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The AgriBusiness Group™

Nutrient Performance and Financial Analysis of Lower Waikato Horticulture Growers

Prepared for: Waikato Regional Council, Ministry of Primary Industries and HortNZ
Prepared by: The AgriBusiness Group
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Contents
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Executive Summary

This report is the result of a joint initiative between the Waikato Economic Joint Venture Project Partners (Waikato Regional Council, Central Government, Dairy New Zealand, Waikato River Authority) and Horticulture NZ (HortNZ), The Pukekohe Vegetable Growers Association and combined vegetable grower product groups.

The Waikato Economic Impact Joint Venture Project studies are being carried out to support decision-making by central government, local government and the wider community on the potential impacts of setting freshwater objectives and limits in the Waikato River Catchment. The overall Waikato work can be used with other data sources to support decision making under the Healthy Rivers Plan for Change/Wai Ora on the way ahead for management of the Waikato and Waipa rivers catchment.

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.

Objective of the study

The objective of the study was to collect primary physical, financial and environmental data from growers in Pukekohe to provide representative models of vegetable systems in the Lower Waikato sub-catchment and to analyse the impact of mitigation practices on the environmental and economic performance of the farms. The results will feed into wider catchment economic modelling of water quality scenarios in the Waikato River Catchment, along with similar information on dairy and sheep and beef farms.

The work in will also inform a broader New Zealand wide HorticultureNZ Nutrient Management Programme which aims to identify and codify good management practices for nutrient management.

Approach of the study

Based on the data and consultation with a panel of growers, three representative rotations and three mitigation techniques for vegetable growing in the Pukekohe growing region were developed. The information was analysed using OVERSEER 6.1 and a financial model to determine the physical and financial impacts of a range of possible mitigation techniques designed to reduce the amount of Nitrogen (N) leaching and the output of Phosphorus (P).

This is the first time that these vegetable systems have been modelled using OVERSEER and the work is an important step forward in benchmarking the systems. The results are not intended to be absolute, and are more indicative of horticultural production in Pukekohe. The challenges related to the use of OVERSEER 6.1 for modelling horticultural crops are discussed in Appendix 2 of this report.

Overview of representative rotations

Three representative rotations were modelled:

- Rotation one was designed to represent the more extensive rotation of major large scale crops such as potatoes, onions and carrots which make up approximately 50% of the land in horticulture production in Lower Waikato.
- Rotation 2 represents the more intensive rotation with the inclusion of more green crops such as broccoli and summer lettuce, which make up approximately 45% of the land in horticulture production.
- Rotation 3 represents a traditional market garden rotation, which are significantly more intensive and make up approximately 5% of land in horticulture production in Lower Waikato.

Overview of mitigation techniques modelled

Three mitigation techniques were modelled:

- Mitigation 1 – Limiting N application: limited any one application of N to 80 kg N / ha per month.
- Mitigation 2 – Reducing N applications: tested the model against a range of N application reductions from 10% to 40% and reduced the yield by an amount determined by reference to research reports and grower experience.
- Mitigation 3 – Active Water Management: tested the impact of altering the irrigation practices to apply only the amount of water required by the crop.

Summary of Findings

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

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M2 40%	M 3
Rotation 1	64	66	59	57	53	49	59
Rotation 2	65	61	57	54	51	47	63
Traditional Market Garden	73	69	65	59	51	44	65

Summary of the N leaching results:

- The results of the status quo indicate that as the intensity of the current rotations increases (and the amount of N used increases) the N leaching increase.
- The annual results varied depending on the intensity of the rotation.
- In one case spreading the N application increased the N leaching in years when the N was applied in the winter.
- Very little mitigation was achieved from mitigation 1 which sought to spread the volume of N applied across the period[1] to avoid applying more than 80 kg / ha / yr. This indicates that the current practice of N timing of application does not contribute to the total amount of leaching.
- The results of mitigation 2 which trialled a range of reductions in N inputs, indicate that there is a strong co relation between the volume of N applied and the subsequent leaching performance at the standard volumes of N used in the crops in this analysis.

[1] The spreading of N application only occurs in years when crops grown require more than 80 kg /ha in one application.

- Mitigation 3 resulted in worthwhile amounts of mitigation in rotations which were heavily summer and therefore irrigation dependant.

Summary of P loss results

The information collected by the survey identified the adherence to various techniques used in the Franklin District to limit the amount of Soil movement, and therefore P discharge. These techniques have been costed and contribute to gross margin impacts and nutrient loss reductions of Phosphorus. However, it is not possible to model these mitigations in OVERSEER 6.1. Therefore the amount of P discharge reported in this report is only a reflection of the amount of P applied in fertiliser and the standard discharge rates assumed in OVERSEER 6.1.

Summary of the financial costs of mitigation techniques:

Table 2: gross Margin results of mitigation strategies.

