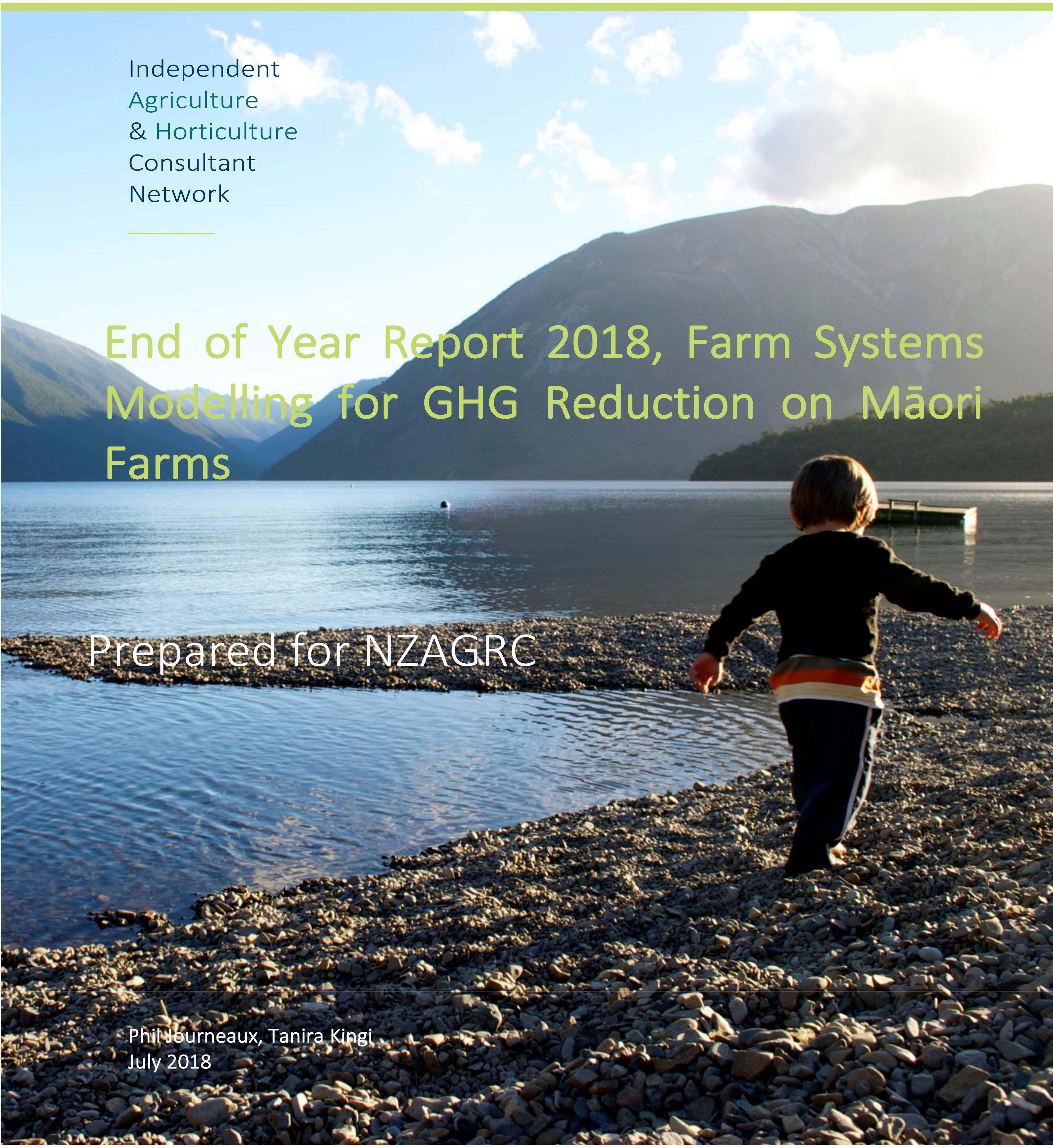

Independent
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End of Year Report 2018, Farm Systems Modelling for GHG Reduction on Māori Farms

Prepared for NZAGRC

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1.0 BACKGROUND

This report covers the period 1 January – 30 June 2018, being the first year of the Farm Systems Modelling for GHG Reduction on Māori Farms project.

