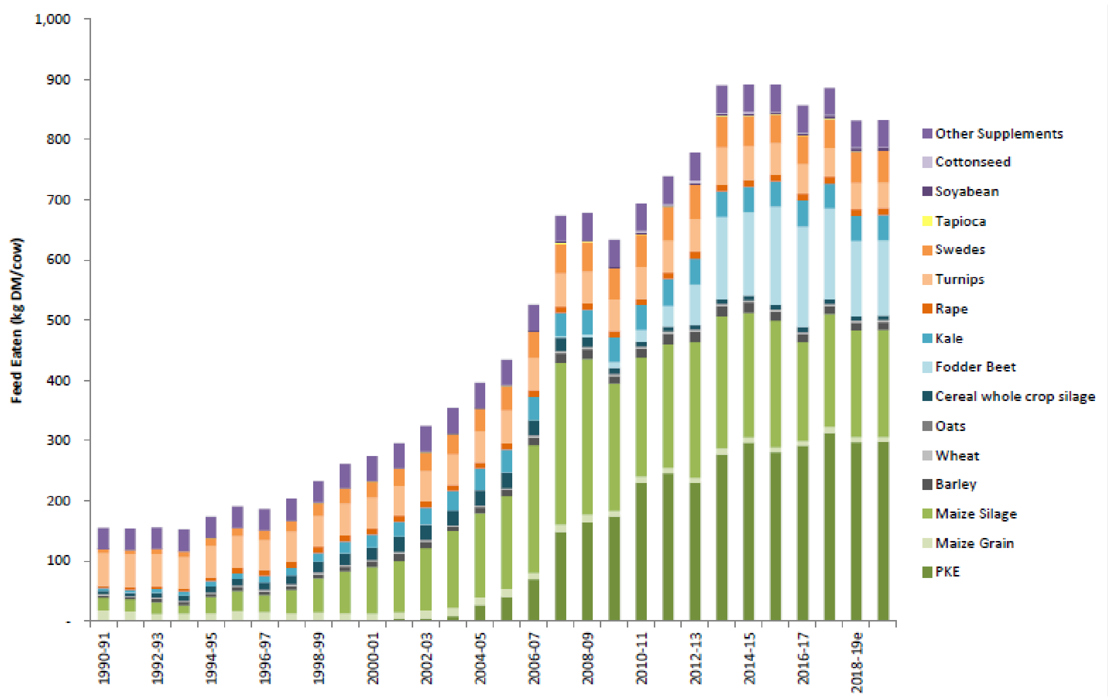


Figure 20: Total supplementary feed eaten on dairy farms by supplementary feed type 1990-91 to 2018-19 (DairyNZ, 2019)

Dairy calves are also a significant user of IPF. In 2020, 4.9 million dairy calves were born in New Zealand (MacDonald, 2021) and DairyNZ estimate that of those:

- 1.4 million (28%) were female cows kept by dairy farmers to replace the 20-30% of older cows who will be culled every year when they are no longer deemed productive.
- 1.3 million (27%) were raised to maturity for beef. Beef animals are generally slaughtered when they reach maturity at around one and half years old.
- 2 million (40%) were bobby calves.
- 196,000 (4%) were born dead or die shortly after birth.

Most farmers feed around 50 kg of meal per calf reared which means currently around 135,000 tonnes of grain-based concentrate is fed to calves.

5.2 Poultry

The poultry sector is the second largest consumer of IPF in New Zealand (USDA, 2023) and it is the largest consumer of locally manufactured compound feed.

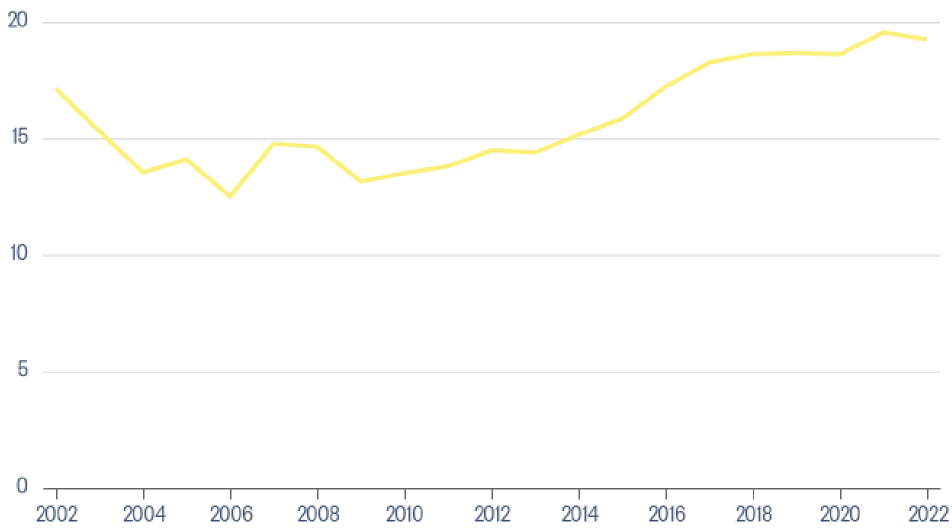


Figure 21: Total chickens (millions) for meat production in NZ (Figure.NZ, n.d)

In 2022 there were 19.2 million broilers and 3.7 million laying hens in New Zealand which was a decrease of just under 300,000 broilers and 450,000 laying hens when compared to the previous season (Figure.NZ, n.d). The reduction in poultry numbers could be attributed to rising feed prices, recent enforcement of welfare standards and labour shortages. Poultry numbers are now recovering.

New Zealand is unique in that it is free of avian influenza, Newcastle disease and Infectious bursal disease (IBD) virus. For biosecurity reasons, imports of in-shell eggs and uncooked poultry meat are prohibited. This effectively protects the industry from overseas competitors and allows it to exist even though farm operating costs are considerably higher than in other nations.

The New Zealand meat chicken industry is modern, highly efficient and vertically integrated, with the chain of production from hatcheries, chicken farms and processing plants largely owned by the major companies (PIANZ, n.d). Some companies also own and operate large feed mills and import feed components. One company grows wheat on their own arable farms in Western Australia. Meat chicken farmers typically work for companies on a contract management basis. Egg production in New Zealand comprises of a few big companies and a large number of smaller family-owned businesses.

Poultry are generally fed a compound feed blend which is formulated using least-cost-ration software. End users shop for feed ingredients on the global market, and it is often cheaper to procure grain offshore than to source it from local growers.

5.3 Pigs

The number of pigs farmed in New Zealand declined from 327,000 in 2011 to 249,000 in 2021 (Figure.NZ, 2022) and currently around 60% of pork consumed is imported. The New Zealand pork sector operates to high welfare standards compared to many other countries. As of 2021, approximately 55% of the commercial herd is indoors, 42% are in free farmed systems and 3% are free range (NZ Pork, n.d).

Superior housing systems combined with high local grain prices means the cost of pork production in New Zealand is high. Imported pork, which in the main comes from countries with less stringent health, welfare and environmental requirements is often cheaper than locally produced product.

5.4 Other ruminants

While other ruminants are relatively small consumers of IPF, it is worth mentioning that the dairy goat industry is very reliant on Australian produced canola and wheat DDGS for protein in milking doe rations.

5.5 Conclusions

New Zealand uses around 3.7 million tonnes of IPF, of which 75% is used for dairy, 12% for poultry and 4% for other animals including pigs.

Dairy farm demand for IPF has lifted due to increased cow numbers, higher stocking rates and greater milk solids production per cow. While cow numbers have likely peaked, the demand for supplementary feed including IPF is predicted to continue to increase as farmers focus on lifting per cow production and the industry moves towards eliminating bobby calves.

Poultry are the second largest user of IPF, and this is likely to continue as the large, vertically integrated companies, which control the meat chicken industry, use least-cost-ration software to drive grain purchase decisions.

6.0 IMPACT OF GLOBAL FEED PRICE RISES OR UNAVAILABILITY

In New Zealand over 90% of IPF is used in livestock rations. This section examines the impact of feed price rises on farmer profitability, discusses the likelihood of feed being unavailable or supply being seriously constrained, and outlines what the impact would be on local livestock farmers.

6.1 Impact on local feed prices

The price of locally produced grain tends to follow global grain price trends. There are a number of reasons for this. High global fuel prices impact the cost of grain production globally (including in New Zealand) either directly (through increases in diesel prices) and indirectly by lifting the cost of fertiliser and herbicide manufacture. Livestock feed companies formulating least-cost-rations, are prepared to pay more for domestically produced grain when global prices are high.

Since 2010, the New Zealand spot prices of feed barley, maize grain and PKE have varied considerably but have trended upwards. Feed barley has ranged from $255 to $655, maize grain $312 to $740 and PKE from $199 to $522 per tonne.

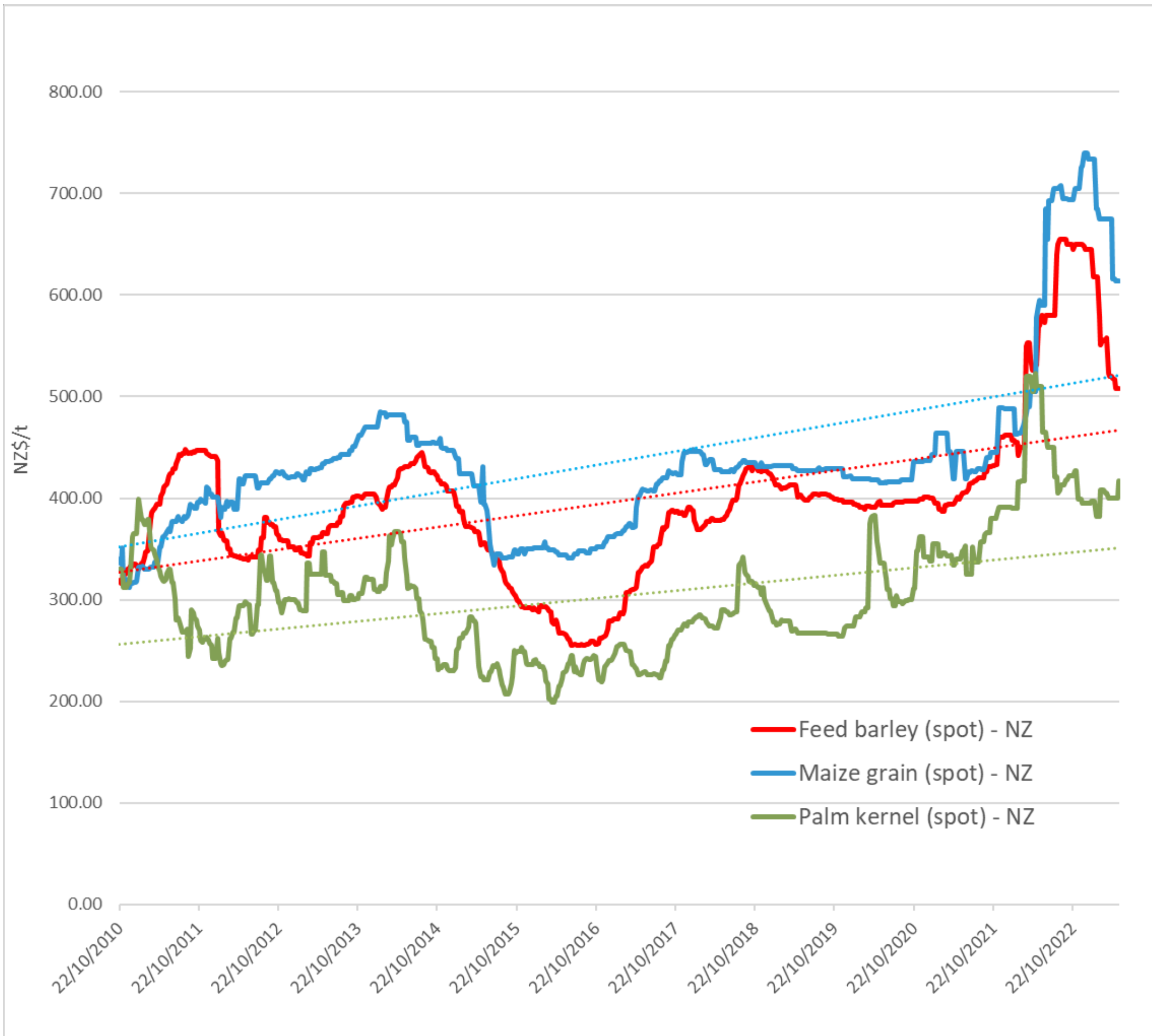


Figure 22: Spot prices and trends for feed barley, maize grain and PKE from 2010 to 2022 (Data supplied by NZX, 2023)

6.2 Implications for farmer profitability

Feed comprises around 45% and 60-70% of the production cost for meat chickens and layers respectively. In contrast, feed (including feed made, purchased or cropped) comprises around 25-28% of operating expenditure on a typical New Zealand dairy farm (DairyNZ, 2022). For this reason, dairy farms are less sensitive to rises in feed price than poultry farmers.

However, changes in the price of supplementary feed also impacts the profitability of dairy farming. For example, assuming an average milk solids conversion of 100 gMS/kgDM fed and a milk solids price of $8.00/kg, each kilogram of supplement fed generates a milk return of $0.80. If the supplement costs $0.40/kgDM ($400/tDM) fed the return is $0.40 or 50%. If the supplement rises to $0.60/kgDM ($600/tDM) fed, the return drops to $0.20 or 25%. High supplement prices can therefore make supplement use less profitable or even unprofitable.

6.3 Is a shortage of IPF likely?

Grain, of varying types, is produced, consumed and exported by a large number of countries around the world. Northern and southern hemisphere cropping systems ensure there are multiple harvest events each year. To a large extent cereals like wheat, barley, maize, and to a lesser extent sorghum, are interchangeable in livestock rations, although the levels of other ingredients may need to be adjusted. Australia, our closest neighbour, exported 40.6 million tonnes of grain (ACCC, 2022) in 2021-22. This is more than 10 times the annual New Zealand demand for IPF and more than 40 times the annual New Zealand demand for grain. For these reasons, there is a low risk that New Zealand would find itself in the position of being unable to source grain, albeit at a higher price.

On the other hand, PKE is almost entirely traded by two neighbouring countries, Indonesia and Malaysia, and since it is a by-product of palm oil production, its long-term supply is inextricably linked to consumer demand for palm oil.

Globally there is some Western consumer resistance to palm oil use. The consumption of foods rich in palm oil is associated with an increased risk of cardiovascular disease, given its high saturated fat content. Palm oil production is at the centre of environmental and social issues related to palm cultivation methods. The environmental consequences of palm oil cultivation are deforestation of rainforests, the loss of biodiversity and the consequent negative effects on the climate and environment. Considering the socio-economic issues, scholars have underlined the rise of conflicts related to the livelihoods of smallholders and the exploitation of workers (Savarese et al., 2022).

On the other hand, the oil palm is a uniquely productive crop. On a per hectare basis, oil palm trees are 6-10 times more efficient at producing oil than temperate oilseed crops such as rapeseed, soybean, olive and sunflower (Murphy, 2015). A recently published paper (Alcock et al., 2022) assessed global systems-wide variation in GHG emissions by performing a unified re-analysis of life cycle input data from diverse palm, soybean, rapeseed, and sunflower oil production systems cited in published literature. The resulting dataset reflected almost 6,000 producers in 38 countries, and was representative of over 71% of global vegetable oil production. Across all oil crop systems, median GHG emissions were 3.81 kg CO_2e per kg refined oil. Crop specific median emissions ranged from 2.49 kg CO_2e for rapeseed oil to 4.25 kg CO_2e for soybean oil per kg refined oil. Life cycle GHG emissions from the median palm oil production system were roughly equal to the across-crop median: 3.73 kg CO_2e per kg refined oil but highly dependent on soil type and choice of methane capture technology for palm oil mill effluent (POME).

Laboratory developed single cell oils could play an important role in reducing global dependence on palm oil. Two biotechnology companies have developed oils made from yeast as a replacement for palm oil. USA-based C16 Biosciences (c16 Biosciences), backed by Microsoft founder Bill Gates, launched their first Palmless product in 2023. While in the UK, the Clean Food Group (Clean Food Group) has been formed to commercialise *Metschnikowia pulcherrima* (MP), the University of Bath's unique strain of oil-producing yeast (Latham, 2023).

Changes in consumer preferences away from palm oil could slowly change the supply of PKE. Extreme weather events, pests and diseases, labour shortages, changes in government policy or geopolitical instability in Southeast Asia could potentially have a larger and more rapid impact on PKE production, and conflict or biosecurity concerns could impact exports to New Zealand.

In 2022 New Zealand imported 1.97 million tonnes of PKE (1.78 m tDM), enough to meet the total feed requirements of 377,951 cows or 8% of the national herd. If this feed was not available, dairy systems would be short of feed, particularly if the inability to source PKE coincided with an extreme weather event in New Zealand (e.g. widescale drought).

Palm kernel extract cannot be directly replaced with imported grain for a number of reasons:

- Imported grain must be milled at an approved facility to render the grain, and any weed seed it contains, non-viable. In contrast, PKE can be transported from the port directly onto farm without the need for further processing.
- Even if the biosecurity requirements did not exist, grain must be milled to break the outer seed coating allowing rumen microbes to access the high energy endosperm.
- Grain contains highly digestible starch which ferments rapidly within the rumen. Animal intakes must be carefully controlled to reduce the risk of acidosis, a serious metabolic disease that occurs when rumen pH levels fall below the normal range. In contrast, PKE can be fed to animals at high rates in feed bin systems.

Another scenario which should be considered is that of IPF being available but not being able to be fed due to milk processor restrictions driven by processing limitations and/or end user requirements.

Even relative low feeding rates of supplements can have significant impacts on the fatty acid and volatile profile of milk. An Irish study investigated the impact on milk quality of including 2 kgDM of grain-based concentrate (CONC), PKE, soybean hulls (SOYA) or molasses beet pulp (BEET) in the diet of lactating Jersey x Friesian cows consuming a total of 16 kgDM/day. Cows fed PKE had higher levels of short chain fatty acids in their milk than cows fed CONC, SOYA or BEET. This has implications for the functional characteristics and processibility of high-fat dairy products. The thrombogenic (TI) and atherogenic (AI) indices are both dietary risk indicators for cardiovascular disease. Milk from cows fed with PKE had the higher AI and TI indexes than milk from cows fed CONC (O'Callaghan, 2019).

6.4 Implication of IPF shortage

Global shortages or freight restrictions which limited the import of IPF could have large implications for livestock production in New Zealand.

