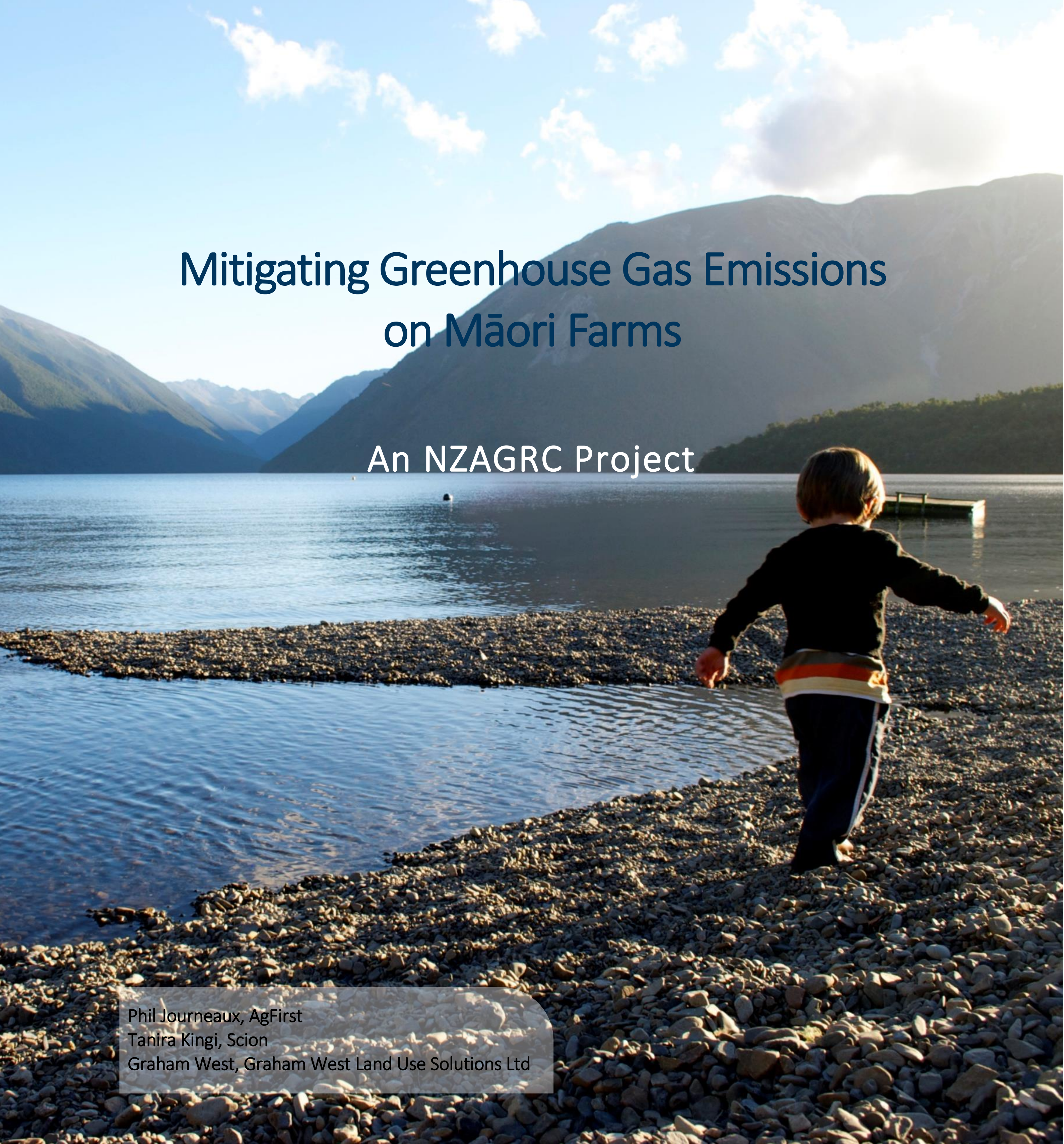
Mitigating Greenhouse Gas Emissions on Māori Farms

An NZAGRC Project



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1.0 EXECUTIVE SUMMARY

This report covers a project to assist the Māori pastoral sector to improve its collective capacity to increase resource efficiency, farm productivity, while reducing GHG emissions. The project was based around the establishment of a network of 29 Māori farms, and intensive modelling on four of these farms to investigate and demonstrate the impact of mitigation strategies on farm profitability and GHG emissions.

Profiling of the 29 farms indicated there is significant variation in GHG emission between farms, with dairy generally averaging 9,700 kg biological CO_2e/ha/yr (standard deviation 2,407 kg CO_2e) and drystock averaging 3,200 kg CO_2e/ha/yr (SD 1,180 kg CO_2e). When compared to a national benchmark from farm monitoring farms the dairy result was found to be slightly higher (perhaps indicating greater intensification) and the drystock farm less than the benchmark.

A typology of the 29 farms was developed to reflect the key characteristics of Māori farming structures and GHG emissions. An initial assessment of the sample of the 29 farms showed that there was very little relationship between governance structure and GHG emissions, compounded by having a relatively small sample. We concluded that the impact of Māori farm governance structure, e.g. trusts, incorporations, partnerships, companies, etc. on GHG emissions was minimal, i.e. that farm performance and investment decisions was largely driven by the capability of governance and management. However, decisions on the structure of the properties proved to be a critical factor in the range of options that a governance group has over mitigation options, e.g. dairy farms in general did not have excess land to establish forestry for carbon sequestration, but an organisation with multiple enterprises/properties would have more mitigation choices especially for land diversification to reduce total emissions.

There are a number of Māori cultural and economic factors which create tensions around GHG mitigations. These include:

- Matauranga and tikanga Māori. From a Māori perspective, the management of land (and water) is a blend of cultural norms and modern practices. This includes balancing the productive aspect of land management with an environmental stewardship ethic, along with balancing the economic and social needs of the current and future owners.

- Māori land is owned by multiple owners, with often many shareholders per title. This ownership, usually based on a genealogical connection to the land, means that Māori land cannot, or won't ever, be sold. While this can present a variety of challenges, it does mean that Māori often take a very long-term view of issues, which can assist with GHG emissions around forestry development.

  - The politics of Māori land in New Zealand, coupled with recent Treaty settlements, has often resulted in a combination of an under-utilisation of that land, and/or a strong desire to improve the productivity/profitability from that land.

Overall therefore, there are some inherent tensions around potential GHG mitigations, and the intense pressure governance bodies are under to improve financial returns. Within the focus farms, the latter was certainly a dominant factor.

Four focus farms were selected from the 29 profile farms:

(i) Two dairy farms - Pukehina (Bay of Plenty), and Te Rua o Te Moko (Taranaki).