1.1 Milestones

Key milestones for the period were:

- Develop criteria for selection of 2 Māori agri-business entities involving multi-enterprise farming activities
- Hold discussions with industry bodies (Dairy NZ 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 2 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 2 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
- Present to the annual NZAGRC workshop

2.0 SELECTION OF AGRI-BUSINESS CASE STUDY ENTERPRISES

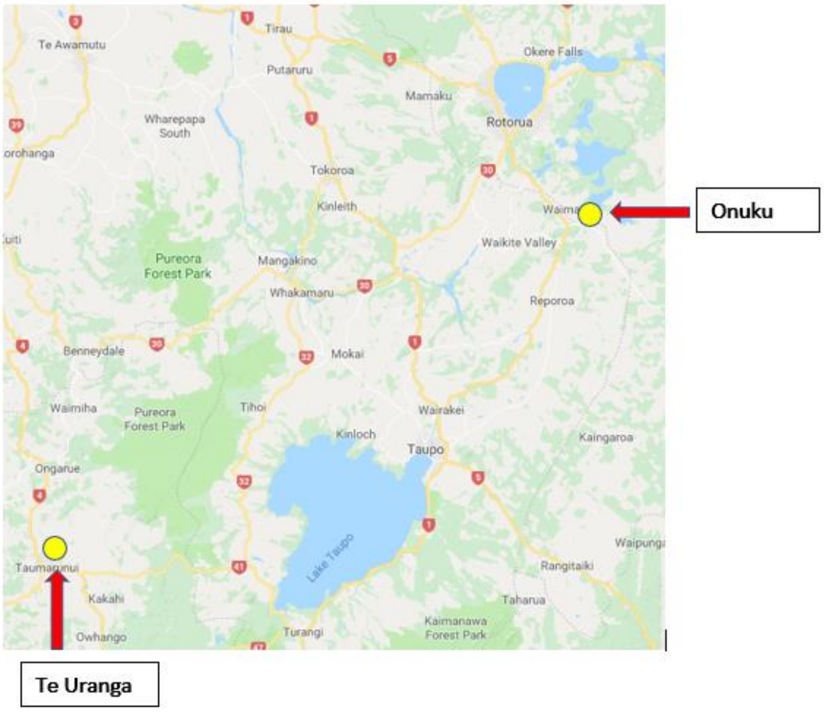
Criteria for the selection of the case study enterprises were developed in consultation with the industry partners (Reference Group) were set as:

(i) Must have a mix of different pastoral farming enterprises; dairy and sheep & 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 5 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 Taumaranui.

Figure 1:Location Map



2.1 Onuku Māori Lands Trust

Onuku consists of:

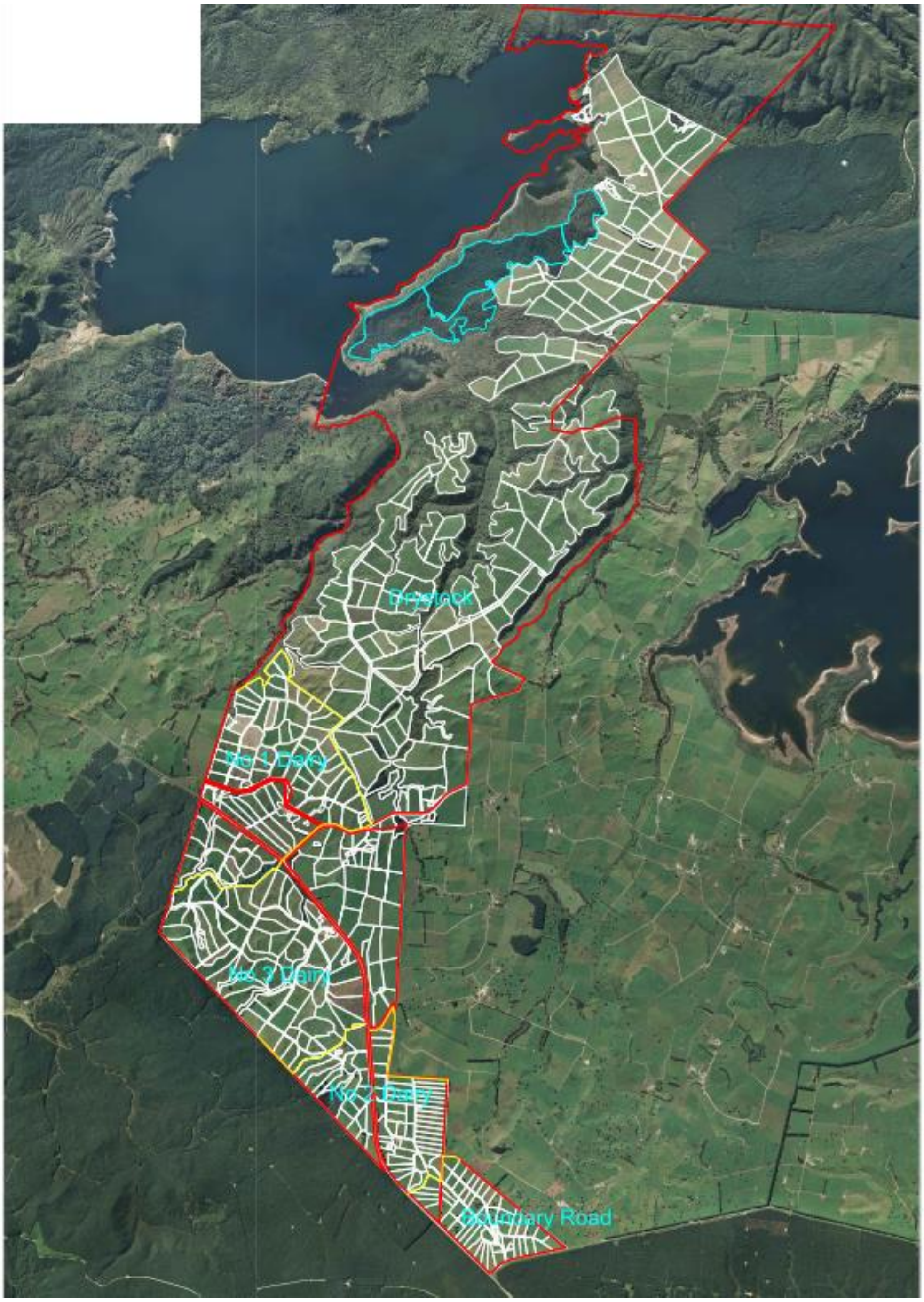
(i) Four dairy farms
- No.1 dairy, 204ha effective
- No.2 dairy 116ha effective
- No.3 dairy 215ha effective
- Boundary Road dairy, 72ha effective

