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Farm Systems Modelling for GHG Reduction on Multiple Enterprise Māori Farms

Prepared for NZAGRC

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1.0 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 NZAGRC.

1.1 Milestones

Key milestones for the project were:

- Develop criteria for the selection of two Māori agri-business entities involving multi-enterprise farming activities.
- Hold discussions with industry bodies (DairyNZ and Beef + Lamb NZ), along with the Federation of Māori Authorities (FOMA) and Te Tumu Paeroa (TPP), on the project objectives.
- Establish a Project Reference Group.
- Meet with the two Māori agri-business entities to discuss participation in the project and mitigation scenarios to model.
- Model the base status quo and initial mitigation scenarios.
- Meet with the two Māori agri-business entities to discuss the results of the modelling, including attitudes to adoption of the mitigations, and further scenarios for modelling.
- Develop scenarios around possible horticultural options.
- Interview the respective Māori agri-business entities to discuss their reaction and intentions following the modelling exercise.

2.0 SELECTION OF AGRI-BUSINESS CASE STUDY ENTERPRISES

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

(i) Must have a mix of different pastoral farming enterprises; dairy and sheep and beef, as well as forestry.

(ii) Involvement with horticulture was highly desirable but not critical.

(iii) A geographic spread if possible.

(iv) Need to be amenable to being involved in the project.

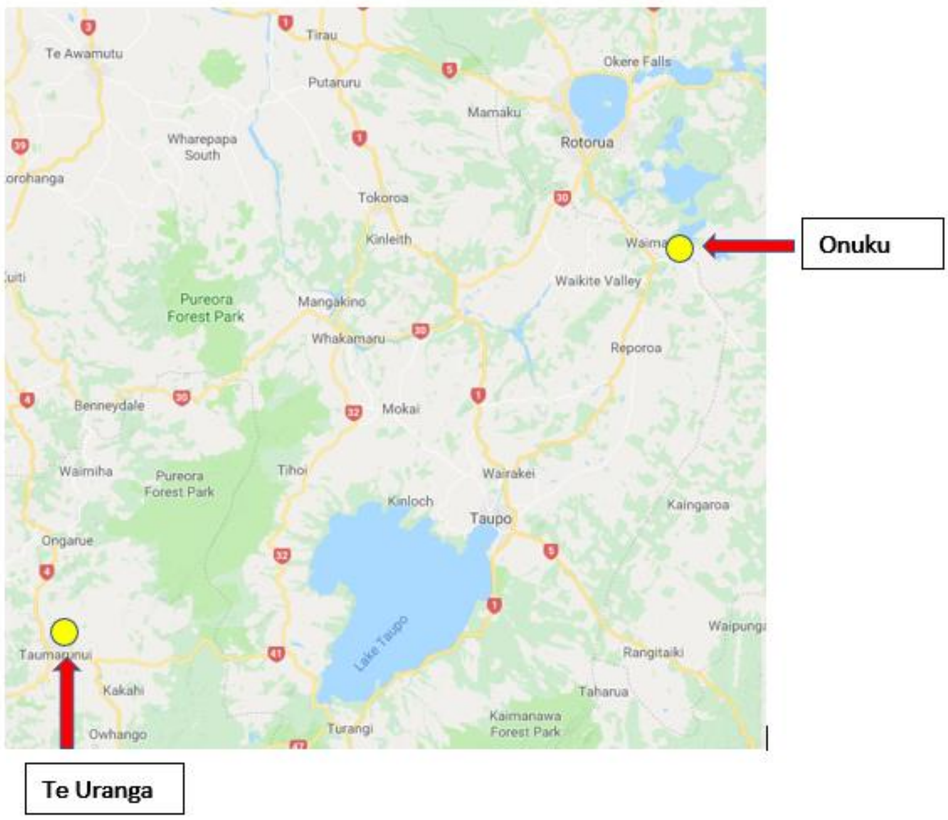
(v) Need to have a consultant involved in the farming enterprises.

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

Initially five enterprises were considered before it was narrowed down to two:

Onuku Māori Lands Trust based south of Rotorua, and Te Uranga B2 Incorporation based just northwest of Taumarunui.

Figure 1: Location Map



2.1 Onuku Māori Lands Trust

Onuku consists of:

(i) Four dairy farms:

No. 1 dairy	204 hectares effective
No. 2 dairy	116 hectares effective
No. 3 dairy	215 hectares effective
Boundary Road dairy	72 hectares effective

(ii) A sheep and beef unit:

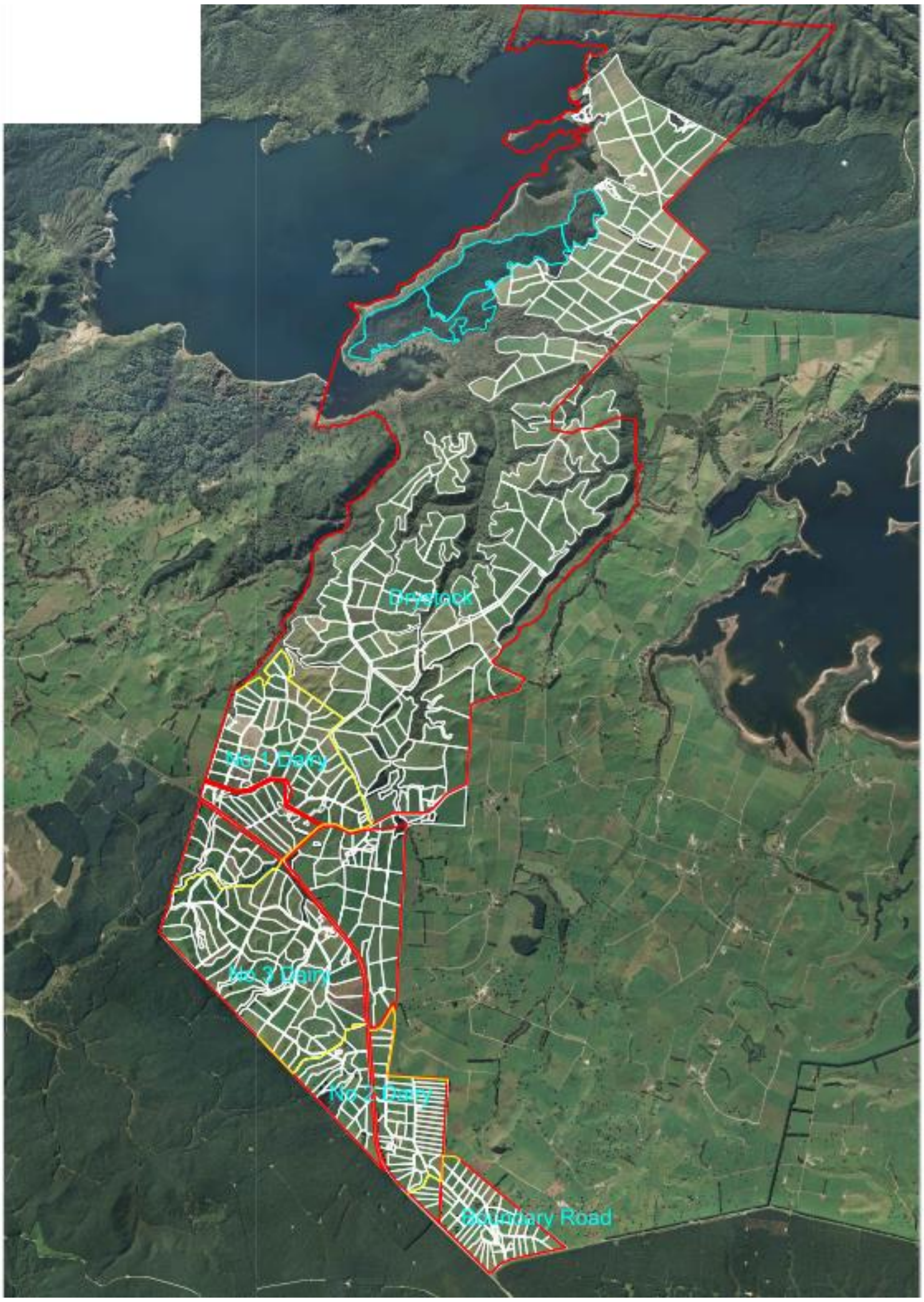
Pasture	908 hectares
Pines	1.2 hectares
Manuka	17.9 hectares
Native forest	26 hectares

(iii) A forestry block:

Pines	117.5 hectares
Douglas Fir	12.5 hectares
Native	678 hectares

Note the manuka block (recently planted) is for the production of Manuka oil, not honey.