(ii) Two sheep and beef farms - Oromahoe (Northland), and Marotiri (East Coast)

The process involved:

(i) Discussions with the farm governance to (a) gain acceptance for the farm to be involved in the project; and (b) discuss initial scenarios for modelling.

(ii) A follow-up meeting with governance and management to discuss the results of the initial modelling, and discuss further scenarios for modelling.

(iii) A public field day to discuss the results of all the scenario modelling and obtain feedback on this, along with any adjustments to the mitigation scenarios.

(iv) A second public field day the following year to present and discuss the scenario modelling, particularly including a spatial framework and demonstrate the Mitigation Matrix calculator.

The modelling was carried out via a range of models:

(i) Initially farm system changes were modelled in Farmax, a feed-budget based model that allows for modelling of farm production and profitability.

(ii) Information from this was then transferred into OverseerFM® to calculate GHG emission and nutrient discharge levels.

(iii) The Radiata Pine calculator was used to calculate economic returns from forests, along with levels of carbon sequestration.

(iv) The results of the above models were then collated within a spreadsheet to show overall impacts of scenarios by focus farm.

A summary of the modelling results is as follows:

Pukehina Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base Model			9.7		9.6		27	
S1: Remove summer and autumn crops and replace with supplements		4%	9.8	1%	9.5	-1%	25	-7%
S2: Partial wintering facilities		0%	9.7	1%	9.6	0%	27	0%
S3: In-shed feeding with increased cow numbers		12%	10.7	11%	8.8	-9%	28	4%
S4: In-shed feeding with young stock on the milking platform		-52%	11.2	16%	10.8	12%	37	37%
S5: Lower stocking rate		14%	9.7	0%	9.0	-7%	26	-4%
S6: Plant 3 ha forest		-1%	9.2	-5%	9.5	-2%	27	0%

Note: Actual $ net profit/ha figures are confidential

Te Rua o Te Moko Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	$2,021		9.0		7.7		27	
S1: Replace maize with fodder beet	$2,058	2%	9.1	1%	7.8	1%	26	-4%
S2: Replace N fertiliser with bought-in feed	$1,663	-18%	8.0	-11%	6.9	-10%	19	-30%
S3: Eliminate N Fertiliser	$1,629	-19%	6.8	-24%	6.9	-10%	18	-33%
S4: Remove crops	$2,160	7%	9.3	3%	7.9	3%	25	-7%
S5: Plant 2 ha forest	$2,004	-1%	8.7	-3%	7.7	-1%	27	0%
S6: In-shed feeding	$2,203	9%	9.9	10%	7.6	-1%	33	22%

Marotiri Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	79		0.4		12.6		8	
S1: Eliminate N fertiliser	75	-6%	0.4	-4%	12.6	0%	8	0%
S2: 50 sheep:50 beef	89	13%	0.4	-10%	12.1	-4%	8	0%
S3: 60 sheep:40 beef	103	30%	0.3	-16%	11.6	-8%	8	0%
S4: Plant 50 ha forest	87	10%	0.0	-100%	12.3	-2%	8	0%
S5: Intensify 100 ha in lamb production	97	22%	0.4	7%	12.4	-1%	8	0%
S6: Plant 50 ha Lusitanica	81	2%	0.2	-53%	12.3	-2%	8	0%
S7: Plant 50 ha Manuka	84	6%	0.3	-35%	12.3	-2%	8	0%

Oromahoe Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from Base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	$223		1.8		12.3		8	
S1: 100 ha Techno beef system	$297	33%	1.9	9%	12.1	-1%	9	13%
S2: Plant 30 ha forest	$227	2%	1.1	-39%	11.7	-4%	8	0%
S3: Increase Techno area (200 ha) + plant 30 ha forest	$366	64%	1.4	-24%	11.3	-8%	9	13%
S4: Winter lambs	$217	-3%	1.8	1%	12.5	2%	8	0%
S5: Increase lambing percentage	$250	12%	1.8	0%	12.1	-2%	8	0%
S6: Plant 30 ha Manuka	$235	5%	1.3	-27%	11.7	-4%	8	0%

These results show that the relationship between changes in profitability and change in GHG emissions vary between the focus farms. As a generalisation, if the change in farm system improved profitability, often GHG emissions also increased, and if GHG emissions decreased, then often profitability decreased.

Exceptions to this generalisation include:

- For Pukehina, a lower stocking rate resulted in a lift in profitability and a decrease in GHG emissions.

  This is an important issue, as at face value there is a direct win-win situation – GHG emissions have decreased, whereas profitability has increased. To some degree this is an artefact of the model; the scenario saw cow numbers reduced, and bought-in supplementary feed reduced. In achieving the same level of production as per the base situation, the model has assumed that pasture quality has not deteriorated, and that grazing efficiency is either similar or better to the base model. In effect, efficiency has improved, because the model assumes efficient management choices have been implemented.

  In practice, things are more complicated. It is possible for farmers to maintain pasture quality and grazing efficiency (i.e. pasture utilisation) with reduced stock numbers, and hence achieve the win-win outcome. This has been achieved on farms in other related studies looking to reduce nutrient discharges[1].But many farmers would struggle to maintain pasture quality at a lower stocking rate, and the very high likelihood is that this would then result in lower production and lower profitability.

[1] Park S., T. T. Kingi, S. Morrell, L. Matheson, M. Sprosnen, and S. Ledgard (2015) The context and practice of nutrient mitigation on Rotorua dairy farms. In L. D. Currie and C. L. Christensen (Eds) Moving Farm Systems to Improved Attenuation. Proceedings of the annual Fertiliser and Lime Research Centre Workshop, published at: http://www.massey.ac.nz/~flrc/workshops/15/paperlist15.htm
Park S., T. T. Kingi, S. Morrell, L. Matheson and S. Ledgard (2014) Nitrogen losses from Lake Rotorua dairy farms - modelling, measuring and engagement. In L. D. Currie and C. L. Christensen (Eds) Nutrient Management for the Farm, Catchment and Community. Proceedings of the annual Fertiliser and Lime Research Centre Workshop, published at: www.massey.ac.nz/~flrc/workshops/14/Manuscripts/Paper_Park_2014.pdf

Interpreting the results of the model therefore needs to be done with caution as it could lead to a false positive.

Essentially the model has realigned its marginal benefit with marginal cost; at the payout and farm costs used, the extra supplementary feed and cows run (in the base model) meant that marginal cost was higher than marginal benefit. The issue that arises is that this MR/MC 'sweet spot' varies with payout and costs (obviously), and hence a different result would be obtained with a different payout/cost structure, which in turn, out on the farm, makes it difficult for the farmer to consistently operate around this 'sweet spot', especially as costs and returns are often not known with certainty until well into the season.

- For Marotiri, increasing the sheep:cattle ratio increased profitability while decreasing GHG emissions, as did planting up 50 hectares into forestry or Manuka, especially given the annuity from forestry and Manuka is higher than the farm EBIT.