(ii) A sheep & beef unit; 908ha in pasture, 1.2ha pines, 17.9ha manuka, 26ha native forest

(iii) A forestry block of 117.5ha pines, 12.5ha Douglas fir, 678ha native

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, 219ha effective
- Paatara, 133ha effective

(ii) A sheep & beef unit (Upoko); 1,153ha in pasture, 36.7ha in pines, 20.3ha in manuka, 220ha natives

(iii) A forestry block; 580ha pines, 142ha native. The pines on this block and the sheep & beef farm are due to be harvested within the next 6 years.

Figure 3: Te Uranga 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 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.

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 5-year averages:

- Milksolids payout = $6.00/kgMS
- Beef schedule = $5.21/kg based on a 295kg prime steer (carcass 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 payments (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 impact 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, 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. BoP / CNI costs used.

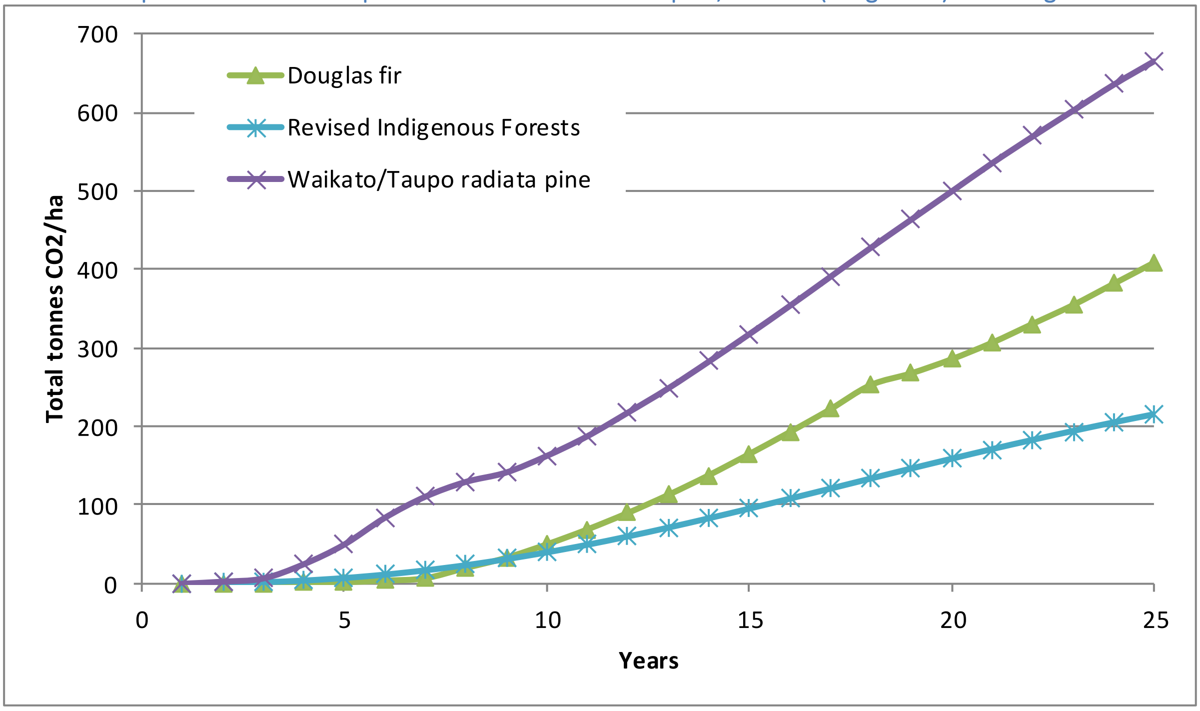
5.0 CARBON SEQUESTRATION

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

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 100kgN/ha/year, but maintain production via increased supplements (maize silage)