Poultry and egg production would be significantly constrained, and this would lead to chicken and egg shortages since these products cannot be imported. Pig production would also be impacted, and we would likely see higher imports of pork products.

The dairy industry would be short of around 2.8 million tonnes of feed (around 2.5 million tDM) on an annual basis. Assuming an annual feed demand of 4.7 tDM/cow/year, this equates to the feed demand of 531,382 cows or 11% of the national herd.

Many dairy farm systems rely on some imported feed as part of their standard feed management regime. Without it they would be essentially overstocked because animal feed requirements exceed the amount of pasture and crop the farm can grow or source from local suppliers. The amount of energy required to maintain an animal is essentially fixed. Less feed energy therefore means less milk production and/or a decrease in cow body condition score.

Most IPF suppliers hold several weeks stock, however if the inability to supply IPF occurred at short notice, coincided with a major weather event (e.g. drought) when sheep and beef farmers are destocking or at the time of the year when dairy farmers normally cull empty or surplus dairy cows (Feb to June), it would take weeks or even months to process the surplus cull cows. To put the number into perspective, in 2022 the national New Zealand adult cattle kill (including beef and dairy) averaged 226,000 head but peaked at 324,000 per month (MIA, 2023). At a farm level, delays in being able to cull cows would impact the feed supply for the entire herd and this could have animal welfare implications.

6.5 Conclusions

The price of locally produced grain tends to follow the trend of global prices. This is because our production costs tend to mirror global costs, and livestock feed companies formulating least-cost-rations, are prepared to pay more for domestically produced grain when global prices are high.

Feed comprises around 45% and 60-70% of the production cost for meat chickens and layers respectively. In contrast feed (including feed made, purchased or cropped) comprises around 25-28% of operating expenditure on a typical New Zealand dairy farm (DairyNZ, 2022). While dairy farms are less sensitive to rises in feed price than poultry farmers, rises in the price of IPF still impacts dairy farmer profitability.

Grain is produced globally and the geographic spread of growing regions, range of grains which are largely interchangeable in livestock rations and the fact Australia is a large exporter, make it unlikely that New Zealand would never be able to procure grain of some type.

In contrast PKE is only produced in Malaysia and Indonesia. Changes in consumer preferences away from palm oil could slowly change the supply of PKE. Extreme weather events, pests and diseases, labour shortages, changes in government policy or geopolitical instability could have a larger and more rapid impact on New Zealand’s ability to source this feed. Currently New

Zealand imports enough PKE to meet the total feed requirement of around 8% of the nation's dairy cows, so any event which restricted or stopped supply would have a significant impact.

Internationally produced feed shortages could impact milk production and cow body condition score. Ultimately farmers would need to destock but there would likely be delays in meat works killing space. This could have animal welfare implications.

7.0 END USER SURVEYS

To gain an understanding of the impact of global disruptions on the price and availability of IPF we emailed a survey to 14 feed supply companies and 12 poultry and pig farmers and four relevant industry organisations (See survey details in Appendix 13.1).

Despite numerous follow up attempts, responses (emailed and verbal) were only collected from six feed supply companies, four poultry and pig farmers and three industry organisations with some responses not being collected until June 2023. As a consequence of the poor response rate, it has not been possible to analyse trends and instead the authors have focused on key themes.

7.1 Feed suppliers

The feed supply company survey highlighted that while a large number of companies manufacture and/or sell stockfeed in New Zealand, only a handful import grain or feed, and many of these bring in a limited range of commodities.

The reasons for the lack of competition in the grain and feed importation business are numerous. Bulk commodities like PKE and grain come into the country in 30,000 plus tonne shipments. Product must be ordered several months in advance and very few industry players can finance or have the facilities to handle the logistics of receiving, processing and storing imports of this volume. A single company would struggle to sell a whole shipload of a single bulk commodity to farmers themselves, therefore they on sell it to other feed manufacturers.

The majority of feed companies in New Zealand procure grain and feed inputs from the importing companies and also use a proportion of locally produced grain in their feed mixes.

All of the entities surveyed who were importing cereal grain were part of larger, multinational companies involved in the global grain trade. Procurement is not really an issue because they have operations in countries or regions which grew and exported grain (e.g. Australia, USA).

Importers commented that they held their margins, and increases in product cost or freight rate were passed onto their clients. Smaller feed suppliers who were not direct importers tended to “sharpen their pencils” and/or change formulations. Product production volume was based on consumer demand which was related to weather conditions and feed on farm as well as the milk price forecast.

7.1.1 COVID pandemic

The main impact of the COVID pandemic was on shipping and not feed price.

During the COVID pandemic oil consumption dropped below oil production which resulted in a rapid decrease in the price of crude oil. However, freight prices to get product to New Zealand rose to 2.5 times the pre-COVID level:

- Container shortages impacted the freight of smaller volume products which are freighted in containers (e.g. wheat DDGS from Australia or high energy fat supplements).
- There were also major loading and unloading delays at ports which caused higher demurrage and shipping charges.

- The impact on the price of PKE and grain was much lower than for small volume products which are freighted in containers.
  - » PKE is backloaded on ships which transport logs from New Zealand to Asia. There is less PKE volume brought back to New Zealand than log volume exported, which means each month several boats return empty and freight rates are competitive.
  - » The large volume of freight in a bulk shipment means rises in costs are spread over a large tonnage and the impact on price per tonne is small. For example, if it cost around $30,000 per day to charter a ship carrying 30,000 tonnes of feed, a delay of two days adds $2/tonne to the cost of the feed.

7.1.2 Ukraine/Russian conflict

All feed suppliers commented that the Ukraine/Russian conflict had impacted price but not really feed supply.

As one supplier interviewed in June 2023 commented:

"Back when the conflict broke out, we thought there would be drastic shortages and to a degree there was some panicking in the market. However, because New Zealand could afford to spend more money than other countries (e.g. Africa and the Middle East), we still got what we wanted, we just had to pay a bit more".

7.1.3 New Zealand produced grain

South Island feed companies were more frequently using locally grown grain which was combined with imported proteins (e.g. soymeal, DDG etc) to produce blended feeds.

North Island feed companies were open to purchasing locally produced grain, but the key issues were supply and price.

In the North Island the growth of demand for maize silage had seen an erosion in maize grain area.

The cost of shifting maize grain between the South Island and the North Island was too high mainly due to the lack of bulk ship loading and unloading facilities in the South Island.

- "We can get PKE from Asia cheaper than we can get grain from the South Island to the North Island".
- "It is cheaper to bring grain in from Australia than to get grain from the South Island".

7.2 Poultry and pig

Large poultry operators were using least-cost-ration software to procure grain and feed globally. For example, wheat was being imported from Australia, Canada, India and Argentina while maize came from Canada, USA, Mexico, Australia, South Africa and Europe.

One supplier noted that while global grain price was impacted by actual supply, it was also impacted by "what people think is going to happen to supply".

Price and availability were the main limitations for not purchasing New Zealand produced grain.

The pig farms surveyed were either procuring feed from feed manufacturers or working with importers to procure small quantities of feed (2,000 to 8,500 tonnes per annum). The impact of global disruptions included needing to carry more feed on farm to compensate for delays in delivery due to shipping issues and large increases in product prices.

Farmers had increased product prices, changed ration formulation, and changed production The cost of production had increased 0-25% up to 50-75% for individual growers. Several pig and poultry contacts commented that the combination of the new welfare standards and rising grain prices had made it very hard to remain profitable and that many smaller operations had closed down.

Pig farmers would consider using locally produced grain, but the key issues were price and availability. One producer commented "Local grain farmers are expecting import parity pricing and are not selling grain".

7.3 Conclusions

While there are a lot of companies which sell stockfeed in New Zealand, there are relatively few importers. The COVID pandemic affected shipping costs, especially for products which were imported by the container load.

For bulk products, the increased price was spread across many tonnes making the impact much smaller. Palm kernel extract freight prices were less impacted because the product is backloaded to New Zealand on log ships which would otherwise return empty. COVID bottlenecks at ports impacted supply chains meaning feed companies and pig and poultry producers needed to hold more feed inventory.

For New Zealand, the Ukraine/Russian conflict impacted grain and feed price more than supply. Feed companies generally increased prices whilst chicken (meat and egg) and pork suppliers changed ration formulations, changed production and increased product prices.

All feed manufacturers were open to using more locally produced grain. Key limitations to using more local grain were availability and price.

8.0 REDUCING NZ'S RELIANCE ON INTERNATIONALLY PRODUCED FEED FOR LIVESTOCK

Earlier sections of this report have highlighted the reliance of the New Zealand dairy, poultry and pig industries on IPF. This section examines what future demand for IPF might look like and discusses ways New Zealand could become less reliant on IPF.

8.1 Future NZ demand for IPF

The New Zealand pig and poultry industries predominantly supply the domestic market which is small on a global scale. Pig production is declining and unlikely to rebound. National poultry numbers peaked in 2018, declined to 2022 and are now showing some sign of a rebound. However, local poultry production is not globally competitive, therefore it seems unlikely that there would be a large increase in production and therefore demand for IPF.

Most industry experts predict that the New Zealand dairy industry has passed peak cow numbers. Dairy farm numbers have decreased in some regions due to competing land use (urban sprawl and horticulture) and the new Resource Management (National Environmental Standards for Freshwater) Regulations 2020 intensification and land use change rules are likely to limit future increases in dairy farm area.

Environmental regulations and labour constraints mean stocking rates are likely to drop slightly and there will be an increasing focus on higher per cow performance. New Zealand per cow production lags behind other major dairy producers (Figure 23, USDA, 2022a). To lift this, farmers will need to improve cow nutrition so animals peak higher, have a slower rate of post-peak decline and/or achieve more days in milk.

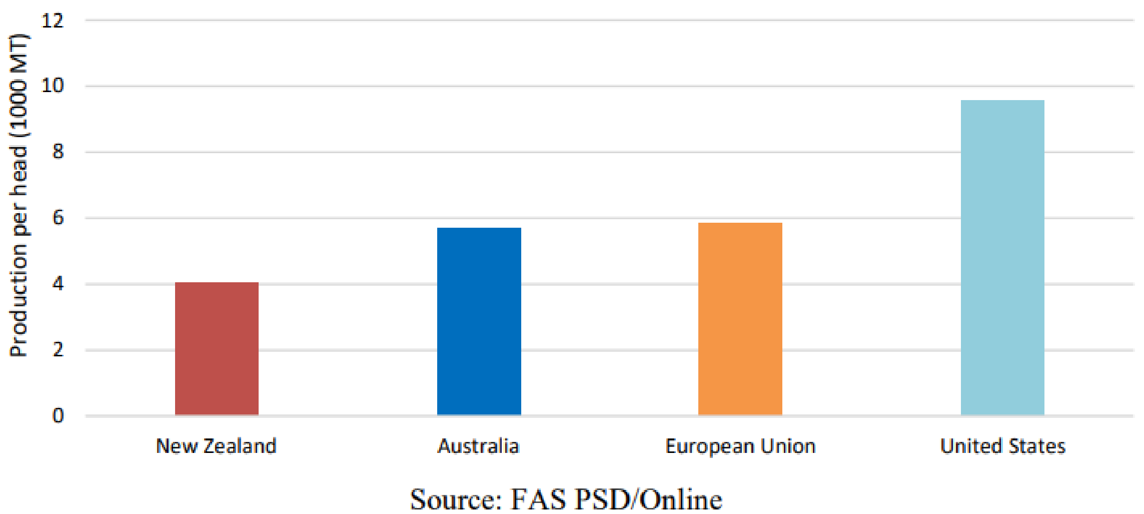


Figure 23: Average milk production per cow

Key challenges to achieving high per cow yields in grass-based farming systems have been the significant variation in annual and in particular, monthly pasture production (Figure 24, Glassey, 2011) and marked seasonal changes in pasture quality (Figure 25).

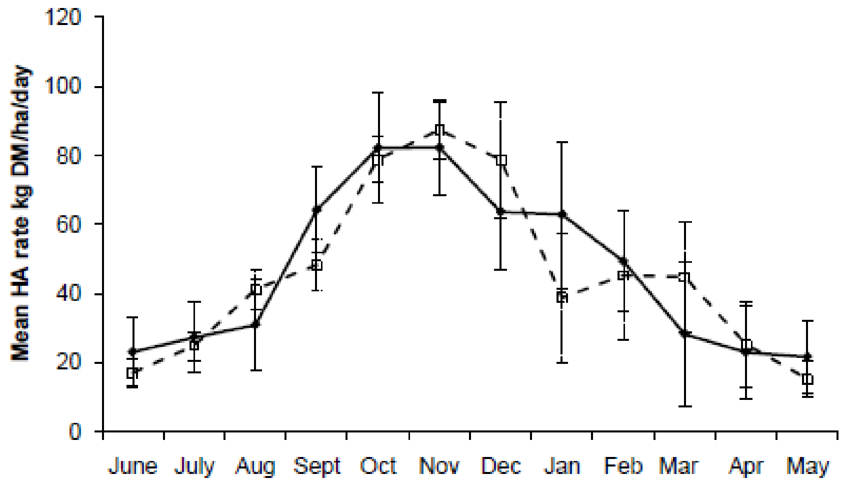


Figure 24: Mean monthly observed (solid line) and modelled (dashed line) pasture herbage accumulation rates (kgDM/ha/day +/-SD) for central Waikato during the years 1990-2004.

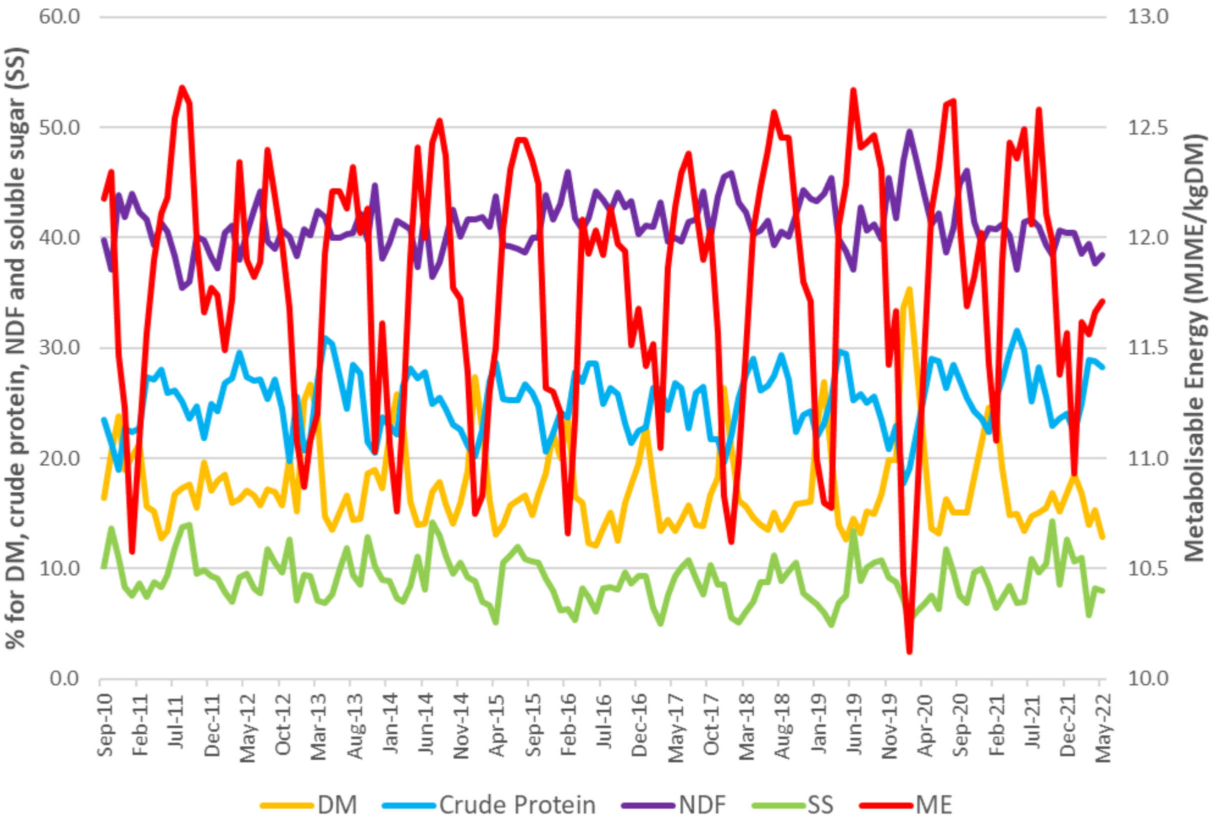


Figure 25: Seasonal changes in the average drymatter and nutritional characteristics of pasture on 10 Waikato farms (2010 – 2022) (Sandbrook, T. Open Country Dairy, unpublished)

While annual pasture yields are projected to be remain stable, and perhaps even increase in more southern regions due to more favourable growing conditions in winter and early spring and increased plant efficiencies from the carbon dioxide fertilisation effect (Keller et al., 2021), seasonal growth is also expected to become more variable and unpredictable particularly in water-limited regions.

Babylon et al. (2022) used the Basic Grassland (BASGRA) pasture growth model to predict changes in annual yields and seasonal pasture growth rate patterns of perennial ryegrass in the Upper North Island. Their modelling showed that summer growth rates and annual yields of perennial ryegrass from the Bay of Plenty to Northland are expected to decline as a result of climate change.

The impact of climate change on pasture silage quality is less clear. Elevated carbon dioxide levels are predicted to lift carbohydrate levels and decrease crude protein content in C3 plants such as ryegrass. As the crude protein content in pasture is generally greater than dairy cow requirements, the latter is unlikely to have any detrimental impact on milk production. However warmer temperatures may result in earlier flowering, more rapid senescence and increased lignin content. There is potential for the normal reductions in pasture quality expected in summer arriving earlier. Increased legume content with warmer temperatures and elevated carbon dioxide is likely to increase the nutritive value of pastures as legumes tend to be more nutritious, with greater crude protein and metabolisable energy (ME) content and reduced fibre. But this needs to be balanced against a likely higher proportion of less nutritious subtropical C4 grasses and weeds. A higher incidence of extreme events, such as drought and high temperatures, is also likely to reduce the quality of pasture and crop plants (Clark et al., 2012).

On balance, it would seem likely that a trend towards higher per cow production coupled with climate change leading to more variable pasture growth and possibly lower quality pastures, will lead to increased demand for supplements and this is likely to include higher rates of IPF.

The dairy industry is also trending towards reducing the slaughter of bobby calves. It is conceivable that in the near future all calves will need to be raised to post-weaning, increasing calf meal requirements by up to 100,000 tonnes per year. This is a sizeable additional demand for grain-based feed, and meeting it will likely result in a further lift the demand for IPF.