- For Oromahoe, planting up 30 hectares into forestry/Manuka also gave a win-win, and the 200 hectare techno beef plus 30 hectares of forestry gave a major boost to profitability along with a decrease in GHG emissions. Increasing lambing percentage (i.e. a productivity improvement) also gave a win-win in the sense that profitability improved while GHG emissions remained at the base level.

One of the drawbacks of the modelling approach was that it had no spatial context. The MyLand model[2] was altered to accept output from Farmax and OverseerFM®, which allowed for the integration of farm production and economics, along with GHG emission levels, and forestry information, to give both a spatial and temporal output. The focus farm scenarios were incorporated within MyLand, and presented at the field days – having spatial representations definitely assisted farmers to visualise the impact and implications of any land use change.

In a similar vein, a spreadsheet based calculator was developed (the 'Mitigation Matrix'), which allows for simplified input as to enterprise and land use mixes, and shows the results (changes in profitability, change sin GHG/nutrient discharge) in graphical form.

Both the focus farm personnel and outside farmers were asked at the field days as to their preference around scenarios modelled.

The response was unequivocal across all the field days:

(i) They were definitely interested in strategies which improved farm profitability, particularly if GHG emissions decreased, or even if they increased slightly.

(ii) They were definitely not interested in any strategies that decreased GHG emissions if it had a negative effect on profitability.

[2] West, G.G, Turner, A.T, (2013) MyLand: a web-based and meta-model decision support system framework for spatial and temporal evaluation of integrated land use.
http://www.tandfonline.com/doi/abs/10.1080/02827581.2013.866690?journalCode=sfor20

2.0 BACKGROUND

The project was designed to assist Māori farmers in New Zealand to improve their collective capacity to increase resource efficiency and farm productivity while lowering greenhouse gas (GHG) emissions. This involved three objectives:

1. Define the characteristics of the Māori agribusiness sector drawing on a network of 30 Māori farm entities that are representative of the main farm typologies (predominant pastoral farming systems) on Māori land;

2. Identify the key factors that underpin farm productivity, resource and emission efficiency and sustainable profitability; and

3. Identify, test and communicate a range of mitigation strategies to other Māori farms and the wider industry.

3.0 METHODOLOGY

The methodology employed for this project involved a number of approaches over the three-year period:

- Development of a typology of Māori farming.

- The collection of farm and GHG emission profiles on 29 Māori farms from around the country. This included 18 sheep and beef farms, and 11 dairy farms.

- The selection of four focus farms - two dairy (Bay of Plenty, Taranaki), and two sheep and beef (Northland, East Coast).

- The development of Farmax files for each focus farm to allow for farm system modelling, and OverseerFM® files to (a) establish the base GHG emission profile; and (b) model the impact of change scenarios.

- Data collated to allow for national benchmarking of the emission profiles.

- Meetings were held with the Trustees of the four focus farms and agreement gained regarding (a) participation in the project; and (b) discussion on scenarios for modelling. Two such meetings were held - to determine the initial scenarios for modelling, then a second meeting to (a) report back on the initial modelling; and (b) determine any further scenarios for modelling.

- Discussions were held with DairyNZ and Beef+Lamb NZ as to the results and means of extending these. Two public field days were held on each of the focus farms - one at the end of the second year following finalisation of the modelling results, and at the end of the third year, supported by DairyNZ and Beef+Lamb NZ, to show the results of better integration of the modelling results using a spatial modelling tool (MyLand) developed during the project.

- The field days were also used to discuss the reaction of the farmers to the scenarios modelled; which ones they would prefer versus ones they did not.

- Three papers have been written based on the project and submitted to international journals.

4.0 SUMMARY OF MĀORI TYPOLOGIES

The selection of the 29 farm entities as a group that was representative of the Māori pastoral sector was established using a typology methodology, which in this context is a classification system for grouping items according to their similarities.

4.1 Approaches to Farm Typologies in New Zealand

In the context of this report, a *typology* is a system for putting things into groups according to their similarities. A typology of Māori farms is simply a classification scheme for grouping Māori farms, with each group labelled a 'type'. At a very broad level, Māori farms are a *type* of farm within a *typology* of New Zealand farms classified according to their ownership. A typology can be hierarchical, allowing types to be amalgamated or disaggregated, but the individual types are non-overlapping.

Such a broad classification is of limited use, although further division is possible based on data collected, such as farm size and production. The main purpose of the Māori farm typology developed by this project is to describe the structure and diversity of the Māori farm resource and to ensure that this diversity is represented by a representative of sample farms selected for further analysis.

There are a number of approaches to classifying New Zealand farms including MPI pastoral farm monitoring reports based on regional dairy, deer and sheep-beef model farms. The ARGOS study on the sustainability of farm management practices classifies sheep-beef farms into one of three production systems: conventional, integrated and organic, and two production systems for dairy farms: conventional and organic, along with attitudinal categories based on off-farm income and the impact of exogenous factors on their farm business. Beef + Lamb NZ classes capture regional variability of farm systems across the country while the DairyNZ classes capture it indirectly through implications for stock feed.

4.2 Māori Land and Māori Ownership Typologies

Defining Māori farmers is often done using one of two approaches (or a combination of both): (i) the ethnicity of the owner of the farm; and/or (ii) the tenure status of the land. A definition of Māori farming and Māori farmers is often made in reference to Māori farming that occurs on Māori land. Māori land refers to land that comes under its own legislation – Te Ture Whenua Māori (Māori Land Act) 1993, and under this piece of legislation there are a number of organisational structures[3]. Given the range of ownership structures within the Māori sector a 'working definition' of Māori farming and Māori farmers include entities that fall into one of the following ownership structure categories under the TTWMA[4]:

1. Ahu Whenua Trust - designed to manage blocks of multiple owned Māori land and are the most common structure used by Māori landowners.

2. Māori Incorporation - a body corporate with perpetual succession and with powers which, in form and basic structure, are similar to the joint stock company.

3. Whenua Topu Trusts – these trusts are similar to the Ahu Whenua Trust in that its structure is designed to manage the entirety or major proportion of a tribal estate. It differs in one aspect however, in that the individual's land owning interests are not maintained.

[3] As of September 2014, the TTWMA 1993 has been under review. The TTWMA 2015 Bill is planned to be presented to the Māori Development Select Committee in October 2015.
[4] Te Ture Whenua Māori Act, 1993

4. Whanau Trusts – trusts used by whanau to halt the fragmentation of share interests. The Whanau Trust holds the interests in the land, and additional members are added to the list of owners without receiving individual interests.