Status Quo	M 1	M2 10%	M2 20%	M2 30%	M2 40%	M 3
3,591	3,578	1,870	-787	-2,397	-3,884	611
4,540	4,527	1,348	-921	-3,593	-5,496	1,560
3,274	3,137	1,110	-666	-2,497	-3,940	294

- Mitigation 1 has virtually no effect on the Gross Margin return for any of the rotations modelled.
- Mitigation 2 has a substantial financial effect as the amount of N applied decreases from 10 to 40 % due to the associated reductions in yield. It causes losses to be occurred from a point between the 10% and 20% reduction in N application which reflects the relative profitability of growing the crops.
- Mitigation 3, which has a fixed cost, reduces the Gross Margin result by a standard reduction.

1 Background

This report is the result of a joint initiative between the Waikato Economic Joint Venture Project, Horticulture NZ (HortNZ), The Pukekohe Vegetable Growers Association and combined vegetable grower product groups.

Horticulture production in the Waikato River Catchment is primarily based in the Lower Waikato Catchment. The regions of Pukekohe and Pukekawa are significant vegetable production regions for both domestic and export food supply. The horticultural regions of Pukekohe / Pukekawa have between 6000 – 7000 hectares in production annually and are unique across the country due to the combination of soil, frost free growing conditions year round, settlement and large local market. Rotations can supply many crops year round, which is unique in New Zealand, due to the frost free conditions.

1.1 Purpose

The Waikato Economic Impact Joint Venture Project studies are being carried out to support decision-making by central government, local government and the wider community on the potential impacts of setting freshwater objectives and limits in the Waikato River Catchment.

The objective of the study was to collect primary physical, financial and environmental data from growers in Pukekohe to provide representative models of vegetable systems in the Lower Waikato sub-catchment and to analyse the impact of mitigation practices on the environmental and economic performance of the farms. The results will feed into wider catchment economic modelling of water quality scenarios in the Waikato River Catchment, along with similar information on dairy and sheep and beef 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 in will also inform a broader New Zealand wide Hort NZ Nutrient Management Programme which aims to identify and codify good management practices for nutrient management.

1.2 Methodology

1.2.1 Survey

The methodology intended for this work was based on the provision of survey information gained from 23 growers of horticultural crops who grew them within the Waikato Basin with the majority of crops grown around the Pukekohe growing area.

The survey was designed to collect both physical inputs required to carry out the required modelling, physical outputs in terms of the yields achieved, the financial performance of growing the individual crops and also included a range of questions about 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. Thirteen of the proposed 23 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 expert panel of growers.

The information collected in the surveys is summarised in Appendix 4. The summaries indicate the mitigation practices currently undertaken by the growers in the area and Hort NZ 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 discussions with an expert's panel made up of some key growers and consultants. Gross Margins were created from a range of sources including data gained from the survey, some previous work done on financial performance of Pukekohe growers and with reference to a similar survey carried out in the Horizons Region. It is worth noting that the financial information provided in the Horizons surveys was far more complete and a greater range of surveys was conducted (19 fully complete). This gives us some useful information to compare with.

1.2.2 OVERSEER Modelling

The modelling of the nutrient performance of the three 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 Pukekohe. 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 at this point of time but could change as further research information becomes available and is able to 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 also a research tool that is under commercial licence to Plant and Food in New Zealand, as opposed to the Overseer model (available to the public).

1.2.3 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. A standard annual rental is used to reflect that renting land to grow crops is a common practice in the growing area. The resultant figure is the Gross Margin return from growing that crop.

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 for to give the average annual return for that farming system.

1.3 Background on 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 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[2] 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.

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

2 Nutrient Performance

2.1 OVERSEER Modelling

2.1.1 Defining the core models.

In consultation with the expert panel, it was decided that there were three types of representative rotations to be modelled. In practice, there is generally not standard crop rotation. However the group agreed that the following rotations best described the activity of growers in the area.

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 (Patumahoe Loam) and the climatic variables being a reflection of those experienced in the growing area.

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.

Rotation 1- Extensive

Rotation one was designed to represent the more extensive rotation of growing the major large scale crops. It is estimated that this rotation represents approximately half the area grown in the Lower Waikato. The rotation is as follows:

Potato (summer) > Onions > Carrots > Squash > Oats and Rye > Barley (grain) > Oats and Rye

Rotation 2 - Intensive

Rotation 2 is considered to be a more intensive rotation with the inclusion of more green crops. It is estimated that this rotation represents approximately 45% of the area grown in the Lower Waikato. The rotation is as follows:

Squash > Broccoli > Oats and Rye > Lettuce (summer) > Mustard > Onions > Oats and Rye > Potato (Winter).

