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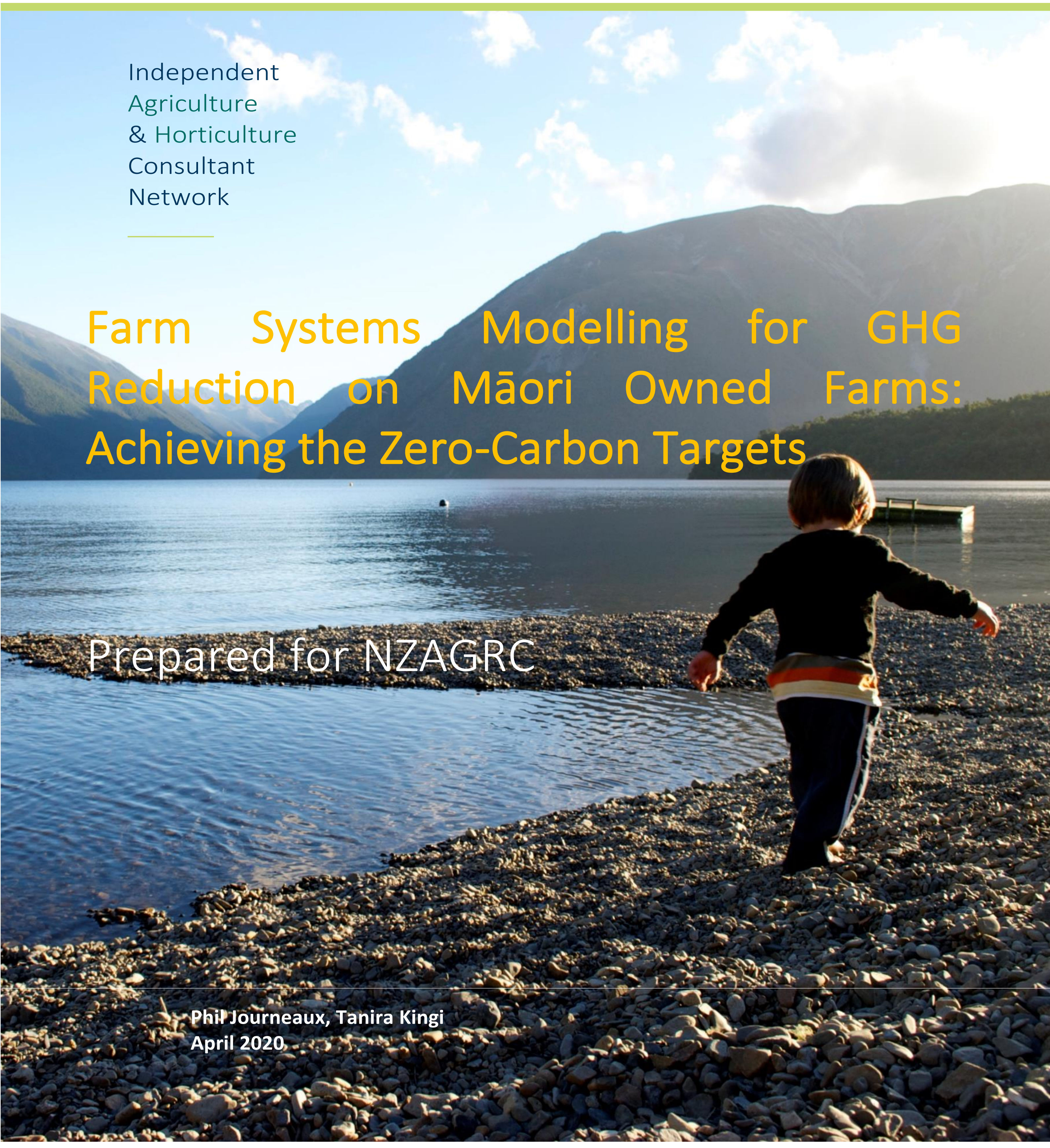
Farm Systems Modelling for GHG Reduction on Māori Owned Farms: Achieving the Zero-Carbon Targets



Prepared for NZAGRC

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An acknowledgement and thanks to the case study farms for the use of their information and input into the project.

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1.0 EXECUTIVE SUMMARY

The objective of this exercise was to model four case study farms, 2 dairy and 2 sheep & beef, as to on-farm strategies that could be adopted so as to achieve the Zero Carbon Act (ZCA) targets for reductions in greenhouse gas (GHG) emissions.

The key drivers of GHG emissions on-farm are:

- Amount of dry matter eaten
- Protein level of the diet
- Amount of nitrogen fertiliser applied

Correspondingly, the key scenarios modelled (via Farmax, Overseer, and Forecaster) were:

- Reduction in stocking rates, with and without improvements in per animal productivity
- Elimination of addition feed inputs into the farm via nitrogen fertiliser and/or bought-in supplements
- Changes in stock types (for the sheep & beef farms)
- Combinations of land use change, mostly forestry, to be used as an offset

The key results from the analysis are:

(i) Changes in farm systems, stock types, elimination of nitrogen fertiliser and supplementary feed, can all get close to, or achieve, the 2030 methane reduction target (-10%)

(ii) While reduction in stocking rates is a key component of reducing GHG emissions, it has to be accompanied by an improvement in per animal productivity in order to reduce/enhance the impact on farm profitability. Such improvements are a moderate-term exercise, requiring an upskilling in farmer expertise, as well as an improvement in the genetic merit of the animals.

(iii) The only current means of achieving the assumed 2030 nitrous oxide reduction (-33%), or the 2050 reduction targets, is via forestry carbon credits as an offset. This raises several issues;

- The availability of land for planting
- The impact on farm profitability
- The short-term nature (16-17 years) of using forestry offsets, before more land is required to be planted.

(iv) The analysis within this report is based around individual farms achieving the ZCA reduction targets. Given that these targets are at a national/sector level, if, for example, there is large-scale land use change to forestry and/or horticulture, such land use change would go a long way towards, if not actually, achieving the targets.

In which case the requirement at the individual farm level would be significantly reduced.

2.0 BACKGROUND

This report covers the results of the modelling component of the Farm Systems Modelling for GHG Reduction on Māori Farms project, a project funded by the New Zealand Agriculture Greenhouse Gas Research centre (NZAGRC).

2.1 Objectives

The two key objectives for the project are:

(i) To develop GHG adaptation strategies for the Māori agribusiness sector by assisting Te Tumu Paeroa and the Federation of Māori Authorities to build their capacity to engage with their members and clients on this critical issue and to provide information that could be used in their climate change communication

(ii) To assist in the alignment between the Māori sector and the pastoral industry partners to increase investment into the information and extension infrastructure to Māori farmers

A major component of this was to model four case study farms, as to strategies to achieve the zero-carbon act (ZCA) targets. These are, with respect to agriculture:

(i) Reduce methane by 10% from 2017 levels by 2030, and 24-47% reduction by 2050
(ii) Reduce nitrous oxide to net zero by 2050

While the 2050 methane targets are to be reviewed, and the trajectory of the nitrous oxide reduction as also to be set, the general assumption is:

Table 1: ZCA Targets

	2030	2050
Methane	-10%	-24 to -47%
Nitrous Oxide	-33%	-100%

Within the modelling, these targets were set as:

Table 2: Modelling GHG Targets

Year	2030	2050	2050
Methane reduction (%)	-10	-24	-47
Nitrous oxide reduction (%)	-30	-100	-100

3.0 SELECTION OF AGRI-BUSINESS CASE STUDY FARMS

Criteria for the selection of the case study enterprises were developed in consultation with the industry partners (Reference Group) and were set as:

(i) Must be a fully commercial farm, either dairying or sheep & beef.
(ii) A geographic spread if possible
(iii) Need to be amenable to being involved in the project

(iv) Preferably have a consultant involved in the farming enterprises

(v) Need to either have Farmax and Overseer files available, or amenable to them being developed for each of the farming enterprises

From this, four farming enterprises agreed to be case-study farms:

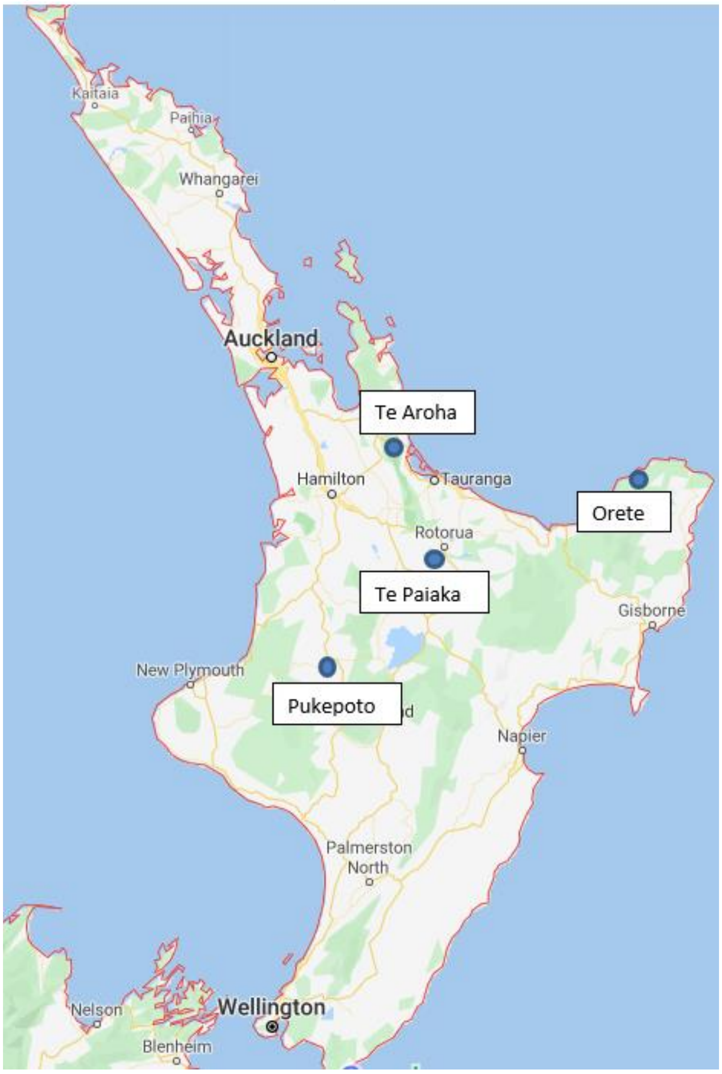
Dairy:

- Orete No. 2 Incorporation, Waihau Bay, Eastern Bay of Plenty
- Te Aroha, Waihi

Sheep & Beef

- Pukepoto Farm Trust, Ongarue
- Te Paiaka Lands Trust, Rotorua

Figure 1: Location of case-study farms



3.1 Case Study Farm Characteristics

3.1.1 Dairy farms

Table 3: Dairy Farm Physical Characteristics

	Pastoral Area (ha)	Forest Area (ha)	Native Bush/Non-Productive area (ha)	Total property (ha)	Cows Wintered 1 July	Cows Milked 15 December	Stocking rate (pastoral area) Cows/ha	Total Milksolids Production (kgMS)	Milksolids/ pastoral ha (kg MS)	Milksolids/ peak cow (kgMS)
Orete	161	0	0	161	432	395	2.7	136,959	851	347
Te Aroha	234	0	246	480	600	592	2.6	165,316	706	279

3.1.2 Sheep & Beef Farms

Table 4: Sheep & Beef Farm Physical Characteristics

	Pastoral Area (ha)	Forest Area for carbon (ha)	Forest Area no carbon (ha)	Native Forest/non-Productive (ha)	Total property (ha)	Sheep SU	Cattle SU	Total SU	Stocking rate (pastoral area) (SU/ha)
Pukepoto	1,050	49	12	324	1,435	8,558	3,858	12,416	11.8
Te Paiaka	507	72	0	315	894	1,054	4,637	5,691	11.2

3.2 Modelling Systems

All the farms were set up in Farmax (whole farm feed budgeting/economic model) which allowed for the farm system modelling. The results were then transferred to Overseer™ (nutrient budgeting model), which calculated nutrient discharges (nitrogen and phosphorus) as well as greenhouse gas emissions (methane, nitrous oxide, and carbon dioxide).

An excel spreadsheet was developed which integrated the information from Farmax and Overseer, as well as incorporating the forestry information.

While it is possible to optimise a farm system within Farmax, this is a time-consuming exercise. Consequently, when the model indicated that the new scenario was feasible, some tweaks were made to endeavour to optimise production, but this was not pursued to the n^{th} degree.

3.2.1 Economics

The farm economics were based on the Farmax modelling, using the default schedules and expenditure built into Farmax, based on the Dairy NZ and Beef + Lamb NZ economic surveys. The exception to this was:

- The Dairy payout was based on the 10-year average of $6.15/kg MS
- The Pukepoto farm expenditure was based on an actual 4-year average provided by the farm.

The farm profitability used in the scenario modelling was the EBITDA calculated via Farmax: Gross farm income less stock purchases, farm working expenditure, and depreciation. The change in profitability between the scenarios was based on the relative change in EBITDA.

3.2.1.1 Kiwifruit

Orete dairy farm has the option of converting some of its land to kiwifruit, which the owners are interested in undertaking. The economics of gold kiwifruit were calculated based on a 20-year investment analysis based in turn on data from Eastpack[1].

The investment analysis was based on a greenfield site development, discounted back to an NPV at a 6% discount rate. This NPV as then turned into an annuity, again at the 6% discount rate.

3.2.1.2 Forestry Economics

An annuity from production forestry (pinus radiata) was calculated[2] for each farm, based on a 28-year harvest rotation, simplified forestry regime, and a 10-quarter average log price, and yields estimated using the Forecaster model. Composite prices for the different log grades were also calculated based on domestic and export log prices. (Refer Appendix 1 for details).

Table 5: Forestry Returns ($/ha)

	NPV*	Annuity*
Orete	$2,451	$183
Te Aroha	$3,665	$273
Te Paiaka	$4,549	$339
Pukepoto	$3,044	$227

*Discount rate used =6% (current government discount rate)

3.2.2 Carbon Sequestration by Forestry

The two sheep & beef farms had existing areas of production forestry which (a) aren't registered within the ETS, but (b) would be eligible to do so. In addition, several of the scenarios on each of the case-study farms involved planting forestry for carbon offsets.

The carbon sequestration regime assumed for the scenario analysis was the new "averaging" scheme effective from 1 January 2021, and mandatory thereafter. The amount of carbon sequestration allowed was based on the MPI look-up tables[3], and calculated as follows:

(i) Total carbon sequestered at year 28 for the relevant region (Te Aroha/Pukepoto = Waikato/Taupo), Orete/Te Paiaka = Bay of Plenty) was determined.

(ii) This was then halved, and the resultant figure compared with the closest figure for years 16 or 17 from the look-up tables. For both regions the closest figure was for year 17.

(iii) The carbon sequestered at year 17 was then divided by 17 to give an annual average for that period.

Resultant carbon sequestration for the regions were:

- 23 tonnes CO_2e/ha/year for Waikato/Taupo
- 21.6 tonnes CO_2e/ha/year for Bay of Plenty

[1] Bay of Plenty kiwifruit packhouse. www.eastpack.co.nz
[2] By Peter Handford, Groundtruth Ltd
[3] https://www.mpi.govt.nz/dmsdocument/4762-a-guide-to-look-up-tables-for-forestry-in-the-emissions-trading-scheme

Essentially these are the carbon offset amounts that could be claimed by the case study farms for 17 years; after this period, in the absence of any other mitigations or technologies, another similar area of forestry would need to be planted.

Inasmuch as the carbon sequestered by the forest was used as an offset to the pastoral emissions, the value of carbon was ignored given that the two netted each other off. The default offset in the analysis for the forestry sequestration was as per the calculated ratio of methane to nitrous oxide for that scenario (normally around 78% methane/22% nitrous oxide), apart from the scenarios where the offset was deliberately differentiated.

The ZCA does not allow a direct offset of methane by forestry sequestration. Nevertheless, this is possible via the medium of money; the carbon from sequestration can be sold, and the money then used to pay any "methane tax". Within the analysis, the assumption was that forestry carbon credits could be readily offset across both the gases.

Pines were used as the base forestry specie, mainly for the reason that there is much more information readily available on their carbon sequestration rates and economic returns. Many farmers, including the case study farms, have voiced a preference for planting native trees as a permanent carbon offset.

There are several issues around natives, one of which is the current very high cost of establishment. But from a carbon offset angle, the main issue is the relatively slow annual sequestration rate compared to other species; approximately one third that of pines. Which means that to achieve the same annual level of offset as a pine forest, an area approximately three times larger must be planted. Which then creates issues of its own.

4.0 METHANE AND NITROUS OXIDE

Methane has several sources, including wetlands, landfills, forest fires, agriculture and fossil fuel extraction. In New Zealand, the main source of methane (95%) is from livestock.

Ruminants such as cows, sheep, deer and goats have four-chambered stomachs, enabling them to readily break down and extract energy and nutrients from fibrous plants like grass. Microbes in the rumen break down complex carbohydrates into simpler molecules, a process known as enteric fermentation. This process results in significant hydrogen ions being released, which are scavenged by methanogens, converted to methane (CH_4) and then belched out.

There is a direct relationship between the amount of methane produced (approximately 21 grams) per kilogramme of dry matter eaten. While there are some forages (e.g. cereal grain, forage rape) which produce less methane, they need to make up over 30% of the diet to have much impact.

Nitrous oxide is emitted into the atmosphere when micro-organisms act on nitrogen introduced to the soil via synthetic fertilisers, legumes such as white clover, or animal urine and dung. About 1% of nitrogen in the soil, from any source, is lost as nitrous oxide.

Most New Zealand pastures are high in protein, of which only a relatively small proportion is used by the animal via rumen digestion. The rest simply passes out the other end in urine and dung, which creates very concentrated nitrogen patches in the soil.

Which means that while New Zealand pastoral agriculture is carbon (atom) neutral, it is not greenhouse gas neutral.

For the average farm, methane makes up around 78% of total biological GHG emissions, and nitrous oxide 22%.

Taking this into account in order to mitigate GHG emissions, the two key tools currently available to farmers is:

(i) Reduce the amount of dry matter eaten. While this is not a recommended practice at an individual animal level, the corollary is to reduce stocking rates.

(ii) Reduce the amount of protein in the diet and/or reduce the amount of nitrogen fertiliser applied. While the former may be possible on some dairy farms feeding a lot of supplement, it does have limits for most pastoral farms.

4.1 Stocking rates and GHG emissions

While reducing stocking rates is currently the main tool for mitigating GHG emissions, the effectiveness of this strategy depends on the starting position of the farm (i.e. stocking rate/per-animal production) and grazing management. Given the direct relationship between methane production and dry matter eaten, a simple reduction in stocking rate will give a linear reduction in methane (and to all practical purposes, nitrous oxide as well).

The issue that arises is that such an approach usually has a significant negative impact on farm profitability and requires a much higher standard of grazing management in order to maintain pasture quality at the lower stocking rate. If pasture quality declines, production will decline even further.

Reducing stocking rate accompanied by increased per animal production, in order to maintain/improve profitability, will still reduce GHG emissions, but to a lesser extent, given that the remaining animals need to eat extra dry matter to achieve the higher production level.

A simplified (dairy) example to illustrate this:

Assume a 400-cow herd producing 160,000kg MS (400kgMS/cow). A 10% reduction in both results in 360 cows producing 144,000kg MS. GHG emissions from the herd has also reduced by 10%, but profitability has significantly reduced.

