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The Value of Nitrogen Fertiliser to the New Zealand Economy

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1.0 EXECUTIVE SUMMARY

Nitrogen fertiliser is an integral component of the farming scene within New Zealand, as it is around the world. It is an important component of our farming systems, significantly aiding in the economic viability of many of those systems. As a result, usage of nitrogenous fertilisers has been increasing over recent decades.

This study analyses the value of nitrogenous fertilisers to the primary sector, both at the farm gate, and to the wider New Zealand economy.

This has been done on a 'with' versus 'without' basis across four sectors:

(i) Pastoral agriculture - dairy, sheep and beef

(ii) Permanent horticulture - tree and vine crops

(iii) Vegetables

(iv) Arable

In all sectors the current profitability of the various farming systems was compared with a system whereby nitrogen fertiliser could not be used, and additionally compared to a system where a substitute for nitrogen fertiliser was used, e.g. supplementary feed in the pastoral systems, and compost/legume cover crops in the permanent horticultural systems.

1.1 Pastoral Sector

This involved the development of representative models in both Farmax and Overseer, whereby the 'with' versus 'without' scenarios could be modelled, as to their impact on production, profitability, and subsequent nitrogen leaching.

The models, developed from industry statistics, were:

Models developed

Dairy	Sheep & Beef
Northland	North Island Hill Country
Waikato/Bay of Plenty	North Island Intensive
Taranaki	South Island Hill Country
Canterbury	South Island Intensive
Southland	

The substitute used in the 'without + substitute' scenario was maize silage and Palm Kernel for the North Island dairy farms, pasture silage and barley grain for the South Island dairy farms, and pasture silage (baleage) for all the sheep and beef farms.

The average amount of nitrogen fertiliser applied, based on industry statistics was:

Average nitrogen fertiliser applied

Dairy	kg N/ha (5yr average)	Sheep & Beef	kg N/ha (5yr average)	Proportion of farm fertilised
Northland	112	North Island Hill Country	12.1	64%
Waikato/Bay of Plenty	128	North Island Intensive	18.0	60%
Taranaki	148	South Island Hill Country	9.1	31%
Canterbury	234	South Island Intensive	13.5	74%
Southland	171			

In the 'without' scenario, any nitrogen fertiliser was eliminated, and stock numbers reduced, but per animal performance held, until the farm system was feasible. In the 'without + substitute' scenario, nitrogen fertiliser was eliminated, and supplementary feed bought in up to the point where the status quo farming system was again feasible.

The impact of this on farm profitability (in $ millions) was:

Summary of Pastoral impacts ($m)

Dairy	No N Fert	No N Fert, plus Supplements	Sheep & Beef	No N Fert	No N Fert, plus Supplements
Northland	-$21.1	-$33.0	North Island Hill Country	-$13.8	-$99.1
Waikato/BoP	-$158.3	-$248.1	North Island Intensive	-$4.6	-$24.1
Taranaki	-$53.9	-$62.6	South Island Hill Country	-$2.6	-$15.5
Canterbury	-$393.1	-$555.9	South Island Intensive	-$1.2	-$34.6
Southland	-$45.9	-$89.5			
National*	**-$824.4**	**-$1,212.9**	**National***	**-$30.4**	**-$237.6**

*Dairy national figure extrapolated across all dairy farms, sheep & beef figure extrapolated across all S&B farms, except South Island High County

The Canterbury dairy model was most affected, given the importance of additional nitrogen fertiliser in an irrigated system.

The impact of the scenarios on nitrogen leaching across the models was:

Nitrogen leaching impacts (kg N/ha/year)

Dairy	Base	No N Fert	No N Fert, plus Supplements	Sheep & Beef	Base	No N Fert	No N Fert, plus Supplements
Northland	34	23	24	North Island Hill Country	12	12	12
Waikato/BoP	39	32	33	North Island Intensive	17	17	17
Taranaki	50	37	40	South Island Hill Country	8	8	8
Canterbury	76	40	47	South Island Intensive	14	13	14
Southland	26	19	20				

As could be expected, the reduction in nitrogen leaching was significant on the dairy models, whereas it was negligible on the sheep & beef models due to the relatively minor amount of nitrogen fertiliser being applied.

The main form of nitrate leaching is from the urine patch, with direct loss from applied nitrogen fertiliser being 3-4%. The main reductions therefore shown in the above Table are reductions in nitrate leaching from urine patches. In other words, livestock account for approximately 80+% of N leached, moderated by the nitrogen content of supplementary feed. This is illustrated in the Table below:

Nitrate leaching (kgN/ha)

Waikato/BoP Dairy					Canterbury Dairy			
	Base	No N Fertiliser	No N + Supplement			Base	No N Fertiliser	No N + Supplement
Total	39	32	33		Total	76	40	47
Urine	31	25	26		Urine	69	33	40
Other	8	7	7		Other	7	7	7
% from urine	79%	78%	79%		% from urine	91%	83%	85%

1.2 Permanent Horticulture

Nitrogen is considered one of the most important macronutrients in horticultural production systems. Nitrogen directly impacts plant vegetative growth, fruit yield and quality, and in the case of grapevines, fermentation kinetics.

The analysis was via gross margin development where the impact of the 'with' versus 'without' was assessed across a range of permanent horticultural crops:

- Grapes
- Kiwifruit
- Pipfruit
- Summerfruit
- Citrus
- Avocados

The 'substitution' scenario involved either the use of compost, or, given that there would be insufficient compost available, the use of legume cover crops grown between the rows of trees/vines. Legume cover crops comes with its own issues, including maintaining a clover dominant sward, particularly in a shaded environment.

The results of the analysis showed:

Summary of Permanent Horticulture impacts ($/million)

	No N Fert	No N Fert, plus Substitutes
Pipfruit	-159.0	-2.2
Summerfruit	-4.1	-1.0
Kiwifruit	-156.9	-7.7
Avocado	-60.2	-2.1
Citrus	-7.9	-0.9
Viticulture	-91.0	-4.4
National	**-479.1**	**-18.3**

Nitrogen fertiliser use in fruit crops is becoming very efficient via the use of fertigation and foliar sprays, which also reduce nitrate leaching.

The analysis as to the impact of no nitrogen fertiliser was carried out on mature orchards, which are more resilient to reduced nitrogen inputs. Nitrogen is an essential requirement in establishing young plants, so the development of new orchards in the absence of nitrogen fertiliser would be much more problematic. Nursery production would be highly impacted.

The impact of no nitrogen fertiliser is also dependent on the quality and fertility of the soil on which the orchard is established; good free-draining/fertile soils would directly buffer the impact, whereas the impact would be much more pronounced on poorer soils.

The impact on nitrogen leaching across the models and scenarios was:

Nitrogen leaching impact (kgN/ha/year)

	Status Quo	No N Fert	Using substitutes
Pipfruit	5.4	5.8	7.4
Summerfruit	4.2	4.2	4.2
Kiwifruit	6.4	6	9.8
Avocado	16.2	17.4	16.8
Viticulture	6	5	5

This shows minimal improvement as a result of non-use of nitrogen fertilisers. In the compost/clover scenarios, plant uptake may become less active by the time the nitrogen is half mineralised. This would increase risk of nitrogen loss and may result in the grower applying more than is necessary to compensate for the lack of ability to time applications and amounts very precisely.

Under the no nitrogen fertiliser/plus substitutes scenario, the crop yield is reduced, meaning less nitrogen is exported from the farm in the crop, which in turn means there is slightly more leaching loss (in that less nitrogen is taken up by the plant, hence more is left available within the soil).

1.3 Vegetables and Arable

The use of nitrogen fertiliser in the arable and vegetable sectors has a number of advantages, namely for both it provides the ability to grow a greater range of crops continuously and at a much higher yield, and provides a greater range of fresh vegetables to the NZ consumer at an affordable price. In the absence of using nitrogen fertiliser all these factors would be adversely affected. In addition, a significant proportion of vegetables produced are exported so there would be the flow on impacts to the supporting and exporting industries of the loss of throughput and profitability

The results of the analysis showed:

Summary of Arable and Vegetable Impacts ($ million)

	National EBIT With N fertiliser	EBIT Without N Fertiliser
Arable	450	171
Vegetables	228	156
Total	678	327
Difference (without versus with)		**-351**

There are no alternatives or substitutes in both the arable and the vegetable sectors to achieve the additional yields that are gained from the use of nitrogen fertiliser. The majority of arable crops are grown for export and therefore these exports would be lost. In the vegetable growing sector there has been little or no evidence of the likelihood of the lost production being substituted by import from overseas, apart from carbohydrates, where limited domestic supplies would most likely divert consumption to alternative food products, for example rice rather than potatoes. The majority of economic activity which would occur in the 'without nitrogen fertiliser with substitution' scenario would therefore occur beyond the farm or horticulturists' financial performance.

In the absence of nitrogen fertiliser, growing arable grain crops such as wheat, barley and maize becomes problematic; while they could be grown via use of legume crops this is more expensive, and in all probability the grain which is used domestically would be imported, at a similar cost to producing it domestically, with nitrogen fertiliser. The cost of this extra importation is estimated at $286 million

The 'no nitrogen fertiliser + substitution' cost therefore, for the arable and vegetable sectors, would be the cost (i.e. lost production) of not using nitrogen fertiliser ($351m), plus the cost of increased imports, as above, giving a total cost of $637 million.

1.4 Macro- Economic Analysis

The summary of the on-farm analysis shows the following impact:

Summary of on-farm impacts ($million)

	Without N fertiliser	Without N fertiliser, + Substitution
Dairy	-$824	-$1,213
Sheep & Beef	-$30	-$238
Permanent Horticulture	-$479	-$18
Vegetables & Arable	-$351	-$637
Total	**-$1,684**	**-$2,105**

Within the input/output industry tables, the arable industry is included within the sheep and beef industry, and vegetables are included within the horticultural industry. Realigning the above table gives:

Summary of Direct Impacts aligning with the I/O tables ($ million)

	Without N fertiliser	Without N fertiliser, + Substitution
Permanent Horticulture & Vegetables	-551	-149
Sheep & Beef & Arable	-309	-743
Dairy	-824	-1,213
Total	**-1,684**	**-2,105**

The macro-economic analysis involved a multiplier analysis, whereby both forward and backward linkages were used: backward relate to the services each industry buys in to provide their goods, while forward linkages relate to the processing/manufacturing process through to the wharf.

Summary of macro-economic impacts ($ million) without N fertiliser

	Units	Horticulture and fruit growing	Sheep, beef cattle and grain farming	Dairy cattle farming	Meat and meat product manufacturing	Dairy product manufacturing	Fertiliser and pesticide manufacturing	Total
Gross Output	NZ$2016m	-$2,602	-$1,447	-$4,906	-$1,909	-$7,866	-$1,068	-$19,798
Value Added	NZ$2016m	-$1,142	-$617	-$1,929	-$530	-$2,173	-$312	-$6,703
Employment	MECs2016*	-19,430	-7,790	-22,960	-6,820	-14,730	-2,020	-$73,760

* MEC = Modified Employment Counts (a head count of employees and work proprietors)

The above results involved simply modelling what would be the economic impacts if N fertiliser was no longer used and no adaptation took place. In reality farmers would adapt and change, in which case the overall impact is likely to be less than that indicated.

1.5 Summary

Nitrogen fertiliser is an important input into the New Zealand primary sector. For the horticultural, vegetable and arable sectors it is a crucial input in ensuring high yielding and good quality crops. In the pastoral sector it is primarily used as a substitute for supplementary feed, especially as nitrogen-boosted pasture is around half the cost of other supplements.

While its removal as a farm input would reduce farming impacts on water quality and GHG emissions, there would also be an associated economic cost. At the farm gate this is estimated at:

- $1.7 billion if N fertiliser is removed and no substitution is used; or
- $2.1 billion if substitution with other supplementary feeds and legume cover crops are utilised.

At the national level, these impacts would flow through as:

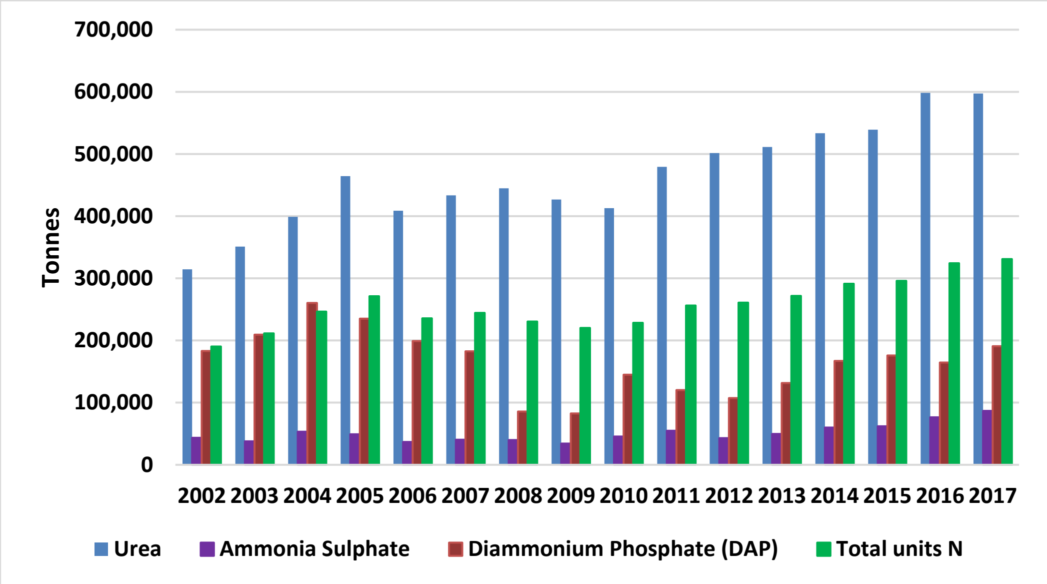
- A drop in gross output by $19.8 billion
- A drop in Value Add (GDP) of $6.7 billion
- A reduction in employment by 73,760

2.0 BACKGROUND

The environmental impact of New Zealand farming systems is under increasing scrutiny, particularly relating to impacts on water quality. One aspect of this is the use of nitrogenous fertilisers and both the direct and indirect influence this has on nitrate leaching.

Most crops, including pasture, are nitrogen limited at various stages of their growth, which means that responses to nitrogen fertiliser are generally good. As a result, nitrogen fertiliser is an integral component of the farming scene within New Zealand, constituting an important input across a wide range of farming systems, and usage of nitrogenous fertilisers has been increasing over recent decades:

Figure 1: Nitrogen fertiliser Use in New Zealand



Source: Statistics NZ

The main driving force of this is that nitrogen-boosted pasture is the cheapest form of supplementary feed available to pastoral farmers, often less than half the cost of any alternatives. Provided the marginal cost of the supplement/nitrogen is less than the marginal benefit, this is an important component of improving the productivity and profitability of the farm business. Given that nitrogen fertiliser is much cheaper than alternative supplements, it much more readily meets the marginal benefit > marginal cost criteria. In the horticultural/vegetable/arable sectors it is a crucial input in ensuring high yields and good quality crops.

Nitrogen fertiliser usage varies across the different agricultural sectors, with the majority used in the pastoral sector, especially on dairy farms.

Table 1: Nitrogen fertiliser usage by sector (2017)

	Tonnes N*	% of Total N
Miscellaneous Horticulture	222	0.05%
Vegetables	5,670	1.3%
Horticulture	1,994	0.45%
Arable	29,415	6.6%
Sheep & Beef	108,668	24.5%
Dairy	294,551	66.5%
Other	2,525	0.6%
Total	**443,044**	**100%**

*This is based on the use of various fertilisers, converted back to their constituent N component
Source: 2017 Agricultural census, Fertiliser Association

3.0 OBJECTIVES AND METHODOLOGY

The objective of this analysis is to investigate the value of nitrogen fertilisers to the agricultural sector, and to the wider New Zealand Economy.

The methodology involved an analysis of the value on a 'with' versus 'without' basis, where the 'with' scenario is essentially the current situation regarding profitability and production.

The 'without' scenario was split into two aspects:

(i) No nitrogen fertiliser + no substitution; and
(ii) No nitrogen fertiliser + use of substitutes (e.g. supplementary feed/organic nitrogen fertiliser) as appropriate.

The analysis considered the profitability, production, and environmental (i.e. level of nitrogen leaching) effects within each sub-scenario.

The analysis was across three sectors:

3.1 Pastoral Sector

This covered the dairying and sheep and beef sectors. It involved the development of representative models, based on Dairy NZ and Beef+Lamb NZ statistics, for analysis in Farmax for production and profitability impacts, and in Overseer for differences in the environmental impact.

These models were:

Table 2: Pastoral Models used

Dairy	Sheep & Beef
Northland	North Island Hill Country
Waikato/Bay of Plenty	North Island Intensive
Taranaki	South Island Hill Country
Canterbury	South Island Intensive
Southland	

The 'with' nitrogen fertiliser scenario is the current status quo situation, where a 5-year average usage of nitrogen fertiliser was included.

The 'without' scenario involved removing all nitrogen fertiliser and adjusting the farming system (reduced stock numbers) until the system was feasible.

The 'without + supplement' scenario involved removing all nitrogen fertiliser, and substituting this with supplementary feed bought in, such that the status quo system was feasible. Where possible this was a low protein (nitrogen) feed such as maize silage. In many situations maize silage is not readily available or least cost, so often the supplement is relatively high in protein.

3.2 Permanent Horticulture (Trees/Vines)

This section covers the following permanent horticultural crops:

- Grapes
- Kiwifruit
- Pipfruit
- Summerfruit
- Citrus
- Avocados

While nitrogen use on these crops is often very limited in a total sense, again it can have a significant impact on yield and quality.

Similar to the pastoral scenarios, the 'with' nitrogen fertiliser scenario is the current status quo, the 'without' scenario discusses the impact of removing any chemical nitrogen fertiliser, and the 'without + substitutes' discusses the use of composts and legume cover crops.

3.3 Vegetable and Arable Crops

This section analyses the impact as to the 'with' versus 'without' scenarios on a range of arable and vegetable crops. While nitrogen usage within these sectors is not great, for many crops the use of nitrogen fertiliser is the difference between an uneconomic or economic crop.

There are no ready substitutes for nitrogen fertiliser within the vegetable and arable industries. The 'no nitrogen fertiliser + use of substitutes' scenario therefore includes a discussion on importation of replacement product from overseas.

3.4 Sectors not covered

The miscellaneous horticulture sector (mainly nursery and crops grown under cover), plus the 'other' sector (covering pigs and poultry, horses, forestry) are not included within this analysis. In total their nitrogen fertiliser use is small, and there is very little information readily available on these farming systems.

3.5 Macro-Economic Impact

On completion of the sector analysis, the economic impact at the farm level was extrapolated as to the impact at the national level, with respect to:

- Gross output
- GDP
- Employment

This involved the calculation (via input/output analysis) of relevant sector forward and backward multipliers, which were then applied to the farm-level information.

4.0 PASTORAL SECTOR

4.1 Background

Nitrogen fertiliser is used in the pastoral sector to boost pasture growth rates at various times of the year, to address feed shortages; most New Zealand pastures are nitrogen limited at various times (Field & Ball, 1978) especially in late winter through to late spring (Cameron *et al*, 2005). Clark and Harris (1996), noted that most New Zealand dairy farms have a clover content in pasture of less than 20%, and at such levels nitrogen fixation by clovers is too low to support the full production potential of ryegrass/white clover pasture, and nitrogen fertiliser is required to correct this deficiency. Clark and Harris also note that systems based on nitrogen fertiliser, despite being more costly (than a clover-based system), are usually a more reliable means of providing increased pasture at critical periods within the dairy season.

Ball (1969) indicated that a pasture growing 10 tonne DM/ha/year requires 400kgN/ha to achieve this. Ledgard and Steel (1992) noted that nitrogen fixation by clovers in a grazed mixed sward varied between 55 to 296 kg/ha/year, depending on varying factors.

All of which shows that while clover in pastures is an important component of nitrogen supply, additional nitrogen fertiliser can significantly increase pasture production. As noted in Section 2, nitrogen fertiliser usage in New Zealand has increased significantly over the last decade, especially on dairy farms. This is particularly so because nitrogen-boosted pasture is around half the cost of alternative supplementary feeds.

As outlined in Section 3.1, models based on representative farming systems on a regional or Island basis were developed, based in turn on statistics from Dairy NZ and Beef + Lamb NZ.

4.1.1 Dairy Models

Table 3: Summary of dairy models

	Northland	Waikato/BoP	Taranaki	Canterbury	Southland
Number farms represented	853	4,659	1,620	1,337	982
Effective Area (ha)	140	127	105	231	205
Cows Wintered (hd)	319	373	295	791	602
Milksolids Production (kgMS)	102,878	130,046	102,234	321,434	242,115

Source: Dairy Statistics 2018

Nitrogen fertiliser use was based on data provided by DairyBase:

Table 4: Nitrogen use by region (kgN/ha)

Farm Region	2013/14	2014/15	2015/16	2016/17	2017/18	Average
Northland	140	107	100	108	102	112
Waikato	117	125	132	136	139	130
Bay of Plenty	106	116	112	124	132	118
Taranaki	149	145	149	141	155	148
Lower North Island	106	102	106	112	94	104
West Coast	195	200	198	194	175	193
Canterbury	238	230	255	226	222	234
Southland	151	163	179	179	185	171
National average	**143**	**147**	**151**	**153**	**155**	**150**

4.1.2 *Sheep & Beef Models*

Table 5: Summary of Sheep & Beef models

	North Island Hill Country	North Island Intensive	South Island Hill Country	South Island Intensive
Effective Area (ha)	544	281	1,495	227
Open Sheep Nos	2,825	1,364	4,600	2,289
Open Cattle Nos	455	324	420	83
Lambing %	126%	129%	123%	142%
Calving %	79%	84%	83%	95%
Total Stock Units	4,785	2,703	6,327	2,505
SU/ha	9.0	9.6	4.2	11.0

Source: Beef + Lamb NZ Economic Service survey 2017

Note: North Island Hill Country = weighted average of Class 3 and 4 farms
North Island Intensive = Class 5
South Island Hill Country = Class 2
South Island Intensive = Class 7

Nitrogen fertiliser usage for these models was:

Table 6: Nitrogen fertiliser use by model

	2012/13		2013/14		2014/15		2015/16		2016/17		Average	
	Area fertilised (ha)	kgN/ha	Area fertilised (ha)	kgN/ha	Area fertilised (ha)	kgN/ha	Area fertilised (ha)	kgN/ha	Area fertilised (ha)	kgN/ha	Area fertilised (ha)	kgN/ha
North Island Hill Country	331	10.3	342	8.9	368	13.5	370	14.2	334	13.4	349	12.1
North Island Intensive	151	17.8	168	12.5	191	16.2	171	22.0	167	21.6	170	18.0
South Island Hill Country	413	4.6	411	9.0	443	8.3	490	11.1	527	12.4	457	9.1
South Island Intensive	154	7.7	164	9.7	176	15.3	165	17.3	176	17.7	167	13.5

Source: Beef + Lamb NZ Economic Service

4.2 Dairy Modelling

The models were setup in Farmax Dairy[1].