Rotation 3 - Traditional Market Garden

The traditional market garden rotation was much more intensive and was designed to represent the sort of rotation grown in market gardens and was somewhat limited by the range of crops available. It is estimated that this rotation represents approximately 5% of the area grown in the Lower Waikato. The rotation is as follows:

Broccoli > Mustard > Lettuce > Cabbage > Mustard > Spinach > Cauliflower > Cabbage > Mustard.

2.1.2 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.

There was some discussion within the reference group around the use of slow release fertilisers and the use of DDE's which act as a retardant to N leaching. 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 Lower Waikato area 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 and P output were related to the amount and timing of application of N and to a lesser extent, the amount of irrigation water used. 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 when it occurred as standard practice. 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 40% reduction in the amount of N applied. The amounts of yield reductions modelled were created by reference to some research reports[3] on the impact of N on yield and informed by the experienced opinion of the reference group. 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

[3] 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.

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.

Mitigation 3 – Active Water Management

This mitigation option was set up to test the impact of altering the irrigation practices. It involved 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.

This mitigation is more of a theoretical improvement in efficiency of water use which is unlikely to be carried out in practice, as it requires static irrigation systems which are unlikely to be adopted because of the transitory nature of horticulture production.

2.2 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 years 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.

2.2.1 N Leaching Results

Rotation 1

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

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M2 40%	M 3
Whole Farm	58	60	54	52	49	46	54
Year 1	75	81	72	72	69	66	63
Year 2	88	87	78	76	69	62	86
Year 3	63	67	58	56	52	47	59
Year 4	6	6	6	6	6	6	6

Status Quo Results

The Status Quo results in 58 kg N leached / ha on average in rotation one. However there is a large difference between years ranging from 6 to 88 kg N / ha. This reflects the relative intensity of N input of the crops and the fact that in some years two crops occur. For example in Rotation 1 there is relatively high use of N in all years except year 4 when the crop is Barley for grain with very low N inputs. This demonstrates the relative N use efficiency of grain crops which are grown over a much longer period, do not require large applications of N early in their growth phase and have most of the crop residue removed after harvest.

Mitigation 1 Results

Mitigation 1 results in 60 kg N leached / ha, which is not significantly different from the status quo results. However in Year 1 and 2 the N leaching is higher under the mitigation used. We can only assume that this is caused by the spreading of N applications earlier during the winter months for those crops grown which increases the amount of leaching which will occur. This indicates that limiting winter applications of N by spreading the applications out has a negative effect on the total leaching.

Mitigation 2 Results

The reductions as a result of the range of options in mitigation 2 range from 4 kg N leached / ha for the 10% reduction to a total of 12 kg N leached/ ha for the 40 % reduction in N applied. As can be seen the results all diminish at a fairly standard rate between the 10% reduction in N applied from that which is applied in the status quo situation.

Mitigation 3 Results

The result for mitigation 3 is a reduction from the status quo of 2 kg N leached / ha which is a relatively insignificant level of reduction in this rotation.

Rotation 2

Table 4: N leaching results for Rotation 2 (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M2 40%	M 3
Whole Farm	65	61	57	54	51	47	63
Year 1	73	65	54	52	53	48	67
Year 2	41	41	32	26	21	17	39
Year 3	61	61	59	58	56	54	60
Year 4	86	79	84	79	74	68	86

Status Quo Results

The whole farm results for the status quo model is 65 kg N / ha. The yearly results are relatively even ranging from 41 to 86 kg N/ha and reflect the intensity of crop rotation which occurs in the different years. The lowest year (41 kg N/ha) represents a year in which a single crop (squash) is grown which has a relatively low amount of N applied while the highest year (86 kg N/ha) has two crops grown in the year with relatively high rates of N applied.

Mitigation 1 Results

Mitigation 1 results in a whole farm reduction of 4 kg N leached / ha (7%) with the reductions occurring in the years when the spreading out of the N application occurs, that is years 1 and 4.

Mitigation 2 Results

The reduction of N application results in a whole farm reduction in N leaching of between 8 kg N leached / ha at the 10% reduction in N applied and 18 kg N leached / ha at the 40% reduction. As can be seen from the results there are quite major differences in the yearly results which apparently reflect the difference between the amount applied and that required by the crop. Years 3 and 4 have very low rates of N leaching reduction whilst years 1 and 2 show much higher rates of reduction. It is expected that this reflects both a change in the amount of N applied but also a lowering yield which would mean that much less produce is retained in the paddock after harvest.

Mitigation 3 Results

Mitigation 3 has very little result in changes of N leaching results.

