“Achieving Outcomes by Building Capability”

Nutrient Performance and Financial Analysis of Horticultural Systems in the Horizons Region

Prepared for: Horticulture NZ
Prepared by: The AgriBusiness Group
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***Cover photo:* Participants in a Nutrient Management Field Trip To Horowhenua growing operations managed by Kapiti Green Ltd, June 2014**

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1 Executive Summary

This report was commissioned by Horticulture NZ (HortNZ) because it was felt that there is a need to further develop our knowledge of the Nutrient Performance and the financial impact of adopting mitigation techniques in order to minimise the impact of leaching of nutrients for Horticultural growers operating within the Horizons Region.

The objective of the study was to collect primary physical, financial and environmental data from growers in the Horizons Region to provide representative models of vegetable systems and to analyse the impact of mitigation practices on the environmental and economic performance of the farms.

HortNZ is working to extend knowledge on good management practice to growers, to develop a better understanding of the practical tools for nutrient management, and the cost of choices that growers have around mitigation practices. The work will also inform a broader New Zealand wide HortNZ Nutrient Management Programme which aims to identify and codify good management practices for nutrient management.

Methodology

The methodology used in gathering the base data for this work was based on the provision of survey information gained from interviewing 19 growers of horticultural crops within the Horizons Region. Base models of the vegetable grower systems and mitigation options to be modelled were created from information gained from the surveys. Gross Margins were created from a range of sources including data gained from the survey and a similar survey carried out in the Pukekohe Region.

Rotations Modelled

Four representative rotations were modelled;

- **Rotation 1 – Cash Cropping**
  Horticultural cropping is secondary to the primary purpose which is grazing of the land. Cropping is a relatively short term operation and is often for specialist crops like seed potatoes.

- **Rotation 2 – Intensive Vegetable/ Mixed Arable**
  These properties are generally of a greater scale than Market Garden. They generally have several years of a break crop such as pasture in the rotation. They use advanced farming systems to achieve the scale of production. They have a broad mix of crops.

- **Rotation 3 – Market Garden**
  These farms represent the historic Pearl River (Guangdong) intensive market garden systems which have many crops in the same field with up to three crops a year in a continuous rotation.

- **Rotation 4 – Waimarino**

This model represents owned and leased land farmed over a typical 12 – 14 year rotation. Typical rotation includes pasture (and cereals in some cases) 8-10 years followed by a mix of vegetable crops.

Mitigation Techniques Modelled.

Five mitigation techniques were originally identified as worthy of modelling.

- **Mitigation 1 – Limiting N application**.

This mitigation technique limited any one application of N to 80 kg N / ha per month.

- **Mitigation 2 – Altering the amount of N and the yield.**

This mitigation option altered the amount of N applied to the crop in 10% deductions from 0 to a 30% reduction in the amount of N applied. The amounts of yield reductions modelled were created by reference to some research reports and grower experience.

- **Mitigation 3 – The use of cover crops.**

For this exercise when the gap between crops was more than two months then a cover crop was put in.

- **Mitigation 4 – Active Water Management**

This mitigation option was initially chosen to test the impact of altering the irrigation practices. On examination of the responses to the questions on irrigation practices in the survey it was obvious that very few growers irrigated at all, when they did they irrigated in response to soil moisture deficits and applied very low volumes at any one irrigation. Therefore it was not possible to model this mitigation technique.

- **Mitigation 5 – Altered Tillage Practices**

To test the theoretical impact of reducing the amount of tillage practiced wherever possible the choice of “minimum tillage” was chosen as opposed to the choice of “conventional tillage”.

Summary of Findings

Table 1: Whole Farm N leaching results (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M 3	M 5
Rotation 1	15	14	15	14	14	14	15
Rotation 2	26	24	25	24	22	26	25
Rotation 3	39	39	37	35	31	36	35
Rotation 4	17	16	17	16	16	16	16

Summary of the N leaching results:

- The inclusion of relatively long periods of pasture in the rotations has a big impact on the whole farm results for Rotation 1 and Rotation 2.
- The ability to be able to specify the cultivated area has reduced the whole farm N leaching result significantly for the more intensive rotations 2 and 3.
- Limiting the amount of Nitrogen applied in any one application has very little effect on the total amount of N leached.
- Reducing the amount of N applied in 10% steps had a significant effect on the more intensive rotations 2 and 3 but very little impact on the more extensive rotations 1 and 4.
- The use of cover crops had its most significant impact on rotation 3 market gardening.
- Altered tillage practices had virtually no effect on any of the rotations.

Financial Impacts

Table 2: Whole Farm Financial results (Average Gross Margin return $ / ha)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M 3	M 5
Rotation 1	1,555	1,545	1,342	1,117	838	1,477	1,555
Rotation 2	10,588	10,108	6,574	3,213	819	10,043	10,588
Rotation 3	16,943	16,843	10,758	5,409	1,566	16,943	16,943
Rotation 4	2,662	2,637	1,977	1,169	677	2,273	2,662

Summary of Financial Results

- Mitigation 1 has virtually no effect on the Gross Margin return for any of the rotations modelled.
- Mitigation 2 has an increasing effect as the proportion of N applied is reduced. At 30% reduction in N applied, the gross margin result is virtually break even.
- Mitigation 3 and 5 have virtually no impact on the Gross Margin results.

2 Background

This report was commissioned by Horticulture NZ (HortNZ) because it was felt that there is a need to further develop our knowledge of the Nutrient Performance and the financial impact of adopting mitigation techniques in order to minimise the impact of leaching of nutrients for Horticultural growers operating within the Horizons Region.

2.1 Purpose

The objective of the study was to collect primary physical, financial and environmental data from growers in the Horizons Region to provide representative models of vegetable systems and to analyse the impact of mitigation practices on the environmental and economic performance of the farms.