Ahu whenua trusts and Māori incorporations are the most common structures used to facilitate decision making over Māori land. While they are considered the most commercially orientated of the structures under Te Ture Whenua Māori Act, they nevertheless have a number of inherent weaknesses when compared to non-Māori structures. In 2008 there were 129 Māori incorporations and 5,201 Ahu Whenua Trusts which together administered around two-thirds of Māori land. Another common structure under the legislation is the Whanau Trust.

4.3 Post-Settlement Governance Entities (PSGEs)

The Post-Settlement Governance Entity (or PSGE) has emerged in recent years through the ongoing Treaty Settlement process. These new iwi-hapu entities have a wider mandate from their tribal constituents and many are now involved in managing large farms returned under settlement (including Landcorp farms).

4.4 Categorising Māori farmers according to scale, diversity and ownership

Māori farming activity within each of these ownership categories vary significantly. The following framework proposes four categories based on farming activity, scale and organisational complexity.

Category 1 Multiple farms, multiple enterprise, multiple structures (TTWMA plus limited liability company/companies).

Category 2 Multiple farms, multiple enterprise, single governance structure.

Category 3 Single farm, multiple enterprise, single governance structure.

Category 4 Single farm, single enterprise.

A more simplified and effective categorisation of Māori farming that is often used is based on a combination of the ethnicity of the owners in combination with the legal status of the land. For the purposes of developing a network of Māori farmers these criteria provide a useful guideline that acknowledges the diversity of tenure and governance structures. Māori farmers include:

(a) Entities that own or manage pastoral land that is defined as Māori land under Te Ture Whenua Māori Act 1993 (e.g. Māori Incorporations and Trusts).

(b) Organisations that administer land defined as General Land where these organisations are owned by Māori (e.g. PSGEs).

(c) Individual Māori that own or manage pastoral land.

4.5 Māori Farming Typology Framework

Applying an amalgam comprising of Whatmore's[5] three approaches along national farming systems and farm classifications, and the Māori land tenure and institutional structures framework that has

[5] Whatmore, S, Munton, R, Little, J, Marsden, T. (2008). Towards a Typology of Farm Business in Contemporary British Agriculture. Sociologia Ruralis. 27. 21 - 37. 10.1111/j.1467-9523.1987.tb00315.x.

historically been used to classify Māori land and Māori land utilisation (outlined above), a Māori farm typology framework was developed. This is outlined below:

The Māori farms selected need to fall into the following categories and sub categories:

1. Regional Spread
   The Māori Land Court regions are commonly used as the reference for the distribution of entities: Taitokerau (Auckland/Northland), Waikato (Waikato region), Waiariki (Bay of Plenty, Rotorua and Taupo), Tairawhiti (East Coast, Gisborne), Aotea Whanganui (Taranaki, Whanganui), Takitimu (Hastings, Wairarapa), Te Wai Pounamu (South Island). Each of these regions needed to be represented in the selection.

2. Farm Type
   The two main farm systems are dairy, and sheep and beef. Enterprise diversity was also important with farms that have forestry and indigenous forestry also selected.

3. Scale
   Entities need to be representative across a range of farm sizes.

4. Structure
   There were three main structures that needed to be represented: Ahu whenua trusts, incorporations and whanau trusts. Others that were sought included post settlement entities.

5. Organisational complexity
   Given the diversity of Māori entities that own farms it is important that small simple structures be represented along with entities that have multiple farms and enterprises.

5.0 TYPOLOGY MATRIX

There are three categories of organisational entities that Māori farmers fall into:

5.1 Ownership Structure

(a) **Te Ture Whenua Māori Act (TTWMA) 1993 entities**

   (i) Ahu Whenua Trust

   (ii) Māori Incorporation

   (iii) Whenua Topu Trusts

   (iv) Whanau Trusts

(b) **Post Settlement Governance Entities (PSGEs)**

(c) **Individual Māori**

5.2 Scale and Enterprise Diversity

Category 1 Multiple farms, multiple enterprise, multiple structures (TTWMA plus limited liability company/companies).

Category 2 Multiple farms, multiple enterprise, single governance structure.

Category 3 Single farm, multiple enterprise, single governance structure.

Category 4 Single farm, single enterprise.

There are no Whenua Topu trusts in the network given the low number of these structures in existence nationally. However, there are two structures that don't come under the TTWMA but are the partnership and company, and are listed in the matrix below.

Table 1: Typology Matrix

Category		Te Ture Whenua Māori Act (TTWMA) 1993 & Other Structures			
	Ahu Whenua Trust	Incorporation	Whanau	Other	TOTAL
1. Multiple farms, multiple enterprise, multiple structures	4	2		1	7
2. Multiple farms, multiple enterprises, single structure	2	5			7
3. Single farm, multiple enterprise, single structure	8	2			10
4. Single farm, single enterprise	2		2	1	5
TOTAL	**16**	**9**	**2**	**2**	**29**

6.0 SUMMARY OF THE PROFILE FARMS

The network consists of:

FARM TYPES:

Sheep and beef farms	18
Dairy	11

SCALE:

The largest farms are sheep and beef ranging from 7,200 hectares for Aohanga Inc., down to 531 hectares for Pouto Topu. Dairy farms ranged in size from 300 hectares down to 77 hectares. The average size of the sheep and beef farms was 2,337 hectares and dairy 202 hectares.

STRUCTURES:

There are two main structures used in the Māori pastoral sector - Trusts and Incorporations. The network has 17 trusts, nine incorporations, two whanau trusts and one partnership (made up of Ahu Whenua Trusts).

REGIONAL COVERAGE:

Selecting a network of organisations that were representative of all of the main regions was a challenge. There are two additional organisations that discussions were held with to join the network including a dairy farm from the South Island and a dairy farm from Taranaki. These two entities are large multi-farm organisations – one an incorporation, the other a post settlement entity.

Hawke's Bay	1
Manawatu	1
Tairawhiti	6
Taitokerau	8
Taranaki	1
Waiariki	3
Takitimu/Wairarapa	1
Waikato	4

A summary of the entities is given below:

Table 2: Profile Farms by Governance Structure

ENTITY	FARM	STRUCTURE	REGION	TYPE	EFFECTIVE	TOTAL
Sheep and Beef						
Aohanga Inc	Owahanga	Incorporation	Wairarapa	S&B	2200	7211
Te Whakaari Inc	Paparatu	Incorporation	Tairawhiti	S&B	3709	5570
Marotiri Partnership	Marotiri	Partnership	Tairawhiti	S&B	1941	3999
Parengarenga Inc	Paua Farm	Incorporation	Taitokerau	S&B	2430	2754
Otakanini Topu Trust	Otakanini	Trust	Taitokerau	S&B	1530	2750
Parengarenga Inc	Te Rangi	Incorporation	Taitokerau	S&B	2100	2513
Nuhiti Inc	Nuhiti Station	Incorporation	Tairawhiti	S&B	900	1299
Te Uranga B2	Upoko	Incorporation	Waikato	S&B	1153	2129
Onuku Māori Lands Trust	Onuku S&B	Trust	Waiariki	S&B	908	1686
Hauiti Trust	Iwinui Station	Trust	Tairawhiti	S&B	1137	1254
Kapenga M Trust	Kapenga Station	Incorporation	Waiariki	S&B	905	1271
Maraetaha Inc	Patemaru	Incorporation	Tairawhiti	S&B	947	1158
Taheke 8C	Taheke	Trust	Waiariki	S&B		952
Rangihamama Trust	Omapere	Trust	Taitokerau	S&B	773	1079
Oparau Trust	Oparau Station	Trust	Waikato	S&B	515	830
Pouto Topu A Trust	Pouto Topu A	Trust	Taitokerau	S&B		531
Hereheretau	Hereheretau	Trust	Wairoa	S&B	1740	2143
Oromohoe Trust	Oromohoe	Trust	Taitokerau	S&B	1079	765
Dairy						
Te Rua O Te Moko	Te Rua O Te Moko	Trust	Taranaki	Dairy	170	
Parekarangi Trust	Parekarangi Dairy	Trust	Waiariki	Dairy	352	427
Pouto Topu A Trust	Pouto Topu D3	Trust	Taitokerau	Dairy	250	301
Rangihamama Trust	Rangihamama Farm	Trust	Taitokerau	Dairy	170	280
Pouto Topu A Trust	Pouto Topu D1	Trust	Taitokerau	Dairy	247	272
Haerepo Trust	Haerpo	Trust	Waikato	Dairy		293
Te Aute Trust	Ngawapurua	Trust	Hawke's Bay	Dairy	223	228
Pukehina M3 Trust	Pukehina	Trust	Waiariki	Dairy		152
Te Uranga B2	Paatara	Incorporation	Waikato	Dairy	120	133
Ngatitu Whanau Trust	Ngatitu	WTrust	Taranaki	Dairy	80	83
Te Hore Farm Trust	Te Hore	WTrust	Manawatu	Dairy	72	77

7.0 GHG AND LEACHING PROFILES FOR THE PROFILE FARMS

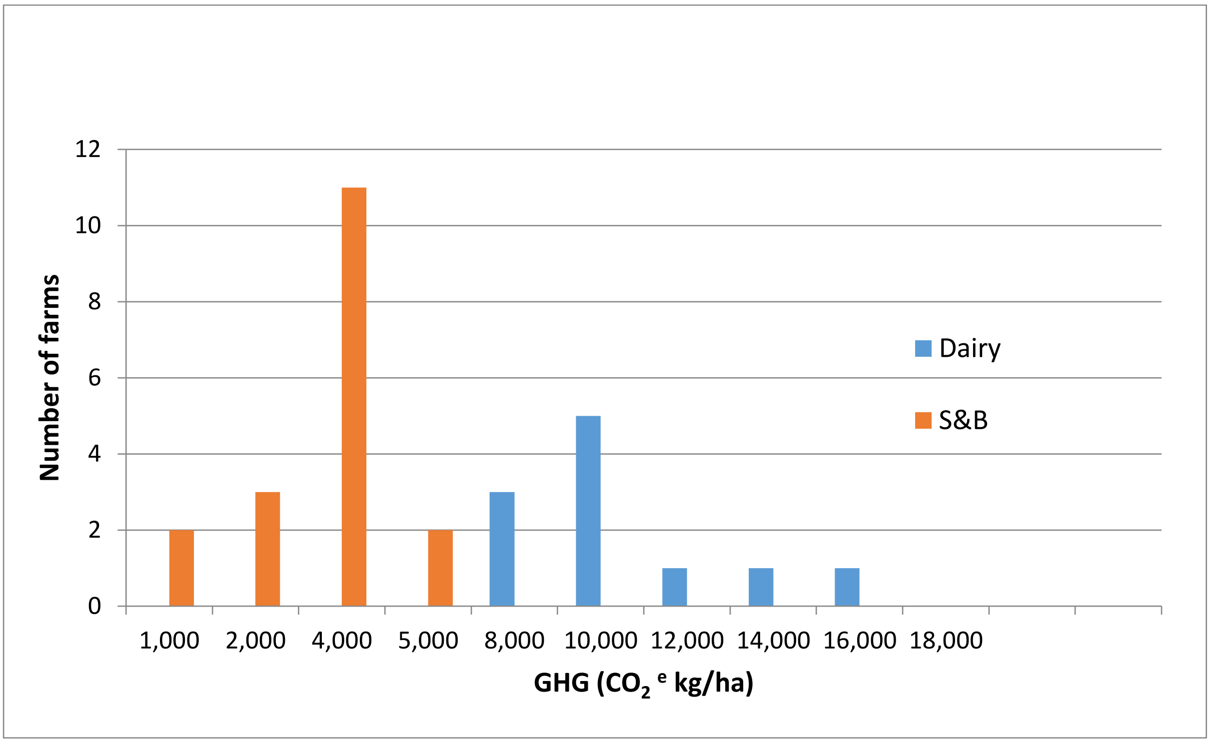
The results of the Overseer (Version 6.2) modelling of GHG and N and P emissions for the 11 dairy farms and 18 drystock farms (S&B) are shown in the table below. These results are for the whole property and show considerable variability. They must be compared in the context of the land uses for the whole property and will be influenced by the area of bush or plantations that make up the farm total. The 29 properties provide a sample of farms to form a benchmark of emissions and gives context to the four focus farms highlighted in green.