Assume then that the 360 cows are fed the (surplus) feed available, resulting in total production holding at the original 160,000 kg MS (i.e. per cow production has increased to 444 kg MS). This will have maintained if not improved farm profitability, while GHG emissions have reduced, but now by 5% relative to the base farm. This 5% reduction is due to two factors:

(i) The maintenance cost of the “missing” 40 cows is taken out of the system, and

(ii) At the margin, the increased per cow production means they are utilising the dry matter eaten more efficiently; in other words, they are eating less dry matter per kg of milksolids, and hence emitting less GHGs.

In noting this, the modelling still showed a reduction in total dry matter eaten in many of the "reduced stocking rate/improve per animal production scenarios. A case in point to illustrate this is from the Orete dairy farm.

Table 6: Orete dairy farm – difference in dry matter consumed

	Cows/ha	kgMS/peak cow	Tonnes DM eaten/ha	Difference from base (T DM/ha)	Tonnes DM eaten/cow	Change in GHG emissions
Base model	2.7	347	12.7		4.7	
Reduce cow numbers 15% - improve productivity	2.3	375	11.7	-1.0	5.1	-10%

This shows that while the amount per cow has increased, because of the increased production, total dry matter consumed has decreased due to the lower stock numbers, and hence GHG emissions have reduced.

5.0 MODELLING SCENARIOS

5.1 Dairy Farms

The various scenarios modelled for the two dairy farms were:

Table 7: Orete Dairy Farm Scenarios

	Scenario	Description
1	Base farm	Current existing farm system
2	Reduce cow numbers 10% - no improvement in productivity	Cow numbers were reduced by 10%, with no change in per cow production. Bought-in supplements were also proportionally reduced
3	Reduce cow numbers 10% - improve productivity	Cow numbers were reduced by 10%, with per cow production improved as much as possible within existing feed supplies
4	Reduce cow numbers 15% - improve productivity	Cow numbers were reduced by 15%, with per cow production improved as much as possible within existing feed supplies
5	Reduce replacement rate	The theory was that improved animal health and animal husbandry results in a reduction in deaths and an improvement in in-calf rates. The result being that less replacements can be reared. For Orete this meant a reduction in replacement heifers run, from 101 to 65.
6	No nitrogen fertiliser	All nitrogen fertiliser applied was eliminated. Base N usage was 59kgN/ha. To compensate for this cow numbers were reduced by 5% and per cow production held at the base level.
7	No bought supplementary feed	All bought-in supplement was eliminated. Total base bought-in supplement was 392 tonnes DM. To compensate, cow numbers were reduced by 10% and per cow production held at the base level.
8	No N fertiliser, No bought supplement	All nitrogen fertiliser and bought-in supplement were eliminated. To compensate, cow numbers were reduced by 15% and per cow production held at the base level.
9	10% of farm in pines	10% of the farm (16ha) was planted in pines. The intent was to use the forestry as a carbon offset in order to meet the 2030 targets. To compensate, cow numbers were reduced by 10% and per cow production held at the base level.
10	10% of farm in pines, reduce SR 10%	This was similar to Scenario (9), with cow numbers reduced further as a means to increase per animal production to help offset the drop in profitability. This resulted in a 19% reduction in cow numbers, with per cow production improved as much as possible within existing feed supplies
11	31% of farm in pines	31% of the farm (50ha) was planted in pines in order to make the farm carbon-neutral by offsetting with forestry. To compensate, cow numbers were reduced by 32% and per cow production held at the base level.
12	10% of farm in gold kiwifruit	The farm is suitable for growing kiwifruit, which is grown on surrounding blocks. The assumption was to plant 10% of the farm (16ha) in gold kiwifruit. To compensate, cow numbers were reduced by 10% and per cow production held at the base level.
13	24ha pines, reduce SR16%, differential offset	15% of the farm (24ha) was planted in pines, with the resultant carbon sequestration differentially attributed to offsetting methane and nitrous oxide, in order to achieve the 2050 targets. To compensate, cow numbers were reduced by 16% and per cow production held at the base level.

Table 8: Te Aroha Dairy Farm Scenarios

	Scenario	Description
1	Base farm	Current existing farm system
2	Reduce cow numbers 10% - no improvement in productivity	Cow numbers were reduced by 10%, with no change in per cow production. Bought-in supplements were also proportionally reduced
3	Reduce cow numbers 10% - improve productivity	Cow numbers were reduced by 10%, with per cow production improved as much as possible within existing feed supplies
4	Reduce cow numbers 15% - improve productivity	Cow numbers were reduced by 15%, with per cow production improved as much as possible within existing feed supplies
5	No nitrogen fertiliser	All nitrogen fertiliser applied was eliminated. Base N usage was 113kgN/ha. To compensate for this cow numbers were reduced by 10% and per cow production held at the base level.
6	No bought supplementary feed	All bought-in supplement was eliminated. Total base bought-in supplement was 158 tonnes DM. To compensate, cow numbers were reduced by 5% and per cow production held at the base level.
7	No N fertiliser, no bought supplement	All nitrogen fertiliser and bought-in supplement were eliminated. To compensate, cow numbers were reduced by 15% and per cow production held at the base level.
8	10% of farm in pines	10% of the farm (23ha) was planted in pines. The intent was to use the forestry as a carbon offset in order to meet the 2030 targets. To compensate, cow numbers were reduced by 5% and per cow production held at the base level.
9	31% of farm in pines	31% of the farm (73ha) was planted in pines in order to make the farm carbon-neutral by offsetting with forestry. To compensate, cow numbers were reduced by 13% and per cow production held at the base level.
10	Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	17% of the farm (40ha) was planted in pines, with the resultant carbon sequestration differentially attributed to offsetting methane and nitrous oxide, in order to achieve the 2050 targets. To compensate, cow numbers were reduced by 15% and per cow production improved as much as possible within existing feed supplies

Note: The Te Aroha farm has an area of 64ha which is not part of the milking platform. By concentrating the planting of trees on that area, the impact on the dairy operation is lessened.

5.2 Sheep & Beef farms

The various scenarios modelled for the two sheep & beef farms were:

Table 9: Te Paiaka Sheep & Beef Farm Scenarios

	Scenario	Description
1	Base farm	Current existing farm system
2	Reduce SR 10% - no improvement in productivity	Breeding ewe and finishing cattle numbers reduced by 10%. No change in dairy grazer numbers. No change in per animal production.
3	Reduce SR 10% - improve productivity	As for scenario (2), but per animal production increased within existing feed supplies: Lambing % increased from 130 to 135%, finishing cattle weights increased by ~20kg CW
4	Eliminate N Fertiliser#1 - Reduce sheep	Nitrogen fertiliser applications (average of 39kgN/ha over 222 ha) was eliminated. Only sheep numbers were reduced (by 25%) to compensate for this, with no improvement in per animal production.
5	Eliminate N Fertiliser#2 - Reduce sheep & cattle	As for scenario (4), but with both sheep and finishing cattle numbers reduced (by 10% each) to compensate. No change in dairy grazer numbers and no change in per animal production.
6	Forestry (Plant additional 65ha)	The farm currently has 72 ha of pines, which could be eligible for the ETS. A further 65 ha was planted (giving 137ha in total), which would be sufficient for the farm to be carbon neutral via offsetting. Sheep & finishing cattle numbers were reduced by 26% to compensate, with no improvement in per animal performance.
7	Remove dairy grazers, finish bulls	All dairy gazers were removed, and replaced with a finishing bull beef regime: 600 100kg LW weaners were purchased, and finished by 18-20 months of age at ~280 kg CW
8	Finish steers at 18-20 months	The cattle finishing regime concentrated on steers only; no heifers were purchased for finishing, instead 340 weaner steers were bought in and finished by 18-20 months at ~260kg CW. No change in dairy grazer numbers
9	Eliminate N Fertiliser#3 - Reduce sheep, no Grazers, finish bulls	Nitrogen fertiliser applications was eliminated. Sheep numbers were reduced by 25%, dairy grazers were removed, and 500 weaner bulls finished to ~ 270/280 kg CW by 18-20 months
10	Reduce SR 10%, improve productivity, differentiate offset	This is the same scenario as (3), except the carbon credits generated by the existing 72ha was differentially used to offset methane and nitrous oxide in order to achieve the 2050 ZCA targets

Table 10: Pukepoto Sheep & Beef Farm Scenarios

	Scenario	Description
1	Base	Current existing farm system
2	Forestry (Plant 140ha)	An additional 140ha of pines planted. Sheep numbers reduced 11%, cattle reduced 10% to compensate. No improvement in animal productivity
3	Forestry (Plant 300ha)	An additional 300ha of pines planted. Sheep and cattle numbers reduced 24% to compensate. No improvement in animal productivity
4	Forestry (Plant 500ha)	An additional 500ha of pines planted. Sheep and cattle numbers reduced 41% to compensate. No improvement in animal productivity
5	Decrease ewes 20% - increase lambing % and beef weights	Breeding ewe and replacement hoggets reduced by 20%. Lambing % increased from 127 to 160%, + steers finished to 300kg CW
6	Decrease SR 10% - no change in performance	Sheep & cattle numbers reduced by 10%. No change in per animal production.
7	Decrease SR 10% - change performance	As for scenario (6), but per animal production increased within existing feed supplies: Lambing % increased from 127 to 135%, lamb weights increased by 1.5kg CW, finishing cattle to 290kg CW
8	No Breeding Cows, finish bulls	Breeding cow herd eliminated and replaced with bull beef: 400 weaner bulls finished to 260kg CW at 18-20 months
9	Increase subdivisional fencing	This was based on the study by Journeaux and van Reneen (2017)[4] which showed an improvement in animal performance due to better subdivision and reticulated water on hill country. The scenario assumed an average improvement in performance relative to this study (lambing % improved to 135, and cattle weights increased by 20kg CW). A capital cost of $262,500 was capitalised into the EBITDA figure.
10	Forestry - plant natives to join Whenua Rahui areas	This assumed an area of 30ha was planted in native trees as a means to join up existing Whenua Rahui areas.
11	Reduce replacement rates	This scenario assumed an improvement in animal health/animal husbandry such that death rates and dry animal rates decreased. Which in turn meant a lower replacement rate could be run; 20% down to 15% for sheep, 27% down to 20% for cattle
12	Decrease ewes 10%, No Breeding cows - finish bulls, increased subdivision	This combined a number of the above scenarios; breeding ewe numbers were reduced 10% (lambing % increased to 140%), breeding cows were swapped for finishing bull beef (450 weaners finished to 300kg CW), and improved subdivision/water supply was installed
13	Decrease SR 10%, improve performance, +33ha pines, differential offset	This is the same scenario as (7), with the addition of an extra 33ha of pines (giving 82ha in total), with the carbon sequestered differentially distributed relative to methane and nitrous oxide emissions, so as to achieve the 2050 targets.