Traditional Market Garden

Table 5: N leaching results for Traditional Market Garden (kg N / ha / annum)

	Status Quo	M 1	M2 10%	M2 20%	M2 30%	M2 40%	M 3
Whole Farm	73	69	65	59	51	44	65
Year 1	37	37	33	30	26	23	36
Year 2	60	60	51	43	35	30	49
Year 3	93	85	82	75	60	50	93
Year 4	102	96	93	89	82	75	84

Status Quo Results

The whole farm result is relatively high at 73 kg N leached / ha reflecting the intensity of the crop rotation modelled and the relatively high rates of N fertiliser applied annually. There is substantial variance between years in the amount of N leached ranging from 37 kg N leached / ha to 102 kg N leached / ha. This reflects partly the choice of crop between years but is mainly influenced by the doubling up of very high N use crops with relatively short growing profiles and a significant amount of N application in the winter, in years 3 and 4.

Mitigation 1 Results

The spreading out of the fertiliser applications had very little effect on the total leaching.

Mitigation 2 Results

The results achieved as a result of the range of amounts of N applied range from 8 kg N leached / ha at a 10% reduction and 29 kg N leached / ha at a 40% reduction. Again there is a significant difference between the years with year 1 being static which reflects that the amount of N applied was close to the crops requirements and it was applied in the summer months. Year 3 has significant drops between the 10% reductions in N leaching which represents the losses which occur with application of N during the winter months.

Mitigation 3 Results

Mitigation 3 results in a reduction of whole farm N leaching of 8 kg N leached / ha.

2.2.2 Phosphorous Output Results

As is discussed in appendix 1 it is not possible to assume the various techniques used in the Franklin District to limit the amount of Soil movement, and therefore P discharge, therefore the amount of P discharge reported here is only a reflection of the amount of P applied in fertiliser and the standard discharge rates assumed in OVERSEER.

Table 6: P output results (kg P / ha / annum)

	Status Quo	Mitigation 1	Mitigation2	Mitigation 3
Rotation 1	1.1	1.1	1.1	1.3
Rotation 2	1.3	1.3	1.3	1.3
Traditional Market Garden	1.9	1.9	1.9	1.8

3 Financial Analysis

The Gross Margin results indicate that there is little true profit in the business of growing vegetables. The Gross Margins as presented include an allowance of $2,000 / ha for land lease costs. This means that the crops can be grown on leased ground (if it is available) and therefore the Gross Margins used here can be considered to go further than traditional Gross Margins which only include the true growing costs of the crop and do not include land ownership costs.

3.1 Gross Margin Analysis

The Gross Margins created resulted in the financial outcomes as shown in Table 5. There is no doubt that there will be considerable variation around the results shown in Table 5 but these numbers are considered to express an average result. The full Gross Margins are displayed in Appendix 3.

Table 7: Gross Margins ($ / ha)

	Total Revenue	Total Variable Expenses	Gross Margin
Potato Summer	22,500	19,450	3,050
Onion	22,500	18,450	4,050
Carrots	21,000	16,585	4,415
Squash	12,500	9,962	2,538
Oats	2,940	1,531	1,409
Broccoli	15,000	13,020	1,980
Lettuce	27,000	22,005	4,995
Potato (Winter)	27,125	20,880	6,245
Cabbage	17,500	16,110	1,390
Spinach	27,000	23,390	3,610
Cauliflower	17,500	16,110	1,390

The financial adjustments made to the mitigation results are:

Mitigation 1
For each additional application of N an amount of $22 / ha was added to the fertiliser costs. The $22 / ha was the amount shown for each fertiliser application in the Lincoln Budget Manual[4].

Mitigation 2
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
An extra cost of $20,000 was added to the costs of production to allow for the addition of sensor technology to the soil to allow for the advanced management of the soil moisture

[4] Lincoln University: Financial Budget Manual

profile and allow for the degree of management required to achieve this outcome. This was then divided by four to cover the costs of its inclusion for all four years of the rotation. Although it is possible to achieve further gains in terms of irrigation efficiency these were not included here because they predominantly require the use of fixed irrigation equipment. Because of the mobile nature of the area grown it was felt that it would not be practical to include the use of these techniques here. The amount was divided by four to allow for averaging per year.

3.2 Results

3.2.1 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 4 40%	M 3
Gross Revenue	20,360	20,360	18,058	14,372	12,179	10,143	20,360
Variable Expenses	16,770	16,782	16,187	15,158	14,576	14,028	19,750
Gross Margin	3,591	3,578	1,870	-787	-2,397	-3,884	611

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 4 40%	M 3
Gross Revenue	26,031	26,031	21,730	18,564	14,941	12,338	26,031
Variable Expenses	21,492	21,504	20,382	19,485	18,534	17,834	24,472
Gross Margin	4,540	4,527	1,348	-921	-3,593	-5,496	1,560

Table 10: Financial results of mitigation strategies Traditional Market Garden. ($ / ha / annum)

	Status Quo	M 1	M 2 10%	M 2 20%	M 3 30%	M 4 40%	M 3
Gross Revenue	30,375	30,375	26,831	23,813	20,925	18,563	30,375
Variable Expenses	27,101	27,238	25,721	24,479	23,422	22,502	30,081
Gross Margin	3,274	3,137	1,110	-666	-2,497	-3,940	294

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 into a negative 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 fixed cost, reduces the Gross Margin result by a standard reduction.