8.2 How can New Zealand reduce its demand for IPF?

It is clear that if New Zealand wants to reduce its reliance in IPF it must either increase the local supply of grain and feed or decrease the reliance of livestock industries, especially dairy, on IPF, or do a combination of both things.

8.2.1 Increasing local grain and feed production

Local grain production can be increased by lifting arable crop yields or bringing more land into arable production.

While average cereal crop yields are high on a global scale, there is a significant yield difference between top and average producers:

- Ashburton grower Eric Watson produced a 17.4 t/ha wheat crop in 2020 (Grain Central, 2023). The average New Zealand yield is around 9.6 t/ha.
- Timaru growers Warren and Joy Darling achieved a barley yield of 13.8 t/ha in 2015 (Grain Central, 2023). The average New Zealand yield is around 6.9 t/ha.
- Gisborne grower Tom Newman produced 23.41 t/ha of maize grain in 2022 (Pioneer® brand Seeds, 2022). The average New Zealand yield is around 11.2 t/ha.

While trial yields are generally higher than those achieved on a whole paddock basis, these results highlight a realistic upper yield potential for cereal crops in New Zealand. Further work is needed within the arable sector to determine key on-farm yield limitations by crop and address them. It is likely that many growers could increase yields by more timely crop management, improving seed bed preparation and planting practises, planting higher yielding hybrids or cultivars, better matching nutrient application rates and timing with crop requirements, improving weed and pest control and/or better irrigation scheduling.

The adoption of precision farming techniques will allow farmers to identify and address yield limiting factors within a crop management zone. Initiatives like Growers Leading Change, a knowledge exchange programme that encourages arable farmers to consider, develop and introduce new ideas, technologies, and ways of working, will also help growers to lift productivity.

The other alternative is to bring more land into arable production. As previously discussed, arable competes with dairying and horticulture which often offer higher returns. However arable cropping has a lower capital and water requirement than horticultural crops and arable crops can be grown on smaller land areas which would be unviable for livestock operations.

There are several obvious opportunities. These include Māori-owned land, lifestyle blocks, sheep and beef farms and smaller, uneconomic dairy units which require significant capital investment to remain environmentally compliant.

The opportunity for cropping on Māori owned land is significant and has been outlined further in Section 9.

Lifestyle blocks present another opportunity. Throughout the country there are a number of these which do not deliver an economic return. Many lack stock handling facilities and stock water systems and the owners are ill-prepared to deal with animal management. Cropping is a viable alternative because grain merchant representatives and local agricultural contractors can typically manage the entire cropping process.

While many sheep and beef farms lack land of suitable contour, there are a number of farms which could diversify their operations, reduce labour requirements and increase profitability (see Table 3) by growing grain.

Recently there have been reports of dairy farmers leaving (or considering leaving) the industry due to increasing environmental compliance costs, labour shortages and soaring interest rates. Cropping offers a viable alternative for these farms. The sale of stock and plant and machinery can significantly reduce debt levels, and labour requirements for cropping are minimal.

Dairy farms which are smaller and less economic could be transformed to arable production systems. Those on the cusp of requiring an extra labour unit and/or wishing to avoid the need for infrastructure investment (e.g. a larger farm dairy or effluent system upgrade) could consider reducing cow numbers and cropping a portion of the farm as an alternative.

8.2.2 Decreasing livestock demand for IPF

The largest opportunity to decrease demand for IPF is within the dairy sector. Dairy cows consume the highest volume of IPF, but they are ruminant animals which are able to perform well on a wide range of diets. This means that homegrown or locally grown forage crops are an alternative feed source. In contrast monogastric animals (like poultry and pigs) need high-energy diets and require high proportions of grain in their diet.

A potential way for dairy farmers to decrease their demand for IPF is to reduce stocking rates and grow more feed on farm. This is a better option for the dairy industry than trying to convert from IPF to brought in, locally produced feed for the following reasons:

- In 2022 the dairy industry consumed around 2.8 million tonnes of IPF. Assuming the current New Zealand average across crop grain yield of around 8.4 t/ha, it would take over 300,000 ha of arable land to displace IPF.
- If the IPF was replaced with contract grown maize silage yielding 20 tDM/ha, it would still require around 156,000 ha of additional cropping land.
- It is not reasonable to expect that arable area would expand to this extent particularly because much of the additional land which is most suitable for cropping is on dairy farms.

The ability of crops to increase dairy farm drymatter yield above that of pasture-only systems is well established. De Ruiter et al. (2009) demonstrated the annual yield potential of crop rotation sequences in Canterbury. The best productivity was with a maize - triticale + tick bean (32.5 tDM/ha) sequence followed by maize - wheat (30.0 tDM/ha), barley - oats + Italian ryegrass (28.1 tDM/ha) and kale - triticale + tick bean (26.1 tDM/ ha). Chakwizira et at (2017) showed the total yield potential of maize silage followed by a range of winter crop options was 27-30 tDM/ha (Canterbury) and 37-42 tDM/ha (Waikato). For Taranaki, crop sequences including a range of crops including maize, turnips, Italian ryegrass, rape, winter cereals, and chicory yielded an average of 28.4 tDM/ha (MacDonald et al., 2012).

A number of modelling studies have investigated the environmental and/or financial impact of cropping on farm versus buying in supplement.

Beukes et al. (2022) simulated three Waikato farmlets using DairyNZ's Whole Farm Model (WFM), APSIM and the Urine Patch Framework (UPF) over five consecutive seasons (2013-14 to 2017-18). The three treatments were (i) the P21 Current Farm (CF) with a stocking rate of 3.2 cows/ha, applying 125 kg N/ha fertiliser on pasture, harvesting grass silage for use during periods of feed deficits; (ii) the P21 Future Farm (FF) with a stocking rate of 2.6 cows/ha, applying 85 kg N/ha fertiliser, high genetic merit cows, imported maize grain as low-N feed, with a standoff pad; and (iii) the maize silage-block farm (Future Farm Plus = FFP) with a stocking rate of 3.2 cows/ha, high genetic merit cows, applying 85 kg N/ha fertiliser on pasture, maize silage grown on a dedicated block occupying 15% of the effective farm area followed by annual ryegrass and fed on a feed pad.

Modelling results showed that adding a dedicated maize silage block on the milking platform can cost-effectively reduce N leaching by an average 26% compared with the CF baseline, provided the crop is followed by a catch-crop (annual ryegrass in this case), effluent captured on the feed pad is recycled as a fertiliser source, crop yields are above 20 tDM/ha, and the low-protein maize silage is used to reduce imported feed-N. The FF system achieved an average 31% N leaching reduction compared with the CF but forfeited $16 profit per kg N reduction compared with $9 for the FFP (Table 6).

Table 6: Predicted results (mean +/- SD) for five consecutive seasons (2013-14 to 2017-18) for Waikato Dairy Farm Systems (Beukes at el., 2022)

	CF	FF	FFP
Pasture yield t DM/ha	16.6±0.5	14.8±0.8	15.5±0.9
Milk prod kg MS/cow	392±4	433±2	435±2
Milk prod kg MS/ha	1266±13	1132±6	1407±7
N leaching weighted average kg N/ha	70±37	49±27	52±29
N leaching reduction from CF %	-	31±4	26±3
N efficiency kg MS/kg N leached	23±13	31±18	36±21
Profit $/ha	3049±2123	2721±2071	2918±2220
Profit reduction from CF %	-	11±23	4±24
$ forfeited/kg N mitigated	-	16±8	9±10

New Zealand dairy farmers will be responsible for paying for on-farm GHG emissions. In 2020, 73% of New Zealand's reported agricultural GHG emissions were enteric methane from ruminant animals. A further 20% was from nitrous oxide, largely from the nitrogen in urine and dung, with a smaller amount from the use of synthetic fertilisers. The remainder was methane from manure management (4%) and carbon dioxide from fertiliser and lime (NZAGRC, 2022).

Potential ways to decrease dairy farm GHG emissions include lowering stocking rate, reducing replacement rates, decreasing N fertiliser applications, eliminating the use of brought in feed and altering the dietary balance to increase fermentable carbohydrates and decrease dietary crude protein.

A recent study (Tacoma et al., 2022), used Udder and OverseerFM to model production, N-leaching and GHG responses from a range of farm systems. The control was an 'average' Waikato farm and for Scenarios 1-4 stocking rate was decreased but cow liveweight and relative genetic merit was increased (Table 7). Production remained static and 2.6 and 8.5% of land was retired in Scenarios 3 and 4.

Table 7: Farm parameters for Farmax and Udder modelling of dairy farm systems (Tacoma et al, 2022)

	Control	Sc. 1	Sc. 2	Sc. 3	Sc. 4	Sc. 5
# of peak cows	344	306	258	247	220	293
Farm Area (ha)	117	117	117	114	107	117
Cow Live Weight (kg)	450	475	500	500	550	450
kg Live Weight / ha	1,323	1,242	1,103	1,083	1,131	1,127
Relative cow genetic merit	100%	101%	104%	105%	107%	100%
Total feed consumed(t DM) *	1,943	1,881	1,762	1,738	1,688	1,686
Feed consumed vs. control		-3.2%	-9.3%	-10.6%	-13.1%	-13.2%
Stocking Rate (cows/ha)	2.94	2.62	2.21	2.17	2.06	2.5
Farm production (kg MS**)	124,890	124,839	124,819	124,941	124,954	111,308

* Including young stock
** kg MS = kg's milk fat + kg's milk protein. 1 kg MS equals approx. 15.7 litres US milk.

While the control imported 133 t/ha of PKE, Scenarios 1, 2, 3 and 4 imported 66, 150, 239 and 272 t of concentrate (soybean hull, 42%; maize grain, 42% and dried distillers' grain 16%) respectively. When compared to the control, Scenario 4 had a 22.2% increase in operating profit. The entire system (including youngstock) reduced N losses by 15.5% and GHG emissions by 15.6% relative to the control. In Scenarios 3 and 4, 2.6% and 8.5% respectively of the land was retired.

There are a number of challenges with this approach including:

- It is difficult to maintain pasture drymatter harvest and pasture quality with low stocking rate systems.
- While dairy farmers operating on steeper land may consider retiring land, those on Class 1-4 are unlikely to retire their land. It would be better used to grow crops and/or grain to support their dairy herds.
- The current New Zealand grain yield is around 900,000 tonnes which is substantially less than the 1,973,749 tonnes of PKE imported (and predominantly used in the dairy sector) in 2022. Moving the entire dairy industry to high concentrate systems is therefore likely to increase our reliance on imported feed.

In Section 10 the authors use Farmax to model the impact of growing all or buying in all supplementary feed when compared to current 'average' farm systems in five key New Zealand dairy regions.

8.3 Conclusions

While poultry and pig demand for grain is likely to remain stable, dairy demand for supplements and IPF is predicted to increase as farmers attempt to drive higher per cow performance and seasonal pasture growth rates and possibly quality are impacted by climate change.

New Zealand can decrease its demand for IPF by growing more grain and decreasing the reliance of dairy farms on bought in supplementary feed.

There is scope to produce more grain from existing arable land. Whenua Māori, lifestyle blocks, sheep and beef and dairy systems which are less economic or on the cusp of requiring an extra labour unit or infrastructure investment could be used to grow additional grain area.

The largest opportunity to decrease demand for IPF is by the dairy sector decreasing stocking rates and increasing cropping on-farm. The ability for cropping systems to increase drymatter yields above that of pasture only systems is well established. Recent modelling studies have shown lower stocking rate dairy farm systems have lower N losses and reduced GHG emissions. Systems that destock but buy in concentrates are likely to increase New Zealand's reliance on IPF. On-farm cropping provides a potential mechanism to decrease our reliance on IPF.

9.0 GROWING GRAIN – AN OPPORTUNITY FOR WHENUA MĀORI

The significance of whenua (land) within Aotearoa (New Zealand) is deeply rooted in its cultural, spiritual, social and economic value, making whenua a vital aspect of Aotearoa's identity and heritage. However, for Māori a considerable portion of land remains underutilised, this situation is a double-edged sword that presents challenges and opportunities not only for Māori but for all owners of small, fragmented lands e.g. lifestyle block owners.

Māori agribusinesses have been integral to New Zealand's agricultural sector, playing a crucial role in economic growth, job creation, and cultural preservation. Notably, Wī Pere Trust, Onuku Farms, Wairarapa Moana, and Tuaropaki have emerged as prominent players in the Māori primary agribusiness sector. The consumption and demand for supplementary feeds, including kibbled maize grain from these agribusinesses is steadily increasing. This emphasises the importance and impact of providing high-quality animal feed to optimise livestock production, health and welfare whilst capitalising on market returns.

This section proposes an innovative approach through the establishment of a vertically integrated maize for grain feed agribusiness on small, fragmented whenua throughout Aotearoa.

9.1 Quantifying the opportunity

There are about 1.47 million hectares of Māori freehold land, which makes up roughly five percent of all land in Aotearoa New Zealand (Te Kooti Whenua Māori, 2022). Overall, an average Māori land block has a size of 53.1 ha and 111 owners. Sixty-one percent of blocks do not have a management structure (Te Kooti Whenua Māori, 2022) which means they are not actively managed. While a significant amount of Māori- owned land is LUC 5 – 8 (Figure 27), there are also a large number of blocks which have suitable contour and soils for cropping.

Table 8: Whenua Māori by region (Te Kooti Whenua Māori, 2022)

Region	No. of Land Titles	Area (ha)
Taitokerau (Northland)	5,478	138,936
Waikato (Waikato/King Country)	3,787	124,197
Waiariki (BOP/Waikato)	5,191	304,667
Tairāwhiti (Gisborne/East Coast)	5,365	269,160
Tākitimu (Hawkes Bay/Wairarapa)	1,417	88,042
Aotea (Whanganui/Taranaki)	4,045	412,558
Te Waipounamu (South Island)	2,235	66,129
Total	**27,608**	**1,403,693**

Flat to rolling land is typically leased for dairy support, sheep and beef or arable cropping with rates ranging from \$500 - \$600/ha for blocks in non-dairy areas to up to \$1,400 - \$1,600/ha for land which is used as dairy platforms or for intensive cropping. The recent Resource Management (Stock Exclusion) Regulations introduced in 2020 have reduced potential returns for blocks which have previously relied on direct access to waterways for stock drinking water.

There is already a significant amount of Māori land used for grain or feed (predominantly maize silage and grass silage) production. Much of this land is leased and generally the tenure is short (1-3 years). Lessees are reluctant to invest in capital fertiliser, lime or drainage because they may not realise a return on their investment over the course of the lease. In some instances, this reduces the yield potential of the land.

Currently, the agricultural practices in place for growing grain crops are inclined towards favouring large-scale operations. However, this preference for large-scale operations poses challenges for smaller landholders who own fragmented pieces of land (Awatere & Harmsworth, 2014). Economically speaking, these small, fragmented land blocks face disadvantages due to their limited economies of scale, higher operational costs, and restricted access to capital and markets (Kingi, 2009). Additionally, owners of small landholdings often lack the necessary infrastructure required for large-scale enterprises. Consequently, these land parcels are typically leased out to individuals or entities that possess the resources and scale, usually for a nominal fee. The main challenge, therefore, lies in finding sustainable compatible economic models that can transform these small land blocks into profitable enterprises.

Growing grain for the animal feed industry presents a transformative opportunity for underutilised parcels of whenua. Vertical integration is a business strategy in which an entity has control of multiple stages of the supply chain, this strategy can offer efficiencies, cost reductions, and the ability to control quality across the production process (Baldwin et al., 2012). By controlling the process from cultivation to production and distribution, owners of small, fragmented lands can capitalise on multiple benefits of controlling the entire chain of supply, thus potentially improving the economic returns of their lands. Simultaneously, this approach of 'collaborated control' aligns with core Māori world views of Tino Rangatiratanga (self-sovereignty) and Mana Motuhake (self-governance), which provides further control over resource management and sustainability control measures such as land management practices and decisions.

Modern arable precision farming practices have significantly improved and now include reduced or no till systems, soil and yield mapping, and variable rate fertiliser application technologies. Precision agriculture enables the grower to measure variability across the paddock and to apply site-specific crop management. Where variation in a paddock exists, precision agriculture can increase crop profitability and reduce environmental impact by improving yield, reducing costs of inputs, and reducing unnecessary nutrient use (van Evert et al., 2017; Reichardt and Jürgens, 2008).

The shift towards reduced tillage and precision agriculture technologies has made grain growing more sustainable and economically viable, despite its previous reputation for being hard on the land. Additionally, the production of grain for animal feed plays a crucial role in meeting the global demand for sustainable and nutritious animal feed options, further contributing to sustainability efforts.

9.2 Rationale for Māori land use change

The shift from pastoral to arable farming on underutilised land presents a compelling argument for Māori landowners. This transition is supported by a range of factors such as the need for land utilisation, reconnection to the land, business strategy, product selection, understanding market demands, and the potential to add value to product development. By diversifying land use outputs, landowners are in a better position to uphold resilience against market volatility and the impacts of a changing market brought on by climate change.

By transitioning to arable farming, landowners can tap into the growing animal feed market by farming crops such as grains, legumes, oilseeds, and grasses that can be processed into high-quality animal feed supplements (Herrero et al., 2020). For increased value, the proposed shift to a vertically integrated animal supplement feed business facilitates value addition at each stage of the supply chain, from crop cultivation to supplement production and distribution. This not only enhances profit margins but also provides opportunities for branding and marketing products as locally grown, sustainable, regenerative, and culturally grounded, thereby appealing to consumers who value ethical and sustainable consumption practices (Bennett et al., 2019).

The transition from pastoral to arable activities offers a compelling opportunity for improving the economic return of underutilised lands, while preserving the lands heritage and fostering in a generation of active landowners who have the ability to manage their lands sustainably.

Exploring the transition from a pastoral-based system to an arable system through in-depth analysis can provide numerous advantages such as:

9.2.1 Product diversification

Transitioning from pastoral to arable farming can significantly diversify product offerings for small block owners. Arable farming can yield a variety of high-value crops that can be used as raw materials in animal feed supplements. This shift allows landowners to cultivate different crops seasonally, thereby reducing dependency on a single product and mitigating risks associated with market volatility or climate change impacts. Moreover, crop rotation inherent in arable farming can enhance soil fertility and biodiversity, aligning with Māori principles of Kaitiakitanga or guardianship over the land (Awatere & Harmsworth, 2014).