- The initial scenario was the status quo, with the 'with' nitrogen fertiliser scenario assumed the nitrogen input as per Table 4.
- In the 'without nitrogen fertiliser' scenario:
  - (i) All nitrogen fertiliser was removed.
  - (ii) Yields on any forage crops grown was assumed to be unchanged, given that they could be fertilised with dairy effluent in the absence of nitrogen fertiliser.
  - (iii) Cow numbers were reduced, but per cow production held at the same level as the 'with' scenario, until a feasible farm system was developed.

[1] www.farmax.co.nz

- In the 'without nitrogen fertiliser + supplement' scenario:
  - (i) All nitrogen fertiliser was removed
  - (ii) Yields on any forage crops grown was assumed to be unchanged, given that they could be fertilised with dairy effluent in the absence of nitrogen fertiliser
  - (iii) Extra supplementary feed was purchased in until total production, and per cow production, was essentially the same as for the 'with' scenario.
  - (iv) For the North Island models the extra supplement bought in was a combination of maize silage and palm kernel, and for the South Island models the extra supplement bought in was a combination of pasture silage and barley grain.

A standardise milksolids payout of $6.00/kgMS was assumed.

The reduction in stock numbers required to achieve a feasible farm system in the absence of nitrogen fertiliser was:

Table 7: Reduction in cow numbers in the absence of nitrogen fertiliser

Northland	Waikato/BoP	Taranaki	Canterbury	Southland
-12%	-12%	-14%	-24%	-15%

The greater reduction in the Canterbury model relative to the others was due to the nature of the irrigation system. As a generality, dryland Canterbury will grow 5-6 tonnes DM/ha/year. With the addition of water (irrigation) this will double to 10-12 t DM/ha/year. The addition of nitrogen to this system increases dry matter production up to (circa) 18 tonnes DM/ha/year. The removal of the nitrogen fertiliser therefore has a proportionally greater effect compared to the non-irrigated systems.

Refer to Appendix 1 for details on the physical summary of the models and scenarios.

4.2.1 Dairy Economic Impact

The removal of nitrogen fertiliser from the farm system has an economic benefit in several areas:

- Eliminates the cost of the nitrogen fertiliser
- The reduction in cow numbers to compensate for the reduction in feed means a reduction in a number of operating costs.

These benefits are then offset by the reduction in production and profitability.

In the scenario where extra supplementary feed is bought in to replace the feed grown by the nitrogen fertiliser, there is also the extra cost of this feed, along with increased operating costs (storage, feeding out). One of the main attractions for using nitrogen fertiliser is that it is effectively around half the cost of alternative supplementary feeds.

The results of the modelling exercise showed:

Table 8: Difference in Dairy EBITDA ($/ha)

				Difference from Base	
	Base	No N Fert	No N Fert, plus Supplements	No N Fert	No N Fert, plus Supplements
Northland	$1,572	$1,396	$1,296	-$176	-$276
Waikato/BoP	$2,515	$2,248	$2,097	-$267	-$418
Taranaki	$2,276	$1,959	$1,908	-$317	-$368
Canterbury	$2,900	$1,626	$1,098	-$1,274	-$1,802
Southland	$2,909	$2,681	$2,465	-$228	-$444

If this is then extrapolated up to the regional and national level, the results are:

Table 9: Cost of scenarios at a regional/national level ($million)

	No N Fert	No N Fert, plus Supplements
Northland	-$21.1	-$33.0
Waikato/BoP	-$158.3	-$248.1
Taranaki	-$53.9	-$62.6
Canterbury	-$393.1	-$555.9
Southland	-$45.9	-$89.5
National*	**-$824.4**	**-$1,212.9**

*Extrapolated across all dairy farms in New Zealand

Again the greatest impact is in Canterbury, given the reliance of the irrigated system on nitrogen fertiliser inputs.

While the above per hectare differences at the farm level due to not applying nitrogen fertiliser are not necessarily high, they do have an impact on the bottom line. The figures calculated are EBITDA, meaning that there is a further range of costs yet to be incurred; debt servicing, depreciation, tax, capital expenditure, drawings, and debt repayment. The impact of this is illustrated below.

Table 10: Impact of no N fertiliser/+supplement on net profitability ($/ha)

	5-year average EBITDA*	5-year average debt servicing & depreciation**	Net	Reduction due to no N fertiliser	Difference	Reduction due to no N fertiliser + Supplements	Difference
Northland	$1,271	$1,184	$88	$176	-$88	$276	-$188
Waikato/BoP	$1,932	$1,657	$275	$267	$8	$418	-$143
Taranaki	$2,046	$1,691	$355	$317	$38	$368	-$13
Canterbury	$2,393	$2,324	$70	$1,274	-$1,204	$1,802	-$1,732
Southland	$2,129	$1,808	$321	$228	$93	$444	-$123

*Source: Dairy NZ Economic Surveys 2013/14 – 2017/18
**Based on national level data extrapolated to the regional level. Other costs; tax, capex, debt reduction, drawings not included

4.2.1.1 Maize Silage

Maize silage is an important supplementary feed for the dairy industry, particularly in the upper North Island, with 41,300hectares of maize silage grown in 2017[2]. As noted, maize silage was used as the basis of substitution in the 'no N fertiliser + supplement' scenarios.

Nitrogen fertiliser is an important input into maize silage growing, as the crop removes 10kgN per tonne of dry matter grown. With typical yields of 20tDM/ha, this equates to 200kgN/ha requirement to replace the removed nitrogen.

Assuming no nitrogen fertiliser input, then:

(i) As noted, maize silage grown on dairy farms may not be that impacted, as they could use dairy effluent as a substitute

(ii) In a non-dairy, regular cropping regime, a legume-based cover crop could be used. Inasmuch as legumes don't fix much nitrogen over the winter, it could well mean moving to a biennial cropping system, which means that the effective total yield of maize silage is halved. This in turn could be ameliorated by importing substitute supplements, e.g. palm kernel, or doubling the area cropped for maize silage.

4.2.1.2 Substitute Supplementary Feeds used in the Modelling

As noted above, maize silage is an important supplementary crop, especially in the upper North Island. This was used as the main (low protein) substitute supplement for the North Island dairy models, although palm kernel (moderate protein) was also used, as this is often a lower cost supplement.

For the South Island dairy models, a combination of pasture silage and barley grain was used, both of which are moderate – high protein supplements.

For all of the sheep and beef models, pasture silage was used as the substitute supplement.

4.3 Sheep and Beef Modelling

As per the dairy modelling, the models were setup in Farmax, with the various scenarios being:

- The initial scenario was the status quo, with the 'with' nitrogen fertiliser scenario assumed the nitrogen input as per Table 6.
- In the 'without nitrogen fertiliser' scenario:
  (i) All nitrogen fertiliser was removed
  (ii) Yields on any forage crops grown was reduced by 20%, on the assumption that no nitrogen fertiliser would/could be applied, although there would be some nitrogen reserves in the soil given it was coming out of pasture.
  (iii) Sheep numbers were reduced but the basic farm system (i.e. proportion of animals finished, finishing weights) were left as per the status quo scenario.

[2] 2017 Ag Production census

- In the 'without nitrogen fertiliser + Supplement' scenario:
  - (i) All nitrogen fertiliser was removed
  - (ii) Yields on any forage crops grown were reduced by 20%
  - (iii) Extra supplementary feed was purchased in until the farm system, and stock numbers, was essentially restored to the same as for the 'with' scenario.

Inasmuch as the amount of nitrogen fertiliser used was relatively small, the change in stock numbers were restricted to sheep. These were:

Table 11: Reduction in stock numbers in the absence of nitrogen fertiliser

	Reduction in breeding ewes and replacement stock
North Island Hill Country	3%
North Island Intensive	4%
South Island Hill Country	2%
South Island Intensive	2%

Refer to Appendix 2 for details on the physical summary of the models and scenarios.

4.3.1 Sheep & Beef Economic Impact

The economic impacts on sheep & beef farms is directly similar to that on dairy farms; the reduction in cost is offset by a reduction in production and profitability.

The results of the modelling exercise showed:

Table 12: Difference in S&B EBITDA ($/ha)

				Difference from Base	
	Base	No N Fert	No N Fert, plus Supplements	No N Fert	No N Fert, plus Supplements
North Island Hill Country	$545	$539	$502	-$6	-$43
North Island Intensive	$777	$764	$709	-$13	-$68
South Island Hill Country	$228	$226	$216	-$2	-$12
South Island Intensive	$501	$497	$383	-$4	-$118

Table 13: Cost of S&B scenarios at a regional/national level ($ million)

	No N Fert	No N Fert, plus Supplements
North Island Hill Country	-$13.8	-$99.1
North Island Intensive	-$4.6	-$24.1
South Island Hill Country	-$2.6	-$15.5
South Island Intensive	-$1.2	-$34.6
National*	**-$30.4**	**-$237.6**

*Extrapolated across all sheep & beef farms, excluding South Island High Country

4.4 Environmental Impact

All the models and scenarios were set up in and run through OverseerSci (V6.3.2) to determine any change in nitrogen leaching as a result of the elimination of nitrogen fertiliser, and addition of extra supplementary feed.

4.4.1 Dairy

The results of the dairy analysis were:

Table 14: Dairy model N leaching (kg N/ha/yr)

	Base	No N Fert	No N Fert, plus Supplements
Northland	34	23	24
Waikato/BoP	39	32	33
Taranaki	50	37	40
Canterbury	76	40	47
Southland	26	19	20

As could be expected, nitrogen leaching decreased in the 'no N fertiliser' scenario, as a direct result of the reduction in stocking rate. The leaching rate then generally increased again, but not majorly, as a result of feeding supplement to make up the difference in feed supply as a result of not applying the nitrogen fertiliser.

The main form of nitrate leaching is from the urine patch, with direct loss from applied nitrogen fertiliser being 3-4%. The main reductions therefore shown in Table 14 are reductions in nitrate leaching from urine patches. In other words, livestock account for approximately 80+% of N leached, moderated by the nitrogen content of supplementary feed. This is illustrated in Table 15:

Table 15: Nitrate leaching (kgN/ha)

Waikato/BoP Dairy					Canterbury Dairy			
	Base	No N Fertiliser	No N + Supplement			Base	No N Fertiliser	No N + Supplement
Total	39	32	33		Total	76	40	47
Urine	31	25	26		Urine	69	33	40
Other	8	7	7		Other	7	7	7
% from urine	79%	78%	79%		% from urine	91%	83%	85%

A similar effect was also identified with biological[3] greenhouse gas (GHG) emissions from the model. The reduction in GHGs in the "No N Fertiliser" scenario is a combination of a reduction in methane (less animals) and a reduction in nitrous oxide (less animals + less nitrogen fertiliser). The reduction in the "No N Fertiliser + Supplements" scenario is basically a reduction in nitrous oxide due to the elimination of nitrogen fertiliser.

[3] Biological GHG = methane + nitrous oxide

Table 16: Dairy model biological GHG emissions (tonnes CO_2e/ha/yr)

	Base	No N Fert	No N Fert, plus Supplements
Northland	9.6	8.6	9.0
Waikato/BoP	12.2	10.5	11.8
Taranaki	11.7	9.5	11.0
Canterbury	16.7	11.5	14.9
Southland	13.5	11.2	12.6

As discussed earlier, clover is an important provider of nitrogen in a mixed sward. Nitrogen fixation by legumes is suppressed by the addition of nitrogen fertiliser, so in the absence of nitrogen fertiliser, additional nitrogen can be fixed by legumes. Which means that reducing or eliminating nitrogen fertiliser will be offset to a degree by such addition nitrogen fixation.

Within the Overseer modelling, this was demonstrated by the increase in nitrogen input via clovers, as illustrated:

Table 17: Dairy model nitrogen input via clover fixation, as modelled in Overseer[4]

	Base	No N Fert	No N Fert, plus Supplements
Northland	146	180	169
Waikato/BoP	190	193	193
Taranaki	146	177	182
Canterbury	204	231	199
Southland	194	232	231

This shows that in the absence of nitrogen fertiliser, nitrogen fixation has increased by an average of 16% across all the models (or 19% if Waikato/BoP is excluded). While this does not totally replace the nitrogen provided by fertiliser, it does help to offset it.

4.4.2 Sheep and Beef

The results from the sheep & beef modelling were:

Table 18: S&B model N leaching (kg N/ha/yr)

	Base	No N Fert	No N Fert, plus Supplements
North Island Hill Country	12	12	12
North Island Intensive	17	17	17
South Island Hill Country	8	8	8
South Island Intensive	14	13	14

This shows no discernible differences, largely due to the relatively small amount of nitrogen fertiliser used.

[4] The amount of nitrogen shown in Overseer is attributed to both rainfall and clover fixation. Inasmuch as the rainfall is constant across all the scenarios, the difference shown is solely due to clover fixation.

Table 19: S&B model biological GHG emissions (tonnes CO_2e/ha/yr)

	Base	No N Fert	No N Fert, plus Supplements
North Island Hill Country	3.3	3.2	3.3
North Island Intensive	4.5	4.4	4.4
South Island Hill Country	1.8	1.8	1.8
South Island Intensive	4.6	4.5	4.5

Again very little difference between the scenarios, given the small changes in stock numbers and fertiliser usage.

There was some evidence of increased nitrogen fixation by clovers in the absence of the nitrogen fertiliser, but again this was relatively minor; average increase across all models was 4%.

Table 20: Sheep & beef model nitrogen input via rainfall/clover fixation, as modelled in Overseer

	Base	No N Fert	No N Fert, plus Supplements
North Island Hill Country	56	58	58
North Island Intensive	76	80	79
South Island Hill Country	33	34	34
South Island Intensive	75	78	76

5.0 PERMANENT HORTICULTURE

5.1 Introduction

Nitrogen is considered one of the most important macronutrients in horticultural production systems. Nitrogen directly impacts plant vegetative growth, fruit yield and quality, and in the case of grapevines (Vitis vinifera), fermentation kinetics.

Nitrogen fertilizer is a tool that horticulturalists can use in order to manage plant nitrogen status. There is, however, a lot of ambiguity regarding the quantity of and timing of nitrogen.

The following analysis reviews the role and requirements of nitrogen in orchard and vineyard production. Three scenarios were explored:

- Present situation with use of chemical nitrogen fertilisers
- No nitrogen, no substitution
- No nitrogen, with substitution (using organic forms of nitrogen only)

The scenarios for each crop cover production levels, profitability and environmental impact (in regard to nitrate loss).

Modelling was conducted in excel using gross margins to show the productivity and profitability impacts. A model orchard was set up for each crop for this cause, which was highly simplified. It was assumed to be a mature (10-year-old) orchard producing an average tonnage for its age and applying nitrogen fertiliser as an 'industry average' application. To show impacts on a national level, the gross margin from the status quo orchard is multiplied up to the total area planted in New Zealand and compared to the same for substitution and no substitution scenarios.

This section also covers the impacts on young trees, repercussions for nursery, and an example of how a small impact year on year suddenly becomes large when you take the 15-year lifespan of an orchard and the setup cost into account. It discusses how clover or cover cropping scenarios would differ from compost substitution which has been modelled and explains how soil depth and fertility affect the outcome modelled.

5.2 Methodology

The methodology included:

- A literature search.
- Developing gross margins for each crop, including yield and tonnage.
- Developing the 'status quo' nitrogen application.
- Altering the gross margin for substitution and no substitute scenarios.
- Altering the gross margin as above for both 'fertile' and 'infertile' soils, to demonstrate the differing impacts depending on soil type.
- Discussions with key people within the various industries to guide decision making on the above points.
- Inputting the model into Overseer to estimate nitrogen leaching loss past 1m in the soil profile.

As a starting point to put these scenarios into perspective a literature search was undertaken to establish levels of nitrogen fertiliser requirements of each of the crops. This included amounts, but also timing and method of application. Any research that linked nitrogen to crop load, and in particular lack of nitrogen, was extremely useful, but was lacking in many cases.

A literature search was also done in regard to any previous measurement of nitrogen leaching losses from these crops, with a focus on NZ work but looking wider where there was no NZ information.

A simple gross margin was set up for each crop, with the following structure.

Table 21: Example of Gross Margin Structure Used

Crop and Scenario Heading	per ha (tonnes)	per plant (kg)
Plants/ha	1560	
Yield (Tonnes)	**80.0**	**51**
Packout	100%	
Income $/kg (weighted)	$5.80	
Income ($)	**$46,400**	**$297**
Post-harvest costs	$17,440	$112
Orchard Gate Income ($)	**$28,960**	**$186**
Total labour expenses	$7,155	$46
Fertiliser and lime	$670	$4
Other direct expenses ($)	$6,000	$38
Total direct expenses ($)	**$13,825**	**$89**
Gross Margin ($/ha)	**$15,135**	**$97**

Industry members were contacted to discuss fertiliser amounts applied to each of the crops currently, as well as to give or verify numbers within the model farm gross margins.

Discussions were also held with compost suppliers, as a source of nitrogen for current organic orchards, which may act as a substitute. Because there is ready information available on the cost and make up of compost and because it can be modelled in Overseer, compost was used as the basis of the 'substitution' scenario.

Gross margins were then altered to show the impact of a substitution scenario. Substitution meant that no chemical nitrogen product was available with its primary use being nitrogen fertilisation. Foliar nitrogen fertiliser products were assumed to be banned, but bud breakers which contain nitrogen are still allowed. Substitution included clover in the sward, as for most orchards a change in management would be needed to sow and support clover growth in the density required. Changes made were to the cost of fertiliser, cartage and spreading, and changes to yield, packout or prices. These were based off any research information that could be found and adjusted with knowledge of how modern-day NZ orchards differ from the research in question. Where research was not available, industry were consulted and AgFirst made a final decision any on any changes expected.

The same process was followed for the 'no substitution' scenario, in which all nitrogen inputs were removed from the orchard systems.

5.3 Overseer modelling methodology

A model farm was created in Overseer FM version 6.3.1. A status quo scenario was created within Overseer with 5 blocks. Each block represented a crop, except for citrus, which is not present in Overseer. Each block was drawn in the main region for that crop, and used 2 soil types, one 'infertile' one 'fertile' judged via commonly farmed soils for those crops. For example, Avocado was modelled with a Te Puke climate, on 60% volcanic allophanic soil built to represent the Ngakura 2a.2 from Te Puke (fertile), and 40% on the raw, recent sandy northland soils which had no S-Maps soil to align to (infertile). The fertility of a soil was relative to soil types the crop is commonly grown on, simply to show a range rather than only one soil.

Table 22: Key Overseer Inputs

Orchard Type	Apple	Avocado	Kiwifruit	Summerfruit	Vineyard
Climate Area	Hastings	Katikati	Te Puke	Alexandra	Marlborough
Soil 1: Order	Recent	Allophanic	Allophanic	Semi-arid	Recent
Soil 1: Based on	Hast_29a.1	Ngak_2a.2	Ngak_2a.2	Moly_8a.1	Awat_17a.1
Soil 1: % Cover	60%	60%	80%	80%	100%
Soil 2: Order	Gley	Raw	Pumice	Recent	-
Soil 2: Based on	Waim_41b.2	-	Opot_1a.1	Galt_12a.1	-
Soil 2: % Cover	40%	40%	20%	20%	-
Drainage	Yes, soil 1	No	No	No	No
Irrigation	Dec-Mar	No	Nov-Apr	Nov-Feb	Dec-Feb
Units N (CAN)	40	100	140	120	5

'Based on' in Table 22 means that the description of the particular soil type was used to inform any additional information inputted about the soil order chosen, for example, the topsoil texture, drainage class and the % of sand silt and clay. A range of climate areas for the crops, as well as the soil type range within this were used. This is because Overseer is greatly affected by soil type and climate more than type of permanent tree crop. Drainage was put in if the soil type was not naturally well drained (only in Hastings) and irrigation applied in months where it would commonly be (irrigation can be necessary outside of these months in different climate years).

The nitrogen tonnage shown in the gross margins is what was removed from the block via produce. In Overseer therefore, tonnages were calculated up by a % reject rate, which was assumed to have been left in the block after harvest. The age of the trees was standardised as 10, the pruning's were always mulched, each block had a herbicide strip and grass sward, and none of the blocks had animals grazing the sward. Fertiliser N was always placed under the drip line.

5.4 Fruit Crop Nitrogen Requirement

Fruit crop nitrogen requirement can be viewed in the following ways:

- Establishment phase
- Cropping phase

5.4.1 The Establishment Phase

This is the period from planting to establishment of a mature fruiting canopy.