3.2.2 Mitigation Costs

Another way of considering the costs of mitigation is to express it as the total change in N leaching divided by the change in Gross Margin. This shown in Table 9. This is expressed as the average cost of the reduction in N leaching.

Table 11: Mitigation costs per unit of reduction of N leaching. ($ / ha / annum).

	M 1	M 2 10%	M 2 20%	M 3 30%	M 4 40%	M 3
Rotation 1	-6	430	730	665	623	745
Rotation 2	3	399	496	581	558	1,490
Traditional Market Garden	34	271	281	262	249	373

For mitigation 1 the results are relatively low which reflects the fact that there is very little cost associated with the mitigation technique. For mitigation 2 the results show a varied impact on the mitigation costs. This is due to the fact that as the amount of N reduces so does the yield and some of the costs reduce accordingly. For some of the crops costs such as harvest, packing and freight are a relatively high proportion of total costs therefore as they reduce the impact of a reduction in N gets less. For mitigation 3 the results reflect that there is a fixed cost of achieving it therefore it reflects the degree of mitigation achieved.

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[5] 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.

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.

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

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.

Inclusion of total area under crop.

It was not possible to select an option which would allow a lower proportion of the total area available being cropped at any one time as a result of an error in the programme. Once this error is fixed it will then be possible to represent the area cropped as a percentage of the total area available.

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

Rotation 1

Potato

	Income	
	Yield	50
	Price	450
	Total Revenue	**22500**
	Expenses	
	Seed	3000
	Cultivation	1500
	Fertiliser	2500
	Agri Chem	1600
	Irrigation	500
	Harvesting	2000
	Land lease	2000
50	Grading	2500
48	Packing	2400
26	Freight	1300
	Commision	
	Levys.	150
	Total Expenses	**19450**
	Gross Margin	**3050**

Onion

	Income	
	Yield	45
	Price	500
	Total Reve	**22500**
	Expenses	
	Seed	675
	Cultivatio	1550
	Fertiliser	1750
	Agri Chem	2150
	Irrigation	500
	Harvesting	1800
	Land lease	2000
75	Grading	3375
75	Packing	3375
25	Freight	1125
	Commision	
	Levys.	150
	Total Expe	**18450**
	Gross Mar	**4050**

Carrots

	Income	
	Yield	60
	Price	350
	Total Reve	**21000**
	Expenses	
	Seed	1900
	Cultivatio	1550
	Fertiliser	1600
	Agri Chem	1125
	Irrigation	350
	Harvesting	2750
	Land lease	2000
26.25	Grading	1575
41	Packing	2460
18.75	Freight	1125
	Commision	
	Levys.	150
	Total Expe	**16585**
	Gross Mar	**4415**

Squash

	Income	
	Yield	25
	Price	500
	Total Reve	**12500**
	Expenses	
	Seed	700
	Cultivatio	1190
	Fertiliser	880
	Agri Chem	760
	Irrigation	350
	Harvesting	1375
	Land lease	2000
24	Grading	600
30	Packing	750
54	Freight	1350
	Commision	
	Levys.	7
	Total Expe	**9962**
	Gross Mar	**2538**

Oats

Income	
Yield	
Price	
Total Reve	**0**
Expenses	
Seed	200
Cultivatio	350
Fertiliser	
Agri Chem	
Irrigation	
Harvesting	
Land lease	
Grading	
Packing	
Freight	
Commision	
Levys.	
Total Expe	**550**
Gross Mar	**-550**

Barley

Income	
Yield	7
Price	420
Total Reve	**2940**
Expenses	
Seed	250
Cultivatio	220
Fertiliser	230
Agri Chem	205
Irrigation	187
Harvesting	250
Land lease	
Grading	
Packing	
Freight	189
Commision	
Levys.	
Total Expe	**1531**
Gross Mar	**1409**

Oats

Income	
Yield	
Price	
Total Reve	**0**
Expenses	
Seed	200
Cultivatio	350
Fertiliser	
Agri Chem	
Irrigation	
Harvesting	
Land lease	
Grading	
Packing	
Freight	
Commision	
Levys.	
Total Expe	**550**
Gross Mar	**-550**