HortNZ is working to extend knowledge on good management practice to growers, to develop a better understanding of the practical tools for nutrient management, and the cost of choices that growers have around mitigation practices. The work will also inform a broader New Zealand wide HortNZ Nutrient Management Programme which aims to identify and codify good management practices for nutrient management.

2.2 Methodology

2.2.1 Survey

The methodology used in gathering the base data for this work was based on the provision of survey information gained from interviewing 19 growers of horticultural crops within the Horizons Region.

The survey was designed to collect both physical inputs required to carry out the required modelling, physical outputs in terms of the yields achieved, financial performance of growing the individual crops and also included a range of questions about growing practice parameters which were of interest to HortNZ.

A letter was sent out to a representative sample of growers informing them of the purpose of the survey information and informing them that they would be contacted to take part. Nineteen of the proposed twenty three were completed. The quality and completeness of the information gathered varied, but provided a basis of information which was built upon through the experience of the modellers. This experience was gained from carrying out the same survey in the Pukekohe District.

The information collected in the surveys is summarised in Appendix 5. The summaries indicate the mitigation practices currently undertaken by the growers in the area and HortNZ will use the information in identifying good management practices for nutrient management.

Base models of the vegetable grower systems and mitigation options to be modelled were created from information gained from the surveys. Gross Margins were created from a range of sources including data gained from the survey and a similar survey carried out in the Pukekohe Region.

2.2.2 OVERSEER Modelling

The modelling of the nutrient performance of the four farm systems was carried out using the OVERSEER 6.1 model. The use of OVERSEER as a means of accurately depicting the performance of Horticultural systems has some challenges that are noted in Appendix 1. One of the key challenges is that range of crops available to model is limited. Therefore the rotations presented in this report are not exact depictions of actual cropping rotations in the Horizons Region. A crop with very similar crop management was substituted where it was necessary to replace a crop.

As highlighted by the FAR (2013) review, the accuracy of the OVERSEER 6.1 model has not been tested against actual N leaching results for Horticultural properties. So the results presented here should be regarded as appropriate for use at this point of time but could change as further research information becomes available and is able to better inform the model.
An alternative model (APSIM) is available and it may be able to better model the performance of N leaching and P output in Horticulture. APSIM is primarily a research tool that is under commercial licence to Plant and Food in New Zealand, as opposed to the Overseer model which is freely available to the public.

2.2.3 Financial Models

The financial models were created based on the standard methodology for Gross Margin analysis. Gross revenue is created with the total yield for the crop multiplied by the price received. From this the Total Variable Revenue is deducted which is all of the expenditure items which are used to grow the crop but excluding items which are related to land ownership. The resultant figure (Revenue minus Expenditure) is the Gross Margin return from growing that crop.

Most of the Gross Margins used in this study are based on the data gained from the survey information. Where there were a number of Gross Margins available from the survey data for any one crop these were combined to create a standard Gross Margin for that crop. Where there was little or no data available from the survey the Gross Margin for that crop was created from previous financial work carried out on Horticulture in the Horizons Region or was taken from the Pukekohe data. A Gross Margin for the pastoral sector was created with reference to the Ministry for Primary Industries Farm Monitoring model Western Lower North Island Intensive Sheep and Beef.

A model was created which included all of the crops grown in each farm system which was then totalled and divided by the number of years that crops were grown end to give the average annual Gross Margin return for that farming system. These models are included in Appendix 3.

2.3 Backgroundon N leaching in Horticulture

It is recognised that there are a number of issues related to horticulture production which result in high N leaching and relative inefficiency of N use compared to other pastoral land uses. However, many horticulture growers have continued to refine their use of N inputs, which has resulted in reduced use of N and therefore the total amount of N leaching over time.

The following quote on the nature and impact of horticultural land use on the rate of N leaching is taken from a report prepared for Environment Bay of Plenty[1] and explains the relative inefficiency of the use of N in horticultural systems. It is concluded that the major source of N leaching is derived from fertiliser and crop residue and that fertiliser N management strategies are key when devising mitigation strategies. The analysis of mitigation techniques in this report concentrates on the two strategies of timing and volume of N application.

The main factors responsible for nitrate leaching in these systems are: high N use (fertiliser and manure), frequent cultivation, relatively short periods of plant growth, low nutrient use efficiency by many vegetable crops, and crop residues remaining after harvest (Di and Cameron, 2002a).

Compared to other agricultural systems, market gardens are the most intensively fertilised and cultivated production systems - hence their propensity to leach N. N application rates used in vegetable crops can be as high as 600 kg N ha-1 yr-1 (Wood, 1997). Large application rates are used to ensure maximum growth because vegetable crops have sparse root systems that are inefficient at recovering applied fertiliser. Also, vegetables typically have short growing periods and are also grown over winter when plant growth and N uptake is slow (Haynes and Francis, 1996; Haynes, 1997). Therefore, the recovery of applied N by vegetable crops is often less than 50%, and can be as low as 20% (Di and Cameron, 2002a). Consequently, a large quantity of fertiliser N remains in the soil surface layers and is susceptible to leaching during rainfall or irrigation. Additionally, following crop harvest large amounts of plant residues are usually incorporated into the soil which, following decomposition, release mineral N into soil. The amount of mineral N derived from fertiliser and crop residue that is present in the soil after harvest can be as high as 200-300 kg N ha-1, and is the major source of leached N, indicating that fertiliser N management strategies are the key to nitrate leaching intervention in these systems.

The issues which cause N leaching in vegetable growing operations therefore are:

- High use of applied N as a result of sparse root systems for the crops (particularly when they are immature).
- Poor N use efficiency.
- Short growth periods and therefore (in some cases) multiple crops in one year.
- Grown over winter when leaching rates are high due to high rainfall and saturated soils.
- Large amounts of crop residue left in the paddock after harvest which is worked into the soil.