Figure 2: Map of Onuku



2.2 Te Uranga B2 Incorporation

Te Uranga consists of:

(i) Two dairy farms

Koromiko	219 hectares effective
Paatara	133 hectares effective

(ii) A sheep and beef unit (Upoko):

Pasture	1,153 hectares
Pines	36.7 hectares
Manuka	20.3 hectares
Natives	220 hectares

(iii) A forestry block:

Pines	580 hectares
Native	142 hectares

The pines on this block and the sheep and beef farm are due to be harvested within the next six years.

Figure 3: Te Uranga B2 Map

3.0 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 OverseerFM® (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.

Spatial models were also developed/used to map out any land use changes.

4.0 ECONOMICS

The farm financial information was provided by the farm's supervisor and modelled in Farmax. The farm economics were based on the Farmax modelling. Farm expenses were based on current expenditure on the various farms, whereas the payouts and schedules used were based on five-year averages:

Milksolids payout	$6.00/kgMS
Beef schedule	$5.21/kg based on a 295 kg prime steer (carcase weight)
Lamb schedule	$5.50/kg all grades
Bull beef	$5.00/kg based on a 295 kg bull
Wool	$3.80/kg greasy
Venison	$8.30/kg

The Farm EBIT calculated by Farmax is:

Gross income less stock purchases, less farm working expenses, less depreciation.

Note that any capital costs involved in mitigations and/or land use change have not been included in the analysis.

4.1 Forestry Financial Information

Comparison of annual income between forestry and agriculture is complicated by the long time frame until first income is received from forestry (in the absence of carbon sales) compared to the annual cash flows generally associated with agriculture.

To overcome this, the approached used in this project was to calculate a Net Present Value (NPV) at a given discount rate (5%) and then convert this figure by the assumed harvest timeframe of 28 years to produce an annual payment (annuity) that could be used to compare the annual EBIT from the status quo and revised livestock systems.

Aspects of terrain, access, scale, transport distance etc. have major impacts on the economics of a particular forestry operation. These can vary markedly from property to property. In calculating a generalised annual income from forestry for the two properties (Onuku and Te Uranga), assumptions have been made about costs (detailed in Appendix One).

The consideration of cashflow and annuity also depends on the scenario being considered for these properties. For this project, the Radiata Pine regime is considered to be at the start of a 28-year rotation, with a single aged forest stand. The Douglas Fir regime is assumed to be at the beginning of a 45-year rotation with a single aged forest stand.

4.1.1 Forestry Returns

4.1.1.1 Radiata Pine

A clearwood regime involving pruning and thinning is assumed, as outlined in Appendix One.

Yield tables from the 2017 National Exotic Forest Description are used (MPI 2017). These yield tables provide regional yields in broad grade mixes of pruned sawlog, unpruned sawlog and pulp. Additional division of log types is identified in the Appendix.

Costs used are from a range of industry sources. Generalised costs are assumed across the different regions (see Appendix).

All cash flows are without carbon income or liabilities.

Log prices are from MPI Indicative New Zealand Radiata Pine Log Prices by Quarter. The 12-quarter average at December 2017 was calculated and used.

Based on this, the calculation of average annual cash flows and equivalent annual annuity is shown below.

Table 1: Pine forestry annuity

	Average annual cashflow ($/ha)	Equivalent annual annuity ($/ha at 5% D rate)	Notes
Onuku	$1,256	$470	Central North Island yields used, Waikato/Bay of Plenty costs etc.
Te Uranga	$748	$217	Taranaki yields and costs used.

4.1.1.2 Douglas Fir

The same exercise was repeated for Douglas Fir. This species only makes up 5% of the exotic forest estate. Consequently, there is less information available on yields and prices. Rotations for Douglas Fir are considerably longer than Radiata Pine at around 45 years. This species does not perform particularly well in the North Island. Its main advantage is in the South Island high country where it can handle higher altitudes and snowfall. Log prices are higher than Radiata Pine, but not majorly so (10-15% higher). This means the species is not generally economically attractive in the North Island. The annuity and average annual cash flow calculated below reflects this.

Table 2: Douglas fir annuity

	Average annual cashflow ($/ha)	Equivalent annual annuity ($/ha at 5% D rate)	Notes
Onuku and Te Uranga	$912	$120	Nelson NEFD yield information used. Bay of Plenty/Central North Island costs used.

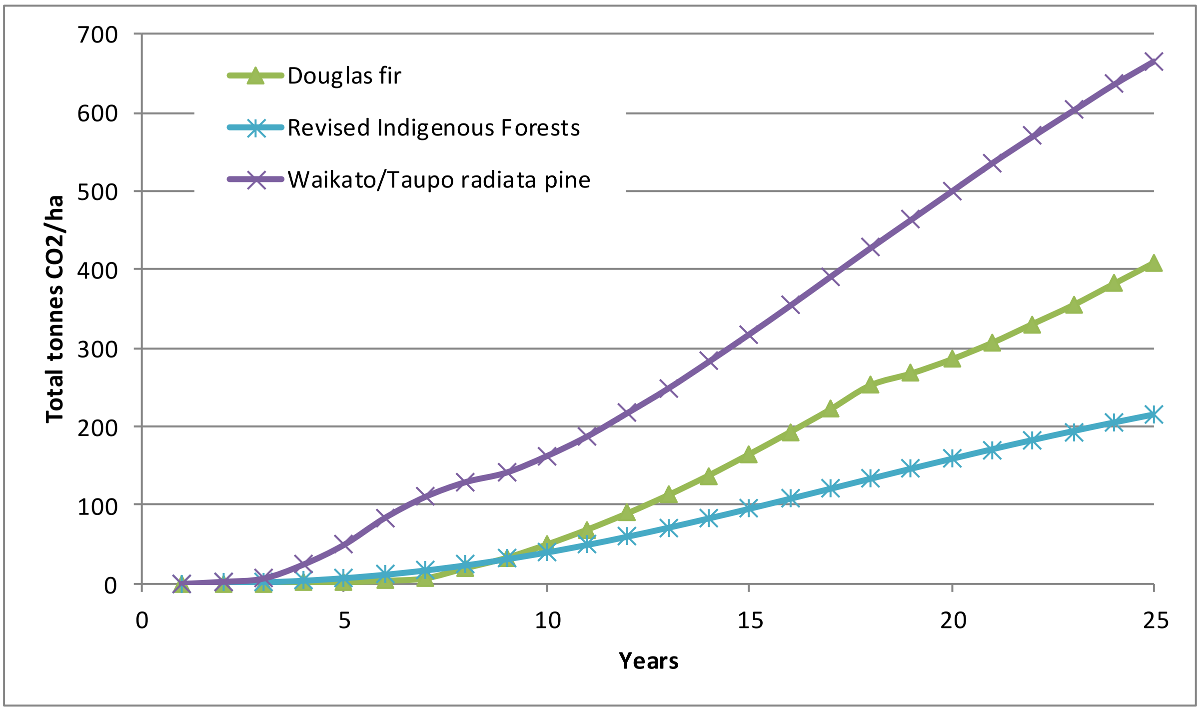
5.0 CARBON SEQUESTRATION

Carbon sequestration rates are based on the MPI look-up tables. These are outlined below.