9.2.2 Value addition

The concept of added value becomes particularly significant in the context of a vertical integration. By managing the entire supply chain, from cultivation of arable crops to production and distribution of animal feed supplements, owners of underutilised lands can add value at every stage, enhancing profitability and economic return on their lands. Firstly, the cultivation of high-value crops such as maize for grain for animal feed production inherently adds value, compared to ineffective and inactive land management activities. Maize grain crops can form being part of a sustainable farming system and they can contribute to improving soil health and biodiversity, thus adding ecological value to the land that also sits in line with core Māori values. Secondly, the growing of grain and processing of these crops into high-quality animal feed supplements creates significant added value. This process allows for the conversion of raw materials into a more valuable product that meets a growing global demand for sustainable, nutritious animal feed options.

Finally, there is potential for value addition through branding and marketing. Products can be promoted as locally grown, sustainable, regenerative, and culturally grounded. These value-added suggestions ties into current trends such as ethical consumption and regeneration where consumers are increasingly seeking products that align with their values related to environmental sustainability and cultural authenticity (Bennett et al., 2019).

9.2.3 Market risk

Maize for grain animal feed is significantly influenced by the performance of New Zealand's dairy and poultry sectors. These industries have experienced record-high farm gate prices for their products in recent years (USDA, 2023a). Nonetheless, there is growing concern among analysts due to increasing inflation in farm inputs like feed, fertiliser and fuel. If the price of imported grain continues to rise or if it became unavailable it would impact the profitability of New Zealand livestock farmers and there are also animal health concerns (see Section 6).

9.3 Synergy with Whenua Māori

The transition from pastoral to arable farming within a vertically integrated agribusiness on underutilised Māori land aligns deeply with core values of Te Ao Māori - the Māori worldview. This alignment manifests through key principles such as Kaitiakitanga, Manaakitanga, Whanaungatanga, Whakapapa, Mauri, and Mana, reinforcing the interconnectedness of people, land and all living things.

Kaitiakitanga, a fundamental principle in Te Ao Māori, embodies the duty to safeguard and sustain the land, sea, and natural resources. Adopting arable farming practices and crop rotation inherently upholds the values of Kaitiakitanga, promoting improved soil health and biodiversity (Pretty et al., 2018). The growth of high-value crops for use in animal feed supplements presents a sustainable approach to land use. This not only aligns with the responsibilities of being a good steward of the land but also epitomises the essence of Kaitiakitanga (Awatere & Harmsworth, 2014).

In the context of land stewardship, **Manaakitanga** - the principle of care and hospitality - manifests through the guardianship and preservation of the land under one's management. It can also be embodied through the provision of quality products to the local community and beyond, upholding a commitment to societal well-being. Within the arable industry, Māori landowners can exemplify Manaakitanga by recognising the interdependent relationship among all beings involved in the processes that are carried out on the land and throughout the business operations.

The concept of **Whanaungatanga**, which underscores kinship and relationship building, finds reinforcement in the vertical integration business model. By keeping the cultivation, processing, and distribution of products within the community, a sense of collaboration is fostered, and social ties are strengthened. This approach can empower the community and enhance local capacity, thereby nurturing Whanaungatanga (Panelli & Tipa, 2007).

Whakapapa, the principle of genealogy and lineage, establishes a profound connection between Māori people, their ancestors, and their land. By treating the land in a manner that acknowledges and respects its ancestors, this project upholds the essence of Whakapapa. Furthermore, the proposed vertical integration of the business reflects the interconnectedness inherent in all aspects of the supply chain. This mirrors the bond that links generations within Whakapapa, reinforcing the concept's significance.

The concept of **Mauri,** which refers to the life force or vitality of a being or entity, is of central importance in this context. By prioritising soil health through sustainable arable farming, the Mauri or life force of the land is not only maintained but also enhanced. This enhanced vitality of the land reciprocally contributes to the Mauri of the crops cultivated and the animal feed supplements produced, fostering a cycle of health and vitality (Durie, 2004).

Finally, this work upholds the principle of **Mana**, which represents authority and respect. By establishing a profitable, sustainable agribusiness that honours both the land and the community, Māori landowners can enhance their own Mana within this space. Additionally, the suggested business model respects the Mana inherent in the land, recognising its worth and treating it with the deference it deserves.

The shift towards a vertically integrated animal supplement feed enterprise on Whenua Māori deeply resonates with the tenets of Te Ao Māori, enhancing Kaitiakitanga, Whakapapa, Manaakitanga, Whanaungatanga, Mauri, and Mana. When owners of underutilised parcels of land come together to achieve scale and create a vertically integrated business in New Zealand, there are several potential achievements and benefits that can be realised. These are:

- Economies of scale.
- Increased market access.
- Improved resource utilisation.
- Enhanced bargaining power.
- Knowledge sharing and innovation.
- Cultural preservation and community development.

Overall, when owners of underutilised parcels of land unite to create a vertically integrated business, they have the potential to achieve economies of scale, expand market access, optimise resource utilisation, enhance bargaining power, fostering innovation, and promoting cultural preservation and community development. This collective approach enables them to overcome individual limitations and unlock new opportunities as a collective for sustainable and prosperous agricultural ventures within the Primary Sector.

9.4 Case studies – economic evaluation

To quantify interest in arable cropping, and to quantify potential returns, interviews were held with shareholders from four Māori land blocks based in the Waikato/King Country region. Two of the blocks were administered by their owner and two on behalf of the owners. Land physical and management structure details are shown in Table 9. The physical attributes have been taken from the New Zealand Land Resource Inventory (NZLRI) and the Ministry for Environment (MfE) low slope maps.

Table 9: Land physical and management structure details for four Waikato/King Country Māori land blocks

Criteria	Block 1	Block 2	Block 3	Block 4
Active governance	Yes	Yes	No	No
Administrator	Ahuwhenua Trust	Ahuwhenua Trust	Māori Trustee	Māori Trustee
Leased	Yes	Yes	Yes	Yes
Lease tenure	Monthly	Monthly	3 Years	7 Years
Total area (ha)	14.2	23.5	9.4	273
Effective area (ha)	12	21	9.4	90
Dominant soil type	Allophanic - well drained	Allophanic - well drained	Gley - poorly drained	Allophanic - well drained
Dominant slope	<10 degrees	<10 degrees	<10 degrees	20% <10 degrees
NZLRI	LUC4e1, LUC 6e9, LUC3w1	LUC4e1, LUC3w1	LUC3w1, LUC4e1	LUC6e15, LUC6e1, LUC6s1, LUC3w1
Current land use	Pastoral-Maize Silage	Pastoral-Maize Silage	Pastoral-Maize Silage/Store Livestock	Store Livestock

All of the blocks were leased and had suitable areas for cropping. Three were already growing some maize for silage.

Details of current land lease costs, rates and management fees were collected and used to determine current net return per effective hectare. This was compared to the likely returns from growing maize for grain assuming a yield of 11 t/ha and a grain price of $550/tonne (Pioneer® brand Products, 2023). It was assumed that the uncroppable land could be leased for grazing at $400/ha (Blocks 1-4) or $300/ha (Block 5).

Table 10: Whenua Māori comparison analysis (current returns vs cropping returns)

	Block 1	Block 2	Block 3	Block 4
Current land use and current returns				
Current Land Use	Pastoral-Maize Silage	Pastoral-Maize Silage	Pastoral-Maize Silage/Store Livestock	Pastoral- Store Livestock
Lease ($/eff ha)	$650	$550	$760	$300
Annual Revenue	$7,800	$11,550	$7,144	$27,000
Rates	$2,828	$3,213	$2,915	$3,165
Base Trustee Fee[1]			$1,475	$1,475
Management Fee[2]			$536	$2,025
Net Profit ($)	$4,972	$8,337	$2,218	$20,335
Net Profit per effective hectare[3]	**$414**	**$397**	**$236**	**$226**
Potential arable area and future returns from owner managed system				
Total area (ha)	14.2	23.5	9.4	273
Effective area (ha)	12	21	9.4	90
Area suitable for grain (ha)	**7**	**8.5**	**6**	**35**
Remaining effective area for grazing (ha)	**5**	**12.5**	**3.4**	**55**
Maize grain return @ $1,431/ha[4]	$10,017	$12,164	$8,586	$50,085
Pastoral return @ $400 (Blocks 1,2 &3) or $300 (Block 4)/ha	$2,000	$5,000	$1,360	$16,500
Rates ($)	$2,828	$3,213	$2,915	$3,165
Net profit ($)	$9,189	$13,951	$7,031	$63,420
Net Profit per effective hectare	**$766**	**$664**	**$748**	**$705**
Increase in net profit/ha (%)	**85%**	**67%**	**217%**	**212%**

In all cases Māori landowners could increase their returns by growing grain rather than leasing their land. The increase in returns was the highest for Blocks 3 and 4 which are currently paying lease management fees.

[1] Māori Trustee (Te Tumu Paeroa). Base Trustee Fee. 2023. https://www.tetumupaeroa.co.nz/trustees/ways-we-work-with-trusts/fees-for-our-services/

[2] Māori Trustee (Te Tumu Paeroa). Property Management Fee. 2023. https://www.tetumupaeroa.co.nz/trustees/ways-we-work-with-trusts/fees-for-our-services/

[3] Effective land that is utilised and cropped.

[4] Pioneer® brand Maize for Grain 2023-24 assuming 11t/ha crop yield and a grain price of $550/t

9.5 Case studies - feedback from Māori landowners

The content of this section is derived from preliminary interactions with trustees of two active and two inactive land trusts, as well as several industry experts. These dialogues occurred from April to June 2023, involving trustees from varied land sections throughout the King Country and the broader Waikato region. For privacy purposes, the discussions presented here are devoid of any identifying information. The feedback chosen by the author offers intriguing insights that underline the unique aspects of being both an active and an inactive Māori landowner.

After the interviews, participants were invited to join an online review discussion. The subject matter of this discussion centred around the report's focus: the establishment of a vertically integrated grain feed business on whenua Māori. Initially, seven land trusts were approached as potential contributors for this report. However, due to various circumstances, three of these interviews were not conducted. While most interviewees expressed positivity towards this research aspect, a representative from one of the inactive trusts opined that the research was somewhat limited. The representative felt that the engagement process did not fully capture the broader cultural values, connections to the whenua, and future aspirations of the whānau.

The key findings of the discussion are summarised as follows:

- Land trusts who actively manage their whenua have a high satisfaction level with the amount of control they have over their lands.
- The active land trusts valued the information and engagement they currently have with agricultural experts and technical advisors.
- There are many positive impacts from land trusts who are actively managing their land, including supporting kaitiakitanga, increasing understanding and confidence, supporting changes to land use and management, building links with communities and personal growth of trustees.
- Landowner satisfaction from the blocks that were managed under the Māori Trustee was exceptionally low. The lack of control and final say over their own land was a sore point for this group of interviewees.
- Industry experts were extremely optimistic about the opportunities for small, fragmented landowners to grow maize for grain. This optimism was contributed to the strong demand for grain feed by the cow, goat and sheep dairy, pig and poultry primary sectors.

Some of the most relevant comments made by interviewees are shown in the sections below.

9.5.1 Block 1

General comments

"*When you're in a deprived community to put it bluntly, doing it rough, sometimes it's hard reconnecting to your whakapapa, the history, and the stories of your whenua, somewhere along the way it just all gets lost. And what we have found is that by reconnecting our whānau back to our whenua, they have started to realise who they are, they've awakened to their history and whakapapa and in a roundabout way, we as a Trust, are now able to contribute to who they are, who we are and where we want to go as a whānau and as a land trust. This brings us Mana* *and with that pride, our people can now see a future in their whenua. Since becoming more active as a land trust we can say for our little slice of paradise, our people can now walk around with their heads held high, a stark difference to only five years ago when we as a whānau had very little say over our own whenua. So, our current situation, well yeah, it's great."*

"As a whānau trust, we talk about what we have learned from those who we work with on our lands. These people include the farmer who leases our whenua, we have also been talking to a farm consultant about future ideas we can do with our land, and we have been working with the regional council to look at putting together an environment plan to protect some of our wetlands on our whenua. With this information we as Trustees can go back to our owners and provide them with this matauranga and kōrero. Also, because we only have monthly lease agreements, we have the opportunity to pass any kōrero back to the farmer if we think things are not going according to our agreement. In the past we never had the opportunity to do this, if we had raruraru most times we were powerless to do anything and just had to bite the bullet and hope that the farmer leasing our whenua would eventually do right by the whenua and right by us as the landowner."

Comments on the report's focus

"I like the idea of being able to use our whenua to help develop a business concept such as the one you are talking about. Over the years we have seen the farmers grow the corn looking stuff on this whenua but other than knowing that you can't eat it we as landowners did not really know too much about it. But if we were to grow it on our land, then create a product then sell it back to the farmers for a good price, well it could end up putting us in a better financial position than we are currently in, sounds good to me."

"If we can have the opportunity to create more jobs for our whānau, build more papakāinga on our whenua and doing it in a way we get to uphold the Mana of our whenua, well count us in."

9.5.2 Block 2

General comments

"*We have been isolated from our whenua from 1972 - 2008 because of debt, exploitation, and alienation so coming back, taking control, well I think it's helped our whanau heal the mamae because they can now see a future, they now have vision...".*

"Succession planning is a huge problem. The younger generation are not coming through and participating. A Facebook page has been developed to try and engage them…".

"*If my Koro could see the farm you see today, seeing us uphold our tikanga and applying kaitiakitanga in a way that uplifts our whenua, I know he would be proud of us."*

"Coming back and being active over our whenua has enabled our trust to think more broadly and not just focus on the traditional leased land model that our elders operated under, the long-

term lease of 7, 14 and 21 years is no longer an option for our whānau. I am not sure if it's the right model but we now only lease on a monthly basis so that we can remain flexible if tough decisions need to be made on our land. Doing this has also enabled us to explore other possibilities for the use of the whenua outside of feeding the farmers cows…".

"The other thing being active has achieved is it has helped us look at the balance between the cultural, historical, and intergenerational values of the land and balance them with commercial as well, which is also a new era for us as we had become so accustomed to just leasing it out and turning a blind eye to what was happening on our lands… and so our thinking is definitely at a different level…".

Comments on the report's focus:

"We are aware of several other land blocks in our rohe that are not being looked after by their owners, I think it's because the whenua is too small or there are too many owners, whatever it is most of that land is just sitting there. But the idea you are suggesting, well those lands would be perfect for this, and by joining us all up not only can we use our lands properly we can also create that whanaungatanga that has been missing in our valley since our Nanny's and Koro's passed away. I like this idea because it can bring our whānau back home, back to the land, just like how we all grew up…".

"If this idea takes off or if you are looking for someone to start it off, I think we could put this idea to our owners for a kōrero, I definitely like the idea, but will still need to get my whānau to back it".

9.5.3 Block 3

General comments

"We have a lot of issues on our whenua at the moment, we have almost no say on how the Māori Trustee looks after our land or who they lease our lands to. Their fees are high, and we make hardly anything, and a lot of us owners miss the hui because the Māori Trustee does not update their owner details regularly, but at the end of the day the main problem is us, most of the whānau live in the cities and no one really comes back unless we have a tangihanga. I have brought the issue up regarding our whenua with my whānau a few times now, but it seems like they are just so far removed that they don't really care…yeah it makes me sad".

"I am 67 and as far as I can remember the farmers down the road have always had our land…I think the last whānau member who farmed our land was my uncle shortly after he returned back from the war in Italy. He was here until about 1955 then I believe he then took his whānau to Auckland for a better life… yeah, it's been ages since we had Mana over our whenua."

Comments about the report's focus:

"The cost to establish key infrastructure would be inhibiting to our trust as we currently have next to no putea to get started. But if there is an opportunity to pull away from the Māori Trustee and earn more putea from our lands for our whānau then we will do it in a heartbeat…".

"If we can join our lands with others and create a business model that will benefit us all, I think it's a no brainer, I mean anything has to be better than the situation we are already in."

"It's interesting you mention growing grain, for as long as I can remember the farmer has been growing his maize on our land for his cows…, I mean it can't be that hard to grow aye, if we can make more return from our own land, I reckon we should just grow it."

"When you start this business idea, please keep us in mind, I will be definitely supportive of it and will take it to my whānau for a wānanga about it…, because one thing that is currently keeping us disengaged and under the Māori Trustee, is that no one has had any good ideas on what to do with the land in the case we ever got it back…, now here you are literally giving us options to act and do something".

9.5.4 Block 4

General comments

"*Just take a look at the state of our whenua, when I was growing up there was not a single gorse bush, now 70% of the whenua is covered with gorse and manuka bush. When Koro was looking after the land, he would make all us boys go up and grub all the thistles and ragwort around here, I mean in his day our whenua was a great source of pride for our whānau."*

"I don't know what happened, it just seemed like one by one we left the area, went looking for mahi or whatever we were looking for and then by the mid 70's Koro and Nan were the only ones left. When Nan passed away in 79, Koro seemed to have lost interest in doing the farm and by 81-82 he was living with Mum in Manurewa. I didn't really understand it all back then, but when Koro finished up on the farm, there was literally no one left to look after it. Over the years the farm was less talked about then Koro passed away in 1989, I think that was the last time the whānau were all together on the whenua, was for Koro's tangi."

"When I was in my 40's, I decided to move back from Australia, I just had this burning desire to come back to my whenua, maybe it was Koro telling me to come back, anyway in 2013 I came back home and did up my Nan and Koro's homestead. But when I tried to get back on my whenua that was another story. Because our whānau had been away from our lands for so long, the Māori Trustee took responsibility for looking after it in our absence, not too sure what they are looking after as the land has never ever been in worser shape."

"Since my return I have helped my whānau create a land trust in the hope that the Māori Trustee would return the management of our lands back to us, for whatever reason it has not been that straight forward…, I think it has to do with the 21 year leases that have been agreed on with

the farmer, as I am aware the farmer is currently two thirds of the way through his second stint of a 21 year lease,…I can't believe this is still happening."

Comments about the report's focus

"The main priority for us is getting the land back under our administration, once that is done we will need to put a plan into action to keep the income coming in so that we can pay for the rates…, once we are in that place I think we as a whānau and as a Trust can start talking about our options…, I really like the idea you are talking about because I can see a clear pathway to using our lands to get the greatest return we can for our lands."

"A vertically integrated grain feed agribusiness? Sounds like we could have a processing or storage facility on our own whenua, this could bring in a couple jobs for our whānau who really want to move back home…, I like that idea."