Table 3: GHG and N &P emissions for whole property modelling with Overseer V6.2

Farm Type	Region	Farm	Methane kg/ha CO_2 e	N_2O kg/ha CO_2 e	CO_2 kg/ha CO_2 e	Total Biological kg/ha CO_2 e	N kg/ha	P kg/ha
Dairy	BOP	Pukehina M3 Trust	7,330	2,366	911	9,696	29	3.4
Dairy	BOP	Parekarangi Dairy	5,461	2,838	1,548	8,299	50	2.4
Dairy	Northland	Pouto Topu A Trust - D1	5,341	1,844	952	7,185	27	2.9
Dairy	Northland	Pouto Topu Trust - D3	5,486	1,675	794	7,161	23	4.0
Dairy	Northland	Rangihamama	7,025	2,295	1,678	9,320	32	0.6
Dairy	Sth HB	Te Hore Farm Trust	6,101	1,738	673	7,839	22	0.5
Dairy	Taranaki	Ngatitu WT2008	9,240	5,613	1,772	14,853	65	2.0
Dairy	Taranaki	Te Rua O Te Moko	6,831	2,758	1,744	9,589	26	0.5
Dairy	Waikato	Haerepo Trust	7,123	2,001	1,325	9,124	46	1.2
Dairy	Waikato	NB Paatara	6,818	2,903	1,338	9,721	54	1.2
Dairy	Wairarapa	Aute Te Case	5,888	5,451	1,575	11,339	37	0.6
		Average	6,604	3,067	1,301	9,466	37	1.8
		Std Deviation	1,172	1,385	414	2,074	15.1	1.3
S&B	BOP	Kapenga Drystock	2,705	767	286	3,472	19	1.8
S&B	BOP	Onuku Sheep/Beef	3,627	992	172	4,619	17	1.6
S&B	BOP	Taheke 8C	729	142	42	871	5	0.9
S&B	East Cape	Iwinui Station	2,650	806	89	3,456	18	1.4
S&B	East Cape	Marotiri Farm Partnership	1,269	723	26	1,992	7	0.8
S&B	East Cape	Paparatu Station	1,475	847	47	2,322	8	0.8
S&B	East Cape	Patemaru Station	2,392	1,037	80	3,429	11	2.2
S&B	East Cape	Nuhiti Station	1,499	778	19	2,277	7	0.6
S&B	East Cape	Hereheretau	2,420	2,554	76	4,974	15	1.7
S&B	Northland	Otakanini	3,080	819	241	3,899	12	1.5
S&B	Northland	Paua Station	2,553	625	149	3,178	6	6.1
S&B	Northland	Pouto Topu A Trust - S&B	3,430	714	39	4,144	19	0.5
S&B	Northland	Te Rangi	3,061	732	87	3,793	4	2.3
S&B	Northland	Omapere	2,731	866	376	3,597	7	5.0
S&B	Northland	Oromahoe Trust	1,962	587	150	2,549	7	1.5
S&B	Waikato	Oparau Station	2,813	1,053	69	3,866	9	0.4
S&B	Waikato	TB2 Upoko	2,697	850	127	3,547	14	1.4
S&B	Wairarapa	Owahanga Station	843	337	17	1,180	5	0.5
		Average	2,330	846	116	3,176	11	1.7
		Std Deviation	850	482	99	1180	5.2	1.5

Figure 1 gives the distribution and range of GHG emissions and compares dairy with sheep and beef. As reported from other research, dairy emissions are higher than sheep and beef, and are related to the number of cows, use of N fertilisers, use of supplementary feed, effluent management, and soil type.

Figure 1: GHG emissions by farm type



7.1 Discussion

As can be seen from Table 3, the average total biological CO_2 equivalent emissions from the dairy farms was 9.6 tonne/ha, with a standard deviation of 2.4 T/ha. The range varied from 7.2 T/ha through to 14.8 T/ha. The 14.8 T/ha farm is based in Taranaki, and is run relatively intensely: 3.5 cows/ha, 1,315 kgMS/ha, total nitrogen input (via fertiliser, clover, and supplements) of 359 kg/ha, and total supplements imported onto the farm of 0.62 tonneDM/cow.

For the sheep and beef farms, average total biological CO_2 equivalents is 3.2 tonne/ha, with a standard deviation of 1.2 T/ha. The range was 0.9 T/ha through to 5.0 T/ha. This latter figure was due to significant cattle numbers being run on the property.

The correlation between CO_2 equivalents emitted and nitrogen leach was also calculated, as shown in Table 4:

Table 4: Relationship between biological CO_2 emitted and N leached

	Total CO_2 vs N leached		N_2O vs N leached	
	Correlation	R^2	Correlation	R^2
Total Sample	88%	0.77	78%	0.62
Dairy farms	58%	0.83	47%	0.30
S&B farms	63%	0.40	38%	0.14

These figures are lower than those indicated by Smeaton[6] et al (2011), who showed R^2 values of 0.90 for total CO_2 vs N leached. It is important to note though that:

(i) The Smeaton et al data was from modelled scenarios within a single farm; and

(ii) The sample (as per Table 2) is relatively small.

7.2 Emission Intensity

The intensity of CO_2 equivalent emissions was also calculated. For the dairy farms this was across milksolids production, whereas for the sheep and beef farms the calculation was somewhat cruder, in that the only information available was total stock units, and 'kg liveweight sold/ha grazed' from Overseer. How this latter factor calculated within Overseer is unknown, and its reliability is suspect – the figures calculated bear no relationship to actual intensities (ref Table 10).

The results are shown in Tables 5 and 6.

Table 5: Intensity of emission from the dairy farms

Farm	Farm Type	Hectares	Total Biological kg/ha CO_2 e	Production (kg MS)	Intensity: kg CO_2/kg MS
Pukehina M3 Trust	Dairy	153	9,672	135,052	9.6
Parekarangi Dairy	Dairy	427	8,299	282,354	12.6
Pouto Topu A Trust - D1	Dairy	180	7,185	102,605	12.6
Pouto Topu Trust - D3	Dairy	250	7,161	146,169	12.2
Rangihamama	Dairy	171	9,320	180,000	8.9
Te Hore Farm Trust	Dairy	72	7,839	68,690	8.2
Ngatitu WT2008	Dairy	74	14,853	103,293	10.6
Te Rua O Te Moko	Dairy	186	9,007	185,871	7.7
Haerepo Trust	Dairy	290	9,124	350,000	7.6
NB Paatara	Dairy	133	9,721	112,022	11.5
Aute Te Case	Dairy	209	11,339	160,883	14.7
Average			9,671	166,085	11.1
Std Deviation			2,407	79,599	2.3

It is interesting to note that the farm with the highest absolute emissions (Ngatitu) has a relatively modest level of intensity of emission, which is below the average.

[6] Smeaton, D.C., Cox, T., Kerr, S., Dynes, R. 2011. *Relationship between farm productivity, profitability, N leaching and GHG emissions: a modelling approach*. Proc NZ Grasslands Association, 73 57-62.