Table 3: Carbon Sequestration Rates

Pine Region	Carbon sequestered at age 28 (tonnes CO_2-eq/ha)	Trade without penalty (tonnes CO_2-eq at age 28/ha)	Trade without penalty (tonnes CO_2-eq/ha/yr)	Annual averaging tonnes CO_2-eq/ha/yr (50% of NZUs at age 28)	Permanent Forest (tonnes CO_2-eq/ha to age 28/yr)
Onuku (BOP)	704	169	6.04	12.57	25.14
Te Uranga (Waikato)	755	163	5.82	13.48	26.96
Douglas Fir (all regions)	857 (45 years)	50 (at 45 years)	1.11	9.52 (at age 45)	19.04 (at age 45)
Indigenous (Manuka)	215	215	8.6		8.6

Table 4: Comparison of carbon sequestration rates for Waikato Pine, Manuka (indigenous) and Douglas Fir.



For the purposes of the initial modelling, the 'Trade without Penalty' (= 'safe carbon') sequestration amounts has been used, particularly as it is the intention of both enterprises to harvest their forests at maturity. Note that the sequestration rate for Manuka is higher than pines under the 'trade without penalty' regime, mainly because it is assumed that Manuka is not harvested and that it grows on naturally to become native bush, and hence there are no harvest emissions.

The Manuka grown on Onuku is for oil extraction. This requires the plants to be coppiced every year, meaning that carbon sequestration would be minimal, and consequently this was set as zero within the modelling.

6.0 MODELLING SCENARIOS

6.1 Te Uranga B2

Modelling scenarios were:

(i) Establish base position.

(ii) Dairy farms:

- Reduce stocking rate (by 10%) and reduce supplementary feed input by taking out all palm kernel.
- Restrict nitrogen fertiliser use to no more than 100 kgN/ha/year, but maintain production via increased supplements (maize silage).
- Increase per cow production to 400 kgMS/cow by reducing stocking rate.
- For the base farm, replace palm kernel with maize silage grown on the farm.
- Lower stocking rate by 10%, and replace palm kernel with maize silage grown on the farm.

(iii) Sheep and beef farm:

- Leave male progeny from the breeding cow herd entire, plus buy in weaner bulls to finish - finish all by 20 months.
- Develop 348 hectares of steeper/erosion prone hill country into forestry.
- Develop 348 hectares of steeper/erosion prone hill country into forestry, plus leave male progeny from the breeding cow herd entire, plus buy in weaner bulls to finish - finish all by 20 months.

(iv) Forestry:

- Replant entire area into Pines.
- Replant area half in Pines and half in Manuka.
- Replant area one-third Pines, one-third Manuka and one-third Totara.

6.2 Onuku

Modelling scenarios were:

(i) Establish base position.

(ii) Dairy farms:

- Reduce stocking rate (by 10%) and reduce supplementary feed input by taking out all palm kernel.
- Install a covered feed pad system on No. 1 Dairy.
- Develop No.1 dairy into a deer unit, finishing weaner deer at 20 months.

(iii) Sheep and beef farm:

- Increase the forestry area (pines) by 129.5 hectares.
- Develop 270 hectares into a deer unit.
  - Finishing 1,100 weaner deer at 18-20 months.
  - Run a breeding herd, finishing all progeny by 18-20 months.
- In conjunction with developing No.1 dairy into deer, develop 66 hectares on the sheep and beef unit into deer, to maintain the 270 hectare unit.
- Increase the forestry area (Pines) by 129.5 hectares, plus plant an additional 34.5 hectares into Manuka (for oil).

(iv) Forestry – no change.

(v) Dairy sheep scenario.

This involved taking 141 hectares out of the sheep and beef unit, plus 17 hectares from No. 1 Dairy, to create a 158 hectare unit, running 1,900 milking sheep plus 600 replacements. This operation involved a hybrid system whereby the sheep were grazed outdoors for much of the time, although they were also feed supplements (lucerne hay, pasture silage) in a covered shed on an on/off grazing system, plus some grain in the milking shed.

Note: Neither Farmax nor Overseer can model milking sheep. The physical/economic modelling was done manually (on a spreadsheet), and the 'milking goats' option was used in Overseer as a proxy.

7.0 MODELLING RESULTS TE URANGA B2

Note that the existing forestry areas on Te Uranga B2 are post-1990, and therefore eligible to be registered within the ETS. Currently the forest is leased out, but due to return to Te Uranga post-harvest, and replanted. Te Uranga B2 therefore have the opportunity to register the forest within the ETS, and use the carbon credits created, to offset pastoral emissions. This has been incorporated within the modelling work. Results of the base modelling show:

Table 5: Summary of Te Uranga Base GHG Emissions (T CO_2e).

	Total Tonnes*	T/ha*
Koromiko (Dairy)	1,632	7.0
Paatara (Dairy)	1,239	7.0
Upoko (S&B)	3,872	2.7
Ue Pango (Forestry)	-3,376	-4.7
Overall Net	3,367	1.4**

*Total tonnes/T per ha is over the total hectares of the individual farms/total property, and includes any forestry sequestration within the farm property
**Weighted average

Figure 4. Summary of Te Uranga Base GHG Emissions; total tonnes (T CO_2e).