Discussions and feedback from industry experts

"Transitioning small, fragmented land blocks into an arable-grain type system and developing a vertically integrated business model at the same time will be a complex process, but, if done right it can greatly benefit those involved in the venture through collaboration with one another, working alongside ag experts, researchers, and other agribusinesses. These partnerships can act as platforms to build knowledge sharing, provide technical support, and offer opportunities for resource sharing such as machinery, equipment and even labour or storage".

"Integrated cropping businesses have many benefits that make them highly effective. Firstly, they bring all the different parts of a business together, making things run smoothly. This means that everyone involved can work together more easily, avoiding any duplication of work and making sure everyone is on the same page. The systems allow for quick and easy coms and info sharing, so decisions can be made faster. By keeping it centralised, this can help those landowners involved to keep track of things more accurately and make better predictions for the future. It also makes it easier to work with other companies involved in the process and will allow for real time feedback from potential customers…".

9.6 Next steps – an implementation roadmap

The realisation of the opportunity to transition from underutilised land to arable farming using a vertically integrated business requires adequate planning, collaboration, and partnerships, as well as access to capital, as well as a staged process to develop, market and distribute product. Further details are shown in Appendix 2 (Reti Kaukau, 2023).

9.7 Conclusion

The potential of establishing a vertically integrated agribusiness on underutilised Māori-owned whenua signals a transformative shift in Māori land management. However, the realisation of this novel endeavour is far from a solitary journey. It necessitates a comprehensive and collaborative approach, pooling knowledge from a diverse range of tohungā (experts) in the agriculture sector, along with the secured provision of capital and resources. These prerequisites serve as foundational blocks in the creation of a robust blueprint that will assist in the transition of passively managed lands to active and productive agribusiness.

The profound significance of this concept goes beyond its economic implications. It paves the way for a culturally rooted based blueprint that sets a precedent for sustainable, culturally compatible land-use models for other Māori landowners across Aotearoa as well as other indigenous groups across the world to consider.

Sustainable farming practices that acknowledge the duty to protect natural resources and nurture the Mauri of the whenua only further augment the underlying spiritual and communal significance of the whenua. In its totality, the vertically integrated agribusiness model offers an innovative, culturally respectful, and economically promising pathway towards the rejuvenation of underutilised Māori land.

The successful implementation of this model would unlock the dormant economic potential of whenua Māori and lay the groundwork for a future wherein economic prosperity is intrinsically linked with cultural preservation and respect for the land. As we stand at the precipice of this new era, it is of utmost importance that we wholeheartedly embrace this opportunity. The era for sustainable, culturally inclusive, and economically prosperous models is here, and the time is ripe to seize it.

10.0 ON-FARM CROPPING – A SOLUTION FOR THE DAIRY INDUSTRY

Over the past three decades New Zealand farmers have used imported feed including IPF to support higher stocking rates and increased per cow production. The primary purpose of this investigation was to use Farmax farm monitoring software and OverseerFM to model the productivity, profitability, and environmental impact (N-leaching and GHG) of dairy farm systems which either imported or grew all their supplementary feed.

10.1 Whole farm system analysis - methodology

A whole farm system model was created to represent an 'average farm' in flat to rolling contour for Northland, Waikato/Bay of Plenty, Taranaki, Canterbury, and Southland using information for each region from the 2020-21 DairyNZ Economic Farm Survey, the 2020-21 New Zealand Dairy Statistics, and the 2019 DairyNZ report on Feed Consumed by NZ Dairy Cows (Table 11).

Table 11: Physical parameters for each region in the base Farmax model

	Northland Base	Waikato/ BOP Base	Taranaki Base	Canterbury Base	Southland Base
Effective area (ha)	140	120	107	233	222
Stocking rate (cows/ha)	2.3	2.8	2.7	3.4	2.6
Potential pasture growth (tDM/ha)	10.0	13.6	12.4	16.0	12.4
Nitrogen use per total ha (excl. crops) (kg N/ha)	112	128	145	167	159
Replacement rate (% peak cows milked)	21	23	22	22	22
Planned start calving	14 July	14 July	24 July	31 July	9 August
Avg. BCS at calving	5.0	5.0	5.0	5.0	5.0

Financial analysis was performed in Farmax using the regional financial information from the 2020-21 DairyNZ Economic Farm Survey on a per cow, per hectare and per kgMS basis. The financial parameters used in the models is shown in Table 12. OverseerFM was used to model nitrogen, phosphorus and GHG losses for each regional model.

Table 12: Financial parameters used in the Farmax models

Milk price ($/kgMS)	$7.00
Pasture silage grown ($/tDM)	$200
Home grown maize silage ($/ha stacked)	$4,000
Bulb turnip grown ($/ha)	$1,800
Fodder beet grown ($/ha)	$3,150
Concentrate price ($/tDM)	$500
Imported maize silage ($/tDM)	$450
Imported pasture silage ($/tDM)	$400
Urea ($/t)	$1,300
Regrassing ($/ha)	$1,000

Two alternate scenarios for each region were modelled in Farmax and OverseerFM using the same methodology as the base models. The physical parameters were kept the same as the base model. Cow numbers (stocking rate), winter cow grazing, cropping programme and levels of imported feed were adjusted. The impacts of these adjustments were compared to the base model for each region for productivity, profitability, nutrient losses and GHG emissions was analysed using Farmax and OverseerFM.

Opening and closing average body condition score (BCS) of the herd and opening and closing pasture cover was equal in each scenario to ensure that milk production was not at the expense of body fat reserves and mining pasture cover.

The base scenarios for each region used a mix of homegrown and brought in (including IPF) supplements. Two additional models were developed for each region to investigate the impact of buying in all supplements (Scenario 1) versus growing all supplements on farm (Scenario 2).

Scenario 1 modelled removing all home-grown crops (excluding home grown pasture silage) and replacing them with imported feed. Cow numbers (stocking rate) did not change. Northland and Taranaki had summer crop turnips replaced with imported maize silage and PKE. Waikato/BOP had home grown maize silage replaced with imported maize silage and PKE. Canterbury had home grown fodder beet replaced with imported maize and pasture silage. The Southland base model had no home-grown crops; however, the whole herd was wintered off for 9 weeks. In Scenario 1 for Southland, the whole herd was wintered on farm and additional pasture silage, hay, barley grain, and PKE imported.

Scenario 2 modelled removing all imported feed and replacing with home grown feed/crops. Cow numbers (stocking rate) was reduced to ensure opening and closing BCS of the herd and pasture covers were the same as the base models and BCS and pasture trends (month ends) throughout the season were as similar as possible to the base models. For Northland, summer crop turnips and maize silage was grown, and total cropping area was increased from the initial base models, whilst the number of cows wintered off was reduced. For Waikato/BOP, and Taranaki, summer crop turnips and maize silage was grown, and total cropping area was increased from the initial base models. In Canterbury, an increased area of fodder beet was grown, and an additional crop of maize silage grown from the base model. The same number of cows were wintered off as the base model. For Southland, the whole herd was wintered off for 9 weeks as in the base model. This was due to the base model not growing winter crops and the Intensive Winter Grazing (IWG) regulations which cap the area of winter grazed crops at current levels. A summer crop of oats was grown for cereal silage.

For the purposes of the model, it was assumed no capital investment in infrastructure was made. Maize and pasture silage were fed out in-paddock (no feed pad), with an assumed feed utilisation of 80% (i.e. 20% wastage).

10.2 Whole farm model - results

Regional results are shown in Appendix 13.3.3 and are summarised in this section.

10.2.1 Total feed costs

For North Island regions, at the feed prices used in the models, it is only slightly more expensive to replace home grown crops with imported feeds such as PKE (Scenario 1). However, in the South Island it is significantly more expensive (10% for Canterbury and 19% for Southland) to replace home grown crops and grazing off with imported feed. For Canterbury, 8 ha fodder beet is grown in the Base scenario at a 25 t DM/ha yield (200 t DM total). Assuming a growing cost of $4,150/ha (incl. regrassing), fodder beet costs 16 - 17 c/kg DM. Replacing the 200 t DM of fodder beet with imported maize silage and pasture silage increases feed costs because these harvested feeds have a significantly higher cost per kgDM than grazed fodder beet. It is the same principle for Southland, the cost of wintering the whole herd off is significantly less (c/kgDM) than buying in the equivalent amount of feed.

Across all the regions, there was a significant decrease in feed costs in Scenario 2 where all imported feed was replaced with home grown crops. Due to a reduction in stocking rate, less overall feed is required, and more pasture is available per cow resulting in less need for supplements. Due to the lower feed demand, there is a greater pasture surplus, and more pasture can be conserved as silage to use during periods of deficit.

Table 13: Total feed costs for the Base model and Scenarios 1 & 2 in five regions

Feed costs (crops + purchased + made + grazing + regrassing)					
Scenario	Northland	Waikato/BOP	Taranaki	Canterbury	Southland
Base	$244,225	$237,518	$226,819	$525,863	$482,737
Scenario 1 (imported feed)	$247,571	$252,893	$228,250	$576,378	$572,244
Scenario 2 (homegrown feed)	$142,488	$114,949	$97,666	$421,248	$319,801
% Change in feed costs					
S1 vs. Base	1%	6%	1%	10%	19%
S2 vs. Base	-42%	-52%	-57%	-20%	-34%

10.2.2 Milk production and total feed offered.

Replacing all homegrown crops with imported feed (Scenario 1) results in similar total feed eaten as the Base scenario (Table 14) and correspondingly similar milk solids production for all regions (Table 15). In contrast, decreasing stocking rate and replacing all imported feed with home grown crops (Base vs Scenario 2) reduces total feed eaten and decreases milk solids production by 5 - 14% (Table 15).

Table 14: Total feed offered for the Base model and Scenarios 1 & 2 in five regions.

Total feed offered (t DM/ha/year)					
Scenario	Northland	Waikato/BOP	Taranaki	Canterbury	Southland
Base	14.5	17.4	17.8	22.5	18.3
Scenario 1 (imported feed)	14.6	17.6	17.8	23.3	18.6
Scenario 2 (homegrown feed)	13.5	15.4	15.6	21.2	16.2
% Change in total feed eaten					
S1 vs. Base	1%	1%	0%	4%	2%
S2 vs. Base	-7%	-11%	-12%	-6%	-11%

Table 15: Milk production for the Base model and Scenarios 1 & 2 in five regions

Milk production (kg MS)					
Scenario	Northland	Waikato/BOP	Taranaki	Canterbury	Southland
Base	104,282	133,917	125,167	352,940	255,928
Scenario 1 (imported feed)	105,306	136,884	124,971	361,968	256,170
Scenario 2 (homegrown feed)	99,163	118,717	108,410	331,673	219,058
% Change in milk production					
S1 vs. Base	1%	2%	0%	3%	0%
S2 vs. Base	-5%	-11%	-13%	-6%	-14%

10.2.3 Profitability

10.2.3.1 Replacing all home-grown crops with imported feed (Scenario 1 vs Base)

For Northland, Waikato/BOP, Taranaki, and Canterbury replacing all home-grown crops with imported feed (Scenario 1) results in similar profitability to the Base scenario due to similar milk production and feed costs. Profitability is reduced in Scenario 1 for Southland due to the large increase in feed costs associated with wintering all the cows on the platform.

10.2.3.2 Replacing all imported feed with homegrown crops (Scenario 2 vs Base)

Northland sees a significant increase in profitability by reducing stocking rate and replacing all imported feeds with home grown feed and crops. There is a 42% reduction in feed costs (and a reduction in direct costs related to milking less cows), whilst only a 5% production decrease. This results in a significant increase in profitability. This shows that the 'average' farm in Northland is likely 'over stocked' and feed imported is being used to maintain cows (maintenance, live weight, walking) and this feed is not being portioned to milk production. Thus, Scenario 2 has significantly higher profitability.

Profitability for Waikato/BOP and Taranaki increases 12% and 15% respectively in Scenario 2. Again, this is as result of the reduction in feed costs being greater than the loss of income associated with the production drop. For Canterbury, profitability of Scenario 2 was similar to the Base scenario. The reduced revenue from lower milk production is similar to the reduction in feed costs and direct costs from lower stocking rates. Southland sees a 5% reduction in profitability through removing all imported feeds and reducing the stocking rate. Although there is a reduction in feed expenses, the reduced revenue from lower milk solids production is greater than the reduction in costs resulting in lower profitability.

Table 16: Profit for the Base model and Scenarios 1 & 2 in five regions

Profitability					
Scenario	**Northland**	**Waikato/BOP**	**Taranaki**	**Canterbury**	**Southland**
Base	$104,763	$316,646	$287,290	$963,053	$648,136
Scenario 1 (imported feed)	$108,446	$321,455	$284,459	$975,115	$559,978
Scenario 2 (homegrown feed)	$196,517	$354,933	$329,470	$963,136	$618,779
% Change in profitability					
S1 vs. Base	4%	2%	-1%	1%	-14%
S2 vs. Base	88%	12%	15%	0%	-5%

10.2.4 Nitrogen application and N-leaching

For Scenario 1, the amount of nitrogen fertiliser applied reduces in all regions except Southland as all crops were removed and replaced with imported feed. Southland grew no crops in the Base scenario thus nitrogen fertiliser applied stayed the same. For Scenario 2 nitrogen use increased slightly in all regions reflecting the higher requirements for on-farm cropping.

Table 17: Nitrogen fertiliser application for the Base model and Scenarios 1 & 2 in five regions

Total nitrogen fertiliser applied (kg N)					
Scenario	Northland	Waikato/BOP	Taranaki	Canterbury	Southland
Base	17,055	17,737	16,163	40,387	35,190
Scenario 1 (imported feed)	15,732	16,744	15,502	38,962	35,190
Scenario 2 (homegrown feed)	18,063	18,723	16,894	42,425	37,144
% Change in nitrogen applied					
S1 vs. Base	-8%	-6%	-4%	-4%	0%
S2 vs. Base	6%	6%	5%	5%	6%

For Scenario 1, Waikato/BOP, Taranaki, Canterbury, and Southland had similar nitrogen loss as the Base scenario. This is due to the difference in nitrogen inputs (fertiliser, supplements, irrigation, rain/clover fixation) and nitrogen outputs (leaching, runoff, direct losses, as product, atmospheric, and supplement and crop residues) are similar in both scenarios. The removal of nitrogen fertiliser from cropping is offset by the increased nitrogen brought in in imported supplements.

For Northland, nitrogen loss decreased significantly in Scenario 1 (all imported feed) compared to the Base. This is a result of the soil and drainage characteristics of Northland's OverseerFM model. The model farm is located in the Maungakaramea area near Whangarei and has poorly drained, brown soils with high predicted N leaching under crops. When the soil type for the Northland model was changed to volcanic/allophanic, the percentage change in nitrogen loss for Scenario 1 compared to the Base was similar to that achieved in the other four regions. This highlighted the fact that the impact of cropping on N-loss will vary by farm according to soil types and modelled drainage.

For Scenario 2, Waikato/BOP, Taranaki, Canterbury, and Southland had a similar nitrogen loss to the Base scenario. The reasoning is the same as for Scenario 1, the difference between nitrogen inputs and outputs is similar to the Base scenario, resulting in similar nitrogen losses.

Table 18: Nitrogen loss to water (kg N) for the Base model and Scenarios 1 & 2 in five regions

Nitrogen loss (kg N/ha) –					
Scenario	Northland	Waikato/BOP	Taranaki	Canterbury	Southland
Base	22	31	58	57	22
Scenario 1 (imported feed)	17	32	56	55	21
Scenario 2 (homegrown feed)	26	32	55	55	23
% Change in nitrogen loss					
S1 vs. Base	-22%	3%	-3%	-4%	-5%
S2 vs. Base	18%	3%	-5%	-4%	5%

Northland sees an 18% increase in nitrogen loss in Scenario 2 compared to the Base scenario. Cropping area increased 50% to 18 ha in Scenario 2 in the Northland model, which due to the soil and drainage characteristics of the OverseerFM model, resulted in a larger increase in nitrogen loss compared to the Base scenario for Northland than the other four regions.

10.2.5 Biological GHG emissions

Biological GHG emissions are similar for all regions for Scenario 1 compared to the Base scenario. This is due to similar production levels as a result of similar total feed eaten. Biological GHG emissions reduced substantially across all regions in Scenario 2, as to be expected with the reduction in stocking rate resulting in lower milk solids production and lower total feed eaten.

Table 19: Biological GHG emissions for the Base model and Scenarios 1 & 2 in five regions

Biological GHG (t CO_2e/ha)					
Scenario	Northland	Waikato/BOP	Taranaki	Canterbury	Southland
Base	8.11	9.36	10.51	13.47	11.39
Scenario 1 (imported feed)	8.21	9.54	10.61	13.72	11.18
Scenario 2 (homegrown feed)	7.34	8.27	9.15	12.62	9.92
% Change in biological GHG					
S1 vs. Base	1%	2%	1%	2%	-2%
S2 vs. Base	-10%	-12%	-13%	-6%	-13%

10.3 Sensitivity analysis – milk solids payout and concentrate price.

An analysis was conducted to assess the impact of changes in the milk or concentrate price on farm profitability for the Waikato/BOP and Canterbury scenarios. Note that only the Base scenario and Scenario 1 had imported concentrates.

Table 20: Impact of concentrate price and milksolids payout on profitability of Base and Scenario 1 (all imported feed)

	Waikato/BOP Base				**Waikato/BOP Scenario 1**			
	Milk Price ($/kg MS)				Milk Price ($/kg MS)			
Concentrate Price ($/t DM)	$ 6.00	**$ 7.00**	$ 8.00	$ 9.00	$ 6.00	**$ 7.00**	$ 8.00	$ 9.00
$ 400	-36%	6%	49%	91%	-36%	6%	49%	91%
$ 450	-39%	3%	45%	88%	-39%	3%	46%	88%
$ 500	-42%	**0%**	42%	85%	-43%	**0%**	43%	85%
$ 550	-45%	-3%	39%	81%	-46%	-3%	39%	82%
$ 600	-49%	-6%	36%	78%	-49%	-6%	36%	79%

	Canterbury Base				**Canterbury Scenario 1**			
	Milk Price ($/kg MS)				Milk Price ($/kg MS)			
Concentrate Price ($/t DM)	$ 6.00	**$ 7.00**	$ 8.00	$ 9.00	$ 6.00	**$ 7.00**	$ 8.00	$ 9.00
$ 400	-35%	2%	39%	75%	-36%	2%	39%	76%
$ 450	-36%	1%	38%	74%	-36%	1%	38%	75%
$ 500	-37%	**0%**	37%	73%	-37%	**0%**	37%	74%
$ 550	-38%	-1%	36%	72%	-38%	-1%	36%	73%
$ 600	-39%	-2%	35%	71%	-39%	-2%	36%	73%

Table 20 shows the impact of milk price and concentrate price on profitability for the Base and Scenario 1 (all feed imported) for both the Waikato/BOP and Canterbury both show similar trends. A $1.00/kgMS movement up or down in milk price at any given concentrate price shows large changes in profitability for both regions and in both scenarios. A $50/tDM change up/down in concentrate price at any given milk price shows the same trend, but as expected the change in profitability is significantly less than for changes in milk price.