Rotation 2

25000 0.6 0.48 12000 45000 0.225 10125

	Squash			Broccoli			Oats			Lettuce	
	Income			**Income**			**Income**			**Income**	
	Yield	25		Yield	25000		Yield			Yield	45000
	Price	500		Price	0.6		Price			Price	0.6
	Total Revenue	**12500**		**Total Reve**	**15000**		**Total Reve**	**0**		**Total Reve**	**27000**
	Expenses			**Expenses**			**Expenses**			**Expenses**	
	Seed	700		Seed	2750		Seed	200		Seed	2820
	Cultivation	1190		Cultivatio	1150		Cultivatio	350		Cultivatio	2200
	Fertiliser	880		Fertiliser	1650		Fertiliser			Fertiliser	750
	Agri Chem	760		Agri Chem	760		Agri Chem			Agri Chem	1015
	Irrigation	350		Irrigation			Irrigation			Irrigation	250
	Harvesting	1375		Harvestin	2000		Harvesting			Harvestin	4850
	Land lease	2000		Land lease	1000		Land lease			Land lease	2000
24	Grading	600		Grading	600		Grading		0.0233	Grading	1050
30	Packing	750		Packing			Packing		0.054	Packing	2420
54	Freight	1350	0.06	Freight	1500		Freight		0.05	Freight	2250
	Commision		0.06	Commisio	1500		Commision		0.05	Commisio	2250
	Levys.	7		Levys.	110		Levys.			Levys.	150
	Total Expenses	**9962**		**Total Expe**	**13020**		**Total Expe**	**550**		**Total Expe**	**22005**
	Gross Margin	**2538**		**Gross Mar**	**1980**		**Gross Mar**	**-550**		**Gross Mar**	**4995**

	Mustard			Onions			Oats			Potato	
	Income			**Income**			**Income**			**Income**	
	Yield			Yield	45		Yield			Yield	35
	Price			Price	500		Price			Price	775
	Total Reve	**0**		**Total Reve**	**22500**		**Total Reve**	**0**		**Total Reve**	**27125**
	Expenses			**Expenses**			**Expenses**			**Expenses**	
	Seed	200		Seed	675		Seed	200		Seed	3000
	Cultivatio	350		Cultivatio	1550		Cultivatio	350		Cultivatio	2400
	Fertiliser			Fertiliser	1750		Fertiliser			Fertiliser	3690
	Agri Chem			Agri Chem	2150		Agri Chem			Agri Chem	1200
	Irrigation			Irrigation	500		Irrigation			Irrigation	
	Harvesting			Harvestin	1800		Harvesting			Harvestin	2000
	Land lease			Land lease	2000		Land lease			Land lease	2000
	Grading		75	Grading	3375		Grading		50	Grading	1750
	Packing		75	Packing	3375		Packing		48	Packing	1680
	Freight		25	Freight	1125		Freight		26	Freight	910
	Commision			Commision			Commision		60	Commisio	2100
	Levys.			Levys.	150		Levys.			Levys.	150
	Total Expe	**550**		**Total Expe**	**18450**		**Total Expe**	**550**		**Total Expe**	**20880**
	Gross Mar	**-550**		**Gross Mar**	**4050**		**Gross Mar**	**-550**		**Gross Mar**	**6245**

Traditional Market Garden

25000 0.7 4 100000

	Broccoli			Mustard			Lettuce	
	Income			**Income**			**Income**	
	Yield	25000		Yield			Yield	45000
	Price	0.6		Price			Price	0.6
	Total Revenue	**15000**		**Total Reve**	**0**		**Total Reve**	**27000**
	Expenses			**Expenses**			**Expenses**	
	Seed	2750		Seed	200		Seed	2820
	Cultivation	1150		Cultivatio	350		Cultivatio	2200
	Fertiliser	1650		Fertiliser			Fertiliser	750
	Agri Chem	760		Agri Chem			Agri Chem	1015
	Irrigation			Irrigation			Irrigation	250
	Harvesting	2000		Harvesting			Harvesting	4850
	Land lease	1000		Land lease			Land lease	2000
	Grading	600		Grading		0.0233	Grading	1049
	Packing			Packing		0.054	Packing	2430
0.06	Freight	1500		Freight		0.05	Freight	2250
0.06	Commision	1500		Commision		0.05	Commisio	2250
	Levys.	110		Levys.			Levys.	150
	Total Expenses	**13020**		**Total Expe**	**550**		**Total Expe**	**22013.5**
	Gross Margin	**1980**		**Gross Mar**	**-550**		**Gross Mar**	**4986.5**

	Cabbage			Oats			Spinach	
	Income			**Income**			**Income**	
	Yield	25000		Yield			Yield	40
	Price	0.7		Price			Price	1700
	Total Reve	**17500**		**Total Reve**	**0**		**Total Reve**	**27000**
	Expenses			**Expenses**			**Expenses**	
	Seed	2750		Seed	200		Seed	2500
	Cultivatio	1800		Cultivatio	350		Cultivatio	1500
	Fertiliser	1000		Fertiliser			Fertiliser	600
	Agri Chem	750		Agri Chem			Agri Chem	1020
	Irrigation	250		Irrigation			Irrigation	250
	Harvesting	3500		Harvesting			Harvesting	6500
	Land lease	660		Land lease			Land lease	660
	Grading			Grading			Grading	
	Packing			Packing		106.5	Packing	4260
0.084	Freight	2100		Freight		76.25	Freight	3050
0.126	Commisio	3150		Commision		68.75	Commisio	2750
	Levys.	150		Levys.			Levys.	300
	Total Expe	**16110**		**Total Expe**	**550**		**Total Expe**	**23390**
	Gross Mar	**1390**		**Gross Mar**	**-550**		**Gross Mar**	**3610**