- Increase per cow production to 400kgMS/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 & 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 ha of steeper/erosion prone hill country into forestry
- Develop 348 ha 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 ½ in pines, ½ in manuka
- Replant area $^1/_3$ pines, $^1/_3$ manuka, $^1/_3$ 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 & beef farm;

- Increase the forestry area (pines) by 129.5 ha
- Develop 270ha 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 66ha on the S&B unit into deer, to maintain the 270ha unit.
- Increase the forestry area (pines) by 129.5 ha, plus plant an additional 34.5ha into manuka (for oil)

(iv) Forestry – no change

(v) Dairy sheep scenario. This involved taking 141ha out of the S&B unit, plus 17ha from No.1 Dairy, to create a 158ha unit, running 1,900 milking sheep + 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

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)	4,153	2.9
Ue Pango (Forestry)	-3,376	-4.7
Overall Net	3,649	1.5**

*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)

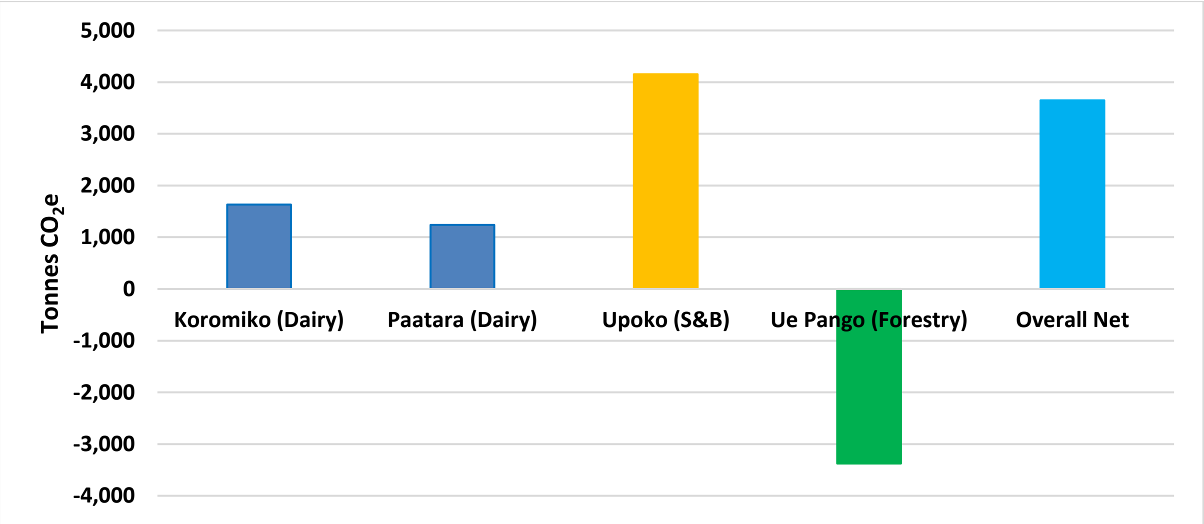
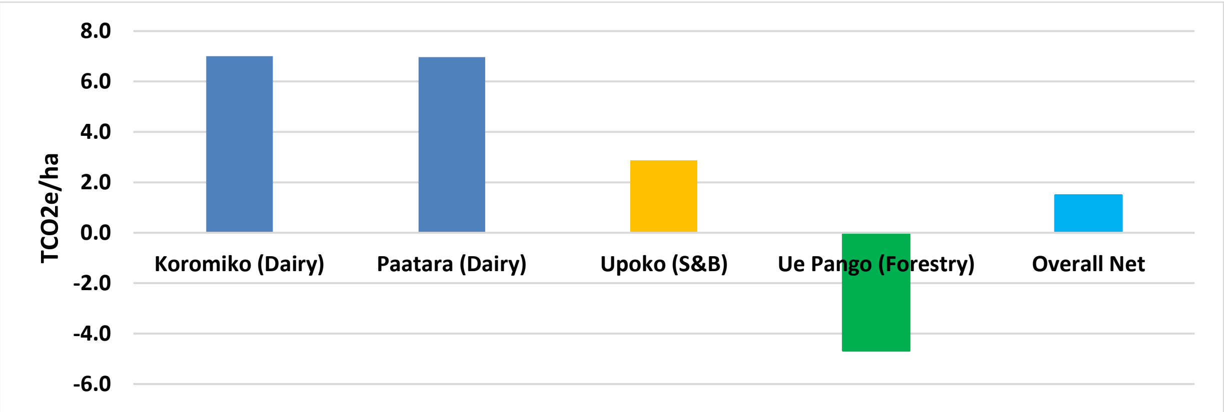