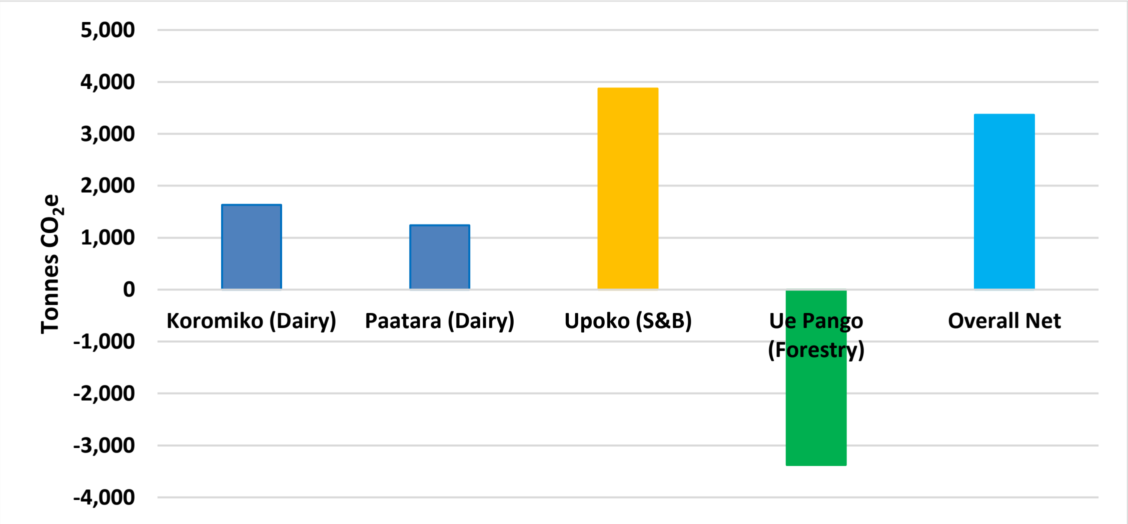
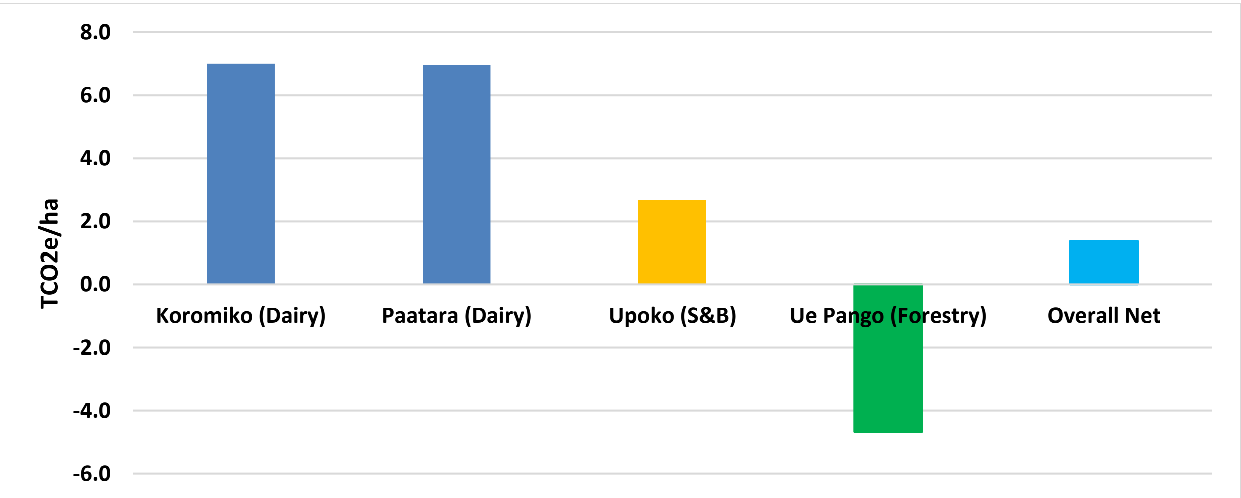


Figure 5: Summary of Te Uranga Base GHG Emissions; tonnes/ha (T CO_2e).



7.1 Te Uranga B2 Scenario Modelling

A summary of the scenario modelling is outlined below.

Table 6. Summary of Te Uranga Scenario Modelling

	Net Biological GHG Emissions (T/ha)	EBIT/ha	kg N leached/ha	kg P loss/ha	Emission Intensity (kg CO_2e/kg product)	Change in GHG	Change in EBIT
Koromiko (Dairy)							
Base	7.0	$479	44	3.5	11.4		
Lower SR 10%	6.5	$602	44	3.5	11.9	-7%	26%
100 kgN/ha	6.7	$421	42	3.5	11.0	-5%	-12%
400 kgMS/cow	6.6	$999	41	3.5	10.5	-6%	109%
Base - Grow maize	6.7	$478	42	3.4	11.0	-4%	0%
Lower SR 10% + maize	6.7	$874	42	3.4	10.6	-4%	83%
Paatara (Dairy)							
Base	7.0	$749	40	6.4	10.4		
Lower SR 10%	6.5	$839	38	6.3	10.4	-6%	12%
100 kgN/ha	6.8	$747	38	6.4	10.2	-2%	0%
400 kgMS/cow	7.0	$1,225	39	6.4	10.2	1%	64%
Base - Grow maize	6.8	$752	40	6.3	10.2	-2%	1%
Lower SR 10% + maize	6.8	$1,036	42	6.2	10.0	-2%	38%
Upoko (S&B)							
Base	2.9	$375	17	1.6	16.7		
Bulls	2.7	$420	16	1.5	14.8	-6%	12%
Increase Forestry (348 ha)	0.8	$305	15	1.2	17.2	-71%	-19%
Bulls + 348 ha forest	0.8	$313	15	1.2	16.5	-71%	-16%
Forestry							
Base	-4.7	$217					
½ Pine, ½ Manuka	-5.8	$229				-24%	5%
⅓ Pine, ⅓ Manuka, ⅓ Totara	-6.2	$179				-32%	-17%

7.2 'Mix and Match' Scenarios

The purpose of this exercise was to 'mix and match' a range of the scenarios across the whole enterprise, so as to gauge the overall impact on total GHG emissions and total enterprise profitability.

Table 7: Summary of mixing mitigation scenarios across the whole enterprise

		Change in GHG including existing forest	Change in GHG excluding existing forest	Change in EBIT
1	Base scenario	0	0	0
2	Lower SR 10% on dairy farms + grow maize + 348 ha forestry on S& B farm + ⅓ forestry option	-202%	-45%	2.6%
3	Base dairy farms + 348 ha forestry on S&B farm + ½, ½ forestry option	-191%	-44%	-9.9%
4	400 kgMS/cow on dairy farms + bull scenario on S&B farm + ½, ½ forestry scenario	-34%	-5%	30.7%
5	400 kgMS/cow on dairy farms + bull scenario on S&B farm + base forestry scenario	-10%	-5%	29.9%
6	400 kgMS/cow + bulls & forestry on S&B farm + ½ forestry option	-195%	-45%	14.3%
7	Lower SR 10% on dairy farms + grow maize + bulls on S& B farm + ⅓ forestry option	-42%	-5%	20.3%
8	Lower SR 10% on dairy farms + grow maize + bulls & 348 ha forestry on S& B farm + ⅓ forestry option	-203%	-45%	3.9%
9	Lower SR 10% on dairy farms + grow maize + bulls on S&B farm + base forestry option	-171%	-45%	6.7%
10	100 kgN/ha on dairy farms + 348 ha forestry on S&B farms + base forestry	-170%	-45%	-12.4%
11	100 kgN/ha on dairy farms + bulls & 348 ha forestry on S&B farms + ½ forestry option	-195%	-46%	-10.3%

Comment

As can be seen from Tables 6 and 7, the mitigation that has the most significant impact in reducing GHG emissions across the whole enterprise is planting the additional 348 hectares on the sheep and beef farm in forestry. This is enhanced if the forestry block replanting is in a combination of Pines and Manuka. These two mitigation options effectively mean the enterprise is carbon neutral (in fact slightly carbon negative), but at a cost of a 10% reduction in profitability in the absence of reducing stocking rate on the dairy farms. If the existing forest is included, plus the 348 hectares on the sheep and beef farm is planted, then the whole enterprise is essentially in a carbon surplus.

In the absence of the forestry option on the sheep and beef farm, other key GHG mitigations are the reduction in stocking rates on the dairy farms, and the planting of part of the forestry area in Manuka or Totara.

Key improvements in profitability are achieved via the increase in per cow production (400 kgMS/cow scenarios), the growing of maize as opposed to buying in palm kernel, keeping beef male progeny entire on the sheep and beef farm, and again planting part of the forestry area into Manuka for honey production.

Possibly the best mix of options is the 400 kgMS/cow on dairy farms plus bull scenario on the sheep and beef farm plus half, half forestry scenario (Scenario 4, Table 7) which gives a 34% reduction (assuming the existing forest is included) in GHG's while lifting profitability by 31%.