Table 6: Intensity of emission from the S&B farms

Farm	Effective Hectares	Total Biological kg/ha CO_2 e	Total SU	Kg liveweight sold/ha	Intensity: kg CO_2/SU	Intensity: kg CO_2/kg LW sold
Kapenga Drystock	1,232	3,472	11,467	315	404	11.0
Onuku Sheep/Beef	855	4,619	11,347	702	361	6.6
Taheke 8C	952	871	2,386	244	364	3.6
Iwinui Station	1,254	3,456	11,361	214	391	16.1
Marotiri Farm Partnership	1,941	1,992	17,245	263	225	7.6
Paparatu Station	5,570	2,322	28,462	98	464	23.7
Patemaru Station	1,158	3,429	9,565	129	425	26.6
Nuhiti Station	1,770	2,277	9,057	244	449	9.3
Hereheretau	2,586	4,974	21,167	134	617	37.1
Otakanini	1,530	3,899	16,473	310	385	12.6
Paua Station	2,600	3,178	21,514	147	402	21.6
Pouto Topu A Trust - S&B	521	4,144	5,727	256	381	16.2
Te Rangi	2,100	3,793	21,000	149	388	25.5
Omapere	773	3,597	7,113	295	432	12.2
Oromahoe Trust	1,042	2,549	6,551	533	382	4.8
Oparau Station	515	3,866	5,801	530	349	7.3
TB2 Upoko	1,575	3,547	15,553	533	372	6.7
Owahanga Station	7,211	1,180	20,688	265	417	4.5
Average		3,176	13,471	298	406	14.0
Std Deviation		1,106	6,923	164	74	9.1

7.3 Emission by Governance Structure (Typology)

The total average CO_2 equivalent emissions by governance structure is shown in Table 7:

Table 7: CO2 Emission by Governance Structure

		Sample	Av Total Biological CO_2 equiv. Emission (kg/eff ha)
Dairy	Trust	8	9,246
	Incorporation	1	9,721
	Whanau Trust	2	11,346
Sheep & Beef	Trust	9	3,553
	Incorporation	8	2,900
	Partnership	1	1,992

Note: These results are derived via OVERSEER, and hence do not include carbon sequestration via trees.

It is difficult to be too definitive on the differences between the total biological CO_2 equivalent emissions between the different entities due to the small sample size for several of the entities. For sheep and beef farms, with a similar sample size for both Trusts and Incorporations, the total emissions from Incorporations is approximately 20% less than those from the Trusts. The main reason behind this is that a number of the Incorporation farms are being run less intensely relative to the Trust farms.

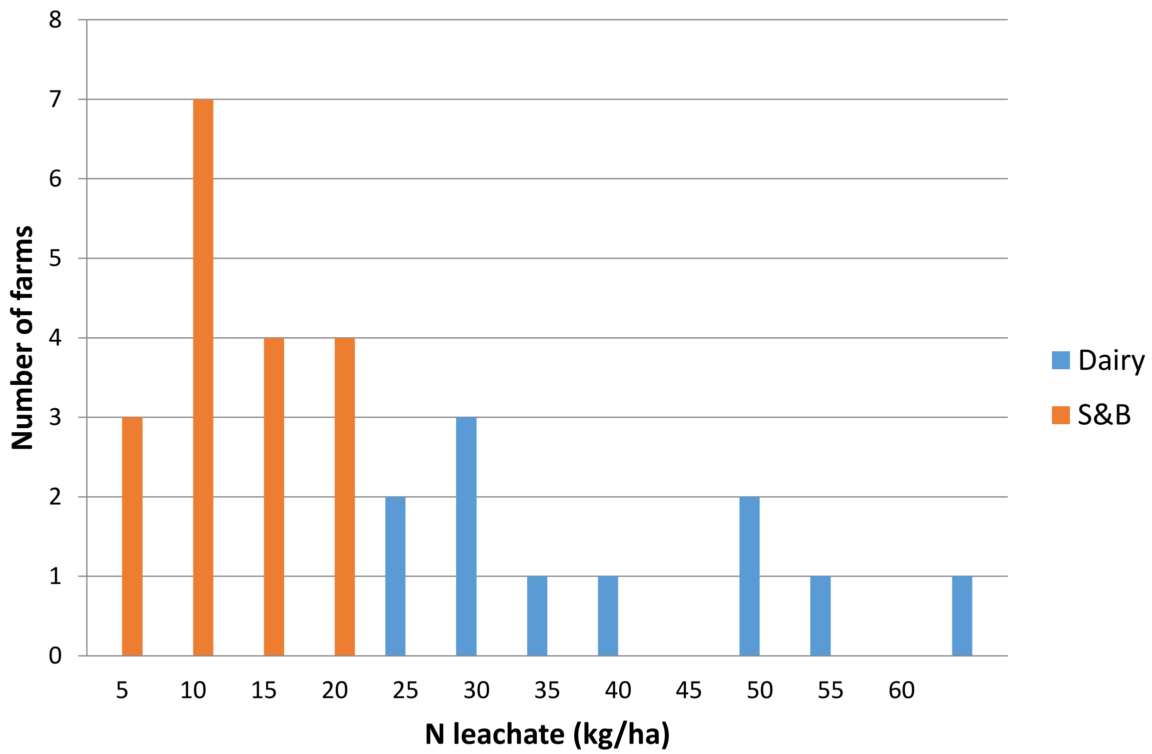
Those Iwi groups with multiple enterprises (e.g. several farms) are likely to have governance with a higher level of skills, and use consultants. In addition, most dairy farms would (a) use consultants; and (b) be much more likely to be pushing the farming system harder compared with sheep and beef farms.

7.4 Nutrient Discharge

As the Overseer modelling system also gives nitrate (N) and phosphate (P) emissions (to ground water) these results have also been reported to give a complete assessment of environmental impact.

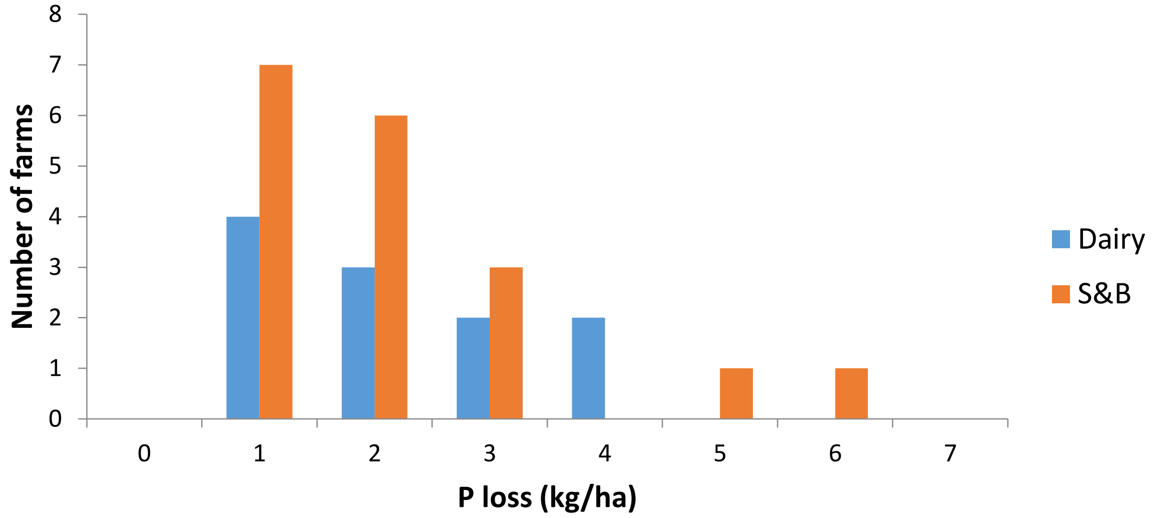
Figure 2 gives the distribution and range of N emissions and compares dairy with sheep and beef. Dairy are significantly higher than sheep and beef, and are related to similar factors that affect GHG (i.e. the number of cows, use of N fertilisers, supplementary feed, effluent management, and soil type).