	Cauliflower			Cabbage			Oats	
	Income			**Income**			**Income**	
	Yield	25000		Yield	25000		Yield	
	Price	0.7		Price	0.7		Price	
	Total Reve	**17500**		**Total Reve**	**17500**		**Total Reve**	**0**
	Expenses			**Expenses**			**Expenses**	
	Seed	2750		Seed	2750		Seed	200
	Cultivatio	1800		Cultivatio	1800		Cultivatio	350
	Fertiliser	1000		Fertiliser	1000		Fertiliser	
	Agri Chem	750		Agri Chem	750		Agri Chem	
	Irrigation	250		Irrigation	250		Irrigation	
	Harvesting	3500		Harvesting	3500		Harvesting	
	Land lease	660		Land lease	660		Land lease	
	Grading			Grading			Grading	
	Packing			Packing			Packing	
0.084	Freight	2100	0.084	Freight	2100		Freight	
0.126	Commisio	3150	0.126	Commisio	3150		Commision	
	Levys.	150		Levys.	150		Levys.	
	Total Expe	**16110**		**Total Expe**	**16110**		**Total Expe**	**550**
	Gross Mar	**1390**		**Gross Mar**	**1390**		**Gross Mar**	**-550**

Appendix Four: Core assumptions made in modelling in OVERSEER.

The standard location parameters for Pukekohe were selected and all models were modelled on Patumahoe Loam soils.

Rotation choice details are as follows.

Rotation 1

Crop	Plant Date	Kg N/ ha.	Fertiliser timing	Harvest Date	Yield T / ha
Potato's	September	200 100 100	Planting Side dressing at 6 week intervals	March	50
Onions	June	50 50 40	Evenly spaced	Dec / Jan	45
Carrots	May	90 90	Monthly One in september	October	60 T
Squash	November	80	at planting	March	25 t/ha
Oats and Rye	April			June	
Barley	July	100 100	October November	Feb	7 T
Oats and Rye	March			July	

Rotation 2

Crop	Plant	Kg N / ha	Fertiliser timing	Harvest Date	Yield T / ha
Squash	Oct	80	at planting	March	25 t/ha
Broccoli	April	120 30 30	Planting – banded Side May Side June	July	12
Oats	Aug		Oct		
Summer lettuce	Nov	50 40	Banded at planting Dec	Feb	10 t//ha
Mustard	Feb		May		
Onions	June	50 50 40	Evenly spaced	Dec / Jan	45 t
Oats	Feb			April	
Potatoes	May	200 75 75	Planting Side dressing at 6 week intervals	Oct	35 tonnes

Traditional Market Garden

Crop	Plant Date	Kg N / ha	Fertiliser timing	Harvest Date	Yield T / ha
Broccoli	October	95 70	At planting banded + 5 weeks	March	12
Oats	April			August	
Lettuce	September	90 50	planting + 4 weeks	April	10 T
Cabbage	May	200 200	Planting banded + 6 weeks	August	100 T
Oats	September			February	
Spinach	March	180 60 80	planting + 4 weeks + 4 weeks	June	40 T
Cauliflower	September	135 100	Planting 6 week interval	November	20
Cabbage	December	80 100	Planting banded + 6 weeks	February	100 T
Oats	March			August	

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	11	1
Purpose	moderate sized tractors wider machinery Reduce soil usage, minimise soil compaction (reduced number of passes). Labour saving (wages soil management yield increase	
Proof of Result	Reduced soil compaction reduced hours on the larger tractor Increases yield improves cultivation	

	Yes	No
Upgrade Tractors	11	1
Purpose	moderate sized tractors wider machinery Reduce soil usage, minimise soil compaction (reduced number of passes). Labour saving (wages soil management yield increase	
Proof of Result	Reduced soil compaction reduced hours on the larger tractor Increases yield improves cultivation	

	Yes	No
Controlled Traffic	10	2
Purpose	soil management Less trafficking Not fully employed. Minimise harvesting machinery in paddocks. soil management yield increase	
Proof of Result	Reduced soil compaction, better yields improves soil condition	

	Yes	No
Advanced farming systems	8	4
Purpose	Better paddock utilisation Accurate placements	

	Crop planning for marketing & yield assessment, more efficient use of crop inputs
Proof of Result	Yields Less wastage more efficient use of nutrient inputs. Reduced fert inputs