[4] Economic Evaluation of Stock Water Reticulation on Hill Country. https://www.mpi.govt.nz/growing-and-harvesting/land-care-and-farm-management/stock-water-reticulation/

6.0 RESULTS

6.1 Dairy Case Study Farms

Note: Impacts on supplementary feed inputs is shown in Appendix 2.

6.1.1 Orete

Table 11: Orete Physical Aspects of the Scenarios

	Pastoral Area (ha)	Forest Area (ha)	Cows Wintered 1 July	Cows Milked 15 December	Stocking rate (pastoral area) Cows/ha	Total Milksolids Production (kg)	Milksolids/pastoral ha (kg)	Milksolids/peak cow (kg)
Base model	161		432	395	2.7	136,959	851	347
Reduce cow numbers 10% - no improvement in productivity	161		389	355	2.4	123,146	765	347
Reduce cow numbers 10% - improve productivity	161		389	355	2.4	133,851	831	377
Reduce cow numbers 15% - improve productivity	161		367	335	2.3	125,758	781	375
Reduce replacement rate	161		432	407	2.7	141,485	879	348
No nitrogen fertiliser	161		410	375	2.5	130,079	808	347
No bought supplementary feed	161		389	355	2.4	106,889	664	301
No N fertiliser, No bought supplement	161		367	335	2.3	101,633	631	303
10% of farm in pines	145	16	389	355	2.7	123,250	850	347
10% of farm in pines, reduce SR 10%	145	16	350	319	2.4	123,360	851	387
31% of farm in pines	111	50	294	267	2.6	94,541	852	354
10% of farm in gold kiwifruit	145	16	389	355	2.7	123,250	850	347
24ha pines, reduce SR16%, differential offset	137	24	363	357	2.6	115,258	841	323

Table 12: Orete Scenario Impact on GHG Emissions and Farm Profitability

	Total property net CO_2e (T/ha)	Total GHG % change from Base	% Change in pastoral methane from base	% Change in pastoral Nitrous Oxide from base	% Change in methane from base, including forestry	% Change in Nitrous Oxide from base, including forestry	EBITDA ($ effective ha/yr)	% change from Base model
Base model	8.4						$1,056	
Reduce cow numbers 10% - no improvement in productivity	7.7	-8%	-8%	-9%	-8%	-9%	$685	-35%
Reduce cow numbers 10% - improve productivity	7.9	-6%	-6%	-6%	-6%	-6%	$1,409	33%
Reduce cow numbers 15% - improve productivity	7.5	-10%	-11%	-6%	-11%	-6%	$1,461	38%
Reduce replacement rate	8.3	-1%	-1%	0%	-1%	0%	$1,181	12%
No nitrogen fertiliser	7.8	-7%	-4%	-19%	-4%	-19%	$1,005	-5%
No bought supplementary feed	7.6	-10%	-12%	-1%	-12%	-1%	$837	-21%
No N fertiliser, No bought supplement	7.0	-17%	-16%	-20%	-16%	-20%	$883	-16%
10% of farm in pines	5.6	-33%	-8%	-9%	-33%	-34%	$981	-7%
10% of farm in pines, reduce SR 10%	5.1	-39%	-14%	-15%	-39%	-39%	$1,296	23%
31% of farm in pines	-0.3	-103%	-25%	-28%	-103%	-103%	$662	-37%
10% of farm in gold kiwifruit	7.7	-8%	-8%	-9%	-8%	-9%	$1,658	57%
24ha pines, reduce SR16%, differential offset	4.1	-51%	-13%	-12%	-38%	-100%	$737	-30%

Note: The "% change in pastoral methane/nitrous oxide" is the change in emission of the gasses from just the pastoral area, whereas the "% change including forestry" is the change in emissions where the forestry offset has been included.

Table 13: Orete Nutrient Losses

	(kg N/ha/yr)	% Change in N from Base	(kg P/ha/yr)	% Change in P from Base
Base model	37		4.4	
Reduce cow numbers 10% - no improvement in productivity	36	-3%	4.4	0%
Reduce cow numbers 10% - improve productivity	35	-5%	4.4	0%
Reduce cow numbers 15% - improve productivity	35	-5%	4.4	0%
Reduce replacement rate	37	0%	4.4	0%
No nitrogen fertiliser	32	-14%	4.4	0%
No bought supplementary feed	34	-8%	4.4	0%
No N fertiliser, No bought supplement	30	-19%	4.4	0%
10% of farm in pines	35	-5%	4.1	-7%
10% of farm in pines, reduce SR 10%	34	-8%	4.1	-7%
31% of farm in pines	28	-24%	2.8	-36%
10% of farm in gold kiwifruit	36	-3%	4.1	-7%
24ha pines, reduce SR16%, differential offset	34	-8%	3.8	-14%

6.1.2 Te Aroha

Table 14: Te Aroha Physical Aspects of the Scenarios

	Pastoral Area (ha)	Forest Area (ha)	Total property (ha)	Cows Wintered 1 July	Cows Milked 15 December	Stocking rate (pastoral area) Cows/ha	Total Milksolids Production (kg MS)	Milksolids/pastoral ha (kg MS)	Milksolids/peak cow (kg MS)
Base model	234	0	480	600	592	2.6	165,316	706	279
Reduce cow numbers 10% - no improvement in productivity	234	0	480	540	532	2.3	148,522	635	279
Reduce cow numbers 10% - improve productivity	234	0	480	540	532	2.3	170,119	727	320
Reduce cow numbers 15% - improve productivity	234	0	480	510	502	2.2	167,825	717	334
No nitrogen fertiliser	234	0	480	540	532	2.3	148,523	635	279
No bought supplementary feed	234	0	480	570	562	2.4	157,032	671	279
No N fertiliser, No bought supplement	234	0	480	510	502	2.2	139,828	598	279
10% of effective area in pines	211	23	480	570	562	2.7	156,827	743	279
31% of effective area in pines	161	73	480	471	463	2.9	129,795	806	280
Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	194	40	480	510	502	2.6	167,795	865	334

Table 15: Te Aroha Scenario Impact on GHG Emissions and Farm Profitability

	Total property net CO_2e (T/ha)	Total GHG % change from Base	% Change in pastoral methane from base	% Change in pastoral Nitrous Oxide from base	% Change in methane from base, including forestry	% Change in Nitrous Oxide from base, including forestry	EBITDA ($ effective ha/yr)	% change from Base model
Base model	4.5						$2,276	
Reduce cow numbers 10% - no improvement in productivity	4.0	-11%	-11%	-9%	-11%	-9%	$1,857	-18%
Reduce cow numbers 10% - improve productivity	4.2	-6%	-6%	-6%	-6%	-6%	$2,444	7%
Reduce cow numbers 15% - improve productivity	4.1	-9%	-10%	-9%	-10%	-9%	$2,320	2%
No nitrogen fertiliser	3.8	-16%	-11%	-30%	-11%	-30%	$2,111	-7%
No bought supplementary feed	4.2	-6%	-6%	-4%	-6%	-4%	$2,258	-1%
No N fertiliser, No bought supplement	3.6	-20%	-16%	-33%	-16%	-33%	$2,043	-10%
10% of effective area in pines	3.1	-31%	-6%	-5%	-31%	-30%	$2,100	-8%
31% of effective area in pines	0.0	-100%	-23%	-20%	-100%	-100%	$1,509	-34%
Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	2.1	-52%	-10%	-9%	-36%	-100%	$2,367	4%

Table 16: Te Aroha Nutrient Losses

	(kg N/ha/yr)	% Change in N from Base	(kg P/ha/yr)	% Change in P from Base
Base model	46		1.2	
Reduce cow numbers 10% - no improvement in productivity	42	-9%	1.2	0%
Reduce cow numbers 10% - improve productivity	41	-11%	1.2	0%
Reduce cow numbers 15% - improve productivity	41	-11%	1.2	0%
No nitrogen fertiliser	34	-26%	1.0	-17%
No bought supplementary feed	43	-7%	1.2	0%
No N fertiliser, No bought supplement	33	-28%	1.0	-17%
10% of effective area in pines	43	-7%	1.1	-8%
31% of effective area in pines	37	-20%	0.8	-33%
Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	41	-11%	1.0	-17%

6.1.3 Dairy Modelling Discussion

As discussed in Section 4.1, for both farms the scenario of reducing cow numbers (by 10%) and not improving productivity, has a direct linear effect on reducing GHGs, but a negative impact on farm profitability. The scenarios where cow numbers are reduced but per cow production increased, saw a reduction in GHGs, with the proportional difference varying between the two farms, but an improvement in farm profitability.