Figure 5: Summary of Te Uranga Base GHG Emissions; Tonnes/ha (T CO_2e)



7.1 Te Uranga 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%
100kg N/ha	6.7	$421	42	3.5	11.0	-5%	-12%
400kgMS/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%
100kg N/ha	6.8	$747	38	6.4	10.2	-2%	0%
400kgMS/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 (348ha)	0.8	$305	15	1.2	17.2	-71%	-19%
Bulls + 348ha forest	0.8	$313	15	1.2	16.5	-71%	-16%
Forestry							
Base	-4.7	$217					
1/2 pine, 1/2 manuka	-5.8	$229				-24%	5%
1/3 pine, 1/3 manuka, 1/3 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

	Net Tonnes Biological GHG Emissions	Total Enterprise EBIT ($)	Change in GHG	Change in EBIT	Change in EBIT#2*
Base scenario	3,649	$754,912	0	0	
Lower SR 10% on dairy farms + grow maize + 348ha forestry on S& B farm + 1/3, 1/3, 1/3 forestry option	-476	$699,731	-113%	2.6%	3.8%
Base dairy farms + 348ha forestry on S&B farm + 1/2, 1/2 forestry option	-103	$602,777	-103%	-9.9%	-9.6%
400kgMS/cow on dairy farms + bull scenario on S&B farm + 1/2, 1/2 forestry scenario	2,504	$993,611	-31%	30.7%	
400kgMS/cow on dairy farms + bull scenario on S&B farm + base forestry scenario	3,310	$986,941	-9%	29.9%	
400kgMS/cow + bulls & forestry on S&B farm + 1/2, 1/2 forestry option	-232	$790,807	-106%	14.3%	14.9%
Lower SR 10% on dairy farms + grow maize + bulls on S& B farm + 1/3, 1/3, 1/3 forestry option	2,236	$912,344	-39%	20.3%	
Lower SR 10% on dairy farms + grow maize + bulls & 348ha forestry on S& B farm + 1/3, 1/3, 1/3 forestry option	-500	$709,540	-114%	3.9%	5.2%
Lower SR 10% on dairy farms + grow maize + bulls on S& B farm + base forestry option	573	$731,542	6.7%		
100kgN/ha on dairy farms + 348ha forestry on S&B farms + base forestry	587	$583,204	-84%	-12.4%	
100kgN/ha on dairy farms + bulls & 348ha forestry on S&B farms + 1/2, 1/2 forestry option	-242	$599,683	-107%	-10.3%	-9.6%

*Surplus carbon sold at $20/tonne CO_2e

Comment

As can be seen from Tables 6 & 7, the mitigation that has the most significant impact in reducing GHG emissions across the whole enterprise is planting the additional 348ha on the sheep & beef farm in forestry. This is enhanced if the forestry block replanting is in a combination of pines and manuka. These 2 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.

In the absence of the forestry option on the sheep & 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 (400kgMS/cow scenarios), the growing of maize as opposed to buying in palm kernel, keeping beef male progeny entire on the sheep & beef farm, and again planting part of the forestry area into manuka for honey production.