[1] Meneer J C, Ledgard S F, Gillingham A G: Land use impacts on nitrogen and phosphorous loss and management options for intervention.

3 Nutrient Performance

3.1 OVERSEER Modelling

3.1.1 Defining the core models.

The definitions and scopes of the four core models were developed in a workshop with Horizons growers. Each model was set up with the parameters (as expressed in Appendix 4) set to be standard with all of the key parameters like Soil Type (Manawatu Silt Loam) and the climatic variables being a reflection of those experienced in the growing area.

The makeup of the actual rotation of the crops was taken from the data collected in the survey.

Rotation 1 – Cash Cropping

Horticultural cropping is secondary to the primary purpose which is grazing of the land. Cropping is a relatively short term operation and is often for specialist crops like seed potatoes. Once the land is worked up for the crop it is then taken for a cereal crop and regrassed back into pasture. The rotation used is as follows:

Pasture (8 years) > Potatoes > Barley > Pasture

Rotation 2 – Intensive Vegetable/ Mixed Arable

These properties are generally of a greater scale than Market Garden. They generally have several years of a break crop such as pasture in the rotation. They use advanced farming systems to achieve the scale of production. They have a broad mix of crops including brassicas, curcurbits, potatoes, onions, melons which are often rotated over many blocks of leased land. They are generally intensively managed through cover crops like oats / mustard / perennial grasses.

Pasture (2 years) > Cabbage > Lettuce > Spinach > Squash > Onions > Pasture

Rotation 3 – Market Garden

These farms represent the historic Pearl River (Guangdong) intensive market garden systems which have many crops in the same field with up to three crops a year in a continuous rotation.

Broccoli > Spinach > Lettuce > Cabbage > Cauliflower > Cabbage

Rotation 4 – Waimarino

This model represents owned and leased land farmed over a typical 12 – 14 year rotation. Typical rotation includes pasture (and cereals in some cases) 8-10 years followed by a mix of potatoes/brussels sprouts/parsnips/carrots. Potatoes, Brussels Sprouts are irrigated on average 1 out of every 3 years.

Pasture (8 years) > Potato > Carrots > Brussel Sprouts

The individual crop parameters such as planting date, fertiliser type and rate, fertiliser timing, harvest date and yield were all set as shown in appendix four.

3.1.2 Choice of Area Cropped

The choice of the area that is cropped has a significant influence on the amount of N leaching which OVERSEER calculates over the total area of the farm. For each crop choice there are three choices of what can be done with the land In OVERSEER. The "cultivated area" is the area of land on which the calculation of the impact of the farming activity is calculated. "Headlands and Tracks" are areas that are cultivated but there is no crop grown on them and "Other areas" are defined as areas where the land is not cultivated.

The issue with horticultural land use is that there are often significant areas within a paddock where the crop is not grown. This is mainly taken up with the beds that are formed to grow the crops in which have a significant area taken up with the areas where tractors, sprayers and harvesters run over the paddock. The headlands and track area are also quite significant areas because of the need to turn quite large machinery. The adoption of technology to spread fertiliser which utilises banding and side application also means that a significant portion of the area also doesn't have fertiliser applied to it.

Therefore in this modelling exercise we have adopted a policy that for all cropping land uses there is 80% of the total area taken up with the cultivated area, 10% is taken up by headlands and tracks and 10% is taken up by other areas. The exception to this is for Rotation 3 Market Garden which in order to demonstrate the impact of unused area on the total impact of the property we have adopted 70% of the area taken as cultivated area , 20% is taken up by headlands and tracks and 10% is taken up by other areas.

This is why we see that the results expressed for the whole farm N leaching figure is less than any of the individual cropping figures.

3.1.3 Mitigation Techniques Modelled

Background research suggests that the mitigation options available to vegetable growers are based around improving nutrient use efficiency. These include:

- Nutrient management planning,
- Proper fertiliser material selection,
- Better application timing and placement,
- Improved irrigation scheduling.

The use of slow release fertilisers and the use of DDE's which act as a retardant to N leaching are both potential mitigation techniques that should be considered. The issue with slow release fertilisers is that there are certain times when vegetable crops have very high demand on N and therefore slow release fertilisers would not be able to adequately meet the crops requirement. Also, it is not possible to model the types of slow release fertilisers that are available at present in OVERSEER.

Our analysis of the current mitigation practices of growers in the Horizons Region was that they are carrying out nutrient management planning, fertiliser material selection and better timing and placement of N application. However, they are limited by the type of system which they could use in terms of improved irrigation scheduling.

Having modelled the Status Quo option which modelled what they were doing now, it became obvious that the major impacts on N Leaching was related to the amount and timing of application of N. Therefore, the following mitigation techniques were trialled:

Mitigation 1 – Limiting N application.

This mitigation technique limited any one application of N to 80 kg N / ha per month. This mainly entailed the splitting of the first application of N by either moving some of it forward into the pre planting cultivation phase and incorporating it into the soil or by evening out the amount of N in subsequent fertiliser applications up to the maximum of 80 kg N / ha. No impact on yield was modelled from this mitigation technique it was assumed that the evening out of the N applications did not have a negative impact on the yield of the crop. This was partly driven by the relatively regular N applications that are made in horticultural crops and the fact that in OVERSEER the smallest window of applications are on a monthly basis. Current best practice is for the application of N to be more regular than once per month, particularly in the early growing stages when the plants are relatively small and growing rapidly and have a high requirement for N.

There is also the requirement to get the application of N on relatively early in the growth phase of many of the crops because experience shows that later application of N can lead to reduced yield and a deterioration of quality of many of the crops as a result of being pushed along later in their maturity.