Nitrogen requirements during this phase are greater than during the mature phase because nitrogen is required to support rapid growth of roots, trunk and fruit branches. The nitrogen then becomes locked up in the permanent structure of the tree or vine.

Shortage of nitrogen during this phase is very detrimental to orchard performance and the economic viability of the orchard development project due to extension of non-productive period and in some situations, lowered yield potential.

5.4.2 The Cropping Phase

Nitrogen requirement usually declines once this stage is reached.

The main demand now for nitrogen is that required for new root and shoot growth, foliage and fruit requirements.

The spring growth flush is largely driven by mobilisation of stored nitrogen reserves taken up during the previous growing seasons. There is also good nitrogen tracer data to indicate that nitrogen root uptake does not begin until most of the stored nitrogen has been mobilised. In most permanent fruit crops spring root uptake does not begin until active shoot growth is underway, some four to six weeks after bud break.

Roots require access to photosynthates to enable nitrogen uptake to occur. This means that for deciduous fruit crops soil nitrogen uptake ceases as leaf fall approaches and does not begin again until significant leaf canopy has been established in the spring.

Much of the annual nitrogen used by the crop is recycled so only that incorporated into permanent new plant structure, and that removed in the harvested crop, plus leaching losses require replacing annually.

Nitrogen requirements for these crops reported in the literature indicate that nitrogen fertiliser requirement tends to fall into two broad groups:

(i) Those that fruit on annual or current seasons growth e.g. peaches, nectarines, kiwifruit, possibly avocado.

(ii) Those that fruit on more permanent sites such as two-year and older wood e.g. pipfruit, plums, apricots, cherries or evergreens which do not need to produce large amounts of new foliage annually e.g. citrus.

Published crop nitrogen fertiliser requirements indicate the first group requires about twice the annual nitrogen fertiliser inputs as the second group.

5.4.3 N Removed in the Crop

In a stable mature producing orchard with nitrogen used by the tree for foliage and annual growth being part of the soil nitrogen cycle, only the nitrogen leaving the orchard with the crop may need to be replaced annually.

Reported data for crop nitrogen removal indicates fruit contains 1 to 2kg N per tonne of crop. Citrus nitrogen content is higher at almost 3kg per tonne of crop.

There is also evidence to show that where nitrogen availability is surplus to requirement these fruit crops are capable of luxury consumption. In many situations elevated nitrogen tissue levels does not result in higher production and usually results in lower fruit quality attributes, including handling and storage.

5.4.4 Soil Fertility and Rooting Depth

Nitrogen fertiliser requirement for these crops is largely driven by soil quality, in particular soil organic matter levels and rooting depth.

Deep, fertile soils require little, if any, applied nitrogen fertiliser for established plantings of many of these fruit crops.

Soil water logging can induce nitrogen deficiency symptoms in fruit crops. This is not necessarily due to low soil nitrogen supply, but more likely a root health problem. Water logging leads to anaerobic conditions which limits root penetration as well as leading to nitrogen losses in the form of nitrogen and nitrous oxide gas.

5.4.5 Nitrogen Uptake Efficiency

Fertiliser nitrogen uptake efficiency under present use patterns (mostly broadcast solid fertiliser) is low, with an estimates uptake of less than 50%.

Application of fertiliser timed to coincide with periods of root uptake and demand will markedly increase efficiency.

For instance, Neilsen & Neilsen (2002) found that applying fertigation nitrogen 8 to 14 weeks after planting when active shoot growth nitrogen demand was high, lifted tree nitrogen uptake by 1.58 times greater than when the nitrogen fertiliser was applied 2 to 8 weeks after planting.

The same paper reports that when fertigation water rates were matched to tree water use nitrogen fertiliser recovery increased from 18% to 38%.

The tree fruit industry is intensifying planting systems and pushing yield boundaries. Micro-irrigation, usually drip or micro-sprinkler systems, is becoming the norm. With these systems, wetted soil volumes are restricted as are root volumes, so tree roots are no longer tapping the whole orchard soil area. This means they are mining the limited wetted soil zone for their nutrient requirements. Delivering nutrients, particularly nitrogen, by fertigation is the most efficient method for supply of fertiliser to this zone.

Access to fertiliser nitrogen is essential for these precision farming methods to continue.

With regular nutrient and soil moisture monitoring, efficient nutrient uptake is maximised and leaching losses minimised.

5.4.6 Foliar Application

Foliar nitrogen fertiliser is becoming an important application method across many of these fruit crops. This involves regular spraying of small amounts of nitrogen in liquid form. Uptake efficiency is very high, often reported to be in the region of 80% recovery compared with well under half this from soil application.

Response is rapid and application can target particular crop phenological stages when nitrogen demand is high. In some crops foliar nitrogen application can influence particular organs, such as fruit or buds, without influencing vegetative growth.

Foliar nitrogen can efficiently supply nitrogen when required and removes the need to raise soil nitrogen reserves, which could be detrimental to fruit quality later in the season, not to mention preventing any nitrogen loss. Foliar nitrogen applications have no impact on nitrogen leaching losses.

5.4.7 General Impact of No Nitrogen Fertiliser

The degree of impact will vary depending on inherent soil quality and the particular crop. Initial soil fertility will be the major factor determining the impact of no nitrogen fertiliser on orchard performance, viability and sustainability.

Deep, well structured, fertile soils with good soil organic matter levels and good drainage may take many years for any decline in orchard performance to appear.

Shallow, marginal soils with low organic matter and other limiting factors that restrict or injure tree or vine root systems will show rapid decline with no fertiliser nitrogen.

It is likely, in the absence of fertiliser nitrogen, fruit growing will shift off marginal soils leading to industry contraction. In some districts, due to the nature of their soils, such as the Central Otago pip and summerfruit industry, and the far north Avocado industry, such a move would be very detrimental on employment opportunities and local GDPs.

Fruit growing established in these districts because their climates give them competitive production advantages which cannot be readily found elsewhere in the country rather than because of the fertility of their soils.

Mature cropping orchards will cope better with a no nitrogen fertiliser regime than a young orchard because their fruiting canopy is already established meaning their nitrogen requirement reduces to that removed with the crop, pruning, and any leaching losses.

Nursery tree production and new plantings will be adversely affected, even in relatively fertile soils.

Nursery trees needs readily available nitrogen because its required to drive good tree vigour and supply adequate supplies of stored nitrogen to drive initial growth flush in the newly planted orchard. For instance, an apple nursery containing 25,000 trees per hectare needs to accumulate around 60kg/ha of nitrogen in the trees prior to transplanting.

The impact of no nitrogen fertiliser applied to new orchard plantings will extend the non-bearing period, raise orchard establishment costs and delay achievement of full production. The following table shows a 15-year apple development budget for the same model farm modelled for this report. It shows the impact of the no nitrogen scenario

Table 23: Estimated Impacts of a No Substitution Scenario over the life of an Apple Orchard

Apple Development	Status Quo	Fertile No N	Infertile No N
Yield delay	None	2 years	3 years
Top yield	70 t/ha	65 t/ha	55 t/ha
Biennial bearing	Minor	Minor	20 t/ha swings
Packout	85%	85%	80% (smaller size)
Price	$1.31/kg	$1.34/kg	$1.19/kg
Years to COS	4	5	8
Years to breakeven	10	12	No breakeven

**COS= cash operating surplus, or EBITDAR*
***Breakeven includes development costs, then year on year operating and overhead expenses, but does not include interest, tax, depreciation or original land costs.*

Note in Table 23, that the costs used are up to date, but industry average yields and prices are used as per the 'model farm' for this project. A real new development should be planting varieties and systems that enable above average yields and prices and will expect to see a faster breakeven. The higher yielding varieties would not necessarily require any more nitrogen fertiliser, although this is often soil type dependant – good soil types would require no or minimal extra nitrogen, whereas poor soils might.

In the no nitrogen scenario, natural soil fertility will determine the length of the establishment period and whether or not the orchard achieves its productive potential.

For many of these fruit crops, general improvement of the orchard environment may alleviate the adverse effects on orchard performance caused by withdrawal of nitrogen fertilisers. For most crops, climate, shelter from wind, absence of weed competition and adequate soil moisture (drainage and irrigation) are factors that inhibit tree growth and productivity over lack of nitrogen.

5.5 No Nitrogen with Substitution

There are numerous nitrogen fertiliser substitution options available.

In most of these fruit crops some growers are growing organically under a regime which does not allow application of chemical fertilisers. There is evidence that better performing organic producers are achieving comparable yields to conventional production that utilises nitrogen fertilisers.

Organic orchards are applying forms of nitrogen fertiliser which are acceptable to the various organic certifying agencies.

These include:

- Compost
- Fish meal
- Leguminous swards
- Animal manures (usually composted)
- Dried blood, and blood and bone
- Organic nitrogen fertilisers based on processing of high nitrogen plants such as soya bean or lucerne to concentrate nitrogen content. Some of these products are soluble amino acid based.

With the exception of leguminous swards, these nitrogen fertiliser substitutes have limited supply in New Zealand. Unlike many countries there is no substantial animal feed lot industry here so supply of animal manures is very limited.

Relative to conventional production systems the area of these fruit crops under organic production is very small. Only around 6% of total pipfruit area is certified as organic and Organic Green kiwifruit is a similar percentage of the total green kiwifruit.

While supplies of non-chemical nitrogen fertilisers are adequate for the limited areas under organic production it would not be possible for the whole fruit industry to obtain sufficient nitrogen fertiliser substitutes to meet its needs. Most compost providers contacted are at or near capacity already.

Adoption of clover dominant swards between tree rows is likely to become the replacement nitrogen source in a no nitrogen fertiliser regime. There is good research data (Ontario MAFFRA, 2018) to show that swards with greater than 50% clover content will fix sufficient nitrogen for crop requirements.

Clover comes with its own problems:

- Very slippery to rubber wheeled vehicles when wet. On sloping ground, it may become necessary for orchards to use high cost crawler tractors.
- Flowers pose a problem when applying insecticides.
- Competition with the crop for water.
- Needs grass weed control to maintain clover dominance.
- Needs good light levels to survive so unsuited to crops such as pergola trained kiwifruit.

Where substitution with materials not available on the orchard is necessary, freight costs are very high relative to chemical nitrogen fertilisers.

Composts in particular, only have nitrogen levels around 1%, whereas the nitrogen content of commonly applied nitrogen fertilisers is in the vicinity of 16% to 46%. Trucking compost is going to release 16 to 46 times at much CO_2 into the atmosphere as trucking nitrogen fertilisers. Often compost sources are some distance away. In the case of Central Otago, compost is being carted from Christchurch to Alexandra at a cost of $60 per m^3. Freight costs for nitrogen substitution materials will be huge compared to nitrogen fertilisers.

Fertiliser use in fruit crops is becoming very efficient, and with careful crop monitoring a general movement to fertigation and foliar application markedly lifts nitrogen fertiliser use efficiency. This approach also minimises nitrogen leaching.

There are soluble nitrogen substitutes for chemical nitrogen fertilisers which could be used for fertigation and foliar application. These include dried blood, and protein nitrogen made from soya bean which has 13% nitrogen. Relative to fertiliser nitrogen, estimated cost of protein nitrogen is 15 to 22 times more expensive.

In the absence of chemical fertiliser nitrogen, the ability to target nitrogen supply to crop requirement and timing is diminished. Nitrogen availability for the crop will be much more dependent on the vagaries of nature, temperature and rainfall.

In poorer soils, it will be necessary to lift overall soil nitrogen levels above their present amounts to ensure an adequate nitrogen supply for the crop. In their present fertility state, innate nitrate leaching from these soils is low compared to more fertile soils. Raising their fertility status to satisfactory levels for economic sustainable yield may well result in more nitrate leaching, when comparing to smart, efficient use of chemical nitrogen fertilisers.

The other alternative for these soils may be to retire them from fruit growing.

6.0 NITROGEN USE BY PERMANENT HORTICULTURAL CROPS

6.1 Pipfruit

6.1.1 Areas

The main pipfruit areas in New Zealand are:

Hawke's Bay	4,750 ha
Tasman	2,400 ha
Otago	430 ha
Canterbury	310 ha
Rest of New Zealand	620 ha

6.1.2 Present and Historical Situation

Nitrogen removed in a pipfruit crop ranges between 0.6 to 1.1kg nitrogen per tonne of fruit. New Zealand pipfruit yields (including young plantings) average 52t/ha but yields can range up to greater than 130t/ha depending on variety. Average crops will remove between 31.2 and 57.2kg nitrogen per hectare while high yielding crops could remove up to 143kg nitrogen per hectare.

Pipfruit tend to accumulate luxury nitrogen levels in their fruit where nitrogen availability is surplus to requirement. It is likely that high quality fruit production would only remove amounts of around 0.6kg nitrogen per tonne of crop. Therefore, nitrogen removed from the orchard in the crop is most likely in the range of 30 to 80kg nitrogen per hectare.

Initially pipfruit fertiliser programmes were based on the Appleby Experiments which were conducted in Nelson and ran from 1932 to 1956. This was a very poor soil deficient in NPK so a complete fertiliser containing all three major nutrients was necessary to remove nutrient limiting factors. These trials showed applied nitrogen response to levels as high as 100kg nitrogen per hectare on this site. Yield response to nitrogen alone in these trials ranged from 25 to 63% and NPK from 41 to 81%.

The site was on a heavy clay soil, sloping ground with cultivation so winter topsoil erosion losses were high reducing year to year nutrient carry over in topsoil.

Sturmer, the consistently highest yielding variety, averaged 21.95t/ha without fertiliser, 29.46t/ha with only nitrogen fertiliser and 39.59t/ha with NPK fertiliser. For comparison, average bearing tree production now across all varieties is 52t/ha, 58% higher than the highest yields in the Appleby trial.

Subsequent, unpublished trial data from Appleby showed that by maintaining a clover dominant sward, which largely eliminated topsoil erosion losses, sufficient nitrogen was available from the clover sward to give comparable production levels to regular application of 100kg N/ha/year.

Since the time of the Appleby trials there has been a huge shift in apple orchard husbandry. The main ones have been higher planting densities on precocious dwarfing rootstocks, use of less phytotoxic pesticides, introduction of growth regulators, universal use of herbicide strips along the rows with grass or clover swards between the rows. Chemical thinning and careful crop load management has led to regular cropping. Further nutrient sprays and fertigation is becoming more widespread.

Tree management practices have been modified to minimise excessive tree vigour and maximise cropping potential. In addition, tree support is widely used to allow cropping to begin in second or third year after planting.

Because excess nitrogen supply adversely affects fruit quality, particularly skin colour, and fruit storage behaviour, careful attention is now being given to managing the nitrogen status of the tree with the objective of achieving nitrogen levels approaching deficiency levels as harvest approaches, then building up stored nitrogen reserves in the immediate post-harvest period with fertiliser nitrogen to provide sufficient nitrogen supply to drive the spring growth flush, pollinate and set the crop. Nitrogen deficiency over the blossom period leads to inadequate fruit set and if nitrogen is low, biennial bearing problems increase.

Information on nitrogen fertiliser use among pipfruit growers was sought. There was wide variation in grower practise which varied with tree age, district practice and soil fertility.

In Hawke's Bay, accountable for 60% of the crop, nitrogen fertiliser use among conventional growers on established orchards range from nil, or some strategic foliar nitrogen supplying 10 or 15kg N/ha to about 40kg N/ha ground application. Low quality or shallow soils would receive more. Most of the fertiliser is applied in the post-harvest period.

Young orchard plantings receive regular small side dressings through the growing season to maintain rapid tree vigour. This might be 3-4 weekly side dressings of a complete fertiliser containing about 16-17% nitrogen at 25 to 50g/tree i.e. about 4 to 8g N/tree or 12-24kg N/ha per application.

Nelson has generally less fertile soils, foliar analysis is used to determine the need for fertiliser nitrogen and where required about 40kg N/ha is applied mainly post-harvest.

Ground application of nitrogen is most commonly in the form of CAN (calcium ammonium nitrate).

6.1.3 No Nitrogen Fertiliser

Effect on yield will be dependent on stage of orchard development.

Established orchards on high quality soils may not see much difference in orchard yields and could even experience improved fruit quality and some reduced production costs due to better tree vigour control. This would be possible with better management of chemical nitrogen too. In the long term, some yield reduction could be expected, and with less growth and leaf cover sunburn injury to fruit would increase.

Less fertile soils would experience yield decline, smaller fruit size and increasing problems with biennial bearing.

The main impact would be in orchard establishment. Tree growth would be slower, with a 20% to 30% reduction in cumulative yield over the first 7 years possible in the absence of nitrogen fertiliser and irrigation in a humid climate. On good quality soils established trees would probably eventually achieve similar yields to those with nitrogen fertiliser.

New orchards planted on marginal soils may never achieve economically viable production levels in the absence of applied nitrogen.

In many situations, improving other husbandry practices such as weed control, soil drainage and water management to avoid water stress may largely overcome the impact of no nitrogen fertiliser.

6.1.4 No Chemical Nitrogen Fertiliser, with Substitution

About 6% of the New Zealand pipfruit industry grows under organic production methods which do not allow use of chemical nitrogen fertilisers. These producers are already using chemical nitrogen fertiliser substitutes.

An organic apple grower in Hawke's Bay has established nitrogen management programmes that enable similar orchard productivity to that achieved by conventional pipfruit growers in the district.

For established orchards applying compost is the basis of the nitrogen fertility program. The amount used depends on soil fertility.

At present the amount used is targeted using tree vigour and productivity plus leaf and soil analysis to determine the amount applied.

Average orchard blocks deemed to require nitrogen receive 25m^3 of compost which will apply around 150kg N/ha at a cost of around $1,100 per hectare to apply. Relative to chemical nitrogen fertiliser use on conventional orchards this nitrogen rate appears excessive, because only a small proportion of the added nitrogen becomes plant available that year. On the assumption that several years' of a 25m^3 application will have built up soil organic matter, it is probable that a sustainable annual application rate would be much lower, perhaps eventually about 5m^3/ha/year as a maintenance dressing which would provide around 30kg N/ha/year.

Orchard establishment on fertile soils has not been difficult, but in the present situation new plantings are run as conventional until February of their first growing season so a nitrogen fertiliser program similar to conventional orchards is possible up until then. The strategy then is to apply compost and a heavy straw mulch. This strategy gives very rapid orchards establishment and high yield performance.

In low fertility soils, low nitrogen levels have caused fruit set problems for organic orchards. Yields are reduced, and length of time to achieve those yields is extended.

In the young orchard situation, new ground out of pasture, or growing a clover dominant cover crop and cultivating it in prior to planting the orchard could provide an adequate nitrogen fertiliser substitute, plus compost, to meet the needs of young tree establishment.

Incidentally, the nursery industry which needs new ground for each crop, obtains much of its nitrogen requirement from decay of the pasture that was ploughed under prior to establishing the nursery.

Discussions with an organic pipfruit grower in Central Otago indicated that, relative to Hawke's Bay, Central Otago soils are infertile, particularly in regard to organic matter and nitrogen levels. Here the nitrogen strategy has been to establish clover sward on the orchard floor. This strategy supplies adequate nitrogen for apples and is giving similar yields to the Otago district average.

The organic orchard experience suggests that pipfruit orchards may be able to manage average production levels without use of chemical nitrogen fertilisers, particularly on the better soils. Many organic orchards were well established prior to being converted to organic production, whereas young tree establishment under an organic regime would be impacted. Recent plantings of organic orchard have been at moderate tree densities using more vigorous rootstocks than present-day intensive conventional pipfruit orchards. Root systems in organic orchards are more able to explore the whole soil area whereas conventional orchards have weaker root stocks which may not be capable of exploring similar soil volumes.

Modern conventional intensive orchards are pushing yield boundaries higher with many harvesting crops in the 80 to 100t/ha range and sometimes higher. These orchards usually have drip, or micro-sprinkler irrigation methods which only wet a limited volume of the soil. In these systems fertigation is often used to supply nutrients to the confined root zone to maintain its fertility as well as target application to crop stages that require it. Foliar nitrogen application is also an important tool for targeting supply to a particular phenological stage. This approach to nitrogen fertiliser use results in more efficient uptake. Nitrogen tracer studies indicate that with well managed fertigation as much as 40% of applied nitrogen is taken up by the tree, and above 80% for foliar application. Rapidly soluble nitrogen fertilisers are essential for this approach to fertilising.

Moving away from chemical nitrogen fertilisers to substitutes such as compost, or more likely legume swards for orchard nitrogen supply, will require more extensive root systems able to explore the whole soil area. Compared to present irrigation practices which are very efficient achieving 90 to 95% effective water use for the best micro system, returning to irrigating the whole orchard floor will require significant increases in water supply for irrigation.

It is probable that for satisfactory crop nitrogen supply overall, soil nitrogen status will need to be raised.

The ability to target nitrogen application to specific phenological stages will be lost and this could have detrimental effects on tree vigour management and fruit quality, particularly fruit colour.

In the absence of fertiliser nitrogen, nitrogen sources will be much more reliant on natural soil processes which are largely driven by weather conditions.

It's also probable that the lifted soil nitrogen status required with substitution may lead to increased nitrate leaching rather than less.

Where animal manures or composts are being used as a regular nitrogen fertiliser substitute, these alternative nitrogen sources also apply both phosphorus and particularly potassium, which if applied in excessive amounts regularly will create imbalances with other cations, particularly calcium. This will be undesirable and lead to increasing problems with calcium related disorders such as bitter pit.