Whether these improvements in productivity could be readily realised would depend on the expertise of the farmer, and the quality of the cows. For many farms such improvements would be achievable, but over a period of time as farmer expertise and the genetic quality of the cows improved – for many it would not be a quick fix.

The reduction in replacement stock numbers (modelled for Orete but not Te Aroha – the latter are currently raising well above normal replacement rates as a means of increasing cow numbers) showed a very modest reduction in GHG emissions (1%), but an increase in profitability due to the lesser number of heifers needing to be reared and grazed. Which in itself is an indicator for improving farm productivity.

Eliminating nitrogen fertiliser and/or supplementary feed has a direct impact in reducing GHG emissions, simply by reducing the amount of feed available for the stock. As could be expected, the loss of nitrogen fertiliser has a bigger effect in reducing nitrous oxide emissions, whereas the loss of bought-in supplements affects methane emissions more.

The various "plant trees" scenarios reduced GHG emissions from the pastoral area directly proportional to the reduction in stock numbers necessary to allow for the planting of trees. The use of carbon offsets though materially affected the amount of net emissions from the farming property.

6.1.3.1 Dairying – Achieving the ZCA Targets

As outlined in Section 2.1, the ZCA targets are:

Table 17: Generalised ZCA Targets

	2030	2050
Methane	-10%	-36%*
Nitrous Oxide	-33%**	-100%

*This is the mid-point between the -24 to -47% reduction
** Assumed 2030 target: linear reduction from 2020 to 2050

As can be seen from Tables 12 and 15, altering the farm system can go some way to achieving the 2030 methane target, but usually falls well short of achieving the nitrous oxide reduction target. As ever, there is some difference between the farms as a result of their differing systems.

- Eliminating nitrogen fertiliser meant that Te Aroha achieved the 2030 target for methane and (largely) for nitrous oxide, whereas Orete fell short for both - mainly due to the fact that Te Aroha uses much more nitrogen than Orete. For both farms though, this scenario resulted in a reduction in farm profitability.

- Eliminating both nitrogen fertiliser and supplementary feed meant that Te Aroha achieved the 2030 targets, but again Orete fell short, and again both farms saw a significant drop in profitability.
- The “reduce cows by 15%/increase productivity” scenario saw both farms achieve the methane reduction target but fall well short of the nitrous oxide reduction target. This scenario did improve farm profitability, but as noted earlier, this is not a “quick-fix” exercise.
- The elimination of nitrogen fertiliser and/or bought in supplementary feed is, farm profitability impact aside, quite achievable – in essence the farm is now being run much more extensively. But there are other implications for this system that need to be considered:
    - The farm system is much more at risk of an adverse climatic event, e.g. drought, where some form of supplementary feed may be necessary to get the stock through the event.
    - While the farm may be more resilient to a lower payout, it cannot readily take advantage of an increased payout.
- Land use change into horticulture is also an option. For Orete, kiwifruit is definitely a possibility, and could be for Te Aroha. The main advantage from a GHG emission perspective is that such emissions from kiwifruit is very low relative to pastoral farming, and the inclusion of such an enterprise allows the business to “average down” its GHG emissions.

  The inclusion of 16ha of kiwifruit (10% of the effective area) for Orete resulted in:
    - The farm getting close to the 2030 target for methane reduction but falling well short of the nitrous oxide target. And would singularly fail to reach the 2050 targets
    - A significant improvement in farm profitability, notwithstanding a capital development requirement of $8+ million.

Achieving the 2050 target is much more problematic. Reducing stocking rates to achieve even a 24% reduction in methane would, increasing per animal productivity included, render the farm financially unviable.

This is where forestry as an offset would become important, at least in the short term.

- Planting 10% of the farm in pines (with attendant stock reduction), for both farms, achieved the 2030 targets, with an over-achievement in the methane reduction. This means that (a) a smaller area of pines could be grown, with (b) a differential offset applied, such that less was used to counter methane, and more applied to offset nitrous oxide. Again, however, this also reduced farm profitability.
- Planting 31% of the effective area of the farms in pines resulted in carbon neutrality, albeit with a significant reduction in farm profitability.
- Planting a set area in pines (24ha for Orete, 40ha for Te Aroha), and differentially applying the carbon offset between methane and nitrous oxide, along with reducing stocking rate but improving per animal productivity, meant that the farm achieved the 2050 reduction targets for both gasses (noting that the methane target was assumed to be -36%, the midpoint between the current -24 to -47% reduction mooted in the ZCA)[5].

[5] If the target is -24% methane/-100% nitrous oxide, then Orete would need to plant 17ha of trees, Te Aroha 32ha

The impact on this on farm profitability varied widely; -30% for Orete versus +4% for Te Aroha. The key reason behind this was that the planting on Orete was all on fully-productive land, whereas for Te Aroha, of the 234ha effective, the milking platform is 170ha, with 64ha of much lower productive land used for grazing dry cows and young stock. The forestry was assumed to be planted on this much less productive area, therefore having a much lesser impact on the milking platform.

A secondary reason is the profitability of the trees as a production forest. Orete is a long distance (230km) to the nearest port, and the profitability of the forest is therefore much less compared with Te Aroha (ref Section 3.2.1.2)

As discussed in Section 3.2.2, the default application of the carbon offset from forestry was 78% to methane, 22% to nitrous oxide, which is the average emission ratio from farms. For the differential offset, it was applied as 52/48% respectively for Orete, and 54/46% for Te Aroha.

The other issue with forestry as an offset is the relatively short period over which this can be done; under the new averaging scheme, any forest planted on both Orete and Te Aroha, could only use offsetting for 17 years, after which (in the absence of any other mitigation strategy) a further area would need to be planted.

Assuming therefore that an area was planted in the next few years in order to achieve the 2030 reduction targets, particularly for nitrous oxide, this benefit would finish in the late 2030's. At which stage another, larger, area would need to be planted to achieve the 2050 reduction targets, thereby compounding the impact on the farming system.

6.1.3.2 Dairying Nutrient Losses

While this study is concentrated on reducing GHG emissions, the modelling also allowed an analysis on nutrient (nitrogen and phosphorus) losses (See Tables 13 and 16 above). Key aspects are:

- The reduction in stocking rate scenarios generally had a relatively modest impact on reducing nitrogen losses (varying from -3 to -11%), and no impact on reducing phosphorus losses.
- Eliminating (particularly) nitrogen fertiliser and/or supplementary feed generally had a larger impact on nitrogen losses
- Planting trees had an impact on both nitrogen and phosphorus losses, but only if significant areas were being planted up.

It is very probable that the farms could be facing a reduction in nitrogen losses once Regional water quality plans are enacted. Obviously, any strategies to reduce such losses would have an impact on GHG emissions, and vice-versa. Which emphasises the need to consider nutrient loss and GHG reduction strategies in a combined manner within farm environment plans.

If the target is -47% methane/-100% nitrous oxide, then Orete would need to plant 29ha of trees, and Te Aroha 48ha

6.2 Sheep & Beef Case study Farms

6.2.1 Pukepoto

Table 18: Pukepoto Physical Aspects of the Scenarios

	Pastoral Area (ha)	Forest Area for carbon (ha)	Forest Area No carbon (ha)	Native Forest/non-Productive (ha)	Total property (ha)	Breeding Ewes (hd)	Breeding Cows (hd)	SSU	CSU	TSU	SU/ha
Base	1,050	49	12	324	1,435	6,400	295	8,558	3,858	12,416	11.8
Forestry (Plant 140ha)	910	189	12	324	1,435	5,700	258	7,617	3,412	11,029	12.1
Forestry (Plant 300ha)	750	349	12	324	1,435	4,867	218	6,520	2,891	9,411	12.5
Forestry (Plant 500ha)	550	549	12	324	1,435	3,778	169	5,049	2,250	7,299	13.3
Decrease ewes 20% - increase lambing % and beef weights	1,050	49	12	324	1,435	5,123	295	6,847	3,814	10,661	10.2
Decrease SR 10% - no change in performance	1,050	49	12	324	1,435	5,764	258	7,703	3,412	11,115	10.6
Decrease SR 10% - change performance	1,050	49	12	324	1,435	5,764	258	7,703	3,412	11,115	10.6
No Breeding Cows, finish bulls	1,050	49	12	324	1,435	6,400	0	8,558	3,973	12,531	11.9
Increase subdivisional fencing	1,050	49	12	324	1,435	6,400	295	8,558	3,858	12,416	11.8
Forestry - plant natives to join Whenua Rahui areas	1,020	79	12	324	1,435	6,212	295	8,302	3,858	12,160	11.9
Reduce replacement rates	1,050	49	12	324	1,435	6,400	295	7,864	3,684	11,548	11.0
Decrease ewes 10%, No Breeding cows - finish bulls, increase subdivision	1,050	49	12	324	1,435	5,764	0	7,703	2,007	9,710	9.2
Decrease SR 10%, improve performance, +33ha pines, differential offset	1,017	82	12	324	1,435	5,764	258	7,703	3,412	11,115	10.9