Mitigation 2 – Altering the amount of N and the yield.

This mitigation option altered the amount of N applied to the crop in 10% deductions from 0 to a 30% reduction in the amount of N applied. The amounts of yield reductions modelled were created by reference to some research reports[2] on the impact of N on yield and informed by the experienced opinion of some of the growers in the Pukekohe District. The assumptions as to average yield reduction by individual crop are attached in Appendix 1. Many of the research reports referenced refer to trials which occurred from the mid 1960’s to the late 1980’s. In that time period the amount of N used was much higher than what is used now. Although very little research has been carried out recently into N use on horticultural crops, many of the growers have continued to develop their knowledge on the timing and volume of N application to be able to maximise crop growth and to try and improve N use efficiency and at the same time reduce costs. This has resulted in much lower rates of N usage than those quoted in the old research reports.

[2] Pearson, Renquist, Reid (1999): MAF vegetable fertiliser trails – A re appraisal using a new model.
Wood (1998): Effect on crop yields from reduced N inputs to selected winter vegetable crops.
Wood (1997): Reduced N inputs to winter vegetable crops – Pukekohe district 1997.
Thomas, Obreza, Sartain : Improving N and P fertiliser use efficiency for Floridas horticultural crops.
MAF (1979): Celery production in Hutt Horowhenua.
Sher (1997): Nutrient uptake of vegetable crops. Summary of results 1993 – 1996.

Mitigation 3 – The use of cover crops.

The use of cover crops is a good mitigation technique to reduce the amount of Nitrogen which leaks through the soil profile, particularly during the winter months when there is high rainfall and the soil is generally saturated, therefore there is a lot of movement through the soil profile. For this exercise when the gap between crops was more than two months then a cover crop was put in. At the end of the cover crop it was worked into the soil profile.

Mitigation 4 – Active Water Management

This mitigation option was initially chosen to test the impact of altering the irrigation practices. It involves setting the option in OVERSEER from defining the actual amount of irrigation water applied to choosing the option to “actively manage” the application of irrigation water. In this way the model chooses to apply only the amount of water which is required by the crop and therefore limits the amount of excessive water running out the bottom of the soil profile or runoff from the top of the soil profile.

On examination of the responses to the questions on irrigation practices in the survey it was obvious that very few growers irrigated at all, when they did they irrigated in response to soil moisture deficits and applied very low volumes at any one irrigation (10mm / application). Therefore choosing the “actively manage” irrigation option was choosing the way that those who did irrigate were already applying the water. Therefore modelling this option in OVERSEER was not continued with.

Mitigation 5 – Altered Tillage Practices

The amount of tillage applied to the soil releases an increasing amount of nitrogen as the amount of tillage increases. In horticultural operations there is a high degree of tillage required to get the soil into a sufficient state to plant some horticultural crops and to be able to form the beds which many of the crops are required to be grown on. To test the theoretical impact of reducing the amount of tillage practiced wherever possible the choice of “minimum tillage” was chosen as opposed to the choice of “conventional tillage” in order to test the impact of this option.

3.2 Results

The results of the OVERSEER modelling are displayed with the whole farm (average) results first (highlighted) and then the results for each of the crops that were modelled going down the rows. Across the columns the results are shown for the status quo option first and then for each of the mitigation options.

3.2.1 Rotation 1 Cash Cropping

Table 3: N leaching results for Rotation 1 (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M 3	M 5
Whole Farm	15	14	15	14	14	14	15

Pastoral	8	8	8	8	8	8	8
Potato	56	58	56	55	53	56	56
Barley	117	95	98	93	90	93	117

Status Quo Results

The whole farm N leaching result is for 15 kg N leached / ha from this rotation. There is however quite a variation with the pastoral years being quite low at 8 kg N leached / ha but the two cropping options being quite high at 56 kg N leached for the potato crop and 117 kg N leached for the Barley crop. The fact that the horticultural regime being a relatively small proportion of the total land use for the property means that the impact of this on average on the farm is minimal.

Mitigation 1 Result

The option to limit the application of any one application of N to 80 kg / ha has the impact of lifting the total N leaching for the potato crop but quite a significant reduction in the barley crop. Overall there is very little impact on the total farm leaching result.

Mitigation 2 Result

The results of limiting the amount of N applied by a 10% reduction through to 30% has a quite significant impact on the N leaching results for the two crops grow in this model but overall there is very little impact on the whole farm result.

Mitigation 3 Result

The use of a cover crop between the two crops has had quite a significant reduction in the total N leached for the Barley crop but very little impact on the whole farm result.

Mitigation 5 Result

The use of minimum tillage techniques has had no impact on the amount of N leached.

3.2.2 Rotation 2 Intensive Vegetable / Mixed Arable

Table 4: N leaching results for Rotation 1 (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M 3	M 5
Whole Farm	26	24	25	24	22	26	25

Pastoral	8	8	8	8	8	8	8
Year 1	43	36	43	43	40	43	43
Year 2	55	55	52	48	44	55	55
Year 3	20	20	19	18	18	20	19

Status Quo Results

The whole farm N leaching result is for 26 kg N leached / ha from this rotation. There is however quite a variation with the pastoral years being quite low at 8 kg N leached / ha but the cropping options being substantially higher varying between 20 and 55 kg N. The fact that the pastoral part of the rotation takes up 2 of the 5 years means that the whole farm N leaching is still relatively low.

Mitigation 1 Result

The option to limit the application of any one application of N to 80 kg / ha has the impact of substantially reducing the N leaching from the first year but no impact on the subsequent years. Overall there is little impact on the total farm leaching result.

Mitigation 2 Result

The results of limiting the amount of N applied by a 10% reduction through to 30% has a varying impact across the years but has the greatest impact on Year 2 with a significant reduction at the 30% reduction in N application..