Table 21: Impact of milksolids payout on profitability of Base and Scenario 2 (all homegrown feed)

Waikato Scenario 2				Canterbury Scenario 2			
Milk Price ($/kg MS)				Milk Price ($/kg MS)			
$ 6.00	**$ 7.00**	$ 8.00	$ 9.00	$ 6.00	**$ 7.00**	$ 8.00	$ 9.00
-33%	0%	33%	67%	-34%	0%	34%	69%

Table 21 shows the change in profitability for Scenario 2 (no imported feed) for Waikato/BOP and Canterbury at a variety of milk prices. As for the Base and Scenario 1, there are significant changes in profitability when milk price changes.

Table 22: Impact of milk solids payout and concentrate price on the profitability of Scenario 2 (all homegrown feed) vs Scenario 1 (all imported feed)

	Waikato Scenario 2 v Scenario 1						**Canterbury Scenario 2 v Scenario 1**				
		Milk Price ($/kg MS)						Milk Price ($/kg MS)			
Concentrate Price ($/t DM)		$ 6.00	**$ 7.00**	$ 8.00	$ 9.00	Concentrate Price ($/t DM)		$ 6.00	**$ 7.00**	$ 8.00	$ 9.00
	$ 400	16%	4%	-1%	-4%		$ 400	0%	-3%	-4%	-5%
	$ 450	21%	7%	1%	-2%		$ 450	2%	-2%	-4%	-5%
	$ 500	28%	**10%**	3%	0%		**$ 500**	3%	**-1%**	-3%	-4%
	$ 550	35%	14%	6%	1%		$ 550	4%	0%	-3%	-4%
	$ 600	43%	18%	8%	3%		$ 600	6%	0%	-2%	-3%

When Waikato farm profitability is evaluated at different milk solids and concentrate prices the results showed that only at a high milk price ($8.00/kgMS or greater) and a low concentrate price ($450/tDM landed or less) was it more profitable to have a higher stocking rate and use imported feed (Scenario 1) than destocking and using home-grown feed and supplements (Scenario 2). This is due to the significant reduction in feed costs in Scenario 2 by replacing all imported feed with home grown crops for the Waikato.

Within the range of milk solids payout evaluated ($6 to $9/kgMS) it is never more profitable to use concentrates sourced for more than $500/tDM landed. If we assume a concentrate drymatter of 90% and a freight charge of $50/tonne, this equates to a purchase price (ex-works) of $400/t.

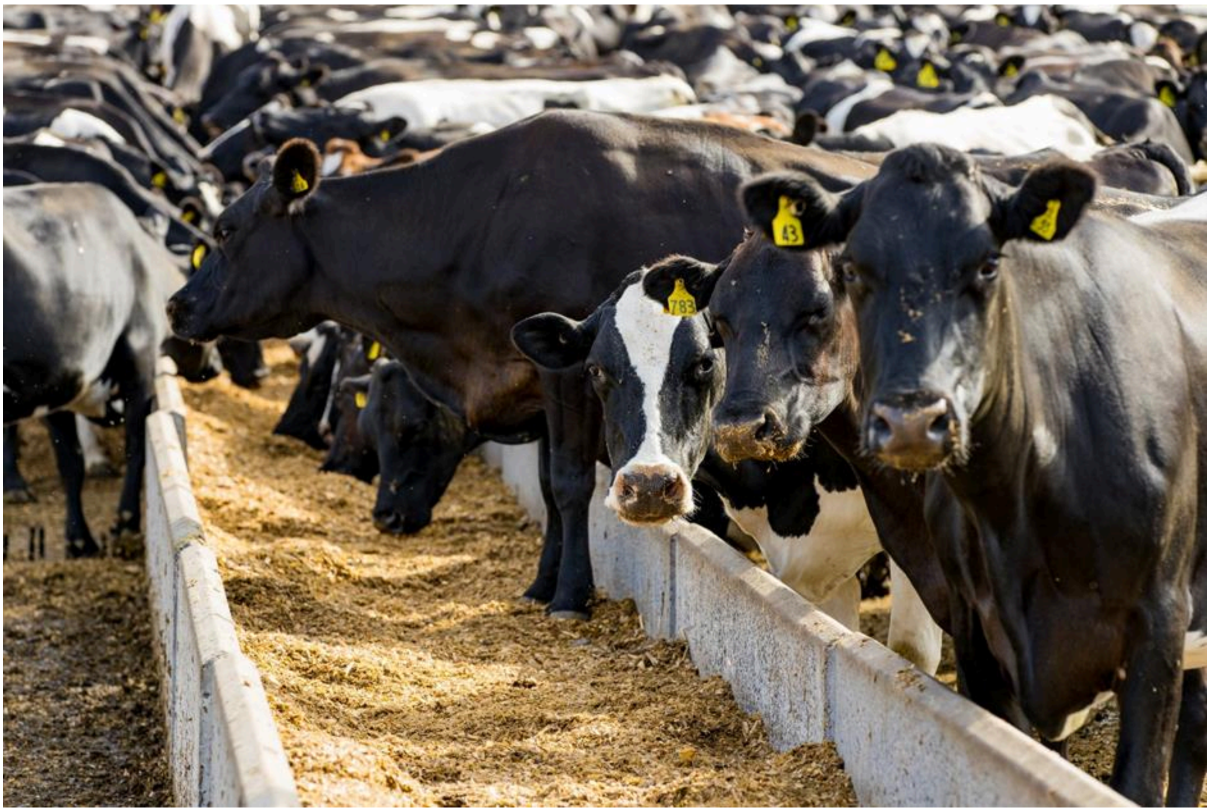
When the same analysis is run for Canterbury, the difference in profitability at different milk and concentrate prices of Scenario 1 compared to Scenario 2 is quite different. At a $6.00/kgMS milk price, it is more profitable to reduce stocking rate and remove all imported feed regardless of concentrate price. At higher milk prices, it is marginally more profitable to have a higher stocking rate and use imported feed.

10.4 Conclusions

This analysis showed that growing all feed on farm resulted in 5-14% lower milk production but on average profit was slightly higher. Both the Base scenario and Scenario 1 (all imported feed) were impacted by the price of concentrate, but the effect was much less than for payout. Relying on homegrown feed was the most profitable option particularly at lower payouts and when the concentrate price was over $500/tDM delivered.

When compared to the regional Base scenarios, Scenario 2 (all homegrown feed) decreased N loss to water in three regions but increased it slightly in two regions. Coupling homegrown low nitrogen feed with a feed pad would be expected to further reduce N loss to water. A feed pad would also increase supplement utilisation, and therefore profitability.

Reducing stocking rate and using all homegrown feed (Scenario 2) decreased biological GHG losses by 6-13% across all regions by 108 - 326 t CO_2e per farm. This will represent a significant cost saving once farmers have to pay for their GHG emissions.



11.0 REDUCING OUR RELIANCE ON IPF – THE WAY FORWARD

This report highlights New Zealand's dependence on IPF and highlights a way forward which could help us to become more self-sufficient by:

» Growing more grain locally, including on Māori-owned land, to support the poultry and pig industry and those dairy farmers who cannot practically crop on farm (e.g. those farming land of unsuitable contour or soil types, or those systems where it is more profitable to purchase New Zealand grown grain).

» Reducing dairy farm stocking rates and growing all supplementary feed requirements on farm where possible, especially in the North Island where there is less grain produced and where it is most economic to crop on farm.

While these solutions are not novel, we believe they are practical and implementable. Growing grain provides an opportunity for Māori landowners to make better returns from their whenua. On-farm cropping would make New Zealand farming systems less reliant on IPF with minimal impact on N-leaching and a significant decrease in GHG production. Key questions include do we have the land, expertise and infrastructure to expand the cropping area in New Zealand and how do we motivate change?

11.1 How much land do we need?

New Zealand imported around 3.7 million tonnes of feed in 2022 (USDA, 2023). Of this, around 91% or 3.4 million tonnes was used for livestock feed. If we deduct soymeal (413,050 tonnes) and DDGS (413,924 tonnes) which are protein concentrates which cannot easily be replaced by NZ-grown feed, we would be looking to replace around 2.5 million tonnes of livestock feed of which around 2.0 million tonnes was PKE and the remaining 500,000 tonnes was grain.

11.1.1 Replacing imported grain

In 2022, New Zealand harvested around 900,000 tonnes of grain from 107,000 ha (an average of 8.4 t/ha). Assuming similar yields and crop percentages, we would need a further 60,000 ha of arable land planted in grain to produce an additional 500,000 tonnes. If we could raise crop yields on existing and new land by 10%, the additional area needed drops to 44,500 ha (Table 23).

Table 23: Additional area required to grow an extra 500,000 tonnes of grain

Scenario	Average grain yield (t/ha)	Total area to grow 1.4 million tonnes of grain (ha)	Additional area above the current area (ha)
2022 average yield	8.4	166,667	59,667
+5%	8.8	158,730	51,730
+10%	9.2	151,515	44,515

Growing the grain area by this magnitude will take considerable effort and time. As already outlined whenua Māori, lifestyle blocks, sheep and beef farms and smaller, less economic dairy farms are all potential options for growing more grain.

The next steps to drive a change towards increased grain production would include a GIS desktop assessment of the suitability of whenua Māori for arable use and the widescale promotion of the economic and environmental benefits of growing grain. There also needs to be consideration to what further development and investment is required for drying and storage.

11.1.2 Replacing imported PKE

The solution for replacing imported PKE lies in dairy farm systems change. We do not need more land per se, rather a change in the way dairy farms operate.

Fonterra have already recognised that reducing imported feed use can decrease GHG losses. In a recent communication with their suppliers (Fonterra, 2023) they state:

"Emission levels in dairy cattle are affected by the feed eaten, including type, quantity and quality, and nitrogen fertilisers used on pasture and crops. Farmers can utilise these factors to help reduce emissions intensity. Importing feed to your farm system will increase emissions, so if you can grow and eat more homegrown feed you can:

» Reduce the requirement for imported supplement;

» Reduce costs; and

» Reduce total emissions due to the embedded emissions of supplement feed (e.g. from transport, cultivation, processing etc).

» Adjust stocking rate (feed demand) to increase home grown feed and reduce bought-in feed".

This report has focused on biological GHG which occur on farm. Using the life cycle assessment approach, the embedded emissions associated with each feed type can be calculated. Using this approach, PKE has the highest emission factor of supplements used in New Zealand predominantly due to where it is grown and how it is processed and transported to New Zealand (Fonterra, 2023).

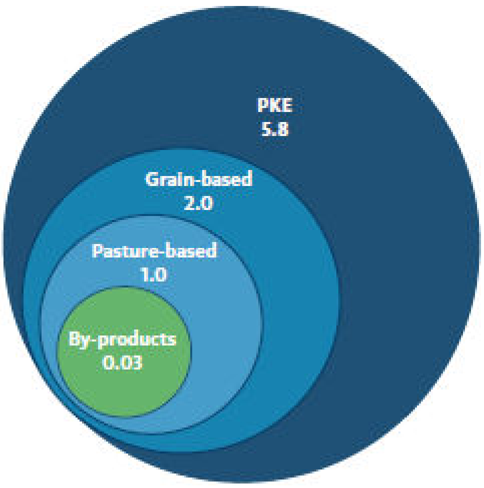


Figure 26: Emissions factors (CO_2e/kgDM) for by-products, pasture-based supplements (e.g. pasture silage), grain-based supplements and PKE (Fonterra, 2023).

If New Zealand wants to increase its reliance on imported feed rural professionals working in the dairy industry (e.g. DairyNZ, dairy farm consultants) will play a key role in advocating farm systems which use more home-grown feed and helping farmers transition into them.

11.2 Do we have enough arable land?

The Land Use Classification (LUC) system has been used in New Zealand to help achieve sustainable land development and management on farms. This classification categorises land areas or polygons into classes, subclasses, and units according to the land's capability to sustain productive use (Figure 27).

Classes 1 to 4 are all suitable for arable use. Class 1 is the most versatile, multi-use land with minimal physical limitations for arable use. While Class 4 land has significant limitations to arable use. It should be noted that some Class 4 land is winter wet and still suitable for summer crop production.

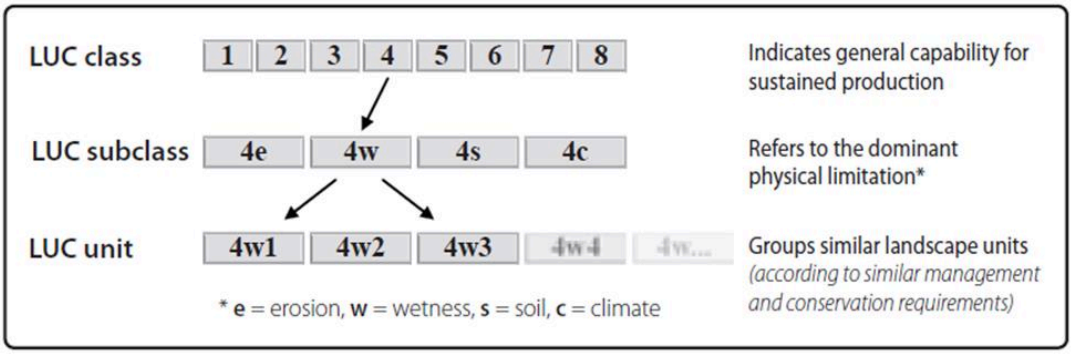


Figure 27: Components of the LUC system (Lynn et al., 2009)

The total area available that is suited for arable use without significant limitations (LUC 1- 3) is approximately 1.4 million ha. This includes non-urban areas that have parcel sizes of greater than 2 ha (Table 24).

Table 24: Land area which is suitable for arable grouped by parcel size (Stats NZ, 2021).

Parcel size		Area (ha)
Small	>2.0 to 4.0 ha	30,607
	>4.0 to 8.0 ha	79,028
Medium	>8.0 to 20.0 ha	135,746
	>20.0 to 40.0 ha	248,632
Large	>40.0 to 100 ha	518,481
Total Area (greater than 2.0 ha parcel size)		**1,447,572**

New Zealand has soils suitable for arable production throughout the country with the largest areas located in the Waikato, Manawatu, Canterbury and Southland (Appendix 13.4).

A high proportion of dairy farms are on Class 1-4 land. This means the conversion of grazed pastoral land to forage crops is entirely feasible.

11.3 Cropping infrastructure

Growing grain or cropping on farm will require an expansion in cropping equipment. Currently much of the grain grown in New Zealand is established using traditional cultivation methods which require multiple machinery passes. Ideally new areas would be established using reduced tillage techniques which would mean that there would be a requirement for more planters, crop spray equipment and harvesting equipment (forage harvesters for silage or combines for grain). There is already additional capacity in the industry in terms of machinery and it is likely that the change away from IPF would occur gradually giving time for capability to build.

Maize grain is harvested and dried to a suitable storage moisture content (usually 14%). There are commercial maize grain driers in most North Island regions with the exception of Central Taranaki. Crops are generally contracted to the drying company around planting time and sold at harvest time with the grower paying the cost of drying. A phone survey of major grain processors in the North Island indicated that most could handle a 25% increase in grain volumes whilst utilising existing drying infrastructure. Grain storage was a potential challenge but could be solved with additional silos or flat storage.

Feed wheat and barley are predominantly grown in the lower North Island, Canterbury, Otago and Southland. While Canterbury growers aim to field dry crops to storage moisture, there is a requirement for mechanical drying on the shoulders of the season and in seasons when the weather is less favourable. Due to climatic conditions, Manawatu, Otago and Southland cereal crops are more likely to need to be mechanically dried. There are a number of commercial cereal dryers in the lower North Island and Canterbury. In the South Island and especially in Otago and Southland, growers are more likely to own their own dryers. Cereal growers are more likely to store crops on farm (particularly if they have been field dried) and grain is sold throughout the season. New arable growers in the lower South Island may need to invest in drying and storage infrastructure.

11.4 Conclusion

Growing more grain locally and reducing dairy farm stocking rates and growing supplementary feed requirements on farm are practical and implementable solutions for New Zealand to reduce its reliance on IPF.

Using current arable crop ratios and current crop average yields, we would require an additional 60,000 ha of land to grow grain, but this would drop to 45,000 ha if we could lift yields on new and existing land by 10%. New Zealand has enough arable land and infrastructure to grow, dry and process more grain in most regions. It is likely that arable expansion would occur slowly enabling infrastructure requirements to keep up with growth. A key will be to identify suitable growing areas and promote the economic and environmental advantage of growing grain to target landowners.

The dairy industry has suitable land for on-farm cropping, all that is needed is a change in the way farm systems operate. Fonterra have already recognised destocking and on-farm cropping as a means of reducing on-farm GHG emissions. It would also decrease dairy farm demand for IPF including PKE which has been identified as having very high embedded GHG emissions.

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13.0 APPENDICES

13.1 Feed suppliers and poultry and pig survey

Name:
Company:
Industry:

1) What products are you importing?
2) Where are they grown?
3) What has been the impact of the Ukraine and Russia conflict on:
   a) Product supply
   b) Product price
4) What has been the impact of shipping/freight on:
   a) Product supply
   b) Product price
5) What has been the impact of Covid 19 on:
   a) Product supply
   b) Product price
6) In order of disruption, can you rank the most to least disruptive.

   ☐ Ukraine/Russian conflict
   ☐ Shipping/Freight
   ☐ Covid 19

7) Do you foresee any shortages in the next 12 months?
8) How have you adapted to deal with these issues?

   ☐Changed formulation
   ☐Changed production volume
   ☐Increased product prices
   ☐Other ………………………………………………………………….

9) To what extent have you seen the landed cost of grain increase (since pre-Covid 19)?

   ☐0-25%
   ☐25-50%
   ☐50-75%
   ☐> 100%

10) How long do you estimate the existing disruptions will last?

   ☐0 – 6 months

☐6 – 12 months
☐1 – 2 years
☐2 – 5 years
☐> 5 years

11) Have you seen a change in buyer behaviours towards imported supplementary feed?

12) Would you purchase more locally grown grain if they were available?