Individual Scenario Comment

1. As in other modelling exercises, the reduced stocking rate/increase per cow production on the dairy farms generally results in a win-win situation where GHG emissions have decreased and profitability improved. This is markedly the case for the 400 kgMS/cow scenario, where stocking rate had to be reduced 15% to achieve the level of per cow feeding.

   There is an implicit assumption within this scenario, namely that management, particularly grazing management, has improved to ensure that pasture quality is maintained at the lower stocking rate; something that many farmers would struggle with. Higher genetic value cows would also be an advantage as they would better express the impact of higher feeding levels.

   In the absence of an improvement in per cow production, reducing stocking rate would directly result in lower profitability.

2. The reduced nitrogen fertiliser/replace with maize silage shows some gain in reducing GHG emissions, but no gain, or reduction in profitability, mainly because the farm is switching a lower cost supplement for a higher cost supplement.

3. Growing maize on the dairy farms showed a small gain in reducing GHG emissions, but no improvement in profitability. While growing maize can be cheaper than buying in supplement, there is also a relatively significant cost involved with regrassing post the maize crop.

4. Reducing the stocking rate on the dairy farms by 10% and growing maize as a replacement for buying in palm kernel again achieved a small reduction in GHG emissions (2-4%; the reduction in cow numbers offset to some degree by increased production), but a significant improvement in profitability, due to the increased per cow production from feeding the maize silage.

5. Keeping all male progeny on the sheep and beef farm entire showed a small reduction in GHG emissions, and an improvement in profitability due to the superior returns achievable from farming bulls.

6. The increased forestry (and Manuka) scenarios on the sheep and beef farm showed a significant reduction in GHG emissions due to the carbon sequestration offset, along with a relatively significant reduction in profitability due to the differential between the farm EBIT and the forestry annuity.

7. The half Pine, half Manuka forestry scenario shows a greater amount of carbon sequestration due to the greater amount of 'safe' carbon sequestration by Manuka, as discussed in Section 5, plus a higher level of profitability, due to the better returns from Manuka honey relative to forestry.

8. The one-third Pine, one-third Manuka, one-third Totara forestry scenario again shows a higher level of carbon sequestration, again due to the greater amount of 'safe' carbon sequestration by Manuka and Totara (all 'native' species are assumed to have the same sequestration level), whereas profitability has dropped due to the lower annuity from Totara.

Note that there is some variation for the same scenario between individual farms, reinforcing that different farms can react differently to the same scenarios.

8.0 MODELLING RESULTS ONUKU

Note that the forested area on Onuku is a pre-1990 forest. In an ETS context therefore, the carbon sequestration from this forest cannot be claimed as offsets.

Results of the base modelling show:

Table 8: Summary of Onuku Base GHG Emissions (T CO_2e)

	Total Tonnes*	T/ha
No 1 Dairy	2,193	10.3
No 2 Dairy	1,068	9.3
No 3 Dairy	2,045	9.3
Boundary Road Dairy	855	11.6
Sheep and beef	3,322	3.5
Forestry	0	0.0
Overall Net	**9,483**	**4.0****

*Total tonnes/T per ha is over the total hectares of the individual farms/total property, and includes any forestry sequestration within the farm property.
**Weighted average.

Figure 6. Summary of Onuku Base GHG Emissions; Total Tonnes (T CO_2e)

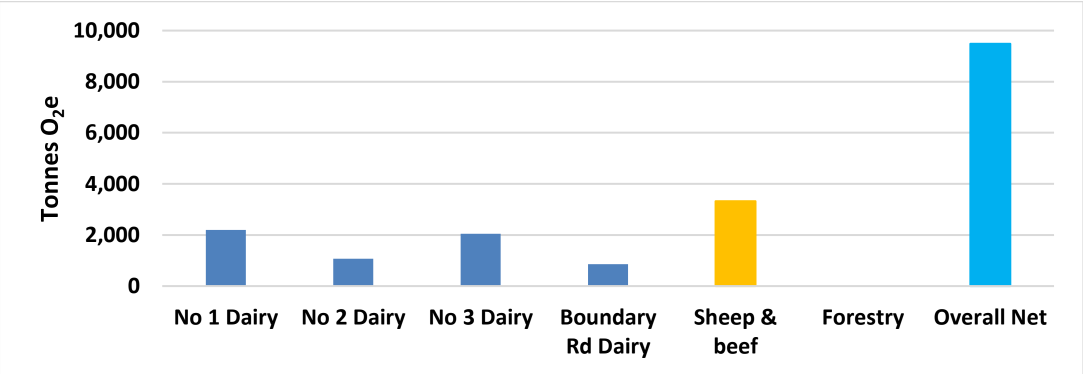
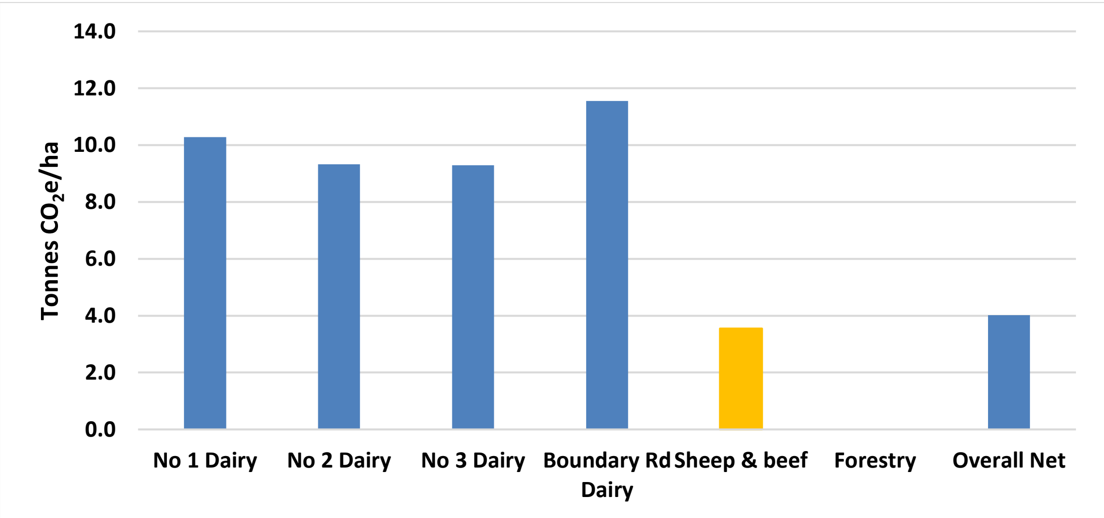


Figure 7: Summary of Onuku Base GHG Emissions; Tonnes/ha (T CO_2e)



8.1 Onuku Scenario Modelling

A summary of the scenario modelling is outlined below.