Mitigation 3 Result.

The use of a cover crop has had no impact on the whole farm result.

Mitigation 5 Result

The use of minimum tillage techniques has a slight impact on the amount of N leached.

3.2.3 Rotation 3 Market Garden

Table 5: N leaching results for Rotation 1 (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M 3	M 5
Whole Farm	39	39	37	35	31	36	35
Year 1	43	53	40	39	33	43	38
Year 2	46	46	42	38	33	46	44
Year 3	65	57	65	64	58	54	58

Status Quo Results

The whole farm N leaching result is for 39 kg N leached / ha from this rotation. Please note the fact that a smaller area cropped has been adopted for this model hence the whole farm result is less than each of the individual results. The individual years fluctuate between 43 kg N leached and 65 kg N leached.

Mitigation 1 Result

The option to limit the application of any one application of N to 80 kg / ha has the impact of increasing the total amount of N leaching in Year 1 and substantially reducing the N leaching from Year 3. Overall there is no impact on the whole farm leaching result.

Mitigation 2 Result

The results of limiting the amount of applied by a 10% reduction through to 30% has a very similar response in terms of the reduction in N leaching between the years, and the treatments. Each of the reductions results in a fairly significant reduction in the whole farm result.

Mitigation 3 Result.

The use of a cover crop has had a small but significant impact on the whole farm result.

Mitigation 5 Result

The use of minimum tillage techniques has a significant impact on the amount of N leached across the whole farm.

3.2.4 Rotation Waimario

Table 6: N leaching results for Rotation 1 (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M 3	M 5
Whole Farm	17	16	17	16	16	16	16
Pastoral	7	7	7	7	7	7	7
Year 1	61	59	61	59	57	61	61
Year 2	101	99	101	99	98	86	101
Year 3	49	42	48	47	46	49	47

Status Quo Results

The whole farm N leaching result is for 17 kg N leached / ha from this rotation. This is mainly to do with the fact that there is a substantial amount of pastoral land use in this rotation. The individual years fluctuate between 49 kg N leached and 101 kg N leached.

Mitigation 1 Result

The option to limit the application of any one application of N to 80 kg / ha has the impact of reducing the amount of N leaching in each of the cropping years with an overall small but significant reduction in the whole farm N leaching result.

Mitigation 2 Result

The results of limiting the amount of N applied by a 10% reduction through to 30% has a very similar response in terms of the reduction in N leaching between the years and the treatments. Each of the reductions results in a small but significant reduction in the whole farm result.

Mitigation 3 Result.

The use of a cover crop has had a small but significant impact on the whole farm result.

Mitigation 5 Result

The use of minimum tillage techniques has a small but significant impact on the amount of N leached across the whole farm.

Table 7: Gross Margins ($ / ha)

	Total Revenue	Total Variable Expenses	Gross Margin
Potato	16,000	11,060	4,940
Barley	3,750	1,531	2,219
Livestock	1,594	545	1,049
Cabbage	25,760	20,603	5,157
Lettuce	30,220	22,938	7,282
Spinach	68,800	40,510	28,290
Squash	12,500	8,122	4,378
Onions	22,500	16,765	5,735
Broccoli	20,004	16,081	3,923
Cauliflower	23,000	19,180	3,820
Carrots	24,500	18,545	5,955
Brussel Sprouts	27,000	21,636	5,364
Maize	4,500	2,025	2,475

The financial adjustments made to the mitigation results are:

Mitigation 1

For each additional application of N an amount of $50 / ha was added to the fertiliser costs. The $50 / ha was the amount shown for each fertiliser application in the Lincoln Budget Manual[3].

Mitigation 2

[3] Lincoln University: Financial Budget Manual

The yield of the crop grown was adjusted by the percentages shown in appendix one. This then flowed through to a reduction in expenditure for those expenditure items which are influenced by the yield of the crop.

Mitigation 3

For each time that a cover crop was added into the rotation an additional cost of $550 / ha was added to the Gross Margin.

Mitigation 5

No financial adjustments were made to the Gross Margins as a result of the adoption of minimum tillage practices.

3.3 Results

3.3.1 Gross Margin Results

Table 8: Financial results of mitigation strategies rotation 1. ($ / ha / annum)

	Status Quo	M 1	M 2 10%	M 2 20%	M 3 30%	M 3
Gross Revenue	3,250	3,250	2,996	2,668	2,466	3,232
Variable Expenses	1,695	1,705	1,654	1,552	1,628	1,755
Gross Margin	1,555	1,545	1,342	1,117	838	1,477

Table 9: Financial results of mitigation strategies rotation 2. ($ / ha / annum)

	Status Quo	M 1	M 2 10%	M 2 20%	M 3 30%	M 3
Gross Revenue	32,594	32,594	28,025	23,434	19,811	32,594
Variable Expenses	22,006	22,066	21,451	20,221	18,992	22,551
Gross Margin	10,588	10,108	6,574	3,213	819	10,043

Table 10: Financial results of mitigation strategies Rotation 3. ($ / ha / annum)

	Status Quo	M 1	M 2 10%	M 2 20%	M 3 30%	M 3
Gross Revenue	63,581	63,581	54,044	45,344	38,149	63,581
Variable Expenses	46,638	46,738	43,287	39,935	36,583	46,638
Gross Margin	16,943	16,843	10,758	5,409	1,566	16,943

Table 11: Financial results of mitigation strategies Rotation 4. ($ / ha / annum)

	Status Quo	M 1	M 2	M 2	M 3	M 3

			10%	20%	30%	
Gross Revenue	8,366	8,366	7,348	6,208	5,383	8,366
Variable Expenses	5,704	5,729	5,371	5,039	4,706	6,093
Gross Margin	2,662	2,637	1,977	1,169	677	2,273

As can be seen the financial returns from the three rotations modelled vary significantly for all of the reported variables. Rotation1 is lower than rotation 2 which is higher than rotation 3.