Table 19: Pukepoto Scenario Impact on GHG Emissions and Farm Profitability

	Gross CO_2e pastoral area (t/ha)	Total property net CO_2e (T/ha)	Total GHG % change from Base	% Change in pastoral methane from base	% Change in pastoral Nitrous Oxide from base	% Change in methane from base, including forestry	% Change in Nitrous Oxide from base, including forestry	EBITDA ($ effective ha/yr)	% change from Base model
Base	3.3	2.5						$446	
Forestry (Plant 140ha)	2.9	-0.1	-105%	-11%	-11%	-104%	-104%	$377*	-15%
Forestry (Plant 300ha)	2.5	-3.1	-226%	-24%	-25%	-196%	-195%	$370*	-17%
Forestry (Plant 500ha)	1.9	-6.9	-378%	-42%	-43%	-312%	-309%	$327*	-27%
Decrease ewes 20% - increase lambing % and beef weights	3.0	2.2	-10%	-8%	-8%	-32%	-32%	$542	22%
Decrease SR 10% - no change in performance	2.9	2.2	-13%	-10%	-10%	-34%	-34%	$369	-17%
Decrease SR 10% - change performance	3.0	2.2	-12%	-9%	-9%	-33%	-33%	$510	14%
No Breeding Cows, finish bulls	3.1	2.3	-6%	-4%	-5%	-28%	-29%	$488	9%
Increase subdivisional fencing	3.3	2.5	2%	2%	2%	-22%	-22%	$491	10%
Forestry - plant natives to join Whenua Rahui areas	3.2	2.3	-8%	-2%	-2%	-13%	-13%	$436	-2%
Reduce replacement rates	3.2	2.5	-1%	-1%	0%	-25%	-25%	$461	3%
Decrease ewes 10%, No Breeding cows - finish bulls, increase subdivision	3.1	2.4	-5%	-3%	-6%	-27%	-30%	$724	62%
Decrease SR 10%, improve performance, +33ha pines, differential offset	3.0	1.7	-33%	-9%	-9%	-35%	-100%	$516	16%

*Excludes sale of surplus carbon credits – see Section 6.3.2.1

Table 20: Pukepoto Nutrient Losses

	(kg N/ha/yr)	% N Change from Base	(kg P/ha/yr)	% P Change from Base
Base	13		0.6	
Forestry (Plant 140ha)	12	-8%	0.5	-17%
Forestry (Plant 300ha)	10	-23%	0.4	-33%
Forestry (Plant 500ha)	9	-31%	0.3	-50%
Decrease ewes 20% - increase lambing % and beef weights	12	-8%	0.6	0%
Decrease SR 10% - no change in performance	12	-8%	0.6	0%
Decrease SR 10% - change performance	12	-8%	0.6	0%
No Breeding Cows, finish bulls	12	-8%	0.6	0%
Increase subdivisional fencing	13	0%	0.6	0%
Forestry - plant natives to join Whenua Rahui areas	12	-8%	0.6	0%
Reduce replacement rates	12	-8%	0.6	0%
Decrease ewes 10%, No Breeding cows - finish bulls, increase subdivision	12	-8%	0.6	0%
Decrease SR 10%, improve performance, +33ha pines, differential offset	12	-8%	0.6	0%

6.2.2 Te Paiaka

Table 21: Te Paiaka Physical Aspects of the Scenarios

	Pastoral Area (ha)	Existing Forestry (ha)	New Forestry (ha)	Native Forest/non-Productive (ha)	Total property (ha)	Breeding Ewes	SSU	CSU	TSU	SU/ha
Base	507	72	0	315	894	950	1,054	4,637	5,691	11.2
Reduce SR 10% - no improvement in productivity	507	72	0	315	894	855	949	4,441	5,390	10.6
Reduce SR 10% - improve productivity	507	72	0	315	894	855	949	4,441	5,390	10.6
Eliminate N Fertiliser#1 - Reduce sheep	507	72	0	315	894	712	790	4,637	5,427	10.7
Eliminate N Fertiliser#2 - Reduce sheep & cattle	507	72	0	315	894	855	949	4,441	5,390	10.6
Forestry#1 (Plant 65ha)	442	72	65	315	894	760	843	4,260	5,103	11.5
Remove dairy grazers, finish bulls	507	72	0	315	894	950	1,054	4,547	5,601	11.0
Finish steers at 18-20 months	507	72	0	315	894	950	1,054	4,289	5,343	10.5
Eliminate N Fertiliser#3 - Reduce sheep, no Grazers, finish bulls	507	72	0	315	894	712	790	4,097	4,887	9.6
Reduce SR 10%, improve productivity, differentiate offset	507	72	0	315	894	855	949	4,441	5,390	10.6

Table 22: Te Paiaka Scenario Impact on GHG Emissions and Farm Profitability

	Gross CO_2e pastoral area (t/ha)	Total property net CO_2e (T/ha)	Total GHG % change from Base	% Change in pastoral methane from base	% Change in pastoral Nitrous Oxide from base	% Change in methane from base, including forestry	% Change in Nitrous Oxide from base, including forestry	EBITDA ($ effective ha/yr)	% change from Base model
Base	3.5	1.8						$666	
Reduce SR 10% - no improvement in productivity	3.4	1.7	-7%	-4%	-3%	-53%	-53%	$603	-9%
Reduce SR 10% - improve productivity	3.4	1.7	-7%	-4%	-3%	-53%	-53%	$646	-3%
Eliminate N Fertiliser#1 - Reduce sheep	3.4	1.6	-7%	-3%	-7%	-53%	-55%	$638	-4%
Eliminate N Fertiliser#2 - Reduce sheep & cattle	3.4	1.6	-8%	-3%	-7%	-53%	-55%	$626	-6%
Forestry#1 (Plant 65ha)	3.2	-0.1	-108%	-10%	-10%	-104%	-104%	$617	-7%
Remove dairy grazers, finish bulls	3.3	1.6	-12%	-6%	-6%	-55%	-55%	$856	29%
Finish steers at 18-20 months	3.7	2.0	10%	6%	4%	-44%	-45%	$732	10%
Eliminate N Fertiliser#3 - Reduce sheep, no Grazers, finish bulls	2.9	1.2	-33%	-16%	-20%	-66%	-67%	$642	-4%
Reduce SR 10%, improve productivity, differentiate offset	3.4	1.7	-7%	-4%	-3%	-40%	-100%	$646	-3%

Table 23: Te Paiaka Nutrient Losses

	(kg N/ha/yr)	% N Change from Base	(kg P/ha/yr)	% P Change from Base
Base	18		0.4	
Reduce SR 10% - no improvement in productivity	17	-6%	0.4	0%
Reduce SR 10% - improve productivity	17	-6%	0.4	0%
Eliminate N Fertiliser#1 - Reduce sheep	17	-6%	0.4	0%
Eliminate N Fertiliser#2 - Reduce sheep & cattle	17	-6%	0.4	0%
Forestry#1 (Plant 65ha)	17	-6%	0.4	0%
Remove dairy grazers, finish bulls	16	-11%	0.4	0%
Finish steers at 18-20 months	18	0%	0.4	0%
Eliminate N Fertiliser#3 - Reduce sheep, no Grazers, finish bulls	15	-17%	0.4	0%
Reduce SR 10%, improve productivity, differentiate offset	17	-6%	0.4	0%

6.2.3 Sheep & Beef Modelling Discussion

The sheep & beef farm modelling threw up a range of responses, depending on the characteristics of the individual farm. As a generality, reducing stocking rates (with or without changing per animal productivity) gave a relatively modest reduction in methane – sometimes reaching the 2030 target of -10%, or at least getting close. None got anywhere near achieving the 2030 nitrous oxide reduction target. Profitability impacts varied, again depending on the farm (Pukepoto is more of a traditional breeding ewes/breeding cows/finishing stock, whereas Te Paiaka has a small breeding ewe flock, but finishes steers and heifers, and runs dairy grazers). The "reduce stocking rate/improve per animal performance" gave a lift in profitability for Pukepoto, whereas for Te Paiaka it reduced the level of loss.

The same caveat as noted in the dairying section also applies here; a stocking rate reduction followed by an improvement in per animal productivity takes time to achieve. A good example would be the "reduce ewes 20%/increasing lambing from 127 to 160%" Pukepoto scenario.

While this is achievable, it is most probably a 10-year exercise, requiring an increase in farmer skills and expertise (i.e. in grazing management and animal husbandry), as well as an improvement in the genetic quality of the breeding stock. Having 160% lambing in spring requires a high level of farm management, especially ensuring ewes are in good condition and well fed, with good pasture covers before them, and shelter is readily available in case of a storm (160% lambing in hill country can be a high risk exercise).

"Mixing and matching" stock types on the farm, for example removing breeding cows or dairy grazers and replacing them with finishing bull beef gave a lift in farm profitability, but very modest reductions in GHGs. The "finishing steers" on Te Paiaka, and the "increased subdivision" for Pukepoto improved profitability, but also resulted in a slight increase in GHG emissions.

Achieving the ZCA targets therefore often came back to planting trees. Both Pukepoto (49ha) and Te Paiaka (72ha) had existing areas of production forestry, which (a) isn't currently registered within the ETS, but (b) easily could be. If the assumption is that the carbon sequestered by these forests is used to offset the pastoral GHG emissions, then in most scenarios the 2030 reduction targets are very largely met, especially for Te Paiaka.

For Te Paiaka, the existing area of trees, along with the "reduce stocking rate 10%/improve productivity" scenario, would, if the carbon credits are differentially split as an offset between methane and nitrous oxide, met the 2050 reduction targets, albeit for a slight (-3%) reduction in profitability. For Pukepoto, the same "reduce stocking rate/improve performance" scenario, plus planting an additional 33 ha of pines (giving 82ha in total), with the carbon credits applied differentially as an offset, mean that the farm would also meet the 2050 reduction targets, with an increase in profitability[6]. The differential split of carbon credits from forestry was 51% to methane/49% to nitrous oxide for Pukepoto, and 57/43% respectively for Te Paiaka.

[6] Again, this is assuming a mid-point -36% reduction in methane.
If the target is -24% methane/-100% nitrous oxide, then Pukepoto would need to plant a total of 64ha of trees (i.e 15 ha more than currently planted), Te Paiaka already has more than sufficient forest area to meet this target
If the target is -47% methane/-100% nitrous oxide, then Pukepoto would need to plant a total of 103ha of trees (i.e. a further 54ha), and Te Paiaka would need a total of 80ha (i.e. 8ha more than currently planted)

For Pukepoto, planting an additional 140ha of pines (giving 189ha in total), means the farm is effectively carbon neutral, albeit with a 15% reduction in profitability. For Te Paiaka, an additional 65ha of pines (giving 137ha in total) would mean the farm was carbon neutral, with a 7% reduction in profitability. This difference in impact on profitability is largely due to the difference in the proportion of the farm planted in trees; for Pukepoto, the total area of trees, to be carbon neutral, is 18% of the original pasture + forestry area, whereas for Te Paiaka it is 12.5% of the original area.