Table 9. Summary of Onuku Scenario Modelling

	Net Biological GHG Emissions (T/ha)	EBIT/ha	kg N leached/ha	kg P loss/ha	Emission Intensity (kg CO_2e/kg product)	Change in GHG	Change in EBIT
No. 1 Dairy							
Base	10.3	$2,263	44	11.7	9.8		
Lower SR 10%	9.6	$2,214	42	11.6	9.9	-7%	-2%
Feed Pad	10.2	$2,256	43	11.8	9.8	0%	0%
Lower SR 10% + Feed pad	9.4	$2,214	41	11.7	9.7	-9%	-2%
Deer Unit	7.1	$1,254	27	11.7	20.1	-31%	-45%
Land taken out for dairy sheep	10.1	$1,936	44	11.6	10.7	-2%	-14%
No. 2 Dairy							
Base	9.3	$1,814	31	3.3	9.9		
Lower SR 10%	8.6	$1,750	29	3.2	9.7	-7%	-4%
No. 3 Dairy							
Base	9.3	$1,292	58	2.4	10.5		
Lower SR 10%	8.6	$1,334	54	2.3	10.5	-8%	3%
Boundary Road Dairy							
Base	11.6	$2,580	36	3.5	10.0		
Lower SR 10%	10.8	$2,462	34	3.5	9.7	-6%	-5%
Sheep & Beef Farm							
Base	3.5	$652	15	0.9	15.1		
Increase Forestry (129.5 ha)	2.5	$643	14	0.7	15.4	-30%	-1%
Deer Unit #1 (270 ha)	3.7	$595	17	0.9	15.3	4%	-9%
Deer Unit #2 (270 ha)	3.5	$530	17	0.9	16.2	0%	-19%
Deer Unit #3 (66 ha)	3.6	$448	18	0.9	15.3	3%	-31%
Increase Forestry (129.5 ha) + Manuka (34.5 ha)	2.3	$622	15	0.7	15.4	-34%	-5%
Land taken out for dairy sheep	3.8	$656	17	0.8	15.2	6%	1%
Forestry							
Base	0.0	$436					
Dairy Sheep							
Base	8.0	$4,500	21	1.4	9.1		

8.2 'Mix and Match' Scenarios

The purpose of this exercise was to 'mix and match' a range of the scenarios across the whole enterprise, so as to gauge the overall impact on total GHG emissions and total enterprise profitability.

Table 10: Summary of mixing mitigation scenarios across the whole enterprise

	Net Tonnes Biological GHG Emissions	Total Enterprise EBIT ($)	Change in GHG	Change in EBIT
Base	9,483	1,782,036		
Reduce dairy SR 10% + 129.5 ha forestry on S&B farm	7,238	1,756,462	-24%	-1%
Base dairy + 129.5 ha forestry on S&B farm	8,462	1,773,333	-11%	0%
Feed pad on No. 1 dairy + reduce SR 10% on rest of dairy + deer unit #1	8,534	1,721,622	-10%	-3%
Feed pad on No. 1 dairy + reduce SR 10% on rest of dairy + deer unit #2	8,395	1,662,853	-11%	-7%
Feed pad on No. 1 dairy + reduce SR 10% on rest of dairy + 129.5 ha forestry on S&B farm	7,199	1,756,462	-24%	-1%
No. 1 dairy converted to deer + reduce SR 10% on rest of dairy farms + deer unit #3 on S&B farm	7,821	1,383,540	-18%	-22%
Reduce SR 10% on all dairy farms + 129.5 ha forestry & 34.5 ha Manuka on S&B farm	6,876	1,716,431	-27%	-4%
Reduce SR 10% on all dairy farms + feed pad on No. 1 dairy + 129.5 ha forestry & 34.5 ha Manuka on S&B farm	6,837	1,716,431	-28%	-4%
No. 1 Dairy + S&B farm (base)	5,515	1,054,902		
No. 1 Dairy + S&B farm + Dairy Sheep	6,435	1,765,902	17%	67%
No. 1 Dairy + 129.5 ha forestry & 34.5 Manuka on S&B farm + dairy sheep	5,091	1,546,951	-8%	47%

Comment

As can be seen from Tables 9 and 10, again it is the forestry/Manuka planting scenarios which give the greatest gain in reducing (or offsetting) GHG emissions. Other than forestry, the other scenarios generally had a relatively modest impact on reducing GHG's. The exception to this was the conversion of the No. 1 dairy unit into deer; while this resulted in a significant reduction (31%) in GHG's, it also resulted in a 45% reduction in profitability.

The 'reduce stocking rate by 10%' scenario on the dairy farm gave mixed results; while GHG emissions decreased by 6-8%, the profitability response varied by -5 to +3%. Again illustrating the variability of individual farms.

Overall, possibly the best mix of options is the reduction in stocking rate on the dairy farms coupled with the forestry development on the sheep and beef farm, giving a 26% reduction in GHG emissions, at a cost of 5% of farm profitability.

Individual Scenario Comment

1. As already noted, there was some variation in the ‘reduce stocking rate by 10%’ scenario with regard to the change in profitability, although the decrease in GHG emissions was reasonably similar at 6-8%.

2. The feed pad option for No. 1 Dairy has minimal impact on GHG emissions or profitability. Its main impact is a means to reduce nitrogen losses.

3. Conversion of No. 1 Dairy into a deer unit reduces GHG emissions significantly, given the change in livestock type, but also significantly reduces profitability.

4. The increase in forestry (and Manuka) has a significant impact in offsetting GHG emissions, with a slight impact on profitability due to the lower returns relative to sheep and beef.

5. Conversion of part of the sheep and beef farm into a deer unit had a minimal impact on GHG emissions (albeit they increased), while depressing farm profitability.

6. Milking sheep. This scenario had a relatively high GHG emission at 8 tonnes CO_2e/ha, as well as a relatively high (compared to the sheep and beef farm) nitrogen loss of 21 kgN/ha/year. Both could be attributed to the high stocking rate of 1,900 ewes + 600 hoggets on the property, equivalent to 15 animals/ha.

9.0 FORESTRY PROFITABILITY: ANNUITY VERSUS AVERAGE

An issue also arises in including the forestry profitability figures along with the farm EBITs. As discussed earlier, the current approach is to use an annuity figure for forestry which is an annualised figure, based on the forestry NPV and using an assumed discount rate.

In essence this is treating the forestry profitability in an investment approach; income less development costs, over the life of the investment.

In the farming situation, the EBIT is treated as the average annual income, with any previous development costs (e.g. land development, sowing of pasture, capital fertiliser, fencing, etc.) being considered a sunk cost.

In the forestry context, the equivalent would be to consider the forestry enterprise over the longer term; once the rotation is established, the original development costs then become sunk, as per the pastoral situation. In this case, the average annual cashflow is a better comparison with the farm EBIT.

This annual cashflow is significantly different, as illustrated below (from Section 4.1.1).

Table 11: Forestry annual cashflow versus annuity

	Average annual cashflow ($/ha)	Equivalent annual annuity ($/ha at 5% D rate)
Radiata		
Rerewhakaaitu	$1,256	$470
Taumarunui	$748	$217
Douglas Fir		
Rerewhakaaitu and Taumarunui	$912	$120

If this is incorporated into the model scenarios, the results are:

Table 12: Impact of forestry annual cashflow versus annuity (excluding pre-1990 forests)

	Tonnes CO_2 Biological Emissions	Tonnes CO_2 Sequestered	Net	Farm EBIT	EBIT/ha	Change in EBIT
Onuku Sheep & Beef						
Base	3,437	115	3,322	$593,219	$652	
Incr. forestry (129.5 ha) with forestry annuity	3,198	897	2,301	$584,516	$643	-1%
Incr. forestry (129.5 ha) with forestry annual cashflow	3,198	897	2,301	$687,246	$756	16%
Te Uranga Sheep & Beef						
Base	4,542	175	4,367	$446,075	$375	
Incr. forestry (348 ha) with forestry annuity	3,621	2,414	1,207	$362,786	$305	-19%
Incr. forestry (348 ha) with forestry annual cashflow	3,621	2,414	1,207	$567,062	$477	27%

As noted, this makes a significant difference to the overall financial return, as well as to the relative comparison with the farm EBIT.