13) What is the limiting factor for not purchasing NZ grown grain?

☐Price
☐Availability
☐Quality
☐Other ……………………………………………………………….

14) Any other feedback/solutions/concerns related to our project and current volatile global situation?

13.2 Developing a grain growing business on Whenua Māori

The realisation of the opportunity to transition from underutilised land to arable farming using a vertically integrated business requires adequate planning, collaboration, and partnerships, as well as access to capital, as well as a staged process to develop, market and distribute product.

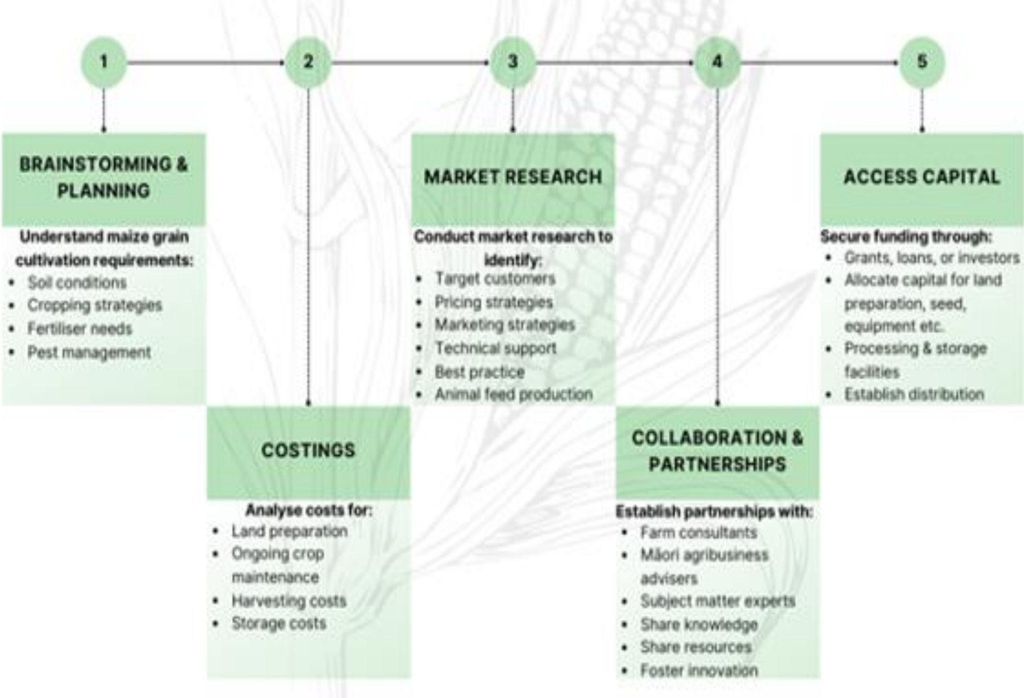


Figure 28: Business implementation plan (part 1) – maize grain for animal supplementary feed

13.2.1 Adequate planning

Thoroughly assessing the costs involved in every stage of the maize cultivation process is essential. This includes evaluating expenses for land preparation activities like clearing, tilling, and fertiliser applications, as well as ongoing maintenance costs and pest control. Additionally, considering the expenses related to harvesting, processing and storage is crucial for effective financial planning.

Market research plays a vital role in understanding the demand for maize grain animal feed supplements. It involves identifying potential customers, such as farmers and feed manufacturers, and analysing their requirements and preferences. Determining appropriate pricing strategies based on market dynamics and competitors, crucial for establishing a competitive edge. Furthermore, identifying effective marketing strategies and channels to reach the target market helps ensure successful product promotion and sales.

13.2.2 Collaboration and partnerships

Collaborating with agricultural experts, researchers, and established agribusinesses provides access to valuable knowledge and expertise. These partnerships can involve consulting agronomists for crop-specific advice, collaborating with researchers for innovative farming practices, and engaging with experienced agribusinesses for insights into successful operations and industry trends.

Partnerships enable the exchange of knowledge and best practices among different stakeholders. This can involve sharing information on successful crop cultivation techniques, providing technical support in areas such as irrigation or machinery maintenance, and sharing resources like specialised equipment or storage facilities. By fostering collaboration and cooperation, the business can leverage collective expertise and resources for mutual benefit. Collaboration encourages innovation in the maize grain animal feed supplement business. By engaging with partners, the company can explore and implement new technologies, sustainable practices, and efficient farming methods. Sharing experiences and collaborating on research and development initiatives can lead to the creation of best practices that optimise crop cultivation techniques and enhance the quality of the final animal feed product.

13.2.3 Access to capital

Access to capital is crucial for establishing and expanding a maize grain animal feed supplement business. Seeking grants from governmental or agricultural organisations that support primary sector growth and sustainable developments can provide funding opportunities (Table 25).

Table 25: Funding opportunities for primary sector growth

AGMARDT: Agribusiness Innovation Grants Website: https://agmardt.org.nz/agribusiness-innovation-grants/
AGMARDT: Market Insight Investment Website: https://agmardt.org.nz/market-insight-investments/
Callaghan Innovation: Research and Development Tax Incentive (RDTI) Website: https://www.rdti.govt.nz/news-and-events/
Ministry for Primary Industries Māori Agribusiness: Pathway to Increased Productivity (MAPIP) Fund Website:https://www.mpi.govt.nz/funding-rural-support/maori-agribusiness-funding-support/maori-agribusiness-pathway-to-increased-productivity-mapip-programme/
Te Puni Kōkiri: Māori Business Growth Fund Website: https://www.tpk.govt.nz/en/nga-putea-me-nga-ratonga/maori-enterprise
Ministry for Primary Industries: Sustainable Food & Fibre Futures (SFF Futures) Website:https://www.mpi.govt.nz/funding-rural-support/sustainable-food-fibre-futures/about-sustainable-food-and-fibre-futures/
For more funding opportunities visit Tupu.nz

Additionally, applying for loans from financial institutions that specialise in agriculture or seeking investments from sustainable business investors interested in agribusiness ventures can help secure the necessary capital.

Once capital is secured, it should be allocated strategically to various aspects of the business. This includes funding for land preparation activities like clearing, levelling, and soil improvement, as well as the procurement of high-quality seeds for maize cultivation. Allocating capital for the purchase or leasing of essential equipment such as tractors, irrigation systems, and harvesting machinery can be evaluated and discussed in more detail with an agriculture specialist. Additionally, allocating funds for the establishment of processing and storage facilities to transform harvested maize into animal feed supplements is necessary for the development of this business concept.

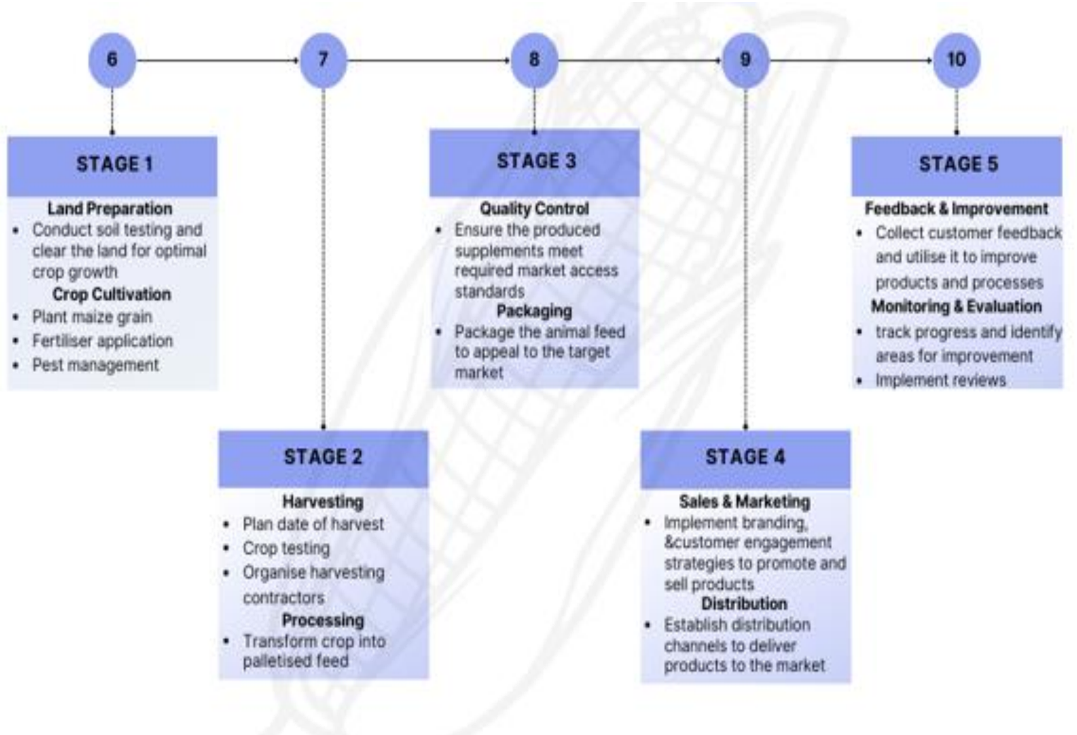


Figure 29: Business implementation (part 2) - maize grain animal supplementary feed

For further details see: Reti Kaukau (2023)

13.3 Farmax and OverseerFM modelling

13.3.1 Feed values

Table 26 shows the feed values used in the OverseerFM and Farmax models for the five regions and three scenario models. (DairyNZ, 2017a).

Table 26: Feed values used in Farmax and OverseerFM

	PKE	DDGS	Barley grain	Pasture silage	Hay	Maize silage	Turnips	Fodder beet	Cereal silage
Energy content (MJ ME/kgDM)	11.0	12.5	13.0	10.0	9.7	10.3	12.0	12.3	10.5
Drymatter (%)	90	90	89	100	100	100	100	100	100
Crude protein (%)	14	29	11	17	17	8	15	12	13
Feed-out wastage (%)	10	10	10	20	20	20	20	20	20

13.3.2 Cropping and homegrown supplements

Table 27 shows supplement inputs and assumptions made for the OverseerFM and Farmax models for the three scenarios and five regional models for the Base scenario and Scenario 2.

Scenario 2 removed all imported supplements therefore it is not shown in the table.

Table 27: Summary of feed imported for the Base and Scenario 1 (S1)

Feed (tDM)	Northland		Waikato/BOP		Taranaki		Canterbury		Southland	
	Base	S1	Base	S1	Base	S1	Base	S1	Base	S1
PKE	148	147	183	179	142	136				122
Maize silage	118	200	133	225	113	160				
Pasture silage							215	308	176	410
Hay					36	36				179
Barley							160	136	207	207
DDGS					17	17				
Total Imported Supplements	**266**	**347**	**316**	**404**	**308**	**349**	**375**	**444**	**383**	**918**

13.3.3 Whole farm modelling and results by region

13.3.3.1 Northland

Table 28: Whole farm modelling for Northland

	Base Scenario	Scenario 1 (imported feed)	Scenario 2 (homegrown feed)
Effective area (ha)	140	140	140
Stocking rate (cows/ha)	2.3	2.3	2.0
Comparative stocking rate (kg LWT/t DM offered)	79.6	78.9	78.4
Feed conversion efficiency (kg DM offered/kg MS)	17.2	17.1	16.6
Peak cows milked	315	315	283
% Change relative to Base		*0%*	*-10%*
Milk solids total (kg MS)	104,282	105,306	99,163
% Change relative to Base		*1%*	*-5%*
Milk solids per total ha (kg/ha)	745	752	708
Milk solids per cow (kg/cow)	331	334	350
Total feed offered per cow (t DM/cow)	5.7	5.7	5.8
Total feed offered per ha (t DM/ha)	14.5	14.6	13.5
% Change relative to Base		*1%*	*-7%*
Supplements and grazing / feed offered	31.5%	29.2%	26.2%
Bought feed / feed offered	14.8%	19.3%	
Cropping (% total farm area)	8.6%	0.0%	12.9%
N Loss (kg N/year)	3,575	2,350	4,134
% Change relative to Base		*-34%*	*16%*
Biological total tCO_2e/ha	8.11	8.21	7.34
Biological total t CO_2e/farm	1,136	1,149	1,027
% Change relative to Base		*1%*	*-10%*
Farm EBITDA ($)	**$104,763**	**$108,446**	**$196,517**
% Change relative to Base		*4%*	*88%*

Scenario 1

EBITDA is 4% higher in Scenario 1 compared to the Base scenario for Northland. There was a slight increase in milk solids production due to lower feed out wastage (higher utilisation) of imported feed compared to summer crop turnips resulting in a higher total feed offered per hectare. Feed conversion efficiency improved in Scenario 1 as due to less feed out wastage. Farm working expenses are slightly less compared with the base scenario with the reduction in cropping and regrassing expenses being greater than the increased cost of additional imported feed.

Total nitrogen loss is 34% lower than the Base scenario predominantly due to no summer turnip crop being grown removing the nitrogen applied that was applied to the crop.

Biological GHG emissions (methane + nitrous oxide) increased 1% compared to the Base scenario. Whist there was a reduction in nitrous oxide emissions (N_2O) due to less total nitrogen being applied with the removal of the summer turnip crop, methane (CH_4) emissions increased due to the increase in production. The increase in CH_4 emissions were greater than the reduction in N_2O resulting in an overall increase in biological GHG emissions.

Scenario 2

Cow numbers (stocking rate) was reduced by 10% compared to the Base scenario. However, production only reduced 5%. This is due to the increase in per cow production (increased feed offered per cow). EBITDA is 88% higher in Scenario 2 compared to the base scenario. The reduction in farm working expenses is significantly greater than the reduction in farm revenue resulting in an increase in EBITDA.

Total nitrogen loss is 16% higher than the Base scenario and is predominantly due to the increase in cropping (summer turnips and maize silage) resulting in additional nitrogen applied to the crops.

Biological GHG emissions reduced 10% compared to the Base scenario. Methane and nitrous oxide emissions were reduced due to the lower cow numbers, and lower milk solids production due to less total feed eaten.

13.3.3.2 Waikato/BOP

Table 29: Whole farm modelling for Waikato/BOP

	Base Scenario	Scenario 1 (imported feed)	Scenario 2 (homegrown feed)
Effective area (ha)	120	120	120
Stocking rate (cows/ha)	2.8	2.8	2.5
Comparative stocking rate (kg LWT/ tDM offered)	78.2	77.8	79.2
Feed conversion efficiency (kg DM offered/kgMS)	15.1	14.9	15.0
Peak cows milked	340	340	300
% Change relative to Base		*0%*	*-12%*
Milk solids total (kg MS)	133,917	136,884	118,717
% Change relative to Base		*2%*	*-11%*
Milk solids per total ha (kg/ha)	1,022	1,045	906
Milk solids per cow (kg/cow)	394	403	396
Total feed offered per cow (t DM/cow)	5.9	6.0	5.9
Total feed offered per ha (t DM/ha)	17.4	17.6	15.4
% Change relative to Base		*1%*	*-11%*
Supplements and grazing / feed offered	24.1%	23.0%	18.0%
Bought feed / feed offered	15.6%	19.8%	
Cropping (% Total Farm Area)	4.0%	0.0%	11.7%
N loss (kg N/year)	4,153	4,182	4,322
% Change relative to Base		*1%*	*4%*
Total t CO_2e/ha	9.36	9.54	8.27
Total t CO_2e/Farm	1,123	1,145	993
% Change relative to Base		*2%*	*-12%*
Farm EBITDA ($)	**$316,646**	**$321,455**	**$354,933**
% Change relative to Base		*2%*	*12%*

Scenario 1

EBITDA is 2% higher in Scenario 1 compared to the base scenario for Waikato/BOP. Milk solids production is higher due to an increase in total feed offered as a result of lower feed out wastage and an increase in feed conversion efficiency. Farm working expenses are slightly less compared with the Base scenario with the reduction in cropping and regrassing expenses being greater than the increased cost of additional imported feed.

Total nitrogen loss is 1 % higher than the Base scenario. Although there is less overall nitrogen applied with no maize silage grown, there is increased nitrogen brought onto the farm in imported feed.

Biological GHG emissions increased 2% compared to the Base scenario. Higher production resulted in greater methane and nitrous oxide emissions.

Scenario 2

Cow numbers (stocking rate) was reduced by 12% compared to the Base scenario and total milk solids production reduced by 11%. Per cow production was similar to the Base scenario as a result of similar total feed offered per cow.

EBITDA is 12% higher in Scenario 2 compared to the base scenario. The reduction in farm working expenses is greater than the reduction in farm revenue resulting in an increase in EBITDA.

Total nitrogen loss is 4% higher than the Base scenario and is predominantly due to the increase in cropping (summer turnips and maize silage) resulting in additional nitrogen applied to the crops.

Biological GHG emissions reduced 12% compared to the Base scenario. Methane and nitrous oxide emissions were reduced due to the lower cow numbers resulting in lower total feed eaten and milk solids production.

13.3.3.3 Taranaki

Table 30: Whole farm modelling for Taranaki

	Base Scenario	Scenario 1 (imported feed)	Scenario 2 (homegrown feed)
Effective area (ha)	107	107	107
Stocking rate (cows/ha)	2.7	2.7	2.3
Comparative stocking rate (kg LWT/t DM offered)	72.6	72.4	72.4
Feed conversion efficiency (kg DM offered/kg MS)	13.5	13.6	13.5
Peak cows milked (cows)	290	290	249
% Change relative to Base		*0%*	*-14%*
Milk solids total (kg MS)	125,167	124,971	108,410
% Change relative to Base		*0%*	*-13%*
Milk solids per total ha (kg/ha)	1,170	1,168	1,013
Milk solids per cow (kg/cow)	432	431	435
Total feed offered per cow (t DM/cow)	5.8	5.9	5.9
Total feed offered per ha (t DM/ha)	17.8	17.8	15.6
% Change relative to Base		*0%*	*-12%*
Supplements and grazing / feed offered	27.9%	26.0%	19.5%
Bought feed / feed offered	18.2%	20.6%	
Cropping (% total farm area)	5.6%	0.0%	9.3%
N loss (kg N/year)	6,213	5,991	6,013
% Change relative to Base		*-4%*	*-3%*
Total t CO_2e/ha	10.51	10.61	9.15
Total t CO_2e/farm	1,125	1,135	979
% Change relative to Base		*1%*	*-13%*
Farm EBITDA ($)	**$287,290**	**$284,459**	**$329,470**
% Change relative to Base		*-1%*	*15%*

Scenario 1

EBITDA is 1% less in Scenario 1 compared to the base scenario for Taranaki. Production is slightly lower resulting in reduced milk income. Farm working expenses are slightly less compared with the base scenario with the reduction in cropping and regrassing expenses being greater than the increased cost of additional imported feed.