6.1.5 Pipfruit Gross Margins

Table 24: Pipfruit Average Mature Orchard Gross Margin- Status Quo

Status Quo Apple Orchard	per Ha	per plant (kg)
Plants/ha	2381	
Yield (Tonnes)	**70.0**	**29**
Packout	85%	
Income $/kg (weighted)	$1.39	
Income ($)	**$97,300**	**$41**
Post-harvest costs	$30,100	
Orchard Gate Income ($)	**$67,200**	**$28**
Total labour expenses	$22,815	$10
Fertiliser and lime	$310	$0
Other direct expenses ($)	$6,237	$3
Total direct expenses ($)	**$29,362**	**$12**
Gross Margin ($/ha)	**$37,838**	**$16**

Changes made were as follows:

Table 25: Scenario Changes made to Status Quo

Scenario	Status Quo	With Substitution		No Substitution	
Soil fertility	-	Fertile soil	Infertile soil	Fertile soil	Infertile soil
Yield	70	70	70	65	40
Packout	85%	85%	85%	85%	80%
Price	1.39	1.39	1.39	1.39	1.19
Nitrogen applied (kg/ha/year)	40	20	60	0	0
Fertiliser cost	310	385	726	215	215

Table 26: Pipfruit Per ha and National Results

<table>
<tr><th>Apple Orchard Scenario</th><th>Gross Margin/ha</th><th>Area (ha)</th><th>National Gross Margin</th><th>Change from SQ ($)</th><th>% Change</th></tr>
<tr><td>Status Quo</td><td>$37,838</td><td>10,218</td><td>$386,628,684</td><td>$0</td><td></td></tr>
<tr><td>Fertile with Substitution</td><td>$37,763</td><td>6,130</td><td rowspan="2">$384,466,160</td><td rowspan="2">$2,162,524</td><td rowspan="2">-1%</td></tr>
<tr><td>Infertile with Substitution</td><td>$37,422</td><td>4,088</td></tr>
<tr><td>Fertile No Substitution</td><td>$33,783</td><td>6,130</td><td rowspan="2">$227,664,694</td><td rowspan="2">$158,963,990</td><td rowspan="2">-41%</td></tr>
<tr><td>Infertile No Substitution</td><td>$5,033</td><td>4,088</td></tr>
</table>

6.2 Summerfruit

6.2.1 Present and Historical Situation

New Zealand grows the full range of summerfruit crops.

Total summerfruit area is 2,140 hectares comprising:

Apricots	445 ha - mostly in Central Otago
Cherries	726 ha - mostly in Central Otago
Nectarines	305 ha - Hawke's Bay, Central Otago
Peaches	374 ha - Hawke's Bay, Central Otago
Plums	290 ha - Hawke's Bay, Central Otago

Central Otago accounts for 59% of total area and Hawke's Bay 31%.

Nitrogen removed in crop from Peaches and Nectarine was shown to be 1.2kg/tonne. No data was found on other summerfruit crops for nitrogen removed in the crop. Fruits are all botanically very similar so it is assumed that N removed in crop would be similar.

Yields vary quite considerably depending on season, type and cultivar. Estimated yields are shown in the following table.

Table 27: Summerfruit Yields and Estimated N Removal from the Crop

Variety	Yield	Kg N/ha removed in Crop
Apricots	16 to 20t/ha	19.2 to 24
Cherries	10 to 12t/ha	12 to 14.4
Nectarines	Early 9 to 10t/ha Mid-late 25-30t/ha	10.8 to 12 30 to 36
Peaches	Early 10 to 15t/ha Mid-late 30-35t/ha Process 30t/ha – good blocks 60t/ha	12 to 18 36 to 42 36
Plums	20 to 30t/ha Process up to 50t/ha	24 to 36 Up to 60

There is little, if any published data on summerfruit nitrogen fertiliser response under New Zealand conditions. Overseas published data on summerfruit response to nitrogen fertiliser and general fertiliser recommendations report the following:

Table 28: Peach Tree Fertigation Requirements (California)

	Yield	N/ha
Early Season	15 t	80 kg
Mid-Season	30 t	110 kg
Late Season	40 t	140 - 150 kg

Average nitrogen use in California is reported to be 60kg/ha for peaches and 52kg/ha for nectarines.

Soil fertility, particularly organic matter and rooting depth determine nitrogen fertiliser requirement.

A trial conducted by Rufat and DeJong (2001) on 7 year old O'Henry peach trees comparing no applied nitrogen fertiliser and a very high rate of 250kg N/ha showed that although the trees took up 38% of the applied nitrogen fertiliser, the nil nitrogen treatment was still largely capable of meeting crop requirements giving similar fruit size at harvest, but total fruit dry matter was down 11% and annual branch dry weight down 25%. Total nitrogen in grams per tree was 193.9g for the high nitrogen against 99.1g for no nitrogen. In this trial the proportion of nitrogen partitioned by the fruit was very similar indicating summerfruit are capable of luxury consumption. Fruit nitrogen % was 0.42 without nitrogen and 0.76 with nitrogen.

The effect of fertiliser nitrogen on fruit behaviour here was to advance flowering by one day and delay harvest by two days. Additionally, the no nitrogen treatment had less than half the leaf dry matter of the fertilised treatment.

On peaches, which crop on only one-year old wood, it is necessary to grow sufficient replacement fruiting wood each year and enough leaf area to supply the photosynthetic requirement of the crop.

Applying higher rates of nitrogen fertiliser than required to achieve this objective will lead to luxury consumption with its associated negative impacts on fruit quality, and due to increased shading and higher humidity with the extra leaf cover leading more trouble with fruit rots.

Foliar nitrogen sprays play an important role in summerfruit nitrogen fertiliser programmes. Experience in California indicates that 20 to 50% of crop requirement can be applied as foliar nitrogen with particular emphasis on post-harvest application when fairly high rates can be used.

In Cherries, where fruit size is particularly important, post-harvest foliar nitrogen sprays have been shown to significantly increase spur leaf size which in turn lifts fruit size potential.

Nitrogen fertiliser use among New Zealand summerfruit growers varies widely. There is general perception that summerfruit, particularly peaches and nectarines, requires more nitrogen fertiliser than pipfruit. Nitrogen fertiliser use on the Heretaunga Plains for one large peach and nectarine producer ranges from 40kg N/ha to 130kg N/ha depending on the soil type and pervious history. The high fertiliser block has a history of many years process vegetable cropping. This includes both ground applications and foliar fertilisers.

6.2.2 No Nitrogen Fertiliser

The effect of no nitrogen fertiliser will be largely dependent on initial soil fertility and effective rooting depth.

On a poor soil with low natural fertility its estimated that yields could be depressed by as much as 50% in the absence of fertiliser nitrogen for peach and nectarines.

On average soils yield depression may be around 25%, whereas very fertile soils may see yield reduction of the order of 10%.

The impact on other summerfruit types would be less than peaches and nectarines because there is less need to replace fruiting wood each year.

In the longer term in the absence of nitrogen fertiliser grasses would become less competitive so the proportion of clover in the orchard sward would increase leaching more soil available nitrogen.

In the absence of applied nitrogen fertilisers establishing new summerfruit orchards would be more difficult and probably uneconomic on poorer soils. This would have serious implications for summerfruit production in some very suitable micro-climates such as Central Otago where soils are naturally poor in organic matter and nitrogen supply.

6.2.3 No Chemical Nitrogen Fertiliser, with Substitution

There is very little summerfruit organic production in New Zealand.

Productivity on a small organic cherry orchard located in Central Otago is very good and above the national average. The nitrogen strategy on this orchard was to maintain a clover sward between the rows for nitrogen supply. These trees would have been established under a conventional regime prior to becoming organic.

In mature summerfruit orchards adopting a clover dominant sward between the rows would be the most likely substitution for chemical nitrogen fertilisers. In some situations, this approach may be supplemented by other nitrogen inputs such as compost.

New orchard establishment would be more of a challenge.

The most likely strategy would be to plant a leguminous cover crop the year prior to planting the orchard, plough it in, possibly with animal manure or compost to aid initial breakdown of the cover crop. This approach would supply adequate nitrogen to support young tree nitrogen requirement for the first year or two.

Compost or another non-chemical fertiliser nitrogen may be used if available. Towards the end of the orchards' first growing season a clover sward could be seeded, which would be expected to become the substitute nitrogen source.

Summerfruit, particularly peach and nectarine are poor competitors with pasture so it's possible higher levels of irrigation would be necessary to minimise competition for soil moisture in the establishment period.

Established summerfruit have a relatively low soil moisture requirement up until 4-5 weeks prior to harvest, then there is need for high soil moisture levels during the final fruit swell period. At this stage it may be necessary to supress sward growth to minimise its competition for moisture.

The use of nitrogen fertiliser substitutes means it should be possible to maintain orchard yields. However, there is less control over nitrogen supply so it may be difficult to target specific phenological stages as is possible with chemical nitrogen fertilisers, in particular foliar nitrogen applications.

6.2.4 Summerfruit Gross Margins

Table 29: Summerfruit Average Mature Orchard Gross Margin- Status Quo

Status Quo Summerfruit Orchard	per ha	per plant (kg)
Plants/ha	1250	
Yield (Tonnes)	**22**	**18**
Packout	100%	
Income $/kg (local)	$3.00	
Income ($)	**$66,000**	**$53**
Post harvest costs	$17,930	$14
Orchard Gate Income ($)	**$48,070**	**$38**
Total labour expenses	$21,187	$17
Fertiliser and lime	$620	$0
Other direct expenses ($)	$6,804	$5
Total direct expenses ($)	**$28,611**	**$23**
Gross Margin ($/ha)	**$19,459**	**$16**

Changes made were as follows:

Table 30: Scenario Changes made to Status Quo

Scenario	Status Quo	With Substitution		No Substitution	
Soil fertility	-	Fertile soil	Infertile soil	Fertile soil	Infertile soil
Yield	22	22	22	17	11
Packout	100%	100%	100%	100%	100%
Price	3.00	3.00	3.00	3.50	4.50
Nitrogen applied (kg/ha/year)	120	90	150	0	0
Fertiliser cost	620	1,107	1,618	340	340

Table 31: Summerfruit Per ha and National Results

<table>
<tr><th>Apple Orchard Scenario</th><th>Gross Margin/ha</th><th>Area (ha)</th><th>National Gross Margin</th><th>Change from SQ ($)</th><th>% Change</th></tr>
<tr><td>Status Quo</td><td>$19,459</td><td>1,414</td><td>$27,515,026</td><td>$0</td><td></td></tr>
<tr><td>Fertile with Substitution</td><td>$18,972</td><td>707</td><td rowspan="2">$26,465,781</td><td rowspan="2">$1,049,245</td><td rowspan="2">-4%</td></tr>
<tr><td>Infertile with Substitution</td><td>$18,461</td><td>707</td></tr>
<tr><td>Fertile No Substitution</td><td>$17,622</td><td>707</td><td rowspan="2">$23,419,729</td><td rowspan="2">$4,095,298</td><td rowspan="2">-15%</td></tr>
<tr><td>Infertile No Substitution</td><td>$15,504</td><td>707</td></tr>
</table>

6.3 Kiwifruit

6.3.1 Present and Historical Situation

The total area in producing kiwifruit is 12,692 hectares as of 2018, comprising of:

- Zespri Sungold 4630 ha
- Zespri Green 7382 ha
- Zespri Organic Green 475 ha
- Zespri Sweet Green 175 ha
- Zespri Gold 30 ha

Location:

- Bay of Plenty 81%
- Northland 3.5%
- Auckland 4.0%
- Waikato 3.5%
- Poverty Bay 2.0%
- Hawke's Bay 1.6%
- Lower North Island 0.6%
- South Island 3.3%

Nutrient removed in each tonne of kiwifruit is between 0.93 and 1.63 kg N/ha (Morton, 2013).

Table 32: Nitrogen Removal with Kiwifruit Yields

Yield	Kg N/ha removed in Crop
6000 trays/ha (21t)	20 - 34
8000 trays/ha (28t)	26 - 46
10,000 tray/ha (35t)	33 - 57
12,000 trays/ha (42t)	39 - 68
15,000 trays/ha (52.5t)	49 - 86

Historically kiwifruit have had high rates of nitrogen fertiliser applied often up to 250kg N/ha or sometimes higher.

In the early days of the crop, most of the canopy was replaced annually. This required the vine to have high vigour in order to grow next seasons fruiting canopy. Average yields under this system were only moderate due to the huge amount of photosynthates going to the new canopy growth.

In recent years vine husbandry has moved away from the more or less total canopy replacement model to retaining the fruit canopy for several seasons. This has lowered the high vine vigour requirement, markedly increased yields and lowered nitrogen fertiliser requirements.

It would now appear that nitrogen fertiliser applications above 180 to 200kg/ha/year could be considered excessive.

Furthermore, recognising mineralisation of nitrogen from soil organic matter which on deep fertile soils could supply as much as 100 kg N/ha/yr or more and moving towards strategic foliar nitrogen applications based on phenological vine stage, soil nitrogen fertiliser applications can probably be pulled back to well under 100kg N/ha/yr.

The industry standard amount assumed for the kiwifruit model is 140 units of nitrogen/hectare, applied in September, October and November in equal instalments.

Kiwifruit, as with other woody fruiting crops drives its initial growth flush with remobilisation of sorted nitrogen accumulated in the previous growing season. Also, as with other woody fruiting crops little soil uptake occurs until the mobilised nitrogen supply has been exhausted. Nitrogen soil uptake therefore does not commence until six to eight weeks after budbreak. Roots need a good supply of photosynthate in order to uptake soil nitrogen. The first soluble nitrogen fertiliser application should be made about one month before flowering.

The investigation on grower fertiliser applications indicates that fertiliser applications usually commence around green tip. Application at this stage of plant growth in a high rainfall free draining soil would probably be largely lost through leaching. The investigation showed 40 to 50kg N of soluble nitrogen fertilisers are applied at this time.

Expert opinion was sought on what was considered the minimum nitrogen fertiliser maintenance rate necessary to maintain productivity. It was thought 20 kg N/ha/yr may be the lower limit, and often 40 kg N/ha/yr was considered marginal on many soils.

There was also anecdotal evidence supplied of a high producing kiwifruit orchard block where no nitrogen fertiliser was applied and compared with an adjacent block under a normal nitrogen fertiliser programme. In this instance it took eight years for any yield differences between the two blocks to show. Reduced vine cane growth became obvious sooner in the no nitrogen block.

6.3.2 No Nitrogen Fertiliser

As with other fruit crops, soil fertility will determine the impact of withdrawing fertiliser nitrogen from kiwifruit. For mature vines on good soils, it is estimated that they would yield at perhaps 85- 90% of normal.

Due to the impact of plant nitrogen reserves that can be re-mobilised, return of foliage and pruning's to the soil, and mineralisation of nitrogen in soil organic material it may take some years to show up. Main effects expected are likely to be poorer budbreak and smaller fruit size.

The impact will also be determined by how the chemical nitrogen fertilisers used in dormancy breaking are classified. If dormancy breaker sprays were unavailable the yield and fruit quality would be seriously affected.

Organic Green kiwifruit, which do not receive dormancy breaker sprays produce 33% less fruit than Green kiwifruit. Most of this reduction in yield is thought to be the result of not using dormancy breakers.

Developing new plantings without nitrogen fertilisers will be a huge challenge because of the high requirement of nitrogen for canopy development. On all but the best soils it may not be economically possible to establish new orchards. The main effect will be an extension of the non-bearing period.

6.3.3 No Chemical Nitrogen Fertiliser, with Substitution

Because kiwifruit are grown on pergola training systems which severely limit light penetration reaching the orchard floor from October through to mid-June when leaf fall occurs, followed by the carpet of fallen leaves, the opportunity to grow leguminous cover crops to supply nitrogen in kiwifruit orchards is severely limited.

Whereas establishing a clover dominant orchard sward is likely to be a very cost-effective substitute for nitrogen in other fruit crops, kiwifruit will have to find other fertiliser nitrogen substitutes. Sowing rapidly growing legumes such as lupin during winter may be a possibility.

Existing organic growers use organic production approved nitrogen fertilisers such as animal manures, composts, fish meals, etc. These alternatives are expensive and unlikely to be able to replace nitrogen fertiliser for the whole industry due to supply limitation.

Soya bean meal, Lucerne hay or pellets and cotton seed meal are potential nitrogen fertiliser substitutes. Adopting these substitutes would involve tying up areas of land for nitrogen fertiliser supply that could be used more productively for food production.

With the appropriate nitrogen fertiliser substitution, it should be possible to maintain mature kiwifruit orchard production levels.

Developing new kiwifruit orchards may be more of a challenge due to their high nitrogen requirement for vine growth and canopy development.

A carefully planned strategy of soil preparation the previous growing season, involving the establishment of clover or legume dominant cover crop when killing or incorporating it prior to planting the vines, would lift plant available soil nitrogen levels in the order of 100kg Nitrogen per hectare or more. This would give the vines a good start. As it takes several years for significant vine canopy to completely shade out the orchard floor a dominant clover sward could be maintained between the rows.

Targeted compost or similar application around the plants would add further nitrogen.

6.3.4 *Kiwifruit Gross Margins*

Table 33: Kiwifruit Average Mature Orchard Gross Margin- Status Quo

Status Quo Kiwifruit Orchard	per ha	per plant (kg)
Plants/ha	416	
Yield (Tonnes)	**35**	**$84**
Packout	95%	
Income $/kg (local)	$3.29	
Income ($)	**$115,150**	**$277**
Post harvest costs	$38,150	$92
Orchard Gate Income ($)	**$77,000**	**$185**
Total labour expenses	$24,200	$58
Fertiliser and lime	$2,436	$6
Other direct expenses ($)	$10,500	$25
Total direct expenses ($)	**$37,136**	**$89**
Gross Margin ($/ha)	**$39,864**	**$96**

Changes made were as follows;

Table 34: Scenario Changes made to Status Quo

Scenario	Status Quo	With Substitution		No Substitution	
Soil fertility	-	Fertile soil	Infertile soil	Fertile soil	Infertile soil
Yield	35	35	35	30	25
Packout	95%	95%	95%	95%	95%
Price	3.29	3.29	3.29	3.29	3.29
Nitrogen applied (kg/ha/year)	140	100	150	0	0
Fertiliser cost	2,436	2,958	3,384	2,106	2,106

Table 35: Kiwifruit Per ha and National Results

Kiwifruit Orchard Scenario	Gross Margin/ha	Area (ha)	National Gross Margin	Change from SQ ($)	% Change
Status Quo	$39,864	12,692	$505,953,888	$0	
Fertile with Substitution	$39,342	10,153	$498,212,322	$7,741,566	-2%
Infertile with Substitution	$38,916	2,538			
Fertile No Substitution	$29,794	10,153	$349,080,934	$156,872,954	-31%
Infertile No Substitution	$18,354	2,538			

6.4 Avocado

6.4.1 Present and Historical Situation

The current planted area (2018) in avocados is 3,795 ha, with the industry in a rapid expansion stage.

Main production areas:

- Bay of Plenty is the major production area with 2,307 ha planted.
- Northland was recorded at 1,347 ha in 2018 and is growing quickly. It is estimated about 500ha are under 5 years old.
- In addition, Gisborne and Hawke's Bay have a few plantings.

Nitrogen removal in crop is 1.13 to 2.2kg N/tonne of fruit.

Historically, Avocados have been planted on seedling rootstocks at wide planting densities giving perhaps 100 to 250 trees per hectare. These trees are not very precocious, take a long time to reach full production, are prone to biennial bearing and susceptible to phytophthora root diseases.

Recently precocious clonal rootstocks with root disease tolerance have been introduced. New orchards on these rootstocks are being planted in the range of 400 to 600 trees per hectare. As a result, commercial crops commence three or four years from planting, with mature canopies 8 to 10 years from planting. Present average production from older plantings is thought to be around 7t/ha. The newer intensive plantings are reaching that level of production 4 or 5 years from planting and on maturity may reach 25t/ha or more on average.

Growers interviewed believed that the economically sustainable production level was around 10 to 12 t/ha.

As with other tree fruit crops, soil quality, fertility and depth have a huge influence on yield and fruit quality.

New Zealand climate is marginal for Avocado. Orchards need very good shelter in our windy climate to develop a satisfactory micro-climate for the crop. The far north of the country has better climate for Avocados than further south, although the crop will grow satisfactorily in sheltered micro-climates as far south as Hawke's Bay. Additionally, avocados are very sensitive to soil water logging, so needs free draining, well aerated soils for good root health.

Feeder roots are generally found in the soil surface layers. It is fairly standard practice to maintain an organic mulch within the drip zone. Soil ridging around the tree to improve drainage and soil aeration is often carried out.

The far north, which has a good climate for avocados, has poor sandy soils incapable of supplying adequate nitrogen for the crop. Fertigation is widely used there to supply nitrogen and other nutrient needs.

Prior to planting some growers apply a locally made compost-based pine chip and bark from the forest industry, and animal manure, usually chicken, to give trees a better root environment.

Elsewhere in the country soils are of much better quality so have lower nitrogen fertiliser requirements.

Foliar nitrogen applications such as low biuret urea applied strategically at times of high requirement, such as around the 'cauliflower' bud stage immediately prior to flowering, and at fruit set, is said to increase yield. Additional nitrogen applied in the spring of a heavy crop year may reduce biennial bearing problems.

Barber et al (1986) produced this table in a Ministry of Agriculture and Fisheries publication.

Table 36: Avocado Fertiliser Recommendations (Barber et al 1986)

Plant Age (Years)	Application Rate Nitrogen kg/ha
2	12
3-4	25
5-7	50
8-9	75
10-14	100
15 or older	150

Investigations into grower practice showed some growers could be using this table as a guide. Other information indicates nitrogen applications of between 75 and 180kg/ha depending on canopy area. This bulletin also warns against excessive nitrogen fertiliser application around young trees due to root burn.

In older Avocado orchards root disease can be widespread giving typical nitrogen deficiency symptoms. In some orchards this may be driving excessive nitrogen fertiliser use.