10.0 SOIL CARBON

Impacts on soil carbon levels due to land use change have not been incorporated into any of the modelling, largely on the basis that (a) it is difficult to estimate such changes; and (b) soil carbon is not included within the ETS.

Never the less, soil carbon levels do change as a result of afforestation, with the land use change factor for low-producing pasture to planted forest calculated as a loss of 15.4 t C/ha, which translates to 56 t/CO_2e/ha, spread over 20 years[1]. This can vary depending on a range of factors, such as slope and soil type.

Incorporating this factor into the modelling shows:

Table 13: Impact of incorporating soil carbon change into land use change scenarios

	Net Biological GHG Emissions without soil carbon change (T/ha)	Net Biological GHG Emissions with soil carbon change (T/ha)	Change from Base without	Change from Base with
Te Uranga S&B				
Increase Forestry (348 ha)	0.84	1.51	-71%	-47%
Bulls + 348 ha forest	0.82	1.49	-71%	-48%
Onuku S&B				
Increase Forestry (129.5 ha)	2.49	2.87	-30%	-19%
Increase Forestry (129.5 ha) + Manuka (34.5 ha)	2.33	2.81	-34%	-21%

[1] L Schipper, Landcare Research, personal communication

11.0 SHADOW PRICE OF CARBON

Within the scenario modelling, the spreadsheet also calculates the 'shadow price' of carbon, or the carbon cost of mitigation, calculated as the change in profit divided by the change in CO_2e emission, due to the impact of the scenario.

Note that:

- A positive price indicates that both profit and CO_2 emissions have either increased or decreased. A negative price indicates that either profit or CO_2 emissions have decreased.
- A large figure means that profit has increased more than CO_2 emissions.
- A small figure means that CO_2 emissions have increased more than profit.
- All of which means the figures should be interpreted with caution.

Table 14: Shadow price of carbon, Te Uranga

	Carbon Cost of Mitigation ($/T) (Change in profit/Change in CO_2)
Koromiko (Dairy)	
Base	$0
Lower SR 10%	-$220
100 kgN/ha	$141
400 kgMS/cow	-$1,013
Base - Grow maize	$3
Lower SR 10 + maize	-$1,126
Paatara (Dairy)	
Base	$0
Lower SR 10%	-$8
100 kgN/ha	$10
400 kgMS/cow	-$92
Base - Grow maize	$9
Lower SR 10 + maize	-$48
Upoko (S&B)	
Base	$0
Bulls	-$230
Increase Forestry (348 ha)	$15
Bulls + 348 ha forest	$13

Table 15: Shadow price of carbon, Onuku

	Carbon Cost of Mitigation ($/T) (Change in profit/Change in CO_2)
No. 1 Dairy	
Base	$0
Lower SR 10%	$67
Feed Pad	$199
Lower SR 10% + Feed pad	$54
Deer Unit	$305
Land taken out for dairy sheep	$2,777
No. 2 Dairy	
Base	$0
Lower SR 10%	$89
No. 3 Dairy	
Base	$0
Lower SR 10%	-$58
Boundary Rd Dairy	
Base	$0
Lower SR 10%	$153
Sheep & Beef Farm	
Base	$0
Increase Forestry (129.5 ha)	$9
Deer Unit #1 (270 ha)	-$388
Deer Unit #2 (270 ha)	$22,939
Deer Unit #3 (66 ha)	-$2,112
Increase Forestry (129.5 ha) + Manuka (34.5 ha)	$42
Dairy Sheep	$281*

*Relative to Sheep and Beef base

12.0 HORTICULTURAL SCENARIOS

The potential for horticultural operations on both Onuku and Te Uranga B2 were investigated. Both farms had suitable soils and adequate rainfall, although both areas have fewer growing degree days relative to other horticultural areas.

This considered that both Manuka (for oil and honey), and chestnuts, could be grown on the farms. Inasmuch as Manuka has already been modelled as part of the land use change scenarios, the following comments concentrate on chestnuts.

The reason for considering a horticultural crop, from a GHG perspective, is that most have a relatively low level of GHG emissions.

12.1 Chestnuts

Chestnuts are a tree that produces an edible nut. The tree can also be harvested as a timber product and/or coppiced and used as stock food. Furthermore, cattle and other grazing animals can graze the grass under the trees as well as the chestnuts. Pork sold from pigs grazing under chestnuts sells for very high prices in Europe. The nuts can be sold fresh or processed into a range of products. Processed products include juice, flour and baby food. Chestnut flesh was at one time the baby food of choice in Asia until the pest and disease load in the chestnut trees in Asia resulted in high levels of pesticides being used. The potential of producing a pesticide free, even organic, baby food for export to Asia is there but limited by capital to develop the processing plant. Currently the pests and diseases causing problems overseas are not in New Zealand. Chestnuts fall from the tree and need to be gathered promptly and then stored appropriately by either chilling or freezing.

Chestnuts will grow well in the mix of climate and soils in the two properties studied. Potential areas were identified on the Paarata dairy farm (Te Uranga) and the Onuku drystock farm.

The financial parameters for chestnuts are illustrated below.

Table 16: Key Assumptions and Outputs of Chestnut Financial Model

Description	Assumption/Output	Notes
Area planted	10 hectares	Scale required for investment in capital equipment
Development Costs	$21,560/ha	$9,560 for planting in Year 1 then buildings and storage facilities required by Year 3
Mature Yield	7,500 kg/ha	Allows for 50 kg/tree with a 25% reject rate
Sales price	$2.50/kg	Assumes minimal processing, i.e. nuts sold fresh or frozen
Mature Gross Margin	$9,825/ha	
Discount Rate	6%	
Net Present Value	$185,210	No salvage value assumed for buildings and machinery
Internal Rate of Return	10%	

12.1.1 Greenhouse Gas Modelling

The GHG and nutrient output from chestnuts was 'modelled' within OverseerFM® ; this is used advisedly, as chestnuts is not currently an option within Overseer, so peaches was used as the closest proxy. This showed:

Table 17: Chestnut GHG Emission Base Figures

	Net Biological GHG Emissions (T/ha)	kg N leached/ha	kg P loss/ha
Onuku (Dry Stock) Base	3.5	15	0.9
Onuku (Dry Stock) 10 ha Chestnuts Only	0.12	10	0.3
Paatara Base	7.0	40	6.4
Paatara 10 ha Chestnuts Only	0.04	12	0.4

The chestnut scenario was modelled on both of the properties, initially as a 10 hectare operation (minimum commercial size) and again as a 40 hectare operation (i.e. as a serious commercial operation). While the sheep and beef/dairy operations are very different to the horticultural enterprise, this approach indicates the difference at a 'parcel of land' level.

Table 18: Impact of including chestnuts into the pastoral enterprise

	Net Biological GHG Emissions (T/ha)	EBIT/ha	kg N leached/ha	kg P loss/ha	Emission Intensity (kg CO_2e /kg product)	Change in GHG	Change in EBIT
Te Uranga Dairy (Paatara)							
Base	7.0	$749	40	6.4	10.4		
10 ha Horticulture	6.6	$1,468	38	6.0	10.4	-5%	96%
40 ha Horticulture	5.3	$3,335	32	4.9	10.5	-24%	346%
Onuku Sheep & Beef Farm							
Base	3.55	$652	15	0.9	15.1		
10 ha Horticulture	3.50	$747	16	0.9	15.2	-1%	14%
40 ha Horticulture	3.46	$1,054	16	0.9	15.2	-3%	61%

This shows that the horticultural block has had a proportionally bigger impact on GHG emissions on the dairy farm, which is not surprising given the higher base GHG emissions. The horticultural enterprise has also had a proportionally larger impact on nutrient discharge on the dairy farm.