Total nitrogen loss is 4% lower than the base scenario predominantly due to no summer turnip crop grown, removing the nitrogen applied that was applied to the crop.

Biological GHG emissions increased 1% compared to the base scenario.

Scenario 2

Cow numbers (stocking rate) was reduced by 14% compared to the base scenario and total milk solids production reduced by 13%.

EBITDA is 15% higher in Scenario 2 compared to the base scenario. The reduction in farm working expenses is greater than the reduction in farm revenue resulting in an increase in EBITDA.

Total nitrogen loss is 3% lower than the base scenario.

Biological GHG emissions reduced 13% compared to the base scenario. Methane and nitrous oxide emissions were reduced due to the lower cow numbers resulting in lower total feed eaten and milk solids production.

13.3.3.4 Canterbury

Table 31: Whole farm modelling for Canterbury

	Base Scenario	Scenario 1 (imported feed)	Scenario 2 (homegrown feed)
Effective area (ha)	233	233	233
Stocking rate (cows/ha)	3.4	3.4	3.2
Comparative stocking rate (kg LWT/t DM offered)	85.3	82.5	81.6
Feed conversion efficiency (kg DM offered/kg MS)	13.1	13.3	13.1
Peak cows milked (cows)	796	796	747
% Change relative to Base		*0%*	*-6%*
Milk solids total (kg MS)	352,940	361,968	331,673
% Change relative to Base		*3%*	*-6%*
Milk solids per total ha (kg/ha)	1,515	1,554	1,423
Milk solids per cow (kg/cow)	443	455	444
Total feed offered per cow (t DM/cow)	5.8	6.0	5.8
Total feed offered per ha (t DM/ha)	22.5	23.3	21.2
% change relative to Base		*4%*	*-6%*
Supplements and grazing / feed offered	25.8%	26.2%	26.2%
Bought feed / feed offered	9.8%	20.2%	
Cropping (% total farm area)	3.4%	0.0%	8.6%
N loss (kg N/year)	13,850	13,560	13,479
% Change relative to Base		*-2%*	*-3%*
Total t CO_2e/ha	13.47	13.72	12.62
Total t CO_2e/Farm	3,139	3,197	2,940
% Change relative to Base		*2%*	*-6%*
Farm EBITDA ($)	**$963,053**	**$975,115**	**$963,136**
% Change relative to Base		*1%*	*0%*

Scenario 1

EBITDA is 1% higher in Scenario 1 compared to the base scenario for Canterbury. Production is higher due to an increase in total feed eaten through reduced feed out wastage resulting in increased milk income. Farm working expenses are higher compared with the base scenario with the increase in imported feed costs more than the reduction in cropping and regrassing costs. However, the increased revenue is greater than the increased farm working expenditure. Total nitrogen loss is 2% lower than the base scenario predominantly due to no fodder beet grown, removing the nitrogen applied that was applied to the crop.

Biological GHG emissions increased 2% compared to the base scenario due to the increased production through more total feed eaten.

Scenario 2

Cow numbers (stocking rate) was reduced by 6% compared to the base scenario and total milk solids production reduced by 6%. Per cow production was similar to the base scenario as a result of similar total feed offered per cow.

EBITDA is similar in Scenario 2 compared to the base scenario. The reduction in farm revenue is essentially the same as the reduction in farm working expenditure.

Total nitrogen loss is 3% lower than the base scenario.

Biological GHG emissions reduced 6% compared to the base scenario. Methane and nitrous oxide emissions were reduced due to the lower cow numbers and lower milk production resulting in lower total feed eaten.

13.3.3.5 Southland

Table 32: Whole farm modelling for Southland

	Base Scenario	Scenario 1 (imported feed)	Scenario 2 (homegrown feed)
Effective area (ha)	222	222	222
Stocking rate (cows/ha)	2.6	2.6	2.2
Comparative stocking rate (kg LWT/t DM offered)	79.0	77.9	78.2
Feed conversion efficiency (kg DM offered/kg MS)	14.0	14.2	14.2
Peak cows milked (cows)	583	583	494
% Change relative to Base		*0%*	*-15%*
Milk solids total (kg MS)	255,928	256,170	219,058
% Change relative to Base		*0%*	*-14%*
Milk solids per total ha (kg/ha)	1,153	1,154	987
Milk solids per cow (kg/cow)	439	439	443
Total feed offered per cow (t DM/cow)	6.2	6.3	6.3
Total feed offered per ha (t DM/ha)	11.4	11.5	10.8
% Change relative to Base		*1%*	*-5%*
Supplements and grazing / feed offered	29.3%	30.2%	23.3%
Bought feed / feed offered	11.1%	25.2%	
Cropping (% total farm area)	0.0%	0.0%	6.8%
N loss (kg N/year)	13,850	13,560	13,479
% Change relative to Base		*-2%*	*-3%*
Total t CO_2e/ha	11.39	11.18	9.92
Total t CO_2e/Farm	2,529	2,483	2,202
% Change relative to Base		*-2%*	*-13%*
Farm EBITDA ($)	**$648,136**	**$559,978**	**$618,779**
% Change relative to Base		*-14%*	*-5%*

Scenario 1

EBITDA is 14% less in Scenario 1 compared to the base scenario for Southland. Although there is a slight increase in milk production, there is a significant increase in feed costs resulting in higher overall farm working expenses, reducing EBITDA.

Total nitrogen loss is 2% lower than the base scenario. Biological GHG emissions reduced 2% compared to the base scenario.

Scenario 2

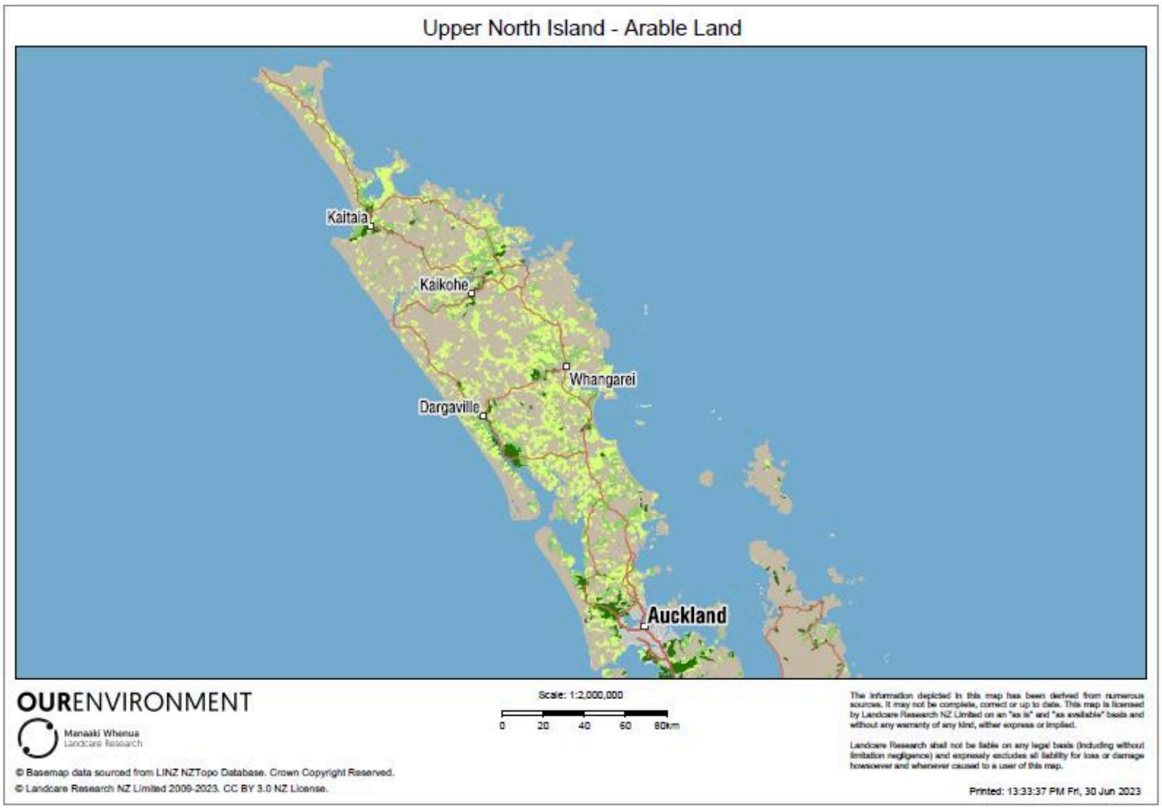
Cow numbers (stocking rate) was reduced by 15% compared to the base scenario and total milk solids production reduced by 14%. Per cow production was slightly higher compared to the base scenario as a result of a small increase in total feed offered per cow.

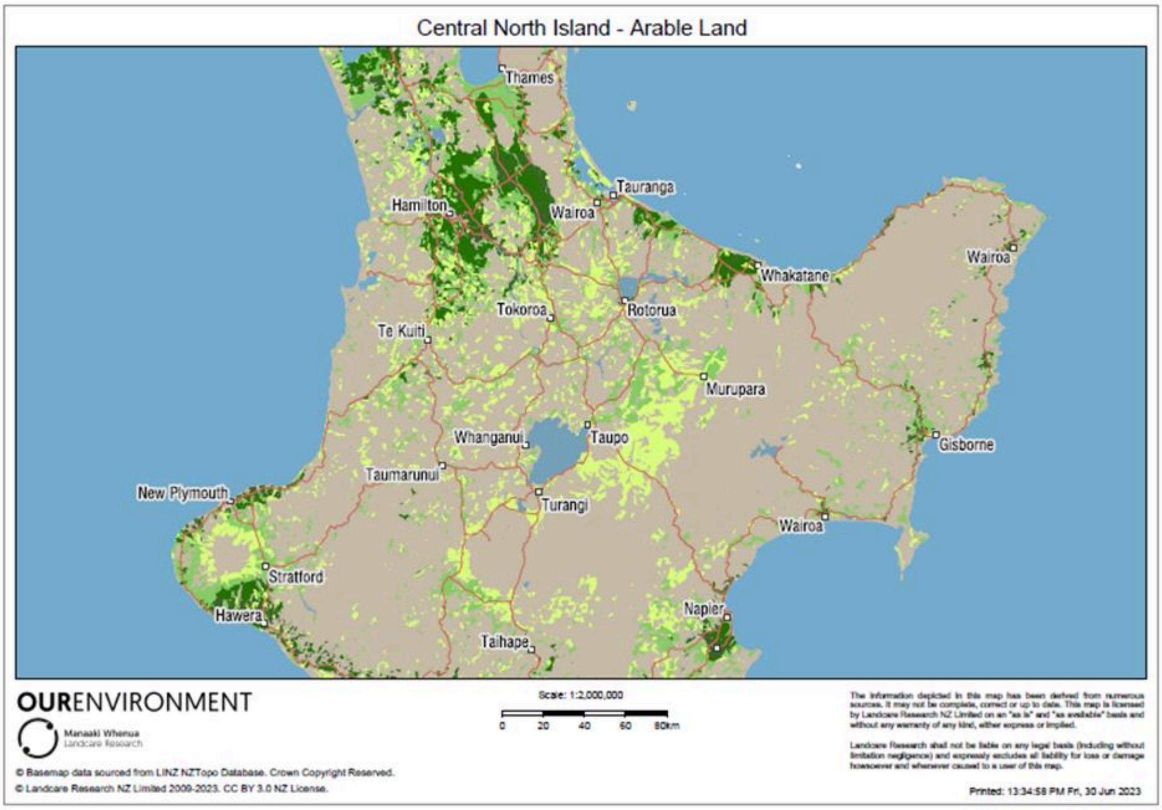
EBITDA is lower in Scenario 2 compared to the base scenario. The reduction in farm revenue is greater than the reduction in farm working expenses.

Total nitrogen loss is 3% lower than the base scenario. Biological GHG emissions reduced 5% compared to the base scenario. Methane and nitrous oxide emissions were reduced due to the lower cow numbers and lower milk production resulting in lower total feed eaten.

13.4 Suitability of land for arable production

The suitability of land for arable production is shown in the Figures below.





Lower Nth/Upper Sth Island - Arable Land

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Scale: 1:2,000,000

0 20 40 60 80km

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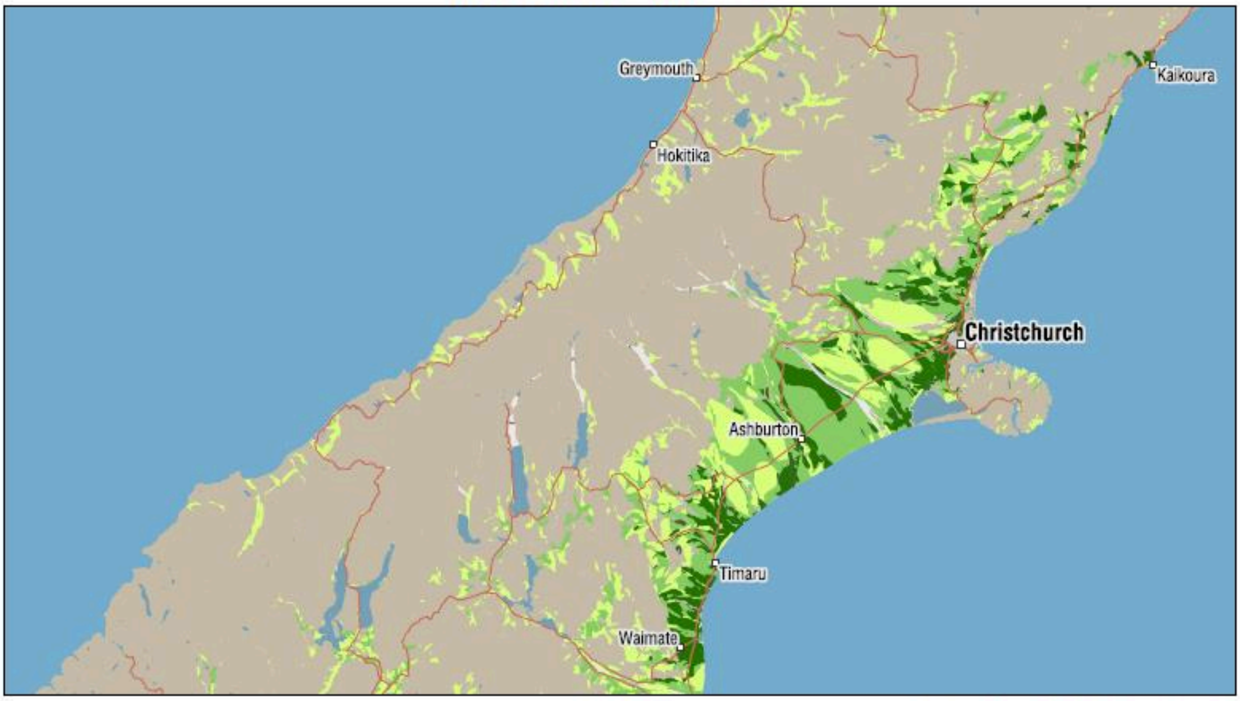
Mid South Island - Arable Land



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Scale: 1:2,000,000

0 20 40 60 80km

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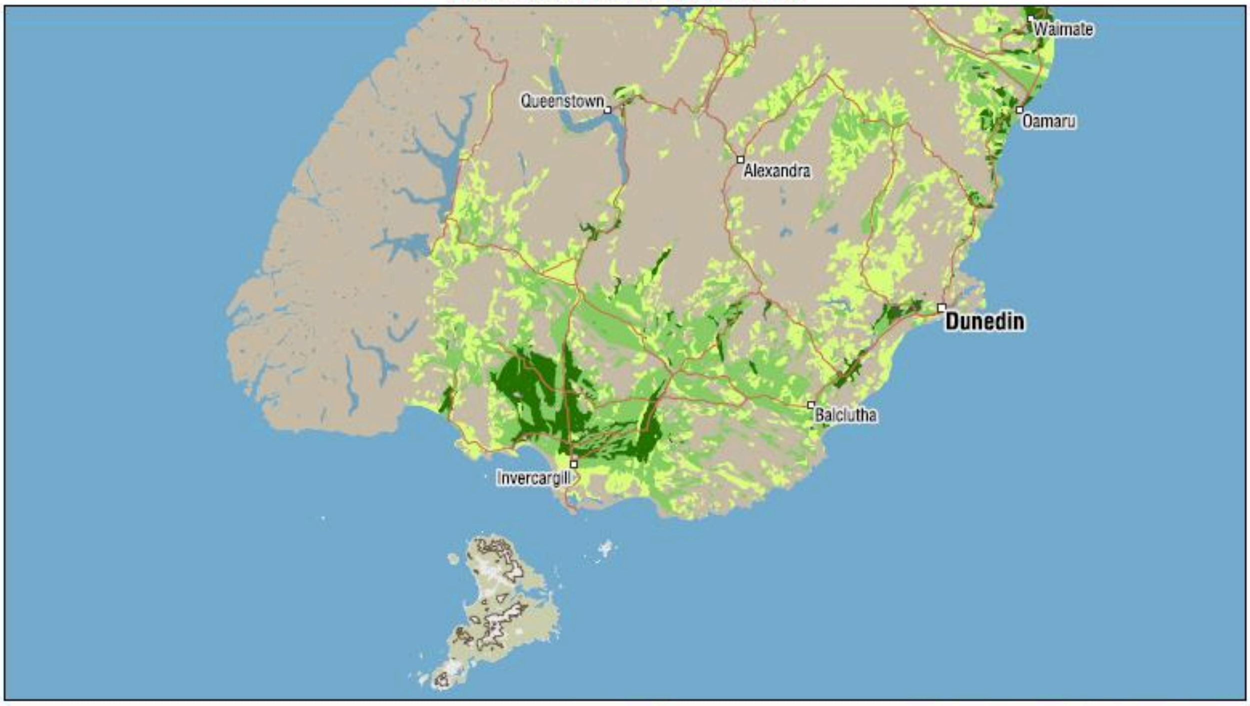
Lower South Island - Arable Land



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Legend

Suitability for Arable Cropping

- Multiple-use land - few limitations
- Good land - slight limitations
- Moderate limitations - restricted crop choice
- Severe limitations for arable use
- Unsuitable

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Contact

Raewyn Densley

Agribusiness Consultant
027 686 8021
raewyn.densley@agfirst.co.nz

AgFirst Waikato (2016) Ltd
26D Liverpool Street
PO Box 9078, Hamilton 3240, New Zealand
07 839 2683
waikato@agfirst.co.nz
www.agfirst.co.nz