Possibly the best mix of options is the 400kgMS/cow on dairy farms + bull scenario on S&B farm + $^1/_2$, $^1/_2$ forestry scenario, which gives a 31% reduction in GHGs while lifting profitability by 32%.

Individual Scenario Comment

1. As in other modelling exercises, the reduce 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 400kgMS/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 re-grassing 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 & 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 (& manuka) scenarios on the sheep & 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 ½ pine, ½ 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 1/3 pine, 1/3 manuka, 1/3 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

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	996	8.6
No 3 Dairy	2,045	9.3
Boundary Rd Dairy	855	11.6
Sheep & beef	3,322	3.5
Forestry	-723	-0.9
Overall Net	8,687	3.7**

*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)

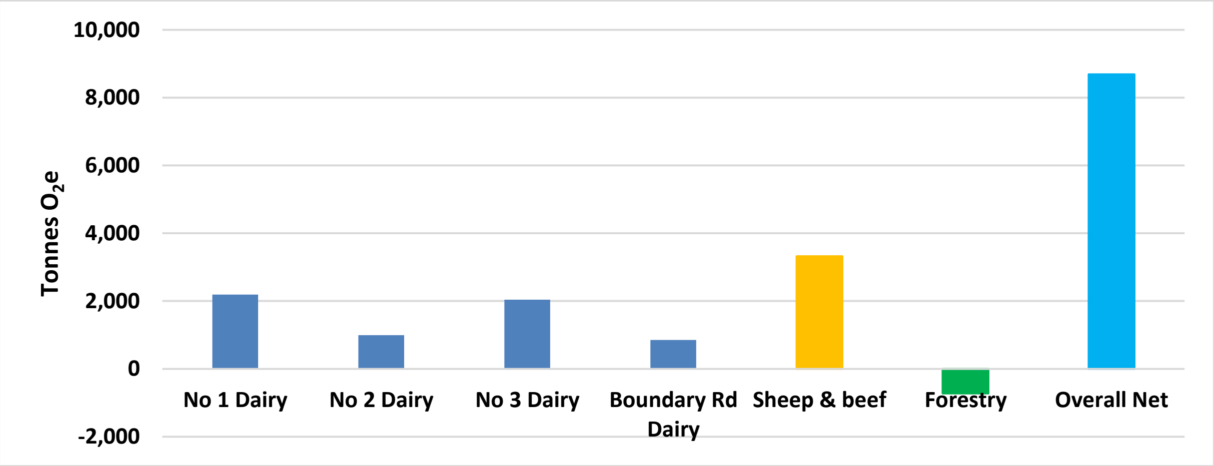
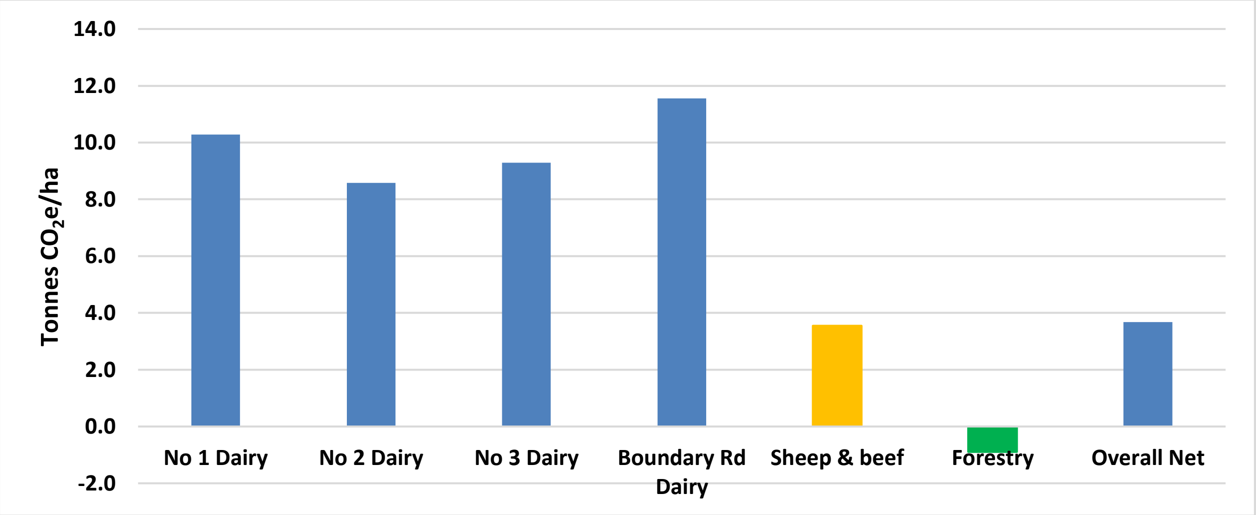