Mitigation 1 has virtually no effect on the Gross Margin return for any of the rotations modelled.

Mitigation 2 has a steady reduction in the financial performance of the models as the amount of N applied reduces. At the 10% reduction in the amount of N applied the Gross Margin result is reduced to approximately one third to a half of that under the Status Quo situation and from there it dips towards a close to break even scenario which means that it would not be economic to grow the crop. This reflects the relatively tight margins which these crops are grown under.

Mitigation 3, which has a standard cost for each time it is used reduces the gross margin result by the number of times that it is used. In this case it is only able to be used one or two times in the rotation therefore the financial impact is relatively small.

Appendix One: Average Estimated Reduction in yield with reduction in applied N.

Reduction in N	Potato (Summer), Onions, Carrots,	Squash, Broccoli, Lettuce,	Cabbage, Spinach, Cauliflower	Potato (Winter)	Barley
10%	10%	15%	15%	25%	25%
20%	20%	25%	30%	35%	35%
30%	30%	40%	40%	50%	45%

Appendix Two : Challenges related to modelling horticultural crops in OVERSEER 6.1

The Foundation for Arable Research[4] carried out an independent review of the use of OVERSEER in the arable sector, which incorporated consideration of the horticultural sector. It came up with the following conclusion:

OVERSEER® is the best tool currently available for estimating N leaching losses from the root zone across the diversity and complexity of farming systems in New Zealand. This review sets out a pathway for improving its fitness for this purpose in the arable sector (see recommendations). It also highlights that the new challenges facing OVERSEER® place demands on the development team and model owners that need to be acknowledged and resourced appropriately.

[4] FAR (2013) : A peer review of OVERSEER in relation to modelling nutrient flows in arable crops.

The review came up with the following recommendations which are relevant to the horticultural sector:

OVERSEER® crop model estimates of N leaching should be evaluated against measurements of N leaching to identify whether there are any systematic errors in predictions.

OVERSEER® crop model estimates of N leaching should be evaluated against predictions of longterm leaching produced by established, detailed research models e.g. APSIM.

The testing outlined in recommendations (1) and (2) is likely to identify and justify areas for further development of OVERSEER® to improve N leaching predictions.

The following list of challenges identified in this modelling exercise is not new as they have been identified in previous modelling of horticultural crops. The challenges are listed here to allow consideration of the impact of these issues on the modeller's ability to correctly model the practices undertaken by the growers. In some cases these practices are undertaken to improve the efficiency of use of N and P, the impact of which are not shown in these results.

Crops that can be modelled.

OVERSEER has a reasonable range of crops that can be modelled, however this is limited from a horticultural perspective. This has meant that the rotations used in Rotation 2 and the Traditional Market Garden were somewhat compromised by the range of crops chosen. This has meant that the rotation does not represent what would actually be grown. However, we have chosen a similar crop both in terms of inputs and outputs so the end result may not be much different. However it may not appear to be logical from a growing perspective.

Monthly time steps.

OVERSEER works on monthly time steps of data entry for items such as cultivation, fertiliser applications and irrigation inputs. Horticultural operations work on much finer time steps which are unable to be incorporated into OVERSEER. Therefore the results would appear to be much more at a gross level than you would expect for horticulture.

Incorporating side dressings.

It is not possible to incorporate the application of fertiliser as a side dressing in OVERSEER. This is a horticultural practice which directly applies the fertiliser into the root zone of the plant, which are predominantly grown in rows. Therefore this practice results in more efficient plant uptake and reduces the total gross amount of fertiliser applied.

Limited range of irrigation options.

The choice of irrigation options is limited to those that are available for pastoral farming. This means that options that are available to horticulturalists such as soak mats etc. cannot be modelled. This can be overcome by selecting the actively managed option which means that the correct amount of irrigation required can be applied. However, this still would apply much more than would be applied if the alternative options were available which just apply water to the root zone of the crop.

Currently work being undertaken which will investigate and compare the way that irrigation is modelled in OVERSEER by including a daily time series for irrigation practice which will more accurately reflect the water balance of the soil.

Fertiliser options limited.

One of the mitigation options which we wished to test in this exercise is the use of slow release fertilisers. The range of fertiliser options available is limited to the standard range from each of the two major companies. Therefore it was not possible to test the impact of the application of slow release fertilisers. However, slow release fertilisers may not be able to adequately meet the crops requirement as there are certain times when vegetable crops have very high demand on N.

Appendix Three: Gross Margins

Gross Margin	Status Quo	Rotation 1			
	Potato	Barley	Livestock		Average
					10
Income	50	10			
Yield	320	375			
Price					
Total Revenue	**16000**	**3750**	**1594**		**3,250**
Expenses					
Seed		250			
Cultivation	2700	**220**			
Fertiliser	480	230			
Agri Chem	1000	205			
Irrigation	520	187			
Harvesting		250			
Land lease	2500				
Grading	1500				
Packing	640				
Freight		189			
Commision	1600				
Levys.					
	120				
Total Expenses	**11060**	**1531**	**545**		**1,695**
Gross Margin	**4940**	**2219**	**1049**		**1,555**