6.2.3.1 *Selling Surplus Carbon*

For the Pukepoto modelling, 3 scenarios were run whereby significantly increased areas of (pine) trees were planted:

- 140 ha
- 300ha
- 500ha

As noted above, the extra 140ha planting effectively meant the farm was (just above) carbon neutral. For the other two scenarios, it would mean that the farm would have significant carbon credits for sale. The returns from selling carbon credits is outlined below, with the key assumption that the “surplus” credits are those above that required to meet the 2050 reduction targets.

Table 24: Pukepoto Income including carbon credit sales

	Area planted (ha)	Area required for 2050 targets (ha)	Area available for carbon credit sales (ha)	Average carbon sequestration (tonnes CO_2e/ha/year)	Total value @$25/tonne	Value per (available) forestry ha	EBITDA* applied across whole farm enterprise ($/ha)	% change relative to base	Total value @$50/tonne	Value per (available) forestry ha	EBITDA* applied across whole farm enterprise ($/ha)	% change relative to base
Base	49	82					$446				$446	
Plant 140 ha	189	82	107	23	$61,525	$575	$433	-3%	$123,050	$1,150	$489	10%
Plant 300 ha	349	82	267	23	$153,525	$575	$510	14%	$307,050	$1,150	$650	46%
Plant 500 ha	549	82	467	23	$268,525	$575	$572	28%	$537,050	$1,150	$816	83%

*Includes the farming and forestry income as per Table 18

As can be seen from Table 23, the inclusion of carbon credits significantly improves the overall enterprise income, with the caveat that the credits, under the new averaging scheme, would last for 17 years before the forestry would essentially revert to a production forest regime. And in the absence of any other mitigation strategy, a further area of forest would need to be planted, to continue to provide carbon offsets.

6.2.3.2 Sheep & Beef Nutrient Losses

Tables 20 and 23 show the nutrient loss from the two case study farms. From a nitrogen loss perspective, both have relatively modest base losses (Pukepoto 13kg N/ha/year, Te Paiaka 18 kg N/ha/year), especially considering they are both on free-draining soils and have a relatively high rainfall.

The impact of the various scenarios is very similar to that for the dairy farms:

(i) Changes in the farm systems gave relatively small changes in nitrogen leaching (generally -6 to -8%), and no change in phosphorus losses

(ii) For Te Paiaka, the reduction in nitrogen loss increased somewhat with the removal of the dairy grazers

(iii) For Pukepoto, there were significant reductions in both nitrogen and phosphorus losses as a result of increasing the amount of forestry area planted.

Again, as for the dairy farms, the advent of any restrictions on nutrient losses will impact on GHG emissions, and vice versa. Which again emphasises the need to consider both within any farm environment plans.

7.0 CARBON SHADOW PRICES

Within the spreadsheet used to calculate the changes in emissions and profitability, etc, there was also a calculation as to the "carbon cost of mitigation", which was calculated as the change in EBITDA divided by the change in GHG emissions. This is in effect a "shadow price" or the price at which carbon would need to be priced to equate to the cost of the mitigation. In other words, if the cost of carbon is less than the shadow price, then the cheapest option is to pay for the emissions directly, and conversely, if the shadow price is lower than the cost of carbon, then it is more profitable to carry out the mitigation. The current price of carbon (as CO_2e) under the ETS, is $25/tonne.

Table 25: Dairy case study carbon shadow prices relative to scenarios

	Shadow price ($/tonne CO_2e)
Orete	
Reduce cow numbers 10% - no improvement in productivity	$522
Reduce cow numbers 10% - improve productivity	-$672
Reduce cow numbers 15% - improve productivity	-$468
Reduce replacement rate	-$2,858
No nitrogen fertiliser	$84
No bought supplementary feed	$270
No N fertiliser, No bought supplement	$124
10% of farm in pines	$26
10% of farm in pines, reduce SR 10%	-$73
31% of farm in pines	$44
10% of farm in gold kiwifruit	-$841
24ha pines, reduce SR16%, differential offset	$75
Te Aroha	
Reduce cow numbers 10% - no improvement in productivity	$424
Reduce cow numbers 10% - improve productivity	-$304
Reduce cow numbers 15% - improve productivity	-$51
No nitrogen fertiliser	$112
No bought supplementary feed	$36
No N fertiliser, No bought supplement	$124
10% of effective area in pines	$62
31% of effective area in pines	$83
Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	-$19

Table 26: Sheep & beef case study carbon shadow prices relative to scenarios

Pukepoto	Shadow price ($/tonne CO_2e)
Forestry (Plant 140ha)	$20
Forestry (Plant 300ha)	$10
Forestry (Plant 500ha)	$10
Decrease ewes 20% - increase lambing % and beef weights	-$290
Decrease SR 10% - no change in performance	$182
Decrease SR 10% - change performance	-$163
No Breeding Cows, finish bulls	-$212
Increase subdivisional fencing	$557
Forestry - plant natives to join Whenua Rahui areas	$40
Reduce replacement rates	-$494
Decrease ewes 10%, No Breeding cows - finish bulls, increase subdivision	-$1,720
Decrease SR 10%, improve performance, +33ha pines, differential offset	-$65
Te Paiaka	
Reduce SR 10% - no improvement in productivity	$320
Reduce SR 10% - improve productivity	$102
Eliminate N Fertiliser#1 - Reduce sheep	$138
Eliminate N Fertiliser#2 - Reduce sheep & cattle	$182
Forestry#1 (Plant 65ha)	$40
Remove dairy grazers, finish bulls	-$590
Finish steers at 18-20 months	$232
Eliminate N Fertiliser#3 - Reduce sheep, no Grazers, finish bulls	$26
Reduce SR 10%, improve productivity, differentiate offset	$102

These shadow prices are obviously important at an individual farm level, and are unique to that farm, when considering what mitigation options to consider, relative to the reduction in GHG emissions gained. As can be seen from the tables above, there are several negative shadow prices. These relate to the scenarios were farm or per animal productivity have improved; the financial benefits of this have outweighed any carbon cost, hence the negative figure. But does give a direct indication of the overall benefit of improving farm productivity.

8.0 GENERAL DISCUSSION

The modelling analysis undertaken for this project highlights several aspects:

(i) Changes in farm systems can get close to, or achieve, the 10% reduction in methane as required by 2030.

(ii) Inasmuch as reducing dry mater eaten is a (current) key factor in reducing GHG emissions, the closest corollary to achieving this is via reducing stocking rates. But reducing stocking rates and production together will significantly adversely impact farm profitability.

The need therefore is to have a combination of reduced stocking rate and improved per animal productivity. This approach again can achieve the 2030 methane reduction target, while maintaining profitability. The drawback is that the new system takes time to develop, particularly around upskilling farmers, and improving the genetic merit of the livestock.

(iii) Eliminating nitrogen fertiliser and bought-in supplementary feed on dairy farms again will go a long way to achieving the 2030 methane reduction target, but not usually the 2030 nitrous oxide reduction target, let alone the 2050 targets. The downside is again an adverse impact on farm profitability, and a higher risk system relative to the impact of adverse climatic events.

(iv) Essentially, while adjusting farm systems can help achieve the 2030 methane reduction target, they get nowhere near achieving the 2030 nitrous oxide reduction target (as assumed) or achieving the 2050 reduction targets for both methane and nitrous oxide.

(v) The only current means of achieving these other targets is via the use of forestry to provide carbon credits as an offset. This presents a number of issues:

- Most dairy farms do not have sufficient "less-productive" land to plant in trees without significantly affecting the farm profitability
- Against this, most sheep & beef farms are likely to have sufficient land, (or at least a reasonable amount) with the profitability impact varying depending on the difference between the farm EBIT and the forestry annuity.
- The key issue with using forestry as an offset (other than the transactional complexity) remains the short-term nature of it. Under the new averaging scheme, farms will have 16-17 years of carbon to use as an offset, before they need to plant a further area of trees, assuming an absence of other mitigating strategies.

  Assuming therefore that farmers planted a small area within the next few years, in order to achieve the 2030 nitrous oxide reduction target, they would then have to plant a larger area in the late 2030's in order to achieve the 2050 reduction targets. And then plant a similar (large) area in the early

2050's in order to maintain the reductions. In which case land availability will be starting to be at a premium.

(vi) The analysis and discussion is based around individual farms achieving the ZCA reduction targets. Given that these targets are at a national/sector level, if, for example, there is large-scale land use change to forestry and/or horticulture, such land use change would go a long way towards achieving the targets, if not achieving all of the targets.

In which case the requirement at the individual farm level would be significantly reduced.

9.0 CASE STUDY FARMER REACTION

As a general recommendation around understand GHG emissions and what is required for reductions, farmers need to:

(i) Understand the current biological GHG emission from their farm
(ii) Understand the basics of what drives methane and nitrous oxide emissions, so that
(iii) Develop options to mitigate emissions, and understand the implications of these options for their farm system, land use, and profitability
(iv) Understand the basics of forestry as an offset, especially that it (a) can be complex, and (b) is short-term
(v) Be aware of what the *He Waka Eke Noa* programme is developing/proposing

In the feed-back session with the case study farms, a presentation was made on the above, including the modelling results for the farm in question.

Feedback on this was quite positive:

- It gave the case-study farmers a much greater understanding of the issue and where their farm stood.
- They were also pleased to have the various scenarios modelled, which gave them an understanding of some of the options available to them, and the financial implications of these, and
- It gave them an understanding of where both government and industry were at regarding policy development.