Figure 7: Summary of Onuku Base GHG Emissions; Tonnes/ha (T CO_2e)



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 Rd 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 (129.5ha)	2.5	$643	14	0.7	15.4	-30%	-1%
Deer Unit#1 (270ha)	3.7	$595	17	0.9	15.3	4%	-9%
Deer Unit#2 (270ha)	3.5	$530	17	0.9	16.2	0%	-19%
Deer Unit #3 (66ha)	3.6	$448	18	0.9	15.3	3%	-31%
Increase Forestry (129.5ha) + Manuka (34.5ha)	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	-0.9	$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	8,760	1,778,676		
Reduce dairy SR 10% + 129.5ha forestry on S&B farm	6,515	1,692,237	-26%	-5%
Base dairy + 129.5ha forestry on S&B farm	7,739	1,709,108	-12%	-4%
Feed pad on No.1 dairy + reduce SR 10% on rest of dairy + deer unit#1	7,811	1,718,262	-11%	-3%
Feed pad on No.1 dairy + reduce SR 10% on rest of dairy + deer unit#2	7,672	1,659,493	-12%	-7%
Feed pad on No.1 dairy + reduce SR 10% on rest of dairy + 129.5ha forestry on S&B farm	6,476	1,692,237	-26%	-5%
No.1 dairy converted to deer + reduce SR 10% on rest of dairy farms + deer unit#3 on S&B farm	7,098	1,380,180	-19%	-22%
Reduce SR 10% on all dairy farms + 129.5ha forestry & 34.5 ha manuka on S&B farm	6,153	1,648,066	-30%	-7%
Reduce SR 10% on all dairy farms + feed pad on No.1 dairy + 129.5ha forestry & 34.5 ha manuka on S&B farm	6,114	1,648,066	-30%	-7%
No.1 Dairy + S&B farm (base)	5,515	1,052,190		
No.1 Dairy + S&B farm + Dairy Sheep	6,435	1,763,190	17%	68%
No. 1 Dairy + 129.5ha forestry & 34.5 manuka on S&B farm + Dairy Sheep	5,091	1,479,234	-8%	41%

Comment

As can be seen from Tables 9 & 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 GHGs. The exception to this was the conversion of the No.1 dairy unit into deer; while this resulted in a significant reduction (31%) in GHGs, it also resulted in a 45% reduction in profitability.

The "reduce stocking rate by 10%" scenario on the diary 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 & 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 as regards 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 (& manuka) has a significant impact in offsetting GHG emissions, with a slight impact on profitability due to the lower returns relative to sheep & beef.

5. Conversion of part of the sheep & beef farm into 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 tonnesCO_2e/ha, as well as a relatively high (compared to the sheep & beef farm) nitrogen loss of 21kgN/ha/year. Booth could be attributed to the high stocking rate of 1,900 ewes + 600 hoggets on the property, =to 15 animals/ha.

9.0 EMISSIONS TRADING SCHEME ISUES

Both the existing forestry areas on Te Uranga and Onuku are pre-1990 forests. In an ETS context therefore, the carbon sequestration from these forests cannot be claimed as offsets. The removal of these credits has a significant impact on the overall "CO_2e balance" as illustrated below.

Table 11: Te Uranga Base GHG Emissions, excluding non-ETS forests

	Total Tonnes*	T/ha
Koromiko (Dairy)	1,632	7.0
Paatara (Dairy)	1,239	7.0
Upoko (S&B)	4,367	3.0
Ue Pango (Forestry)	0	0.0
Overall Net	7,239	2.9**

*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

This shows that the total GHG and per hectare emissions have increased by almost 100% compared to those shown in Table 5.

For Onuku the figures show:

Table 12: Onuku Base GHG Emissions, excluding non-ETS forests

	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 Rd Dairy	855	11.6
Sheep & 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

Total GHG and per hectare emission have increased by 9% relative to the earlier calculation (Table 8).

This in turn has implications for the "mix and match" scenarios.