The horticultural enterprise has also lifted the total farm EBIT, although this is distorted for the drystock farm as, although the EBIT from the horticultural block is the same between the dairy farm and the drystock farm, the horticultural EBIT is spread over a larger land area.

13.0 DISCUSSIONS WITH THE FARM OWNERS

Interviews were carried out with senior members of the farm governance, as to the entities attitude to environmental management/greenhouse gas mitigation, and their thoughts on adoption of the information from the modelling work.

13.1 Onuku Maori Lands Trust

Onuku Māori Lands Trust was established in 1981 under the auspices of the Māori Land Court, with ten trustees appointed. Variations to this court order have occurred since with only six nominated trustees today.

Onuku has an overarching vision statement with two main components. The first outlines that the land is whakapapa land that has been handed down to future generations of Ngati Rangitihi, with a conditional imperative that the land as a 'taonga' should remain for future generations. *'Onuku, he taonga tuku iho, mo ake tonu atu'* [Onuku, a heritage, forever].

The second component outlines an intent for success. As follows:

"*To be a pre-eminent farming and forestry operation within the district, for which the beneficial owners can feel justly proud and well rewarded*".

Also, with respect to the *taonga tuku iho* noted above, this means that the land and decisions associated be beneficial to future generations, productivity and profitability are embraced within this understanding with long-term strategies for development at the forefront. This differs to land governance approaches which seek to make short-term high profit returns, which may have future impacts on the generative state of the land.

Within this, the Trust has a strong environmental ethic, and while there is a clear push to improve the productivity and profitability of the land, this must not be done to the detriment of the environment.

In that sense profitability is balanced with environmental policies (maintaining water quality, carbon reduction); affordability (what can be bought given balance sheets); working the land to the landscape (what is the land best used for); business information and networks (extent to which there is information flow across a wide spectrum); and expertise and leadership (diverse, well-skilled trustees; decisions made in conjunction with advisors).

Currently Onuku is looking at land use diversification options - dairy sheep, deer, Manuka, forestry, as well as management changes on existing farms as discussed in this report. As a result of this project, they are well aware of the GHG implications of these and intend to be cognisant of this when making a decision.

Currently, no decision has been made on GHG mitigations strategies; given the advent of the zero-carbon bill, the Trust is waiting to see exactly what the government proposes to do and what the regulations are, before enacting any changes on-farm.

13.2 Te Uranga B2 Incorporation

Te Uranga B2 Incorporation (originally known as Rangitoto Tuhua 74B 6G) was established in 1910, with 49 original owners of Waikato Maniapoto and Tūwharetoa descent.

The Incorporation manages its assets on behalf of its shareholders, with its core business being to grow the assets, develop the business and provide benefits for its people. Its strategy aims to operate an effective, efficient and integrated primary industry operation; one that effects positive physical and financial performance, the enhancement of the environment and balances cultural and social responsibility.

Part of this environmental ethos is shown in the placing of 123 hectares of regenerating native bush under Nga Whenua Rahui, the fencing off and planting of various riparian zones, and investing up to $40,000 annually on environmental issues, partnering in this with Horizons Regional Council.

As discussed in this report, Te Uranga B2 currently leases 580 hectares of land which is in forestry, and is shortly to be harvested, replanted, and returned to Te Uranga B2. This, in conjunction with the proposed 348 hectares of land modelled to be planted in forestry on the sheep and beef farm, would effectively mean that Te Uranga B2 would be in a carbon ‘surplus’ situation (noting that this could change if the zero-carbon bill does result in methane being unable to be offset by forestry).

As with Onuku, the modelling exercise on Te Uranga B2 covered a range of farm system and land use change options, meaning that the Board is well aware of the greenhouse gas implications of these options.

And again, similar to Onuku, no decisions have been made as yet, as the Board needs to consider the options, and wait to see where the zero-carbon bill lands.

14.0 APPENDIX ONE FORESTRY SILVERCULTURE COSTS

Radiata Pine

Silviculture costs

A clearwood regime was assumed for the Radiata Pine scenario. Genetically improved tree stock and timely management was assumed to mean this regime could be achieved with two pruning operations and 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	0	$1,070
Prune 1	5	$750
Prune 2	8	$900
Thin to waste 1	8	$500

Yield tables

National Exotic Forest Description (NEFD) 2017 regional yield tables published by MPI for Central North Island were used for the Rerewhakaaitu site. Southern North Island West tables were used for Taumarunui. Post 1989 pruned stand tables were used. These yield tables give volumes per hectare in the general grade mixes of pruned, unpruned sawlog and pulp. General assumption on the split of these grades was made as follows:

NEFD Grade category	Assumed grade composition
Pruned	25% P1, 25%P2, 50% Export pruned
Unpruned	25%A, 25%K, 25%S1/S2, 25% L1/L2/L3/S3
Pulp	100% domestic pulp

Log prices

Log prices are from MPI Indicative New Zealand Radiata Pine Log Prices by Quarter. The 12-quarter average at December 2017 was calculated and used. Composite prices for the Pruned, Unpruned, and pulp were calculated based on the assumed grade composition above. Export JAS fob log prices were reduced by $18/m3 to allow for wharfage and JAS conversion. Composite prices used are set out below.

NEFD Composite log grade	$/m^3 at mill or wharf gate
Pruned sawlog	$167
Unpruned sawlog	$115
Pulp	$48

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	Rerewhakaaitu	Taumarunui
Road and skid construction	$4	$4
Logging and loading	$25	$28
Management	$4	$4
Contingency/RMA	$1	$1
Transport	$18	$25
Total harvest costs	$51	$62

Douglas Fir

Silviculture costs

A thin to waste regime was assumed for the Douglas Fir scenario. The table below sets out the generalised regime used and cost assumptions.

Operation	Year	Cost /ha
Tree stocks, planting and releasing	0	$1,620
Thin to waste 1	8	$700

Yield tables

National Exotic Forest Description (NEFD) 2017 regional yield tables published by MPI for Nelson were used for both the Rerewhakaaitu and Taumarunui sites. Tables for the Central North Island appeared to be too low and influenced by historic management across that area. There is a lack of other North Island tables.

These yield tables give volumes per hectare in the general grade mixes of unpruned sawlog and pulp. General assumption on the split of these grades was made as follows:

NEFD Grade category	Assumed grade composition
Pruned	25% P1, 25%P2, 50% Export pruned
Unpruned	25%A, 25%K, 25%S1/S2, 25% L1/L2/L3/S3
Pulp	100% domestic pulp

Log prices

Log prices were based on MPI Indicative New Zealand Radiata Pine Log Prices by Quarter. The 12-quarter average at December 2017. These prices were increased by 15% to allow for the usual premium received for Douglas Fir.

Composite prices for the unpruned logs were calculated based on the assumed grade composition above. Export JAS fob log prices were reduced by $18/m3 to allow for wharfage and JAS conversion. Composite prices used are set out below.

NEFD Composite log grade	$/m^3 at mill or wharf gate
Unpruned sawlog	$133
Pulp	$48

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	Rerewhakaaitu and Taumarunui
Road and skid construction	$4
Logging and loading	$25
Management	$4
Contingency/RMA	$1
Transport	$18
Total harvest costs	$51

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