	Yes	No
Record keeping	12	0
Purpose	Better understanding of costs Muddy boots Tracks N use NZGAP Insure tasks completed & to monitor seasonal variation in quality/yield. GAP, traceability & budget planning Cvompliance ??	
Proof of Result	Better understanding of costs Less wastage Required Fert inputs have been optimised	

	Yes	No
Increased Training	8	4
Purpose	Modern equipment means this is necessary	
Proof of Result		

	Yes	No
Agronomy advice	11	1
Purpose	more experience independent advice BMP for all crops to achieve best possible yields Applying product if & when required, cost saving	
Proof of Result	reduced costs, greater yields Better disease control, < fert applied minimal crop wastage reduces use of chemical & fert, soil health	

Good Nutrient Management

	Yes	No
Nutrients applied according to standards	12	0
Purpose	Cost reduction, better souil condition Compliance placement important Informs fert recommendations off soil test results	
Proof of Result	Yield, N reduction	

	Yes	No
Soil Testing every 3 to 5 years.	12	0
Purpose	soil management To tailor fert needs to individual fields	
Proof of Result		

	Yes	No
Spreading equipment is available.	13	0
Purpose	Accurate use, cost saving Required by Globalgap	
Proof of Result	Calibration records	

Good Irrigation Management

	Yes	No
Irrigation applied allows	11	1
Purpose	Yield, all fert used to lock fert into profile where needed Yield specifications important	
Proof of Result	Rain guages following crops	

	Yes	No
Equipment is calibrated.	12	1
Purpose	mm applied monitored	
Proof of Result		

	Yes	No
Water is applied to achieve.	12	1
Purpose	Max yield lowest cost	
Proof of Result		

Beat Nutrient Management

	Yes	No
Soil testing	7	6
Purpose	efficient use of fert	
Proof of Result	soil test shows reduction ? Incresases Soil test results	

	Yes	No
Petiole testing.	9	4
Purpose		
Proof of Result		

	Yes	No

Tarra type systems.	5	8
Purpose		
Proof of Result		

	Yes	No
Technology informs variable rate	3	10
Purpose		
Proof of Result		

	Yes	No
Proof of placement.	7	6
Purpose		
Proof of Result		

Best Irrigation Mangement

	Yes	No
Soil Moisture Monitoring	10	3
Purpose	Tensiometers/ prevent leaching	
Proof of Result	Extra fert not required	

	Yes	No
Variably applied.	4	9
Purpose		
Proof of Result		

	Yes	No
Irrigation efficiency.	11	2
Purpose		
Proof of Result		

	Yes	No
More frequent application	2	8
Purpose	Better yield lower cost	
Proof of Result	Yield increase	

Soils that you seek.	Clay loams
Soil properties that you look for.	previous history, disease, nutrients, organic matter, depth, fertility, drainage, structure if previously cropped
How often do you achieve target yields	range from 60% to 85%.
If not why not.	Disease, lack of water, weather (flood) Water, disease, weather event Disease, lack of water, weather events Drought or flood, disease weather event Lack of sunshine, too much rain, cold soil temp Adverse weather, seed failure, disease Weather events, Disease. Lack of water. Most common reasons = weather events - frost, flood, hail Water availability for irrigation.. Some cases diseases as well Weather events Adverse weather, seed failure, disease
What do you do if not economic yield	Depends on the year - follow as soon as with cover crop or follow rotation - always following incorporation. Rotations are short enough to capture residuals May plough in Cover crop or fellow crop if timing is right Salvage what you can, depend on crop. Rotary hoe in if Brassicas N/A always get economic return Cover crop is added to rotation to improve soil structure Cover crop or put in successive veg crop Used by cover crops, incorporation, successive crop Paddock residues incorpotrated after harvesting then plant cover crop Review crop planning & reconsider rotations. Look at the introduction of a cover crop if appropriate Cover crop, incorporate, soil test to confirm Cover crop or put in successive veg crop
Is your information well documented.	Use of muddy boots & requirements of NZGAP. Excel spreadsheets to calculate inputs by crop by time of year. Less accurate for fuels and conceded to update moderately accurate

	Well documented, electronic. Accuracy unknown Good records for fert and chem via muddy boots. Limited on costs like seed costs, but good for $ values for fert and chem. Limited on returns NZGAP requirement. Most info in head Yes crop walker is very thorough on inputs. Soil analysis is kept on file Electronics - very thorough & 15 yrs historical. Use of Muddy boots and in house very accurate Long history of records dating back 50+years & highly accurate Evidence well documented, fert, irrigation, pesticide us with 60+ years of historical data. Financials are detailed by crop direct & indirect expenses includes budget and actual for per tonne basis Yes, recommendations match application records GLOBALGAP requirement. Use of muddy boots, very accurate Electronics - very thorough & 15 yrs historical. Use of Muddy boots and in house very accurate