Table 13: Te Uranga mix and match scenarios without carbon from pre-1990 forests

	Net Tonnes Biological GHG Emissions	Total Enterprise EBIT ($)	Change in GHG	Change in EBIT
Base scenario	7,239	$777,302		
Lower SR 10% on dairy farms + grow maize + 348ha forestry on S& B farm	3,972	$797,637	-45%	2.6%
Base dairy farms + 348ha forestry on S&B farm	4,079	$700,683	-44%	-9.9%
400kgMS/cow on dairy farms + bull scenario on S&B farm	6,899	$1,016,001	-5%	30.7%
400kgMS/cow on dairy farms + bull scenario on S&B farm	6,899	$1,009,331	-5%	29.9%
400kgMS/cow + bulls & forestry on S&B farm	3,951	$888,713	-45%	14.3%
Lower SR 10% on dairy farms + grow maize + bulls on S& B farm	6,898	$934,734	-5%	20.3%
Lower SR 10% on dairy farms + grow maize + bulls & 348ha forestry on S& B farm	3,949	$807,446	-45%	3.9%
Lower SR 10% on dairy farms + grow maize + bulls on S& B farm	3,949	$829,448	-45%	6.7%
100kgN/ha on dairy farms + 348ha forestry on S&B farms	3,963	$681,110	-45%	-12.4%
100kgN/ha on dairy farms + bulls & 348ha forestry on S&B farms	3,940	$697,589	-46%	-10.3%

Table 14: Onuku mix and match scenarios without carbon from pre-1990 forests

	Net Tonnes Biological GHG Emissions	Total Enterprise EBIT ($)	Change in GHG	Change in EBIT
Base	9,483	1,782,036		
Reduce dairy SR 10% + 129.5ha forestry on S&B farm	7,238	1,756,462	-24%	-1%
Base dairy + 129.5ha 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 + 129.5ha 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 + 129.5ha 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 + 129.5ha forestry & 34.5 ha manuka on S&B farm	6,837	1,716,431	-28%	-4%

10.0 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) are 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 15: 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 16: 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 (129.5ha) with forestry annuity	3,198	897	2,301	$584,516	$643	-1%
Incr Forestry (129.5ha) 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 (348ha) with forestry annuity	3,621	2,414	1,207	$362,786	$305	-19%
Incr forestry (348ha) 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.

11.0 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 56t/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 17: 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 (348ha)	0.84	1.51	-71%	-47%
Bulls + 348ha forest	0.82	1.49	-71%	-48%
Onuku S&B				
Increase Forestry (129.5ha)	2.49	2.87	-30%	-19%
Increase Forestry (129.5ha) + Manuka (34.5ha)	2.33	2.81	-34%	-21%

12.0 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

[1] L Schipper, Landcare Research, personal communication

Table 18: 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
100kg N/ha	$141
400kgMS/cow	-$1,013
Base - Grow maize	$3
Lower SR 10 + maize	-$1,126
Paatara (Dairy)	
Base	$0
Lower SR 10%	-$155
100kg N/ha	$8
400kgMS/cow	$7,569
Base - Grow maize	-$24
Lower SR 10 + maize	-$1,332
Upoko (S&B)	
Base	$0
Bulls	-$230
Increase Forestry (348ha)	$26
Bulls + 348ha forest	$23

Table 19: 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 (129.5ha)	$9
Deer Unit#1 (270ha)	-$388
Deer Unit#2 (270ha)	$22,939
Deer Unit #3 (66ha)	-$2,112
Increase Forestry (129.5ha) + Manuka (34.5ha)	$42
Dairy Sheep	-$55*

*Relative to Sheep & Beef base

13.0 HORTICULTURAL SCENARIOS

The potential for horticultural operations on both Onuku and Te Uranga were investigated (see separate report).

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.

13.1 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, flower 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 20: 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%	

13.1.1 Greenhouse Gas Modelling

The GHG and nutrient output from chestnuts was "modelled" within OVERSEER; this is used advisedly, as chestnuts is not currently an option within OVERSEER, so peaches was used as the closest proxy.

This showed:

Table 21: 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 10ha operation (minimum commercial size) and again as a 40ha operation (i.e. as a serious commercial operation). While the sheep & beef/dairy operations are very different to the horticultural enterprise, this approach indicates the difference at a "parcel of land" level.

Table 22: 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		
10ha Horticulture	6.6	$1,468	38	6.0	10.4	-5%	96%
40ha 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		
10ha Horticulture	3.50	$747	16	0.9	15.2	-1%	14%
40ha 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 [Why nitrogen leaching has increased on the drystock farm is uncertain; possibly as a result of modelling in a newer version of OVERSEER (6.3.0)]

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.

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

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