Rosecrance *et al* (2012) recommended timing fertiliser applications to meet tree demand. "Avocado fruit accumulated most of its nutrients between full bloom in the spring and autumn." Nitrogen fertilisation in spring increased both fruit size and yield and reduced the severity of alternate bearing compared with trees receiving nitrogen at any other time of the year besides spring.

Precise fertiliser timing for the avocado flowering period is likely to be only possible by applying nitrogen fertilisers. This is because soil sourced nitrogen from organic matter requires relatively high soil temperatures, and at time of flowering soil temperatures in many areas may not be high enough to supply soil nitrogen in adequate amounts.

Excess nitrogen fertiliser can be detrimental by driving tree vigour at the expense of cropping. There is anecdotal evidence to indicate that this could be happening on some orchards.

6.4.2 No Nitrogen Fertiliser

The effect of no nitrogen fertiliser will depend on inherent soil fertility.

Growers interviewed thought that young tree growth without nitrogen fertiliser may make only 20 to 30% of the growth that could be expected with nitrogen fertiliser.

For trees with poor root health foliar applications may be a more effective way of lifting tree nitrogen uptake and this option would not be possible in a no nitrogen fertiliser regime.

Well established trees on fertile soils with healthy root systems may not show the effects of no nitrogen fertiliser on production for a number of years.

6.4.3 No Chemical Nitrogen Fertilisers, With Substitution

The bottom line for long term yield sustainability lies in developing a nitrogen substitution programme which is capable of balancing new nitrogen inputs with the amount being lost from the soil nitrogen cycle in the harvested crop, that built into permanent tree structure, and leaching losses. Apart from the crop, the bulk of annual tree nitrogen uptake goes into maintaining the canopy foliage. Foliage nitrogen is largely recycled through leaf drop. Leaves have a limited life on the tree, even with evergreens such as avocado.

Relative to deciduous fruits which enable leguminous sward to supply nitrogen there is very limited scope in full canopy avocado orchards to use leguminous cover crops as a nitrogen source.

As avocados need an organic mulch within the drip zone to provide a suitable root growth environment the obvious nitrogen substitution supply will be adding a high nitrogen supplement to the mulching materials. Among legumes Lucerne hay is reported to be the best source of nitrogen. A limited supply of Lucerne hay could be grown in the non-shaded orchard floor and this could be harvested and transferred to the area underneath the canopy. This strategy would probably work quite well in developing orchards where a high proportion of the orchard floor is not shaded.

Mature avocado orchards would need to import some of their nitrogen requirements. Composts, animal manures and legume dominant hay are the most likely sources.

For new plantings, careful pre-planting site preparation involving pre-plant incorporation of a legume crop such as clover could supply adequate nitrogen to get the trees started. Addition of compost to the planting site as is done by some growers at present is another approach or even used in conjunction with a legume cover crop should be an adequate substitution for nitrogen fertiliser.

In the absence of nitrogen fertiliser, nutrient costs would be expected to increase.
Provided the substitution strategies were able to meet nitrogen requirements it is felt that similar productivity could be achieved, and in some instances improved, where present fertiliser practices may be excessive, leading to root injury or excessive tree vigour at the expense of possible yield increases.

6.4.4 Avocado Gross Margins

Table 37: Avocado Average Mature Orchard Gross Margin- Status Quo

Status Quo Avocado Orchard	per ha	per plant (kg)
Plants/ha	156	
Yield (Tonnes)	**10**	**64**
Packout	100%	
Income $/kg (local)	$5.80	
Income ($)	**$58,000**	**$372**
Post-harvest costs	$21,800	$140
Orchard Gate Income ($)	**$36,200**	**$232**
Total labour expenses	$7,515	$48
Fertiliser and lime	$670	$4
Other direct expenses ($)	$6,000	$38
Total direct expenses ($)	**$14,185**	**$91**
Gross Margin ($/ha)	**$22,015**	**$141**

Changes made were as follows;

Table 38: Scenario Changes made to Status Quo

Scenario	Status Quo	With Substitution		No Substitution	
Soil fertility	-	Fertile soil	Infertile soil	Fertile soil	Infertile soil
Yield	8	8	8	6	3
Packout	100%	100%	100%	100%	100%
Price	5.80	5.80	5.80	5.80	5.80
Nitrogen applied (kg/ha/year)	100	90	150	0	0
Fertiliser cost	670	967	1,478	200	200

Table 39: Avocado Per ha and National Results

Apple Orchard Scenario	Gross Margin/ha	Area (ha)	National Gross Margin	Change from SQ ($)	% Change
Status Quo	$22,015	3,795	$83,546,925	$0	
Fertile with Substitution	$21,718	1,898	$81,451,933	$2,094,992	-3%
Infertile with Substitution	$21,207	1,898			
Fertile No Substitution	$13,885	1,898	$23,320,275	$60,226,650	-72%
Infertile No Substitution	$(1,595)	1,898			

6.5 Citrus

6.5.1 Present and Historical Situation

1660ha of citrus is planted in New Zealand, with just over half grown in Gisborne and one third in Northland. The rest is a small amount in Auckland and Bay of Plenty regions.

Citrus crops comprise of oranges, mandarins, lemons and a very small amount of lime, tangelos and grapefruit. Oranges occupy the largest area at 783 ha, followed by mandarins at 556 ha.

Nitrogen removed in the crop is about 2.9kg N/tonne of fruit, but will vary between citrus species.

Industry contacts indicate that average orange yields are around 40t/ha while good growers would expect 50-60 t/ha. Poverty Bay yield data indicates Navel oranges yields of 40t/ha, Valencia oranges 50 to 70t/ha (mainly used for juice), and mandarins 25 to 30t/ha. A yield of 40 t/ha has been used in the model based on Navel oranges.

Fertiliser nitrogen use is estimated to be 40 to 50kg/ha in spring and about 35kg/ha in autumn where necessary.

Strategically timed foliar urea sprays at phenological stages where nitrogen demand is high, are often applied to citrus. Foliar uptake is rapid, and efficiency of uptake is high, two to three times that of soil applied nitrogen fertilisers.

As with other tree fruit crops, flowering and the spring growth flush is largely driven by remobilised stored nitrogen accumulated in the tree in the previous growing season.

Early spring leaves are often yellow indicative of nitrogen deficiency symptoms. These symptoms are more likely to be chill injury and will disappear once temperatures warm up.

New South Wales DPI recommendations for nitrogen fertilisers for citrus trees are in the range of 100 to 180kg/ha/yr.

6.5.2 No Nitrogen Fertiliser

Expert opinion indicated that in Poverty Bay the nitrogen fertiliser requirement for young citrus trees was well behind the need for good shelter from wind, freedom from competing weeds and adequate irrigation and drainage.

In a no-nitrogen fertiliser regime satisfying these requirements would, on Poverty Bay soils which naturally have very good nitrogen status, mitigate much of the adverse impact of not applying nitrogen fertilisers. Generally, soils in the other citrus districts are also fertile.
A Department of Agriculture nitrogen trial was carried out in Kerikeri on oranges during the 1960s and early 1970s which showed no response to nitrogen fertilisers.

Lack of precisely timed nitrogen application would make it more difficult for growers to manage biennial bearing, which would reduce long term average tonnage and quality.

Undoubtedly applying no nitrogen fertiliser on poor soils with low nitrogen reserves would drastically reduce tree growth and yields and initiate large swings in production year on year. On such soils, citrus growing would probably become non-viable.

6.5.3 No Chemical Nitrogen Fertiliser, With Substitution

The substitution options would be similar to those already discussed in the previous fruit crops.

Citrus orchards generally have a significant proportion of the between row area open to good light so it is probable that the strategy of establishing a legume dominant orchard sward with the mower clippings thrown sideways onto the tree row could supply a substantial proportion of the nitrogen requirement.

It is probable that foliar urea sprays applied strategically in the fertiliser nitrogen programmes play an important role in citrus nutrition at times of high demand. This may not be possible in the 'no fertiliser nitrogen with substitution' regime, and if possible, the substitute nitrogen sources are many times more expensive than urea.

Use of seaweed products is often mentioned as an alternative to nitrogen fertilisers, however, there is no published scientific trial data that shows significant effects from applying these products.

Provided nitrogen fertiliser substitution strategies can meet crop nitrogen requirement it is probable that yields would be similar to where chemical nitrogen fertilisers are used.

6.5.4 Citrus Gross Margins

Table 40: Citrus Average Mature Orchard Gross Margin- Status Quo

Status Quo Navel Orange Orchard	per ha	per plant (kg)
Plants/ha	667	
Yield (Tonnes)	**40.0**	**60.0**
Packout (local)	100%	
Income $/kg (weighted)	$0.50	
Orchard Gate Income ($)	**$20,000**	$30.0
Total labour expenses	$6,533	$9.8
Fertiliser and lime	$317	$0.5
Other direct expenses ($)	$5,178	$7.8
Total direct expenses ($)	**$12,028**	**$18.0**
Gross Margin ($/ha)	**$7,972**	**$12.0**

Changes made were as follows:

Table 41: Scenario Changes made to Status Quo

Scenario	Status Quo	With Substitution		No Substitution	
Soil fertility	-	Fertile soil	Infertile soil	Fertile soil	Infertile soil
Yield	40	40	40	36	20
Packout	100%	100%	100%	100%	100%
Price	0.50	0.50	0.50	0.45	0.30
Nitrogen applied (kg/ha/year)	60	60	150	0	0
Fertiliser cost	12,028	10,399	11,166	8,588	7,288

Table 42: Citrus Per ha and National Results

<table>
<tr><th>Citrus Orchard Scenario</th><th>Gross Margin/ha</th><th>Area (ha)</th><th>National Gross Margin</th><th>Change from SQ ($)</th><th>% Change</th></tr>
<tr><td>Status Quo</td><td>$7,972</td><td>1,660</td><td>$13,233,520</td><td>$0</td><td></td></tr>
<tr><td>Fertile with Substitution</td><td>$7,601</td><td>1,328</td><td rowspan="2">$12,363,139</td><td rowspan="2">$870,381</td><td rowspan="2">-7%</td></tr>
<tr><td>Infertile with Substitution</td><td>$6,834</td><td>332</td></tr>
<tr><td>Fertile No Substitution</td><td>$4,832</td><td>1,328</td><td rowspan="2">$5,325,280</td><td rowspan="2">$7,908,240</td><td rowspan="2">-60%</td></tr>
<tr><td>Infertile No Substitution</td><td>$(3,288)</td><td>332</td></tr>
</table>

6.6 Viticulture

6.6.1 Present and Historical Situation

Nitrogen is the most abundant soil-derived macronutrient in a grapevine and plays a major role in many of the biological functions and processes of both grapevine and fermentative microorganisms (Bell and Henschke 2005). Manipulation of grapevine nitrogen nutrition has the potential to influence quality components in the grape and, ultimately, the wine. In addition, fermentation kinetics and formation of flavour-active metabolites are also affected by the nitrogen status of the must, which can be further manipulated by addition of nitrogen in the winery. The only consistent effect of nitrogen application in the vineyard on grape berry quality components is an increase in the concentration of the major nitrogenous compounds, such as total nitrogen, total amino acids, arginine, proline and ammonium, and consequently yeast assimilable nitrogen (YAN).

Nitrogen influences the productivity and fruit composition of winegrapes and is often the most important nutrient to manage in vineyards, since it has a large impact on vine productivity (Bell and Henschke 2005). Excessive nitrogen supply results in increased vegetative growth (vigour), often at the expense of reproductive growth and/or fruit ripening (Wheeler and Pickering 2003).

High nitrogen supply resulting in increased vegetative growth can also lead to undesirable effects in berries due to increased shading of clusters that decreases colour development (Keller 2015) and an increased incidence of Botrytis infection (Austin et al. 2011). Too little nitrogen can reduce fruit yield and quality by reducing fruit set or berry growth directly, or by reducing vegetative growth too severely to ripen the fruit (Bell and Robson 1999). Low nitrogen concentrations in berries leading to low yeast assimilable nitrogen (YAN) levels can reduce fermentation rates and presumably wine quality in many grapegrowing regions (Bell and Henschke 2005).

6.6.1.1 Nitrogen requirements for Vitis vinifera

It is generally accepted that soil nitrogen status is transient and is not considered a reliable measure metric for basing grapevine nitrogen requirements and therefore plant tissue analysis is recommended for determining plant nitrogen requirements. Grapevine nitrogen status is most commonly determined through leaf petiole analysis. Target nitrogen values for petiole analysis are 1.2%-2.2% at bloom or 0.8%-1.2% post-bloom (70-100 days after bloom) (Wolf 2008).

Adding nitrogen under condition of low nitrogen status stimulates nitrogen metabolism and consequently protein synthesis, resulting in higher rates of photosynthesis and increased total yield.

When the initial nitrogen status of the vine is adequate, further addition of nitrogen does not increase the growth and yield past the maximum value obtained by adding a lower amount of nitrogen (Bell and Robson 1999).

Indiscriminate use of nitrogen has detrimental impacts on grape composition and yield. When vine nitrogen status is high, grape composition is primarily influenced by the consequences of increasing vine growth (e.g. sink-source relationships, canopy microclimate). High vine nitrogen status may disrupt vine balance, leading to a limited supply of carbohydrates if the vine becomes over-cropped or excessively vegetative due to further applications of nitrogen. However, in a number of studies that measured the effect of increasing rates of nitrogen application on both vine growth and yield it appeared that growth was maintained at the expense of yield. The reduction in yield following high rates of nitrogen application in the vineyard can be explained largely by changes in the canopy microclimate resulting in shading in the renewal zone.

6.6.1.2 Nitrogen Use, Removal and Recommendations in New Zealand Vineyards

Nitrogen is the mineral nutrient which grapevines have the highest demand for and most often limits growth. It takes approximately, 20g-50g of N to produce one 1kg of biomass (Wolf 2008). Fixed Nitrogen is permanently removed from the vineyard soil at harvest. Vineyards typically lose 2kg-3kg N t^{-1} of fruit removed but can be reduced to less than 1kg N t^{-1} if stalks and marc are recycled back to the vineyard (Wolf 2008). To put this into context New Zealand vineyards yield approximately 10 t ha^{-1}, therefore it is reasonable to assume that fixed nitrogen is removed at a rate of approximately 10-30kg N t^{-1}.

Nitrogen recommendations are largely be determined by soil type, soil fertility, and previous land use. Generally, it is recommended to apply 30kg N ha^{-1} at planting for vine establishment and this should only be done once in the first season. To maintain vegetative growth and yield, and to replace nitrogen lost through harvest, the recommended rate of nitrogen application globally ranges from 0kg-100kg N/ha/year depending on soil fertility (Ovalle et al. 2010).

Anecdotal evidence shows that New Zealand vineyards are very low users of nitrogen fertilizers. Typical yearly nitrogen applications range from 0kg-15kg/ha/year, with most of the nitrogen being applied through foliar seaweed sprays and ground application of grape marc. A case study of four vineyards in the Hawke's Bay show that two of the vineyards have applied no nitrogen in the last 5 years and the remaining two vineyards have only supplied nitrogen through applications of grape marc and foliar seaweed spray. There is no evidence that foliar seaweed sprays and other biostimulants lead to any commercial benefits for fruit growers (Thalheimer and Paoli 2002).

6.6.2 No Nitrogen Fertiliser

Grapevines are relatively low users of nitrogen fertilizers. Even though grapevines have low nitrogen requirements, nitrogen status is still important and nitrogen imbalances can impact yield, fruit quality, and wine fermentation kinetics.

It appears that winegrapes in New Zealand could still be successfully grown if nitrogen fertilizer was removed from the production system. This is especially true if the vineyard soil has high natural fertility, however, a loss of yield would be expected if the vineyard had low natural fertility. The loss of yield is not necessarily a negative impact, because lower yields in grapevines are often associated with higher quality grapes and therefore higher quality wine. In fact, many vineyards incur significant cost by fighting vine vigour (e.g. leaf plucking and shoot thinning) and manually limiting yield (e.g. fruit thinning and adjusting crop load at veraison) to improve grape and subsequent wine quality; in theory removing nitrogen fertilizer could significantly reduce manual labour costs.

The establishment of a vineyard on marginal soil might be difficult in this scenario, however, removing weed competition at vine establishment is likely to have a greater impact on vine performance than nitrogen fertilizer.

6.6.3 No Chemical Nitrogen Fertiliser, with Substitution

Maintaining bare soil under the vine row by applying herbicide is the most common vineyard floor management practice worldwide (Chou and Heuvel 2019). However, the standard practice of bare soil under vines exacerbates vigour problems and has detrimental impacts on grape yield and quality (see above).

It is becoming common practice to use cover crops under the vine in vineyards with moderate to high vigour. Various studies have shown that cover crops decrease the soil nitrogen availability in Mediterranean vineyards. The reduction of soil nitrogen availability caused by the cover crops has potential negative effects on grapevines such as limited vine vigour and yield reduction, but these effects can vary according to soil fertility, grapevine cultivar, and the cover crop species. These potentially negative effects however can be judged as beneficial in fertile soils where vines have a high vigour. In those cases, the cover crop can reduce the excessive grapevine vegetative growth that is unfavourable to high-quality wine production. Moreover, a moderate nitrogen status in vines reduces the potential for fermentation haze or conditions that can lead to excess thiol formation (Bell and Henschke 2005).

The amount of legume nitrogen estimated to be recovered by cover cropped vines (12–15 kg N ha^{-1}), was similar to the calculated contribution from 40 kg of fertilizer-N applied to vines (11-12 kg ha^{-1}) (Ovalle et al. 2010). Again, to put this into perspective, the loss of nitrogen from established vineyards is estimated at 10-30kg N ha^{-1}, and therefore the nitrogen contributed by leguminous cover crops is more than enough to meet the nitrogen requirements of most New Zealand vineyards.

The use of leguminous cover crops and grape marc can replace more than 100% of the fixed nitrogen removed from the soil during harvest. Vine establishment should not be impacted from insufficient nitrogen if cover crops are grown and cultivated into the soil prior to vine planting. This scenario would provide the lowest risk in terms of maintaining yield and quality in marginal soils and would likely be the most palatable to winegrape growers.

6.6.4 Vineyard Gross Margins

Table 43: Vineyard Average Mature Gross Margin- Status Quo

Status Quo Vineyard	per ha	per plant (kg)
Plants/ha	1761	
Yield (Tonnes)	**10.0**	**5.7**
Income $/tonne	$1,285	
Income ($)	**$12,850**	**$7.30**
Total labour expenses	$4,515	$2.60
Fertiliser and lime	$257	$0.10
Other direct expenses ($)	$2,148	$1.20
Total direct expenses ($)	**$6,920**	**$3.90**
Gross Margin ($/ha)	**$5,930**	**$3.40**

Changes made were as follows:

Table 44: Scenario Changes made to Status Quo

Scenario	Status Quo	With Substitution		No Substitution	
Soil fertility	-	Fertile soil	Infertile soil	Fertile soil	Infertile soil
Yield	10	10	10	10	8
Packout	$1,285	$1,285	$1,285	$1,285	$1,285
Price	5	0	20	0	0
Nitrogen applied (kg/ha/year)	$257	$245	$416	$245	$245
Fertiliser cost	10	10	10	10	8

Table 45: Vineyard Per ha and National Results

Citrus Orchard Scenario	Gross Margin/ha	Area (ha)	National Gross Margin	Change from SQ ($)	% Change
Status Quo	$5,930	37,969	$225,156,170	$0	
Fertile with Substitution	$5,942	9,492	$220,751,450	$4,404,720	-2%
Infertile with Substitution	$5,771	28,477			
Fertile No Substitution	$5,942	9,492	$134,117,582	$91,038,588	-40%
Infertile No Substitution	$2,729	28,477			

6.7 Summary of Economic Impact on Permanent Horticultural Crops

A summary of the economic impacts of the removal of nitrogen fertiliser or substitution is:

Table 46: Summary of impact of no nitrogen fertiliser or substitution ($ million) relative to the base situation

	No N Fert	No N Fert, plus Substitutes
Pipfruit	-159.0	-2.2
Summerfruit	-4.1	-1.0
Kiwifruit	-156.9	-7.7
Avocado	-60.2	-2.1
Citrus	-7.9	-0.9
Viticulture	-91.0	-4.4
National	**-479.1**	**-18.3**

7.0 PERMANENT HORTICULTURE NITROGEN LOSS ESTIMATION

The status quo is nitrogen being readily available in synthetic and organic forms for use as fertiliser. Much of the research on losses in permanent tree crops is modelled using SPASMO[5] or Overseer software rather than measured. More and more measured data is becoming available but less so for the less common crops such as summerfruit, citrus and avocado.

The following sections summarise a literature search on nitrogen loss from each of the fruit crops.

7.1 Pipfruit

In a study based on the Waimea Plains of Nelson, Fenemore et al (2015) showed using SPASMO modelling that N leaching loss from apples over 40 years averaged between 3kg/ha/year and just over 18kg/ha/year. The nitrogen loss was not dependant on irrigation water allocation at all, rather it was soil type which indicated differences. It was based on applications of 40 kg N per year, applied as 20 kg/ha post-harvest foliar spray and 20 kg/ha solid fertilizer applied in spring.

- The Richmond was lowest at 3kg/ha/year and is a heavy soil with a high WHC[6].
- The Waimea soil was next lowest at about 7kg/ha/year. It is a heavy soil with only slightly lower WHC than Richmond.
- The Wakatu/Dovedale soil was next at about 9kg/ha/year. It is an intermediate soil.
- The Ranzau soil was by far the highest with 18kg/ha/year average loss. This is a gravelly soil with a low WHC.

Year to year variation was also a factor of significance with the Ranzau ranging from 5 to 30kg/ha/year and the Waimea ranging from 1 to 13 kg/ha/year.

A study in Hawke's Bay by Archer & Brookes (2018) using the same SPASMO modelling showed pipfruit loss averaging 15kg/ha/year across all soil types in Hawke's Bay, while the range was from 9kg/ha/year to 24kg/ha/year for different soils. This was under different N application rules to the Waimea study, of 40kg/ha/year applied in May and 2kg/ha applied monthly October through January as foliar applications.