With respect to the above three bullet points, this meant the case study farmers are currently in the top few percent of farmers with such knowledge.

10.0 APPENDIX ONE: FORESTRY ECONOMICS BACKGROUND

By Peter Handford, GroundTruth Ltd. NZ Institute of Forestry, Registered Forestry Consultant.

A desktop discounted cashflow analysis was undertaken for forestry investment on the four case-study properties. This was used to estimate an annuity – a theoretical estimate of annual income from forestry that could be included in modelling of impacts on farm income. The numbers provided are indicative only. Particular limitations of this analysis include:

- The properties have not been visited to assess growth potential or costs
- The modelling is undertaken on a per hectare basis, but assuming a larger area of possibly 20 hectares or more would be established to spread fixed operational costs such as roading.
- Cost, yield and revenue information is generalised and will vary on these sites.
- No land cost or land rental is included. It is assumed that landowners are choosing to establish an area of their current property in forest.
- Main cost and other assumptions are listed below for common assumptions across all properties. Specific cost assumptions relating to individual properties are listed under property headings.
- No carbon income is included in the economic modelling used to generate estimated annuities.

It is important to consider this information only for the purpose it was prepared. It is not intended as a complete analysis of forestry returns. The forestry modelled in this exercise assumes that forest is established on the farm property. This will often not be the best option. Where a property is all high value land used for dairy production, it is unlikely to be appropriate to plant areas of the property in forest. In these cases, a separate off farm forest investment could be undertaken, on land with greater limitations, more suited to forestry.

No attempt is made to take an integrated land use approach to economic modelling for properties. Forestry can form a valuable component of a farm business, often without significantly impacting on other farm income, if it is well planned onto areas of the property with relatively low returns. This requires more detailed property level planning and analysis

1. Key Assumptions

Where costs and other aspects were considered likely to be relatively similar across properties, standard assumptions were made across the properties. These are set out below.

Silviculture costs

A low input regime to produce structural timber was assumed. This simple regime involves one thin to waste. The table below sets out the generalised regime used and cost assumptions:

Operation	Year	Cost /ha
Tree stocks, planting and releasing 1000 stems per hectare	0	$1,200
Thin to 450 stems per hectare	9	$700
Management	All	$80

Yield tables

The forecaster calculator was used to help estimate yields by log type for the site. This calculator was developed by Scion and uses the same set of models as the Forecaster desktop application, which is widely used by the forest industry for yield table generation (i.e. log product volumes by age), regime evaluation and silvicultural scheduling. It provides a rough estimate of the volume and log product mix produced on a particular site at a particular age. In this case a harvest age of 28 years was assumed.

Because these properties have not had an on-site assessment, and forecaster provides only a broad estimate, a conservative approach has been taken and estimated yields reduced by 20%

Log prices

Log prices are from MPI Indicative New Zealand Radiata Pine Log Prices by Quarter. A 10-quarter average at December 2019 was used.

Composite prices for the different log grades were calculated based on domestic and export log prices. This assumed 50% of the volume was sold as export grades, and 50% as domestic. Export JAS fob log prices were reduced by 15% to allow for wharfage and JAS conversion. Composite prices used are set out below.

Composite log grade	$/m3 at mill or wharf gate
Small branch unpruned	$137.93
Large branch unpruned	$126.50
Pulp	$83.88

Carbon

Carbon is not included in this cash flow. If the sale of NZ Units under the NZ Emissions Trading Scheme (ETS) is included, returns and annuities increase by 2-3 times those stated without carbon.

Discount Rate

A discount rate of 6% is used in calculating annuities and net present value. This is the current discount rate used in NZ Government economic modelling.

2. Farm Examples & Results

- **Orete**

Property Type: Dairy

Property Area

161 hectares in pasture.
Forest planting will occur in areas currently in pasture.

Location

54 Orete Forest Road, Waihau Bay
Kawerau 182 km

Mt Maunganui 230km

Harvesting costs
Harvesting costs were based on general industry knowledge and expectations of the type of land and likely broad location where forests might be established.

Operation	$/m3
Road & skid construction	3.14
Logging & loading	38.00
Management	3.50
Contingency / RMA	1.00
Transport	38.00
Total harvest costs	83.64

Results of cashflow modelling

Indicator	Value
Net Present Value / LEV*	$2,451 / ha
Internal Rate of Return (IRR)	9.1%
Equivalent Annual Annuity**	$183 / ha
Average Annual Cashflow	$760 / ha

Notes
* Land Expectation Value (LEV) equates to the maximum value that could be paid up front for land and still make a return equivalent to the project discount rate (in this case 6%).
**The Equivalent Annual Annuity is the annual income that would be required over the project period (28 years) if a 6% discount rate was applied, to achieve the same net present value.

- **Te Aroha**

Property Type: Dairy

Property Area
480 hectares total area
234 hectares in grass.
Forest planting will occur in areas currently in pasture.

Location
341 Old Tauranga Road, Waihi
Kinleith 140km
Mt Maunganui 65km

Harvesting costs
Harvesting costs were based on general industry knowledge and expectations of the type of land and likely broad location where forests might be established.

Operation	$/m3
Road & skid construction	$3.47
Logging & loading	$38.00
Management	$3.50
Contingency / RMA	$1.0
Transport	$21.25
Total harvest costs	$67.22

Results of cashflow modelling

Indicator	Value
Net Present Value / LEV*	$3,665
Internal Rate of Return (IRR)	$10.0%
Equivalent Annual Annuity**	$273
Average Annual Cashflow	$974

Notes
* Land Expectation Value (LEV) equates to the maximum value that could be paid up front for land and still make a return equivalent to the project discount rate (in this case 6%).
**The Equivalent Annual Annuity is the annual income that would be required over the project period (28 years) if a 6% discount rate was applied, to achieve the same net present value.

- **Te Paiaka**

Property Type: Sheep and beef

Property Area
894 hectares total area
507 hectares in grass.
72 hectares existing forest
Forest planting will occur in areas currently in pasture

Location
State Highway 30. South of State Highway 5 turn off.
Kinleith 50 km
Mt Maunganui 75 km

Harvesting costs
Harvesting costs were based on general industry knowledge and expectations of the type of land and likely broad location where forests might be established.

Operation	$/m3
Road & skid construction	$5.74
Logging & loading	$45
Management	$3.50
Contingency / RMA	$1.00
Transport	$14.00
Total harvest costs	$69.24

Results of cashflow modelling

Indicator	Value
Net Present Value / LEV*	$4,549
Internal Rate of Return (IRR)	10.7%
Equivalent Annual Annuity**	$339
Average Annual Cashflow	$1,130

Notes
* Land Expectation Value (LEV) equates to the maximum value that could be paid up front for land and still make a return equivalent to the project discount rate (in this case 6%).
**The Equivalent Annual Annuity is the annual income that would be required over the project period (28 years) if a 6% discount rate was applied, to achieve the same net present value.

- **Pukepoto**

Property Type: Sheep and beef

Property Area
1435 hectares total area
1050 hectares in grass.
Forest planting will occur in areas currently in pasture

Location
509 Ohura Road, Taumarunui
Kinleith 130km
Mt Maunganui 217km

Harvesting costs
Harvesting costs were based on general industry knowledge and expectations of the type of land and likely broad location where forests might be established.

Operation	$/m3
Road & skid construction	5.17
Logging & loading	50.00
Management	3.50
Contingency / RMA	1.00
Transport	28.00
Total harvest costs	87.67

Results of cashflow modelling

Indicator	Value
Net Present Value / LEV*	$3,043.86 / ha
Internal Rate of Return (IRR)	9.6%
Equivalent Annual Annuity**	$227.05 / ha
Average Annual Cashflow	$865 / ha

Notes
* Land Expectation Value (LEV) equates to the maximum value that could be paid up front for land and still make a return equivalent to the project discount rate (in this case 6%).
**The Equivalent Annual Annuity is the annual income that would be required over the project period (28 years) if a 6% discount rate was applied, to achieve the same net present value.

11.0 APPENDIX TWO: FARM BACKGROUND INFORMATION

11.1 Changes in Supplementary Inputs on the Dairy Case Study Farms

Orete

	Tonnes DM				
	Bought in Maize silage	Palm Kernel	Pasture silage (grown on-farm)	Pasture silage bought in	Chicory (ha)
Base	250	92	10	30	15
Reduce cow numbers 10% - no improvement in productivity	224	83	9	27	15
Reduce cow numbers 10% - improve productivity	250	0	10	30	15
Reduce cow numbers 15% - improve productivity	101	0	10	30	15
Reduce replacements to 15%	250	92	10	30	15
No nitrogen fertiliser	250	87	10	30	15
No bought supplementary feed	0	0	10	0	15
No N fertiliser, No bought supplement	0	0	10	0	15
10% of farm in pines	224	83	10	27	15
10% of farm in pines, reduce SR 10%	205	76	10	25	15
31% of farm in pines	184	68	9	23	15
10% of farm in gold kiwifruit	224	83	10	27	15
24ha pines, reduce SR16%, differential offset	210	78	9	26	15

Te Aroha

	Palm Kernel (wet tonnes)	Bought in baleage (bales)	Made silage (tonnes DM)	Made baleage (bales)
Base model	140	25	60	150
Reduce cow numbers 10% - no improvement in productivity	125	19	48	113
Reduce cow numbers 10% - improve productivity	140	25	60	150
Reduce cow numbers 15% - improve productivity	140	25	60	150
No nitrogen fertiliser	125	19	48	113
No bought supplementary feed	0	0	60	150
No N fertiliser, No bought supplement	0	0	60	150
10% of effective area in pines	132	20	48	120
31% of effective area in pines	109	16	38	100
Reduce SR 15%, Improve productivity, 40ha forest/offset differentially split	140	25	60	150

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