Gross Margin		Rotation 2							
	Cabbage	Lettuce	Spinach	Squash	Onions	Livestock	Average		
Income									
Yield	70	10	40	25	50				
Price	368	3,022	1,720	500	450				
Total Revenue	**25,760**	**30,220**	**68,800**	**12,500**	**22,500**	**1594**	**32,594**		**162,968**
Expenses									
Seed	1,411	2,641	480	700	850				
Cultivation	2,715	2,964	1,995	1,190	1,190				
Fertiliser	1,573	1,419	1,600	880	1,750				
Agri Chem	1,089	1,089	710	760	2,150				
Irrigation	-	-	-	-	-				
Harvesting	1,500	1,650	15,000	1,375	1,800				
Land lease	1,625	1,625	1,625	1,000	1,000				
Grading	1,500	1,650	3,750	600	3,375				
Packing	1,500	1,650	3,750	260	3,375				
Freight	4,500	4,500	3,050	1,350	1,125				
Commision	3,075	3,625	8,250	-	-				
Levys.	115	**125**	**300**	**7**	**150**				
			-		-				
Total Expenses	**20,603**	**22,938**	**40,510**	**8,122**	**16,765**	**545**	**22,006**		**110,028**
Gross Margin	**5,157**	**7,282**	**28,290**	**4,378**	**5,735**	**1049**	**10,588**		**52,940**

Gross Margin		**Rotation 3**						
	Broccoli	**Spinach**	**Lettuce**	**Cabbage**	**Cauliflower**	**Cabbage**		**Average**
Income								
Yield	12	30	10	70	20	70		
Price	1667	2,200	3,022	368	1150	368		
Total Revenue	**20004**	**66,000**	**30,220**	**25,760**	**23000**	**25,760**		**63,581**
Expenses								
Seed	315	480	2,641	1,411	2700	1,411		
Cultivation	1120	1,995	2,964	2,715	1055	2,715		
Fertiliser	1850	1,600	1,419	1,573	1230	1,573		
Agri Chem	1700	710	1,089	1,089	550	1,089		
Irrigation	0	-	-	-		-		
Harvesting	2000	15,000	1,650	1,500	1500	1,500		
Land lease	2500	1,625	1,625	1,625	1750	1,625		
Grading	0	3,750	1,650	1,500	0	1,500		
Packing	1650	3,750	1,650	1,500	4055	1,500		
Freight	2325	3,050	4,500	4,500	4125	4,500		
Commision	2530	8,250	3,625	3,075	2100	3,075		
Levys.	91	**300**	**125**	115	115	115		
		-						
Total Expenses	**16081**	**40,510**	**22,938**	**20,603**	**19180**	**20,603**		**46,638**
Gross Margin	**3923**	**25,490**	**7,282**	**5,157**	**3820**	**5,157**		**16,943**

Gross Margin		Rotation 4					
Income	**Potato**	**Carrots**	**Brussel Sp**	**Maize**	**Livestock**		**Average**
Yield	55	70	12	18			
Price	300	350	2250	250			
Total Revenue	**16500**	**24500**	**27000**	**4500**	**1594**		**8,366**
Expenses							
Seed	1955	1650	1366	400			
Cultivation	600	2400	1320	300			
Fertiliser	1044	1200	2800	750			
Agri Chem	1600	700	1900	575			
Irrigation	0	0					
Harvesting	788	1320	3600				
Land lease	1500	1700	1500				
Grading	0	0	2640				
Packing	625	0					
Freight	2750	6000	2160				
Commision	0	3375	4200				
Levys.	157	200	150				
Total Expenses	**11019**	**18545**	**21636**	**2025**	**545**		**5,704**
Gross Margin	**5481**	**5955**	**5364**	**2475**	**1049**		**2,662**

Appendix Four: Core assumptions made in modelling in OVERSEER.

The standard location parameters for Horizons Region were selected and all models were modelled on Manawatu Silt Loam soils.

Rotation choice details are as follows.

Rotation 1 Cash Cropping

Crop	Plant Date	Kg N/ ha.	Fertiliser timing	Harvest Date	Yield T / ha
Potato's	September	200 75 75	Planting Side dressing at 6 week intervals	March	50
Barley	July	100 100	October November	Feb	10 T

Rotation 2 Intensive Vegetable / Mixed Arable

Crop	Plant	Kg N / ha	Fertiliser timing	Harvest Date	Yield T / ha
Cabbage	May	200 200	Planting 6 weeks later.	August	70
Lettuce	Sept	25 50 75	Planting 4 weeks post 8 weeks post	Feb	10
Spinach	March	180 60 80	Planting 4 weeks post 8 weeks post	June	40
Squash	Oct	80	Planting	March	25
Onions	June	50 50 40	Evenly spaced	Dec / Jan	50 t

Rotation 3 Market Garden

Crop	Plant Date	Kg N / ha	Fertiliser timing	Harvest Date	Yield T / ha
Broccoli	October	95 70	At planting banded + 5 weeks	Feb	12
Spinach	March	180 60 80	Planting 4 weeks post 8 weeks post	June	40
Lettuce	September	90	planting	Feb	10 T

		60	+ 4 weeks		
Cabbage	May	200 200	Planting banded + 6 weeks	August	70
Cauliflower	September	135 100	Planting 6 week interval	November	20
Cabbage	December	80 100	Planting banded + 6 weeks	February	70

Rotation 4 Waimarino

Crop	Plant Date	Kg N / ha	Fertiliser timing	Harvest Date	Yield T / ha
Potato	Oct	200 75 75	Planting Side dressing at 6 week intervals	April	55
Carrots	Oct	180 90 90	Planting 4 weeks post 8 weeks post	March	75
Brussel Sprouts	April	135 100	planting + 4 weeks	August	12
Maize	Oct	100 150	Planting + 6 weeks	March	18

Appendix Five: Results of Practice Questions in the Survey.