Overseer results from 10 pipfruit growers in The AgriBusiness Group (2016) report were within similar ranges to the above.

[5] Soil Plant Atmosphere System Model - http://tools.envirolink.govt.nz/dsss/soil-plant-atmosphere-system-model/

[6] WHC = Water Holding Capacity

7.2 Summerfruit

The Hawke's Bay based study (Archer & Brookes, 2018) showed summerfruit losing 14 kg/ha/year on average across all soils types, while the range according to soil type was 9 to 23kg/ha/year. The applications were a mix of foliar and ground based applications best described by the following table from Archer & Brookes (2018).

Table 47: Summerfruit Nitrogen Applications made in the study by Archer & Brookes (2018)

Product	kg/ha	Month	Ground/Foliar
Nitrogen	25	Sept	Ground
	1	Oct	Foliar
	1	Nov	Foliar
	1	Dec	Foliar
	20	Jan	Ground
	20	Feb	Ground
Total N	**68**		

7.3 Kiwifruit

The Hawke's Bay based study (Archer & Brookes, 2018) using SPASMO modelling showed kiwifruit losing 13 kg/ha/year on average across all soil types, while the range according to soil type was 9 to 23 kg/ha/year. The application regime was ground based applications for the three months of spring, receiving 70, 50 and 20kg/ha/year in each respective month.

The AgriBusiness Group (2016) report showed 2 kiwifruit orchards in the Hawke's Bay at an average of 25kg/ha/year loss, which is at the upper end of the range of Archer and Brookes (2018).

A study in Poverty Bay flats (Gentile et al, 2014) was based on yields of 50t/ha and N fertiliser applied in September and October of 92 units and 46 units of N respectively. The modelled results showed losses ranging from 4 to 27 kg/ha/year of N loss. This was related to the level of drainage from the soil, with more well drained soils leaching more N. This is a limitation of all the SPASMO studies because a well-drained and less well drained soil should have N applied in different ways to reduce N loss from well drained soils.

Real bore nitrate concentration monitoring was conducted under a kiwifruit orchard in the Bay of Plenty on a sandy loam soil (McIntosh, 2009). The modelled nitrate leaching results from this study also ranged between 2 and 18 kg/ha/year of nitrogen.

A study using SPASMO applying 120 kg N/ha/year estimated much larger annual losses of between 40 and 75 kg N/ha/year (Green et al, 2007).

7.4 Avocado

A California based article (Lovatt, C, 2001). described the current practice as applying 140 kg N/ha/year to produce 12 t/ha avocado crop. This included an assumption of 30% loss to leaching, volatilisation and fixation (i.e. crop requirement with 100% efficiency of uptake was 100 kg/ha/year).

7.5 Citrus

A study in Poverty Bay flats (Gentile et al, 2014) based on yields of 40 t/ha and N fertiliser applied in September and October at 36 units and 27 units respectively, resulted in losses of nitrogen of between 8 and 30 kg/ha/year.

7.6 Vineyards

In the Waimea Plains study (Fenemore et al, 2015) the results for grapes were similar to those of apples. The average N loss over the 40 years was very similar by soil type, ranging from 4 to 18kg/ha/year. The fertilizer regime was assumed to involve application of an average of 5kg N per year.

The Hawke's Bay based study (Archer & Brookes, 2018) showed grapes losing 9kg/ha/year on average across all soils types, while the range according to soil type was 1 to 18kg/ha/year. Under this scenario the application regime was foliar applications only, from November through February totalling 21kg/ha/year.

A study by Gentile et al (2014) of the Poverty Bay flats using SPASMO with no fertiliser applied resulted in between 3 and 14 kg N/ha/year loss.

7.7 Overseer Modelling

In the status quo, the N leaching loss ranges from 4 to 16 kg N/ha/year, which is in line with the literature search done previously.

As expected, substitution with compost did not reduce nitrogen leaching compared to well applied nitrogen fertiliser. There may be some improvements from slower release, which in some situations may mean nitrogen is more efficiently taken up by roots (as they have a longer period where it is being released). However, in other situations the tree may have active roots when the nitrogen is applied and become less active by the time the nitrogen is half mineralised. This would increase risk of nitrogen loss and may result in the grower applying more than is necessary to compensate for the lack of ability to time applications and amounts very precisely. Also, with years of composting the soil organic matter level lifts, and its speed of internal mineralisation increases as conditions improve for soil biota and more organic matter is available. This is not taken account of in the Overseer budget, hence rather than similar results shown, it is possible that there would be an increase in nitrogen leaching under compost.

The no nitrogen substitution scenario simply deleted all fertiliser input applications, and reduced tonnages in line with what was estimated would occur in the gross margin analysis. Under this scenario less nitrogen is exported from the farm in the crop, and Overseer in some cases calculates that there is slightly more leaching loss (in that less nitrogen is taken up by the plant, hence more is left available within the soil).

Table 48: Nitrogen leaching summary (kgN/ha)

Crop	Status Quo	No N Fert	Using substitutes
Pipfruit	5.4	5.8	7.4
Summerfruit	4.2	4.2	4.2
Kiwifruit	6.4	6	9.8
Avocado	16.2	17.4	16.8
Viticulture	6	5	5

The avocado leaching loss is higher than other crops due to its low yield in the model. The yield was set at 10 t/ha; some blocks however are reaching upwards of 25 t/ha. At 25 t/ha the same model shows leaching loss in avocados of 13.4 kg N/ha/year, and likewise, the substitution and no N fertiliser scenarios would be similarly lower.

It should also be acknowledged that some growers are not applying fertiliser as best practice would recommend, but that this requires more science and extension support for growers using nitrogen fertilisers, rather than using organic substitutes.

Overall, the substitution scenario does not improve the environmental impact relative to a well-managed nitrogen fertiliser regime.

8.0 VEGETABLES AND ARABLE

8.1 Background

This analysis involved reports on the commercial vegetable and the arable sectors. This entails reporting on the five land use classes as described in the Statistics New Zealand (Stats NZ) Agricultural Production Statistics: June 2017 (final) being:

- A012200. Vegetable Growing (Under Cover)
- A012300. Vegetable Growing (Outdoors)
- A014500. Grain-Sheep or Grain-Beef Cattle Farming
- A014900. Other Grain Growing
- A015900. Other Crop Growing n.e.c.

The methodology used was a 'with N fertiliser' scenario which was created by matching the average output per crop to the nitrogen usage. An attempt was made to verify this by reference to the Stats NZ data on nitrogen fertiliser usage per land use class but it was not possible to get a sensible total of nitrogen fertiliser usage which matched the given data on nitrogen usage by land use class.

Total yield data was then factored by the average price per crop to derive the total value of output from the growing of the crops.

For the 'without N fertiliser' scenario the original intent was to create two without scenarios. The first was a 'without N with no substitution' which was created by assuming the possible yields for the crops without the use of nitrogen fertiliser, and without use of any nitrogen fertiliser alternatives. This was derived by reference to scientific information and discussions with growers. The area grown was factored by the assumptions as to yields and by the assumptions as to prices received, to derive the total value of output from the growing of the crops.

The second 'without N fertiliser' was no usage of nitrogen fertiliser, but with substitution of an alternative. There are, however, no alternatives in both the arable and the vegetable sectors to achieve the additional yields that are gained from the use of nitrogen fertiliser. The substitution scenario was intended to be made up of the cost of replacement of the crop lost as a result of the non-use of nitrogen fertiliser by the importation of the crop from overseas. Because the majority of arable crops are grown for export this was not a likely scenario in the Arable sector. In the vegetable growing sector there was little or no evidence of the likelihood of the lost production being substituted by import from overseas. The consumption of foodstuffs would just divert to alternative food products (e.g. rice instead of potatoes). The majority of economic activity which would occur in the 'without nitrogen fertiliser with substitution' scenario would therefore occur beyond the farm or horticulturists' financial performance.

8.2 Methodology

This involved determining the various crops grown under the Stats NZ categories noted above, which was split into three broad categories; Horticultural, Arable and Pastoral land uses. The proportion of crops grown relative to these categories is outlined below.

Table 49: Vegetable land use split

	A012200. Vegetable Growing (Under Cover)	A012300. Vegetable Growing (Outdoors)	A014500. Grain-Sheep or Grain-Beef Cattle Farming	A014900. Other Grain Growing	A015900. Other Crop Growing n.e.c.
Broccoli	2.6%	5.6%	0.0%	0.2%	0.0%
Cabbage	1.4%	2.2%	0.0%	0.0%	0.0%
Carrots	0.9%	4.9%	0.0%	0.4%	0.0%
Cauliflower	0.0%	2.0%	0.0%	0.0%	0.5%
Green beans	2.9%	0.9%	1.4%	3.0%	1.8%
Kumara	13.2%	3.1%	0.0%	0.0%	0.0%
Lettuce	10.2%	4.2%	0.0%	0.0%	0.0%
Melon water / rock	0.0%	0.4%	0.0%	0.0%	0.0%
Onions	0.9%	15.4%	0.0%	9.6%	0.0%
Peas	0.7%	4.1%	68.8%	33.6%	9.8%
Potatoes	1.1%	20.5%	16.8%	27.1%	3.1%
Pumpkin	3.3%	2.9%	0.0%	0.1%	0.2%
Squash (buttercup)	0.0%	14.0%	1.6%	9.5%	0.0%
Sweet corn	0.0%	6.1%	11.4%	16.4%	4.0%
Tomatoes	0.60%	1.10%	0.00%	0.00%	0.00%
Leafy vegetables	30.4%	0	0	0	0
Other vegetables or herbs	24.5%	0	0	0	0
Total outdoor vegetable crops (ha)	**70**	**36,538**	**566**	**3,263**	**364**

Table 50: Arable Land Use

	A012200. Vegetable Growing (Under Cover)	A012300. Vegetable Growing (Outdoors)	A014500. Grain-Sheep or Grain-Beef Cattle Farming	A014900. Other Grain Growing	A015900. Other Crop Growing n.e.c.
Wheat for bread / milling	0.0%	10.4%	9.5%	9.5%	5.9%
Wheat for other uses	0.0%	17.8%	16.5%	16.4%	5.6%
Barley	88.8%	16.6%	23.6%	17.1%	34.4%
Oats	0.0%	0.6%	4.9%	2.0%	4.0%
Other Grains	0.0%	1.8%	1.3%	1.7%	1.0%
Maize	0.0%	12.8%	7.0%	12.0%	32.1%
Peas	0.0%	4.8%	7.3%	5.8%	2.3%
Other Pulses	0.0%	0.0%	1.1%	0.5%	0.0%
Herbage Seed	0.0%	19.8%	21.0%	23.0%	3.4%
Vegetable Seed	11.2%	12.6%	4.5%	8.2%	5.0%
Total grain and seed crops (ha)	**30**	**12,705**	**44,386**	**73,387**	**2,321**

Table 51: Pastoral land use (ha)

	A012200. Vegetable Growing (Under Cover)	A012300. Vegetable Growing (Outdoors)	A014500. Grain-Sheep or Grain-Beef Cattle Farming	A014900. Other Grain Growing	A015900. Other Crop Growing n.e.c.
Dairy	75	6,101	23,184	12,382	134,688
Sheep and Beef	526	17,135	21,390	21,226	72,379
Arable	36	14,829	54,735	78,210	14,470
Horticulture	494	36,286	1,428	2,820	1,113
Other	291	2,545	4,054	4,429	23,545
Total	**1,422**	**76,896**	**104,792**	**119,067**	**246,194**

8.2.1 Financial Models

A range of financial models were developed – Refer Appendix 3 for details.

8.2.2 Arable Model

The Arable model is based on the MPI's Arable Farm Monitoring model. The productive assumptions for the arable model revenue are shown in Table 52.

Table 52: Assumptions made in the Arable model revenue.

	Hectares	t/ha	Total yield (tDM)	$/t	Total $
Ryegrass seed	40	1.5	60	2,200	132,000
Peas	40	9.0	360	400	144,000
Kale	-	12.0	480		-
Barley	40	8.0	320	390	124,800
Forage oats	-	3.5	-		-
Maize silage	40	20.0	800	200	160,000
Wheat	40	10.0	400	440	176,000
Total	**200**				**736,800**
Dairy grazing			**Total yield (kgDM)**	**$/kgDM**	**Total $**
Kale	40	12.0	480,000		144,000
Forage oats	40	3.5	140,000		42,000
Total	**80**		**620,000**		**186,000**

The assumptions as to yield and value result in the revenue for the model as shown in Table 53

Table 53: Revenue for the Arable model.

	$ Total	$/ha (eff)
Cereals	300,800	1,504
Small Seeds	132,000	660
Other Crops	304,000	1,520
Crop Residues	20,000	100
Total Crop	**756,800**	**3,784**
Grazing	186,000	930
Other Farm Income	8,600	215
Gross Farm Revenue	**$951,400**	**$4,929**

All expenditure is derived and expressed on a per hectare basis.

8.2.3 Horticulture – Leafy Greens – Root Crops

This model is based on work carried out by The AgriBusiness Group in the Lower Waikato[7], Horowhenua[8] and Plant and Food in the Canterbury[9] region for HortNZ. The leafy greens model was used to represent the horticultural land use mix in the Vegetable Growing (under cover) land use, and the Root Crops model was used in the remaining land uses because they best represented the crop mix in each of these scenarios.

8.2.4 Leafy Greens

The area, yield, and price assumptions which drive the revenue of the leafy green model are shown in Table 54.

Table 54: Revenue assumptions in the leafy green model.

	Hectares	t/ha	Total yield	$/t	Total $	$/ha
Cauliflower	10	30	302	1,150	346,739	4,334
Spinach	10	22	221	2,200	486,915	6,086
Onions	10	70	704	500	351,993	4,400
Broccoli	10	8	83	1,667	138,957	1,737
Squash	10	25	250	700	174,730	2,184
Spinach	10	22	221	2,200	486,915	6,086
Cabbage	10	60	599	1,150	688,870	8,611
Sweetcorn	10	16	155	350	54,378	680
Total	**80**				**2,729,497**	**34,119**

The expenditure items which drive the leafy greens financial model are driven by known variable costs per tonne of production by the individual crop types and fixed and administration costs also by each crop type as shown in Table 55.

[7] Nutrient Performance and Financial Analysis of Lower Waikato Horticulture Growers
[8] Nutrient Performance and Financial Analysis of Horticultural Systems in the Horizons Region
[9] Nitrate Leaching Under Various Land Uses in Canterbury

Table 55: Expenditure items for the leafy green financial model.

	Variable $/T	Fixed cost $/ha	Admin $/ha	Total Variable	Total Fixed	Total Admin
Cauliflower	484	7,750	453	145,932	77,500	4,530
Spinach	852	13,335	453	188,495	133,348	4,530
Onions	12	12,380	453	8,448	123,800	4,530
Broccoli	498	7,606	453	41,505	76,060	4,530
Squash	186	2,797	453	46,357	27,970	4,530
Spinach	852	13,335	453	188,495	133,348	4,530
Cabbage	129	9,978	453	77,017	99,781	4,530
Total				**$696,249**	**$671,807**	**$31,710**

8.2.5 Root Crops

The area yield and price assumptions which drive the revenue of the root crop model are shown in Table 56.

Table 56: Revenue assumptions in the root crop model.

	Hectares	t/ha	Total yield (t)	$/t	Total $	$/ha
Potatoes (summer)	10	50	500	450	225,000	4,500
Onions	10	45	450	500	225,000	4,500
Carrots	10	60	600	450	270,000	5,400
Squash	10	25	250	700	175,000	3,500
Barley (grain)	10	7	70	420	29,400	588
Total	**50**				**924,400**	**18,488**

The expenditure items which drive the leafy greens financial model are driven by known variable costs per tonne of Wages, Grading, Packing and Freight by the individual crop types and fixed and administration costs per hectare as shown in Table 57.

Table 57: Expenditure items for the root crop financial model ($/T).

	Wages	Grading	Packing	Freight
Potato	40	50	48	26
Onion	40	75	75	25
Carrots	46	26	41	19
Squash	55	24	30	54

8.3 Determination of Nitrogen Fertiliser Use in the With Scenario

The N use in each model was determined as follows:

8.3.1 Arable

Nitrogen use on the arable model was assumed by reference to The AgriBusiness client data.

The assumptions made are shown in Table 58.

Table 58: Nitrogen use in the Arable model.

Crop	Kg N / ha
Ryegrass seed	185
Peas	125
Kale	100
Barley	210
Maize silage	250
Wheat	250

8.3.2 Leafy Greens

The N usage by crop area in the leafy greens rotation was taken from the report into vegetable growing in the Lower Waikato region as is shown in Table 59.

Table 59: Nitrogen use in the leafy greens rotation

Crop	Kg N / ha
Cauliflower	235
Spinach	150
Onions	140
Broccoli	150
Squash	80
Spinach	150
Cabbage	400
Sweetcorn	150

8.3.3 Root Crops

The N usage by crop area in the root crops rotation was taken from the report into vegetable growing in the Lower Waikato, Horowhenua and Canterbury region as shown in Table 60.

Table 60: Nitrogen use in the root crops rotation.

Crop	Kg N / ha
Potatoes (summer)	350
Onions	140
Carrots	125
Squash	80
Barley (grain)	200

8.4 Determination of production in the without N scenario.

8.4.1 Arable

In the arable rotation the use of N has the dual advantages of allowing a more continuous range of depletive crops that can be grown and it increases the yields of those crops. Without nitrogen fertiliser there is a requirement to grow more restorative crops in order to build up the soil N bank with less depletive crops which are able to grow at a much lower average yield.

The rotation that represents the without N scenario constitutes two years of white clover as a restorative crop and then wheat and then peas. The wheat yield is reduced by 50%.[10] There is no grazing of dairy cows in the winter.

There is no economical substitute for N in the arable scenario.

8.4.2 Leafy Greens

In the Leafy Greens rotation the same issues apply as in the arable situation with the number of crops being diminished and the length of the rotation shortened to four years with two of them being pasture as a restorative measure and three crops being grown over the two years of the cropping rotation. The yields of those crops are reduced by the amount suggested in the Lower Waikato report, but the prices received are increased by 58% as suggested in the Deloittes[11] report because of scarcity of the produce. The extra pasture grown is sold as silage.

8.4.3 Root Crop

In the Root Crop rotation the same issues apply as in the arable situation with the number of crops being diminished and the length of the rotation shortened to five years with two of them being pasture as a restorative measure and three crops being grown over the three years of the cropping rotation. The yields of those crops are reduced by the amount suggested in the Lower Waikato report but the prices received are increased by 58% as suggested in the Deloittes report because of scarcity of the produce. The extra pasture grown is sold as silage.

[10] L. Litke, Z. Gaile: 2019. Effect of nitrogen fertilization on winter wheat yield and yield quality

[11] Deloitte: New Zealand's food story: The Pukekohe hub. Prepared for Horticulture New Zealand

8.5 Results

The following results were obtained:

8.5.1 With N Fertiliser Scenario

Table 61: Economic analysis summary, with N fertiliser

Vegetable Growing (Under Cover)	Area (ha)	Gross Farm Revenue ($)	Farm Operating Expenses ($)	Cash Farm Surplus ($)
Arable	36	177,444	77,613	99,831
Vegetables	493.9	16,851,231	8,641,802	8,209,428
Total				**8,309,259**
Vegetable Growing (Outdoors)	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	14,829	73,093,620	31,970,784	41,122,835
Vegetables	36,286	670,846,324	479,240,741	191,605,583
Total				**232,728,418**
Grain-Sheep or Grain-Beef Cattle Farming	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	54,735	269,787,829	118,003,850	151,783,979
Vegetables	1,428	26,408,259	18,865,593	7,542,666
Total				**159,326,645**
Other Grain Growing	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	78,210	385,498,569	168,615,150	216,883,419
Vegetables	2,820	52,139,858	37,247,792	14,892,066
Total				**231,775,485**
Other Crop Growing n.e.c.	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	14,470	71,322,630	31,196,162	40,126,468
Vegetables	1,113	20,567,900	14,693,344	5,874,556
Total				**46,001,024**

Table 62: Summary economic analysis with N fertiliser ($ million)

	Area (ha)	Gross Farm Revenue ($m)	Farm Operating Expenses ($m)	Cash Farm Surplus ($m)
Arable	162,280	800	350	450
Vegetables	42,141	787	559	228
Total		1,587	909	**678**

8.5.2 Without N Fertiliser Scenario

Table 63: Economic analysis summary, without N fertiliser

Vegetable Growing (Under Cover)	Area (ha)	Gross Farm Revenue ($)	Farm Operating Expenses ($)	Cash Farm Surplus ($)
Arable	36	105,696	67,779	37,917
Vegetables	493.9	13,152,517	7,820,001	5,332,516
Total				**5,370,433**
Vegetable Growing (Outdoors)	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	14,829	43,538,825	27,919,678	15,619,147
Vegetables	36,286	471,239,789	350,065,505	121,174,283
Total				**136,793,430**
Grain-Sheep or Grain-Beef Cattle Farming	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	54,735	160,701,373	103,051,255	57,650,118
Vegetables	1,428	18,550,631	13,780,534	4,770,097
Total				**62,420,215**
Other Grain Growing	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	78,210	229,625,441	147,249,456	82,375,985
Vegetables	2,820	48,680,036	27,857,007	20,823,029
Total				**103,199,014**
Other Crop Growing n.e.c.	**Area (ha)**	**Gross Farm Revenue ($)**	**Farm Operating Expenses ($)**	**Cash Farm Surplus ($)**
Arable	14,470	42,483,920	27,243,210	15,240,710
Vegetables	1,113	14,448,038	10,732,879	3,715,159
Total				**18,955,869**

Table 64: Summary economic analysis without N fertiliser ($ million)

	Area (ha)	Gross Farm Revenue ($m)	Farm Operating Expenses ($m)	Cash Farm Surplus ($m)
Arable	162,280	476	306	171
Vegetables	42,141	566	410	156
Total		1,043	716	**327**

8.5.3 Summary: With N Fertiliser versus without N Fertiliser

Table 65: Summary - With N Fertiliser versus without N Fertiliser ($ million)

	Gross Farm Revenue ($m)	Farm Operating Expenses ($m)	Cash Farm Surplus ($m)
N fertiliser	1,587	909	678
No N fertiliser	1,043	716	327
Difference	**-544**	**-193**	**-351**

The differentiation between arable and vegetables are:

Table 66: Arable and Vegetables - With N Fertiliser versus without N Fertiliser ($ million)

	Gross Farm Revenue ($m)	Farm Operating Expenses ($m)	Cash Farm Surplus ($m)
Arable			
With N Fertilisers	$800	$350	$450
Without N Fertilisers	$476	$306	$171
Difference	**-$324**	**-$44**	**-$279**
Vegetables			
With N Fertilisers	$787	$559	$228
Without N Fertilisers	$566	$410	$156
Difference	**-$221**	**-$149**	**-$72**

8.6 Comment

8.6.1 With Scenario

Nitrogen has the following impacts on the range of land uses modelled:

- In the arable sector it provides for a much greater range of crops that can be grown continuously for a much longer period and increases the yield of most of those crops significantly.
- It allows the arable sector the opportunity to grow a significant amount of winter feed which growers can offer to the dairy industry.
- For the vegetable industry it provides the ability to grow a greater range of crops continuously and at a much higher yield.
- It allows the vegetable industry to provide a greater range of fresh vegetables to the NZ consumer at an affordable cost.

8.6.2 Without Scenario no substitution.

The complete loss of Nitrogen to farming systems would have the following impacts:

- A significant impact on the arable industry on both the range of crops which can be grown and their subsequent profitability which in turn would have major impacts on land values.
- A significant impact on the commercial vegetable production sector on both the range of crops which they were able to grow, the yields possible, and their subsequent profitability which again would have major impacts on their land values.

- A significant proportion of the products produced are exported so there would be the flow on impacts to the supporting and exporting industries of the loss of throughput and profitability.

8.6.3 Without Scenario with substitution.

- There are no substitutes that are available in the arable and commercial vegetable production sector that are able to provide for the systems that have been developed for both the range of crops and the yields achieved.
- The major arable crops grown in New Zealand which are consumed domestically are the cereal crops of Wheat and Barley and the feed crop of Maize. Both of the cereal crops could be easily substituted by importing both crops from Australia at a very similar price to the price that they are supplied at in New Zealand as they are produced in extensive systems in Australia at a much lower cost compared to in New Zealand. Maize could also be imported at a similar cost to that in New Zealand or it could be substituted with an alternative feed supplement.
- The other specialist seed crops which are grown in New Zealand are predominantly exported and they can be grown successfully in other areas of the Southern Hemisphere.
- The production of Leafy Greens in New Zealand is entirely for domestic consumption. The demand for leafy greens is quite elastic as to the price so if there is less available on the market and the price is higher, as has been modeled in this exercise, consumers will change to other alternatives such as frozen greens or go to another alternative.
- For the Root Crops of Potatoes and Onions the amount produced in the without scenario is approximately half that produced in the 'with' scenario. This would be sufficient to meet the local demand, as the remainder has been traditionally exported. Demand for these vegetables however is also elastic and there has been an increasing trend for consumers to substitute cheaper and more convenient alternatives such as rice and pasta.
- Carrots will reduce by approximately half and the price will lift by approximately half in the without scenario. Demand is again highly elastic to price and so consumers are most likely to substitute with other alternatives.

8.7 Import Substitution

As noted above, in the absence of nitrogen fertiliser, growing arable grain crops such as wheat, barley and maize becomes problematic, and in all probability the grain would be imported, at a similar cost to producing it domestically, with nitrogen fertiliser. The cost of this is illustrated below.

Table 67: Estimate of grain imports and cost

	5 Year Av Production (tonnes)	Assume 80% Substitution (tonnes)	Import cost to wharf ($/t)	Total Cost ($ million)
Wheat	412,518	330,014	$370	$122
Barley	376,876	301,501	$337	$102
Maize	208,269	166,616	$376	$63
				$286

Source: Statistics NZ

The 'no nitrogen fertiliser + substitution' cost therefore would be the cost of not using nitrogen fertiliser ($351m), plus the cost of increased imports, as above, giving a total cost of $637 million.

8.8 Arable and Vegetable Nitrogen Leaching

Modelling via Overseer as to the impact on nitrogen leaching rates showed the following:

Table 68: Arable and Vegetable N leaching, with and without N fertiliser (kg N/ha/year)

Model	Base	No N Fertiliser
Arable	48	28
Root Vegetables	79	20

As illustrated, not applying nitrogen fertiliser has a significant impact on N leaching levels.

9.0 MACRO ECONOMIC ANALYSIS

9.1 The Multiplier Effect

The multiplier effect is where a change in spending in one area of the economy stimulates a change in spending in other areas. For example, farmers spend money on buying in inputs such as fertiliser, which in turns means the fertiliser company spends money on inputs and wages, with the workers in turn spending money on further services they need, and so on.

In economic jargon, this is explained as: if there is an increase in final demand for a particular product (or service), it can be assumed that there will be an increase in the output of that product, as producers react to meet the increased demand: this is the 'direct effect'. As these producers increase their output, there will also be an increase in demand on their suppliers and so on down the supply chain: this is the 'indirect effect' (i.e. Type I multipliers). As a result of the direct and indirect effects the level of household income throughout the economy will increase as a result of increased employment. A proportion of this increased income will be re-spent on final goods and services: this is the 'induced effect' (i.e. Type II multipliers) (Butcher, 1985).

Value-add multipliers provide estimates of value added to products resulting from the sale of a good or service to another sector. This Value Add includes the cost of employee compensation, indirect business taxes, and proprietary and other property income.

In this study Value-add multipliers were applied across the changes in income for the relevant sector. This gives an indication of the impact on GDP of change in economic activity as a result of not using nitrogenous fertilisers, or the use of substitutes.

The multipliers used were the Type II multipliers for each of the sectors, derived at the national level. These were applied across the economic differences calculated for each sector.

In addition, both forward and backward linkages were used: backward relate to the services each industry buys in to provide their goods, while forward linkages relate to the processing/manufacturing process through to the wharf.

9.2 Summary of Farm-Gate Impact

The impact at the farm gate, across the four sectors analysed, are:

Table 69: Summary of Impacts ($ million)

	Without N fertiliser	Without N fertiliser, + Substitution
Dairy	-$824	-$1,213
Sheep & Beef	-$30	-$238
Permanent Horticulture	-$479	-$18
Vegetables & Arable	-$351	-$637
Total	**-$1,684**	**-$2,105**

Within the input/output industry tables, the arable industry is included within the sheep & beef industry, and vegetables are included within the horticultural industry. Re-aligning the above table gives:

Table 70: Summary of Direct Impacts aligning with the I/O tables ($ million)

	Without N fertiliser	Without N fertiliser, + Substitution
Permanent Horticulture & Vegetables	-551	-149
Sheep & Beef & Arable	-309	-743
Dairy	-824	-1,213
Total	**-1,684**	**-2,105**

9.3 Macro-Economic Modelling Summary

- Gross output and value-added impacts are expressed in NZ$$_{2016}$millions and are for a single year.
- Employment impacts are expressed in Modified Employee Counts or MECs. MECs are equivalent to a head count of employees and working proprietors. Importantly, these are end-of-February 2016 equivalents. Thus, they may not pick up impacts on seasonal workers, including troughs and peaks, which exist at other times throughout the year.
- The modelling considers direct, indirect and induced impacts associated with N fertiliser use, principally through farming but also direct losses to the fertiliser industry itself. This includes the loss of forward linkages to meat and dairy processing.
- Small interdependencies exist between the farming industries (horticulture and fruit growing' sheep, beef cattle and grain farming; and dairy cattle farming), processing industries (meat and meat produce manufacturing and dairy product manufacturing) and fertiliser and pesticide manufacturing industry which are not fully accounted for.

9.3.1 Scenario 1: Without Fertiliser

This scenario involves simply modelling what would be the economic impacts if N fertiliser was no longer used and no adaptation took place. In the real world, unlike the scenario modelled, farmers would likely not only change their farm systems, but also change their land use, potentially to farming activities not seen before. So, assuming impacts can be measured, with and without fertiliser, the figures below arguably overstate the impact. Some key caveats of the findings are given below.

General equilibrium effects would kick in; not only structural change, but also pricing, substitution and transformation impacts. Reduced earnings at the farm gate would, for example, see investors move capital out of farming, freeing up capital for uses in other types of business within New Zealand. Thus, the impacts are likely to be less than those portrayed by a simple multiplier analysis. Significantly more work would be required to capture these changes, particularly if adaptation through time was considered, as well as the myriad of other general equilibrium impacts that might occur as the New Zealand rebalances to the removal of N fertiliser. Overall, the real economic impact is likely to be significantly less than stated.

Table 71: Summary of macro-economic impacts without nitrogen

	Units	Horticulture and fruit growing	Sheep, beef cattle and grain farming	Dairy cattle farming	Meat and meat product manufacturing	Dairy product manufacturing	Fertiliser and pesticide manufacturing	Total
Gross Output	NZ$2016m	-$2,602	-$1,447	-$4,906	-$1,909	-$7,866	-$1,068	-$19,798
Value Added	NZ$2016m	-$1,142	-$617	-$1,929	-$530	-$2,173	-$312	-$6,703
Employment	MECs2016*	-19,430	-7,790	-22,960	-6,820	-14,730	-2,020	-$73,760

* MEC = Modified Employment Counts (a head count of employees and work proprietors)

To avoid double counting, indirect and induced impacts calculated for meat product manufacturing and dairy product manufacturing exclude downstream impacts on dairy cattle farming and sheep, beef cattle and grain farming (and subsequent rounds therefrom).

Overall therefore, the impact is:

- A drop in gross output by $19.8 billion
- A drop in Value Add (GDP) of $6.7 billion
- A reduction in employment by 73,760

(refer Appendix 4 for more detailed analysis)

9.3.2 Scenario 2: Without Fertiliser, but with Substitutes

The scenario involving substitution of inputs to replace fertiliser entails structural change in the economy and is not very amenable to analysis under a multiplier type approach.

At an initial glance, because the purpose of substitution is presumably to allow for production on farms to be maintained under constraints of limited fertiliser inputs, outputs from farms will be maintained. Thus, forward linkages to processing (particularly meat processing and dairy processing will not be affected) i.e. zero economic impacts to processing. By corollary, the industries that normally supply inputs to processors, labour employed in processing, and so on, will also not be affected. Similarly, if it is assumed (except for fertiliser) that farms will continue to purchase as they currently do from other supplies (e.g. fencing contractors, electricity etc) then there will not be any substantial backward-linkage effects from the farming industries either. The exception will be the loss of income on farms themselves which will generate some flow on impacts in terms of spending within the economy. So, overall under this type of multiplier analysis the net effects would be:

- Losses in value added on farms themselves (i.e. NZ_{2016}$-149m for the horticulture and fruit growing industry, ~NZ_{2016}$-740m for the sheep, beef cattle and grain farming industry, and ~NZ_{2016}$-1,210m for dairy cattle farming).
- Losses directly to fertiliser manufacturing and negative flow on backward indirect effects this causes (i.e. same as assessed for the without fertiliser scenario or ~NZ_{2016}$-540m).
- Gains directly to domestic industries responsible for providing additional inputs to substitute fertiliser (e.g. maize growers) and positive flow on backward indirect effects this causes (but only negligible gains if substitutes were imported instead of sourced domestically).
- Relatively small-to-modest induced effects caused by losses in income to farm owners.
- In reality, the impacts would be more complex than as represented by such a simple multiplier type approach. In particular:

- The additional demand for farm-based inputs to substitute fertiliser would generate a shortage in supply and would raise the price of these inputs. Landowners would be faced with decisions about whether to continue current practices of supplying to processors or instead supply more to other farmers – some structural change would ensue. Overall, the expectation would be for some losses of supply to processors, with subsequent flow on effects, but the relativities of these changes cannot be assessed through multiplier-type approach. Similarly, structural changes within farms in terms of what is chosen to be produced will change farm's demands for supplies of goods and services, but it is not possible to account for such changes in a multiplier-type approach. Capturing these impacts would require the use of a general equilibrium approach supported by in-depth understanding of capacities for structural and land use change within agriculture – which is beyond the scope of this work.
- Some input substitution is also likely to be sourced from imports (e.g. palm kernel). Depending on the size of the value of these inputs this will potentially impact on exchange rates and subsequently commodity prices, with flow-on impacts to demand/supply relationships.

9.4 A note on Environmental Impacts

As noted at the start of the report, the use of nitrogenous fertilisers has both a direct and indirect influence on water quality. To date, these impacts – i.e. loss of ecosystem services associated with degradation of waterways, have largely been internalised by society.

There are a range of costs associated with restoration of ecosystems. These include reduction in farm value added associated with clean up (including mitigations) if farmers become responsible for this, increases in the value added of agricultural services and construction associated with activities aimed at N mitigation (e.g. contracting services for fencing, building for feedlots or wetlands), and negative impacts to communities as rates/taxes are likely to be needed to clean up waterways.

10.0 DISCUSSION

Nitrogen fertiliser is a crucial input into the New Zealand primary sector both as a nutrient for plant growth, and as a (cheap) substitute for supplementary feed. The issue is the externality this imposes on the environment, particularly via the indirect impact through grazing animals.

If nitrogen fertiliser was not available, then the transition cost to farmers and the economy would be considerable. Inevitably, farming systems would evolve, which is difficult to capture directly via the modelling; farms and orchards would still need nitrogen inputs in order to function, but these would be from 'natural' sources, such as legumes and composts, and in general the vast majority of the “no nitrogen fertiliser” systems which evolved would be of lower production intensity.

- Some pastoral farming systems would extensify, reducing output to correlate with a lower nitrogen input
- Many horticultural, vegetable and arable operations would look to use legume cover crops, resulting in a combination of either an expansion in area grown, and/or a lower level of output.
- Some pastoral farming systems would remain relatively intensive, using supplements as a substitute, with potentially much of this imported.
- As noted in this report, the main sectors impacted would be dairying, vegetable production, and arable farming.
- Within dairying, the main region affected would be Canterbury, given the importance of nitrogen fertiliser within an irrigated system.

One thing is certain – dairy shed effluent would become an even more valuable fertiliser, because of its nitrogen content, and the inability of this source to meet overall requirements!

11.0 REFERENCES

11.1 Pastoral

Ball, R, 1969. Legume and nitrogen fertiliser in New Zealand pastoral farming. Proceedings of NZ Grasslands Society, 31, 117-126

Cameron, K., Hong, J, Di., Moir, J., Christie, R., Pellow, R., 2005. Using Nitrogen: What is Best Practice? South Island Dairy Event (SIDE) Proceedings, Lincoln University

Clark, D.A., Harris, S.L., 1996. White clover or nitrogen fertiliser for dairying? Agronomy Society of New Zealand Special Publication No. 11 / Grassland Research and Practice Series No. 6

Field, T.R.O., Ball, R., 1978. Tactical Use of Fertilizer Nitrogen. Proceedings Agronomy Society of New Zealand 8; 129-133

Ledgard, S./F., Steele, K.W., 1993. Biological nitrogen fixation in mixed legume/grass pastures. Plant & Soil 141: 137-153

11.2 Horticulture

11.2.1 General

BioRich (2019) Conventional Compost Hill Lab Results. Retrieved from http://www.biorich.co.nz/our-compost

Concklin, M. (2016). Nutrient Management for Tree Fruit. University of Connecticut.

D Neilsen and G. H Neilsen (2002). *Efficient use of Nitrogen and Water in High Density Apple Orchards*. Hort Technology 12, (1) pp 19-25

Fruit tree nutrition – monitoring and assessing the nutrient needs of the orchard. British Columbia Fruitgrowers Association.

Nitrogen Management Training. University of California.

Nutrient Requirements for tree fruits and small fruits. University of Maryland Co-operative Extension. Aug 2005. Regulatory Citation COMAR 15.20.08.05.

Ontario Ministry of Agriculture, Food and Rural Affairs (2018). Soil management, fertiliser use, crop nutrition and cover crops for food production. Retrieved from http://www.omafra.gov.on.ca/english/crops/hort/soil_fruit.htm#Nitrogen

S-maps (2019). Soil Maps. Retrieved fromhttps://smap.landcareresearch.co.nz/

Using Organic Nutrient Sources. Penn State College of Agricultural Sciences. Agricultural Research and Co-operative Extension.

11.2.2 Pipfruit

Booth, E. (1963). Post harvest urea sprays show striking results with apples. The Grower July 20, 1963 p863 and The Grower Nov 16, 1963.

Cheng, L. (2013). Growth performance of apple nursery trees in relation to reserve nitrogen and carbohydrates. Compact Fruit Tree, 36, 2 pp46-49.

De Villiers J, Kotze WAG, Joubert M (1983) Effect of seaweed foliar sprays on fruit quality and mineral nutrition. The Deciduous Fruit Grower 33: 97–101.

Hee-Myong Ro & Jin-Myeon Park (2000) Nitrogen requirements and vegetative growth of pot-lysimeter-grown ‘Fuji’ apple trees fertilized by drip irrigation with three nitrogen rates, The Journal of Horticultural Science and Biotechnology, 75:2, 237-242.

Neilson, D., Neilson, G.H. (2002). Efficient use of Nitrogen and Water in High Density Apple Orchards. Hort Technology 12, pp19-25.

NZ Statistic Annual 2017/18. NZ Apples and Pears.

Pavek, P. and D. Granatstein. 2014. The potential for legume cover crops in Washington apple orchards. PMS Technical Note 22, USDA-NRCS, Spokane, WA. 34 pp. (2,5,6).

Sanchez, E., Righetti, T. (1990). Excess Vigour, Poor Quality can result from excessive nitrogen. Good Fruit Grower, Oct 15, 1990, pp12-16.

Sanchez, E.E., Cichon, L.I., Fernandez, D. Effects of soil management on yield, growth and soil fertility in an organic apple orchard.

Swarts, N. (2016). Strategically managing water and nitrogen. Apple and Pear Australia.

Swarts, N. (2016). Precision fertigation to improve apple orchard productivity. Apple and Pear Australia.

Thalheimer, M. and Paoli, N. (2002). Effectiveness of various leaf-applied biostimulants on productivity and fruit quality of apple. Acta Hortic. 594, 335-339.

Tiller, L.W., Roberts, H.S., Bollard, E.G. (1959). The Appleby Experiments. DSIR, Bulletin 129.

11.2.3 Summerfruit

Rufat, J., DeJong, T.M. (2001). Estimating seasonal nitrogen dynamics in peach trees in response to nitrogen availability. Tree Physiology 21, pp 1133-1140.

Summerfruit New Zealand Statistics.

11.2.4 Kiwifruit

C. J. Clark, S. F. Ledgard, Uptake of 15N by Kiwifruit Vines from Applications of Nitrogen Fertilizer Prior to Budbreak, Annals of Botany, Volume 71, Issue 4, April 1993, Pages 311–316.

Morton, A (2013). *Kiwifruit (Actinidia spp.) vine and fruit responses to nitrogen fertiliser applied to the soil or leaves*. Massey University, Palmerston North. Retrieved from: https://mro.massey.ac.nz/bitstream/handle/10179/6856/02_whole.pdf

Regional Production analysis. New Zealand grown kiwifruit. Zespri Annual Review 2017/18, pp40-41.

Zhao Z, Tong Y, Wang J. Nutrient uptake and distribution in field-grown Kiwifruit vines. ISHS Acta Hort. 2013; 984, 219–226.

11.2.5 Avocado

Barber. R. F. *et al* (1986) in the MAF publication 'Fertiliser Recommendations for the horticultural crops, pp17-18,

New Zealand Avocado (2019) Annual Report page 22-24. Retrieved from file:///C:/Users/leander.archer/Downloads/NZA%20Annual%20Report%202019%20FA%202.pdf

New Zealand Avocado (2018). Becoming an Avocado Grower. Retrieved from https://industry.nzavocado.co.nz/grow/becoming-an-avocado-grower/

Rosecrance, R *et al* (2012) 'Patterns of Nutrient Accumulation in Hass Avocado Fruit' Better Crops with Plant Food 2012 Vol.96 No.1 pp.12-13

11.2.6 Citrus

Citrus Industry Statistics (26/08/19) retrieved from: https://www.citrus.co.nz/frequently-asked-questions/

Citrus Nutrition (16/07/2019). New South Wales Department of Primary Industries.

HortResearch (2001). Growing Citrus in New Zealand, A Practical Guide. Retrieved from https://www.citrus.co.nz/wp-content/uploads/2018/10/NZCGI-Growing-Citrus-in-NZ-A-Practical-Guide.pdf

Obreza, T.A., Morgan, K.T. (2008). Nutrition of Florida Citrus Trees. IFAS Extension, University of Florida.

11.2.7 Vineyard

Austin, Craig N., Gary G. Grove, James M. Meyers, and Wayne F. Wilcox. 2011. 'Powdery Mildew Severity as a Function of Canopy Density: Associated Impacts on Sunlight Penetration and Spray Coverage.' American Journal of Enology and Viticulture 62 (1): 23 – 31. https://doi.org/10.5344/ajev.2010.10077.

Bell, Sally-Jean, and Paul A. Henschke. 2005. 'Implications of Nitrogen Nutrition for Grapes, Fermentation and Wine.' Australian Journal of Grape and Wine Research 11 (3): 242–95. https://doi.org/10.1111/j.1755-0238.2005.tb00028.x.