How much history is available of lease blocks	Long term only
Do you factor rainfall into your irrigation	Yes
Information sought from the leasor.	Yes
Are you able to list or describe….	Crop history, nutrient history, presence of disease etc. Yes important & required by the operator

	Yes	**No**
Upgrade Tractors	16	3
Purpose	less cost of inputs Soil management,↓ compaction, ↑ efficiency and accuracy of all operations To enable GPS use More efficient	
Proof of Result	improved yields Reduce N use	

	Yes	No
Controlled Traffic	9	10
Purpose	less cost of inputs Soil management,↓ compaction, ↑ efficiency and accuracy of all operations More efficiency Reduce environmental impact	
Proof of Result	yields have increased Accurate placement	

	Yes	No
Advanced farming systems	7	12
Purpose	less cost of inputs Soil management, ↑ efficiency and accuracy of all operations Cost effectiveness Right amount of fert & water is the aim. NZGAP has been a trigger in helping improve efficiency	
Proof of Result	yields have increased Cost effectiveness	

	Yes	No
Record keeping	16	2
Purpose	To achieve better yields NZGAP less cost of inputs Traceability, comparisons within years and crops Good business practice	
Proof of Result	yields have increased Accurate placement Better yields Accurate placement	

	Yes	No
Increased Training	7	12
Purpose	less cost of inputs ↑ efficiency all operations/safety operations/↓Hazards Must take long term custodial view Better soil management	
Proof of Result	yields have increased ↓cost, ↑yield,↓accidents Yields of some varieties have increased	

	Yes	No
Agronomy advice	12	7
Purpose	Fertiliser management less cost of inputs ↑ efficiency in all operations/ saving / better systems/Improve the quality of crops to increase yields Fertiliser efficiency	
Proof of Result	yields have increased ↓cost, ↑max yield Believes is now	

Good Nutrient Management

	Yes	No
Nutrients applied according to standards	16	3
Purpose	Need to look after lessors land to ensure they can lease again Testing means acting on today's issues & not based on historical views Soil management, ↑efficiency in use and application of fertilisers Always important to ensure costs are kept down. Costs drive efficiencies	

	Lush growth does not mean better results Don't want to waste nutrients and therefore money Soil management & yield increase
Proof of Result	Are now able to crop land previously no go. Years of growing history tells what works on a farm Seen benefits on occasion when did not use recommendations

	Yes	No
Soil Testing every 3 to 5 years.	12	7
Purpose	Testing means acting on today's issues & not based on historical views Soil management, max yield, Every crop every year Fert cots $1000/t. you don't want to use more than you have to Don't want to waste nutrients and therefore money	
Proof of Result	Are now able to crop land previously no go ???? ↓fertilizer usage, ↓cost, ↑yield	

	Yes	No
Spreading equipment is available.	17	2
Purpose	More efficiency Save Fert, ↓cost, application efficiency	
Proof of Result	↓fertilizer usage	

Good Irrigation Management

	Yes	No
Irrigation applied allows	3	15
Purpose	Area has high water table level so good drainage is important to retain nutrients in root zone	
Proof of Result	Overall farm costs have come down. Yields are now at a much higher level	

	Yes	No
Equipment is calibrated.	4	13
Purpose	Soil management, Fertilizer management	
Proof of Result		
	Yes	No
Water is applied to achieve.	4	14

Purpose	Economic and environment reasons Better sustainab;le soils
Proof of Result	Yield improvements and better soil structure

Best Nutrient Management

	Yes	No
Soil testing	6	13
Purpose	Soil management, Fertilizer management	
Proof of Result	↓ amount of fert usage	

	Yes	No
Petiole testing.	1	17
Purpose		
Proof of Result		

	Yes	No
Tarra type systems.	0	19
Purpose		
Proof of Result		

	Yes	No
Technology informs variable rate	0	19
Purpose		
Proof of Result		

	Yes	No
Proof of placement.	0	19
Purpose		
Proof of Result		

Best Irrigation Management

	Yes	No
Soil Moisture Monitoring	3	13
Purpose		
Proof of Result		

	Yes	No
Variably applied.	3	13
Purpose	Save water, ↑ Yield, ↑quality crop	
Proof of Result	↓cost, Max yield	

	Yes	No
Irrigation efficiency.	2	14
Purpose		
Proof of Result		

	Yes	No
More frequent application	3	13
Purpose		
Proof of Result		

Soils that you seek.	Fertile Free draining
Soil properties that you look for.	Depth & no stones No. Crop rotation is dependent on land availability Paddock history (crop rotation and disease P°), Irrigation availability, Soil type, Harvest time Free draining: uncropped fresh ground Depth of topsoil, zero erosion, flat land, no runoff to streams Disease Depth, Organic matter
How often do you achieve target yields	range from 80% to 100%.
If not why not.	Water related Climate extremes Climatic conditions Pest and Diseases, supply and demand, limiting factors Weather, market conditions Insect pest & climate Too much water Never happened Disease & lack of water
What do you do if not economic yield	Cropped ripped and lessors stock clean it up Ploughed back in Graze off fruit & incorporate remainder Incorporated back into the ground, fed to stock

	Harvest available, incorporate residuals Sell some. Rest is incorporated Residuals always incorporated, no clear cut answers Ploughed back in Try & talk market up, residuals are incorporated Stock food, sometimes juicing.
Is your information well documented.	Problematic, most in head but fert in diary Well organised grower with good computerised records. Once again costs of grading & packing an area of difficulty Absolutely, very professional We have records of all our operations; we use Cropwalker and crop books Good fert & agchem. C.O.P figures are father's domain and phone calls had to be made to verify some costs Fert and application records were well kept Fert & Agchem = yes. Not for other inputs Make the call. Harvest if market allows & incorporate what is left the head I would suspect that record keeping is not good. Some info is in his Iphone but most of it is in his head All records in head Some very detailed information regarding planting densities, fert rates & applications & agchem use. Most data i.e cost of production while good is on the head Yes I believe itis good. However some serious deficiencies in records in respect of costs of production