Bell, Sally-Jean, and A Robson. 1999. 'Effect of Nitrogen Fertilization on Growth, Canopy Density, and Yield of Vitis Vinifera L. Cv. Cabernet Sauvignon.' American Journal of Enology and Viticulture, no. 50: 351–58.

Chou, Ming-Yi, and Justine E. Vanden Heuvel. 2019. 'Annual Under-Vine Cover Crops Mitigate Vine Vigor in a Mature and Vigorous Cabernet Franc Vineyard.' American Journal of Oenology and Viticulture 70 (1): 98–108. https://doi.org/10.5344/ajev.2018.18037.

Keller, Markus. 2015. The Science of Grapevines: Anatomy and Physiology. Second Edition. San Diego, CA: Elsevier Inc.

Ovalle, Carlos, Alejandro del Pozo, Mark B. Peoples, and Arturo Lavín. 2010. 'Estimating the Contribution of Nitrogen from Legume Cover Crops to the Nitrogen Nutrition of Grapevines Using a 15N Dilution Technique.' Plant and Soil: An International Journal on Plant-Soil Relationships, no. 1–2: 247. https://doi.org/10.1007/s11104-010-0379-1.

Thalheimer, M, and N Paoli. 2002. 'Effectiveness of Various Leaf-Applied Biostimulants on Productivity and Fruit Quality of Apple.' Acta Hort 594.

Wheeler, SJ, and GJ Pickering. 2003. 'Optimizing Grape Quality through Soil Management Practices.' J Food Agric Environ, no. 1: 190–97.

Wolf, Tony K. 2008. Wine Grape Production Guide for Eastern North America. Ithaca, New York: Natural Resource, Agriculture, and Engineering Service.

11.2.8 Leaching Loss

AgriBusiness Group (2015). Nutrient Performance and Financial Analysis of Horticultural Systems in the Waimea Catchment. Horticulture New Zealand. Retrieved from http://www.hortnz.co.nz/assets/Natural-Resources-Documents/Nutrient-Performance-and-Financial-Analysis-of-Horticultural-Systems-on-the-Waimea-Plains-Final-May-2015.pdf

AgriBusiness Group (2016). Hawkes Bay Horticultural Nutrient and Financial Benchmarking Results. Horticulture New Zealand. Retrieved from: http://hortnz.co.nz/assets/Natural-Resources-Documents/Hawkes-Bay-Horticultural-Nutrient-and-Financial-Benchmarking-Results-FINAL.pdf

Archer, L and Brookes, J. (2018). *Modelling Water Restrictions and Nutrient Losses for Horticulture in the TANK Catchment – An Economic Analysis*. Hawke's Bay Regional Council. Retrieved from: https://www.hbrc.govt.nz/assets/Document-Library/TANK/TANK-Key-Reports/Modelling-Water-Restrictions-and-Nutrient-Losses-for-Horticulture-AgFirst-2018.pdf

Fenemore, A., Green, S., Dryden, G., Samarasinghe, O., Newsome, P., Price, R., Betts, H. and Lilburne, L. (2015). *Crop Production, Profit and Nutrient Losses in relation to Irrigation Water Allocation and Reliability – Waimea Plains, Tasman District*. Ministry for Primary Industries, Wellington NZ. Technical paper no: 2015/36. Retrieved from https://www.mpi.govt.nz/dmsdocument/9899/send

Gentile, R., Green, S., Mason, K., van den Dijssel, C., Johnstone, P. and Clothier, B. (2014). Land Management Practices and Nutrient Losses from Farms on the Poverty Bay Flats. Gisborne District Council. Retrieved from http://www.hortnz.co.nz/assets/Uploads/Plant-and-Food-Land-management-practices-and-nutrient-losses-from-farm-.pdf

Green, Sivakumaran, van den Dijssel, Mills, Blattmann, Snelgar, Clearwater and Judd (2007). *A water and nitrogen budget for 'Hort 16A' kiwifruit vines.* Acta Hortic. 753, 527-535. https://www.ishs.org/ishs-article/753_69

Lovatt, C. (2001). Nitrogen Fertilisation of the Hass Avocado in California. AvoResearch Volume 1, Issue 3, California Avocado Commission. Retrieved from: http://www.avocadosource.com/journals/avoresearch/avoresearch_01_03_2001_lovatt_n%20fert.pdf

McIntosh, J. (2009). Kiwifruit and Dairying Effects on Shallow Groundwater. Environment Bay of Plenty publication 2009/06. Retrieved from: https://www.boprc.govt.nz/media/32389/EnvReport-0906-Kiwifruitanddairyingeffectsonshallowgroundwater.pdf

Parliamentary Commissioner for the Environment (PCE) (2004). *Growing for good - Intensive farming, sustainability and New Zealand's environment*. Wellington, NZ. Retrieved from: https://www.pce.parliament.nz/media/1684/growing-for-good-full.pdf

11.3 Macro-Economic Analysis

Butcher, G.V. (1985). Regional Income output and employment multipliers: Their uses and estimates of them. Cost Benefit Handbook, Volume Four. A commissioned study for the Economics Division, Ministry of Agriculture and Fisheries, 1985

12.0 APPENDIX 1: DAIRY FARM SCENARIO PHYSICAL SUMMARY

Northland				
		With N	Without N	Without N/ + Supplement
Farm	Effective Area (ha)	140	140	140
	Stocking Rate (cows/ha)	2.2	1.9	2.2
	Potential Pasture Growth (tDM/ha)	10	10	10
	Nitrogen Use (kgN/ha)	112	0	0
Herd	Cow Numbers (1st July) (hd)	319	281	319
	Peak Cows Milked (hd)	309	272	309
Production	Milk Solids total (kg)	102,709	90,295	102,425
	Milk Solids per ha (kg)	734	645	732
	Milk Solids per cow (kg)	332	332	331
Feeding	Pasture Offered per ha (tDM)	9.2	7.9	7.8
	Supplements Offered per ha (tDM)	3.0	2.7	4.3

Waikato/BoP				
		With N	Without N	Without N/ + Supplement
Farm	Effective Area (ha)	127	127	127
	Stocking Rate (cows/ha)	2.8	2.5	2.8
	Potential Pasture Growth (tDM/ha)	14	14	14
	Nitrogen Use (kgN/ha)	128	0	0
Herd	Cow Numbers (1st July) (hd)	373	328	373
	Peak Cows Milked (hd)	361	317	361
Production	Milk Solids total (kg)	130,265	114,522	130,198
	Milk Solids per ha (kg)	1,026	902	1,025
	Milk Solids per cow (kg)	361	361	361
Feeding	Pasture Offered per ha (tDM)	12.8	11.2	11.0
	Supplements Offered per ha (tDM)	3.3	2.9	5.3

Taranaki				
		With N	Without N	Without N/ + Supplement
Farm	Effective Area (ha)	105	105	105
	Stocking Rate (cows/ha)	2.7	2.3	2.7
	Potential Pasture Growth (tDM/ha)	11	11	11
	Nitrogen Use (kgN/ha)	148	0	0
Herd	Cow Numbers (1st July) (hd)	295	254	295
	Peak Cows Milked (hd)	285	245	285
Production	Milk Solids total (kg)	102,379	88,003	102,409
	Milk Solids per ha (kg)	975	838	975
	Milk Solids per cow (kg)	359	359	359
Feeding	Pasture Offered per ha (tDM)	10.5	9.0	8.7
	Supplements Offered per ha (tDM)	3.5	3.0	5.5

Canterbury				
		With N	Without N	Without N/ + Supplement
Farm	Effective Area (ha)	231	231	231
	Stocking Rate (cows/ha)	3	2	3
	Potential Pasture Growth (tDM/ha)	12	12	12
	Nitrogen Use (kgN/ha)	235	0	0
Herd	Cow Numbers (1st July) (hd)	791	585	791
	Peak Cows Milked (hd)	761	563	761
Production	Milk Solids total (kg)	321,484	237,742	321,435
	Milk Solids per ha (kg)	1,392	1,029	1,391
	Milk Solids per cow (kg)	422	422	422
Feeding	Pasture Offered per ha (tDM)	14	10	9
	Supplements Offered per ha (tDM)	3	2	9

Southland				
		With N	Without N	Without N/ + Supplement
Farm	Effective Area (ha)	205	205	205
	Stocking Rate (cows/ha)	2.8	2.4	2.8
	Potential Pasture Growth (tDM/ha)	13	13	13
	Nitrogen Use (kgN/ha)	172	0	0
Herd	Cow Numbers (1st July) (hd)	602	512	602
	Peak Cows Milked (hd)	581	495	581
Production	Milk Solids total (kg)	242,234	206,236	242,229
	Milk Solids per ha (kg)	1,182	1,006	1,182
	Milk Solids per cow (kg)	417	417	417
Feeding	Pasture Offered per ha (tDM)	11.8	10.1	10.1
	Supplements Offered per ha (tDM)	2.9	2.5	4.8

13.0 APPENDIX 2: SHEEP & BEEF FARM SCENARIO PHYSICAL SUMMARY

NI Hill Country	With N	Without N	Without N/ + Supplement
Effective Area (ha)	544	544	544
Pasture Eaten (t DM/ha)	5.5	5.5	5.5
Nitrogen Boost (tDM/ha)	0.08	0	0
Supplements Eaten (t DM/ha)	0.35	0.35	0.43
Sheep (%)	55	54	55
Beef (%)	45	46	45
Total Sheep	2,825	2,741	2,825
Total Beef	435	435	435

NI Intensive	With N	Without N	Without N/ + Supplement
Effective Area (ha)	281	281	281
Pasture Eaten (t DM/ha)	6.4	6.2	6.3
Nitrogen Boost (tDM/ha)	0.13	0	0
Supplements Eaten (t DM/ha)	0.32	0.32	0.44
Sheep (%)	52	51	52
Beef (%)	48	49	48
Total Sheep	1,364	1,309	1,364
Total Beef	324	324	324

SI Hill Country	With N	Without N	Without N/ + Supplement
Effective Area (ha)	1,495	1,495	1,495
Pasture Eaten (t DM/ha)	2.7	2.6	2.7
Nitrogen Boost (tDM/ha)	0.03	0	0
Supplements Eaten (t DM/ha)	0.18	0.18	0.20
Sheep (%)	62	62	62
Beef (%)	38	38	38
Total Sheep	4,596	4,503	4,596
Total Beef	421	421	421

SI Intensive	With N	Without N	Without N/ + Supplement
Effective Area (ha)	227	227	227
Pasture Eaten (t DM/ha)	6.6	6.5	6.5
Nitrogen Boost (tDM/ha)	0.12	0	0
Supplements Eaten (t DM/ha)	1.22	1.22	1.41
Sheep (%)	91	90	91
Beef (%)	9	10	9
Total Sheep	2,284	2,239	2,284
Total Beef	85	85	85

14.0 APPENDIX 3: VEGETABLE/ARABLE CROP ROTATIONS

14.1 Leafy Greens Model

	Variable costs	Fixed cost $ / ha	admin $ / ha	Total Variable	Total Fixed	Total Admi
Cauliflower	484	7,750	453	145,932	77,500	4530
Spinach	852	13,335	453	188,495	133,348	4530
Onions	12	12,380	453	8,448	123,800	4530
Brocolli	498	7,606	453	41,505	76,060	4530
Forage oats/ annual ryegrass				-	-	0
Squash	186	2,797	453	46,357	27,970	4530
Spinach	852	13,335	453	188,495	133,348	4530
Cabbage	129	9,978	453	77,017	99,781	4530
				696,249	671,807	31,710

Other regions (MGM rotation- Intensive vege rotation >80% of time)

Physical Characteristics						
	Hectares	**t/ha**	**Total yield (tDM)**	**$/t**	**Total $**	
Effective area (ha)						
Cauliflower	10	30	302	1,150	346,739	
Spinach	10	22	221	2,200	486,915	
Onions	10	70	704	500	351,993	
Brocolli	10	8	83	1,667	138,957	
Forage oats/ annual ryegrass		3.4	-		-	
Squash	10	25	250	700	174,730	
Spinach	10	22	221	2,200	486,915	
Cabbage	10	60	599	1,150	688,870	
Sweetcorn	10	16	155	350	54,378	
Total/ average	**80**	**29**	**2,536**		**2,729,497**	
Dairy grazing			**Total yield (kgDM)**	**$/kgDM**	**Total $**	
	0	3.4	-	0.30	-	
Total	**0**		**0**		**0**	

Financial Data						
			Unit	**$ Total**	**$/ha (eff)**	
Revenue						
Cereals				-	-	
Process/ fresh vege				2,729,497	34,119	
Other Crops				-	-	
Crop Residues		100	/ha	-	-	
Total Crop				2,729,497	34,119	
Grazing				-	-	
Other Farm Income			/ha	-	-	
Gross Farm Revenue				**2,729,497**	**34,119**	17,497
Farm Working Expenses		**$/ha**		**$ Total**	**$/ha (eff)**	
Total Variable				696,249	8,703	
Animal Health				-	-	
Breeding				-	-	
Electricity				-	-	
Feed (Imported Supp.)				-	-	
Feed (Stock Grazing)				-	-	
Feed (Other)				-	-	
Fertiliser				-	-	
Lime				-	-	
Freight				-	-	
Seed dressing				-	-	
Seeds				-	-	
Shearing				-	-	
Weed & Pest				-	-	
Fuel				-	-	
Vehicle Costs				-	-	
Total Fixed growing costs				671,807	8,398	
Communications				-	-	
Accountancy				-	-	
Legal & Consultancy				-	-	
Admin.				-	-	
Water Charges				-	-	
Rates				-	-	
Insurance				-	-	
ACC.				-	-	
Total Admin				31,710	396	
Total Farm Operating Expenses				**1,399,766**	**17,497**	

14.2 Root Vegetables Model

	Wages	Grading	Packing	Freight	
Potato	40	50	48	26	
Onion	40	75	75	25	
Carrots	46	26	41	19	
Squash	55	24	30	54	
Barley					
	181	175	194	124	

Horticulture

Pukekohe

Physical Characteristics

	Hectares	t/ha	Total yield (tDM)	$/t	Total $
Effective area (ha)	50				
Potatoes (summer)	10	50	500	450	225,000
Onions	10	45	450	500	225,000
Carrots	10	60	600	450	270,000
Squash	10	25	250	700	175,000
Oats and rye			-		-
Barley (grain)	10	7	70	420	29,400
Oats and rye			-		-
Total/ average	**50**	**37**	**1,870**		**924,400**
	4				
Dairy grazing			**Total yield (kgDM)**	**$/kgDM**	**Total $**
Oats and rye?	0	0	-	0.30	-
Total	**0**		**0**		**0**

Financial Data

			Unit	$ Total	$/ha (eff)
Revenue					
Cereals				29,400	588
Process/ fresh vege				895,000	17,900
Other Crops					0
Crop Residues		0	/ha	-	-
Total Crop				924,400	18,488
Grazing				-	0
Other Farm Income			/ha	-	0
Gross Farm Revenue				**924,400**	**18,488**

Farm Working Expenses		**$/ha**		**$ Total**	**$/ha (eff)**
Wages		1984	1983.75	99,188	1,984
				-	-
Breeding				-	-
Electricity				-	-
Grading		2009	2008.75	100,438	2,009
Packing		2246	2246.25	112,313	2,246
Freight		1229	1228.75	61,438	1,229
Fertiliser		1392	1392	69,600	1,392
Lime				-	-
Freight				-	-
Seed dressing				-	-
Seeds		1385	1385	69,250	1,385
Shearing				-	-
Weed & Pest		1168	1168	58,400	1,168
Fuel		671	671	33,550	671
Vehicle Costs		671	671	33,550	671
Repairs & Maintenance		136	136	6,800	136
Communications		16	16	800	16
Accountancy		21	21	1,050	21
Legal & Consultancy		16	16	800	16
Admin.		17	17	850	17
Water Charges		57	57	2,850	57
Rates		50	50	2,500	50
Insurance		94	94	4,700	94
ACC.		15	15	750	15
Other		31	31	1,550	31
Total Farm Operating Expenses				**660,375**	**13,208**
Cash Operating Surplus				**264,025**	**5,281**

14.3 Arable Model

Physical Characteristics					
	Hectares	**tDM/ha**	**Total yield (tDM)**	**$/tDM**	**Total $**
Effective area (ha)	200				
Ryegrass seed	40	1.5	60	2,200	132,000
Peas	40	9.0	360	400	144,000
Kale	0	12.0	480		-
Barley	40	8.0	320	390	124,800
Forage oats	0	3.5	-		-
Maize silage	40	20.0	800	200	160,000
Wheat	40	10.0	400	440	176,000
Total/ average	**200**	**9**	**2,420**	**3,630**	**736,800**
Dairy grazing			**Total yield (kgDM)**	**$/kgDM**	**Total $**
Kale	40	12	480,000	0.30	144,000
Forage oats	40	3.5	140,000	0.30	42,000
Total	**80**		**620,000**		**186,000**

Financial Data					
			Unit	**$ Total**	**$/ha (eff)**
Revenue					
Cereals				300,800	1,504
Small Seeds				132,000	660
Other Crops				304,000	1,520
Crop Residues		100	/ha	20,000	100
Total Crop				756,800	3,784
Grazing				186,000	930
Other Farm Income		43	/ha	8,600	215
Gross Farm Revenue				**951,400**	**4,929**
% change from Hinds model expenses to 2017 expenses				104%	
Farm Working Expenses		**Hinds model per hectare ($)**		**$ Total**	**$/ha (eff)**
Wages		195		40,560	202.80
Animal Health		**0**		-	-
Breeding		**0**		-	-
Electricity		86		17,888	89
Feed (Imported Supp.)		**0**		-	-
Feed (Stock Grazing)		**0**		-	-
Feed (Other)		**0**		-	-
Fertiliser		439		91,312	457
Lime		26		5,408	27
Freight		94		19,552	98
Seed dressing		120		24,960	125
Seeds		110		22,880	114
Shearing		0		-	-
Weed & Pest		334		69,472	347
Fuel		136		28,288	141
Vehicle Costs		80		16,640	83
Repairs & Maintenance		136		28,288	141
Communications		16		3,328	17
Accountancy		21		4,368	22
Legal & Consultancy		16		3,328	17
Admin.		17		3,536	18
Water Charges		57		11,856	59
Rates		50		10,400	52
Insurance		94		19,552	98
ACC.		15		3,120	16
Other		31		6,448	32
Total Farm Operating Expenses				**431,184**	**2,156**
Cash Operating Surplus				**520,216**	**2,773**

15.0 APPENDIX 4: MACRO ECONOMIC ANALYSIS

15.1 2016 National Input-Output & Multiplier Summary

		Units	Horticulture and fruit growing	Sheep, beef cattle and grain farming	Dairy cattle farming	Meat and meat product manufacturing	Dairy product manufacturing	Fertiliser and pesticide manufacturing	NZ Economy
Gross Output (NZ$$_{2016}$m)		NZ$$_{2016}$m	3,624	6,767	9,024	10,883	18,326	1,759	802,307
Value Added (NZ$$_{2016}$m)		NZ$$_{2016}$m	1,500	2,764	2,943	1,945	3,738	366	226,564
Employment (MECs)		MECs$_{2016}$	33,523	40,016	40,979	30,441	12,820	1,341	2,413,686
Value Added : Gross Output Ratio		Dimensionless	0.4139	0.4085	0.3261	0.1787	0.2040	0.2081	
Employment : Gross Output Ratio (MECs/$m)		MECs/NZ$$_{2016}$m	9.25	5.91	4.54	2.80	0.70	0.76	
Backward linkage multipliers									
Gross Output	Type I	Dimensionless	1.94	1.90	1.92	2.45	2.49	1.97	
	Type II	Dimensionless	1.95	1.91	1.94	2.47	2.51	1.98	
Value Added	Type I	Dimensionless	2.05	1.97	2.31	4.54	3.87	2.74	
	Type II	Dimensionless	2.07	2.00	2.34	4.60	3.92	2.78	
Employment	Type I	Dimensionless	1.57	1.73	1.98	3.69	10.24	4.84	
	Type II	Dimensionless	1.58	1.74	2.00	3.72	10.38	4.93	

15.2 2019 Direct, indirect and induced backward and forward linkage impacts per year (Nil N Fertiliser scenario)

		Units	Horticulture and fruit growing	Sheep, beef cattle and grain farming	Dairy cattle farming	Meat and meat product manufacturing	Dairy product manufacturing	Fertiliser and pesticide manufacturing	Total
Direct impacts	Gross Output	NZ$2016m	-1,331	-757	-2,527	-1,258	-4,918	-539	-11,329
	Value Added	NZ$2016m	-551	-309	-824	-225	-1,003	-112	-3,024
	Employment	MECs2016	-12,310	-4,470	-11,470	-3,520	-3,440	-410	-35,630
Indirect impacts	Gross Output	NZ$2016m	-1,250	-677	-2,336	-635	-2,889	-520	-8,307
	Value Added	NZ$2016m	-580	-301	-1,082	-297	-1,138	-195	-3,594
	Employment	MECs2016	-7,010	-3,260	-11,290	-3,220	-11,000	-1,570	-37,350
Induced impacts	Gross Output	NZ$2016m	-21	-13	-43	-16	-60	-8	-162
	Value Added	NZ$2016m	-11	-7	-23	-8	-31	-4	-85
	Employment	MECs2016	-100	-60	-210	-80	-290	-40	-780
Total backward linkage impacts	Gross Output	NZ$2016m	-2,602	-1,447	-4,906	-1,909	-7,866	-1,068	-19,798
	Value Added	NZ$2016m	-1,142	-617	-1,929	-530	-2,173	-312	-6,703
	Employment	MECs2016	-19,430	-7,790	-22,960	-6,820	-14,730	-2,020	-73,760

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