Figure 2: N leachate by farm type



Although phosphate loss is not a major problem in most regions it can influence water quality in lakes and streams. Phosphate loss is given by farm type in Figure 3.

Figure 3: Phosphate loss by farm type



To give context to these emissions a national benchmark was sought. The best available is the National Monitor farms assembled in 2011/12 run through Overseer and averaged for each region.

The National Monitor farms were originally run in Overseer 5.11. Thirty-six dairy monitor farms from the Waikato/BOP region were rerun in Overseer 6.2. The average difference between versions was found to be +3.1% in total GHG. This was used to adjust all the averages for the regions in the National Monitor farm data to make them comparable to the Māori farms run in Overseer 6.2, as shown below.

Figure 4: Comparison of regional averages for Dairy farm GHG emissions

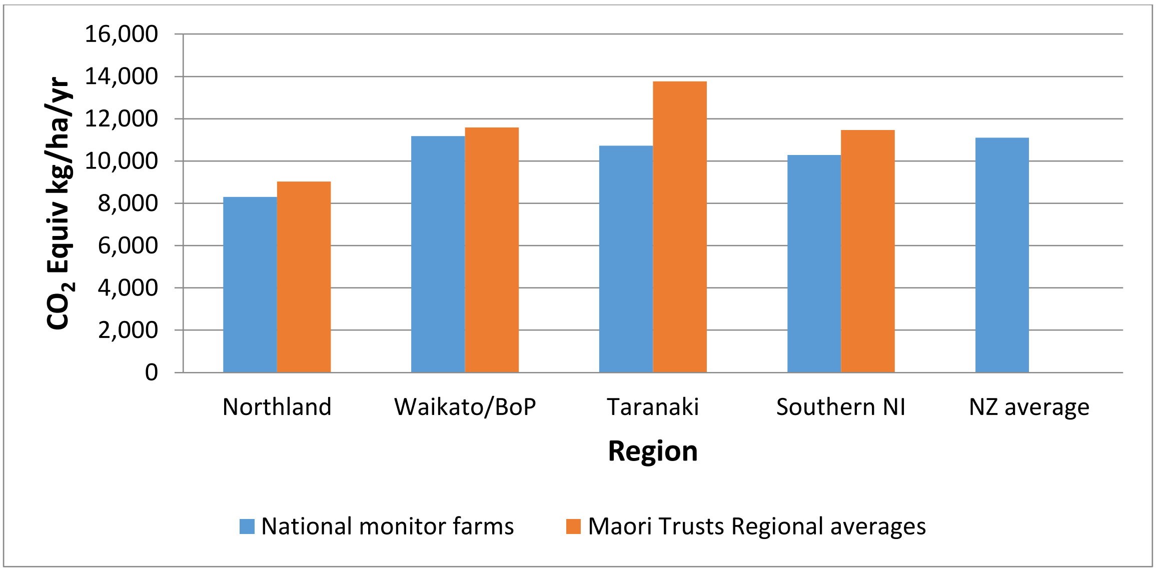
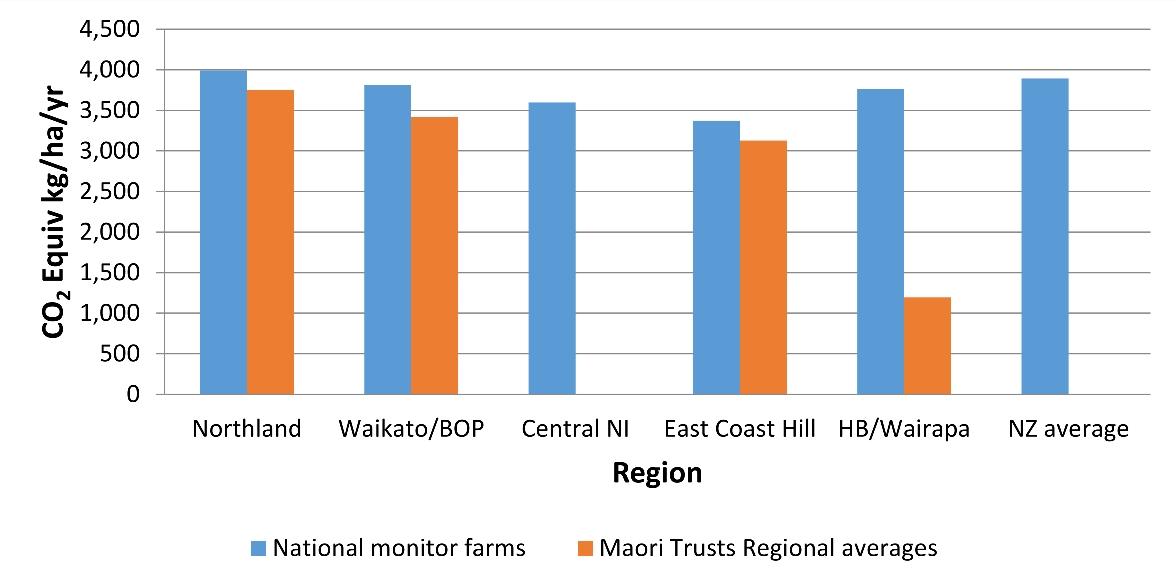


Figure 5 gives results that compare the Māori sheep and beef farms in this project with the regional estimates from the National Monitor farms.

Figure 5: Comparison of Māori S&B farms GHG with National Monitor farms



From this it appears that the Māori dairy farms are reasonably on a par with the benchmark, albeit slightly higher, and with the Taranaki comparison clouded by the fact there are only two farms, one of which is run quite intensively.

For the sheep and beef farms, the Māori profile farms are below the benchmark, mostly because they are run less intensively. The Hawke's Bay/Wairarapa comparison is not valid as there is only one Māori profile farm involved.

8.0 CRITERIA FOR SELECTION OF THE FOCUS FARMS

The criteria used to select the focus farms were:

(i) A geographic spread: The intent was to ensure a reasonable spread of farms around the country, and on differing soil types. With the bulk of the farms located in the North Island, the focus farms were distributed as widely as possible within the North Island (refer map below).

(ii) A mix of dairy and sheep and beef: Given there were four focus farms, the intent was that two would be dairying, and two sheep and beef.

(iii) Size: Ideally there would be a range of farm size, albeit restricted given two farms of each type.

(iv) Intensity of farming: Again ideally a range of farming intensity to be represented by the focus farms.

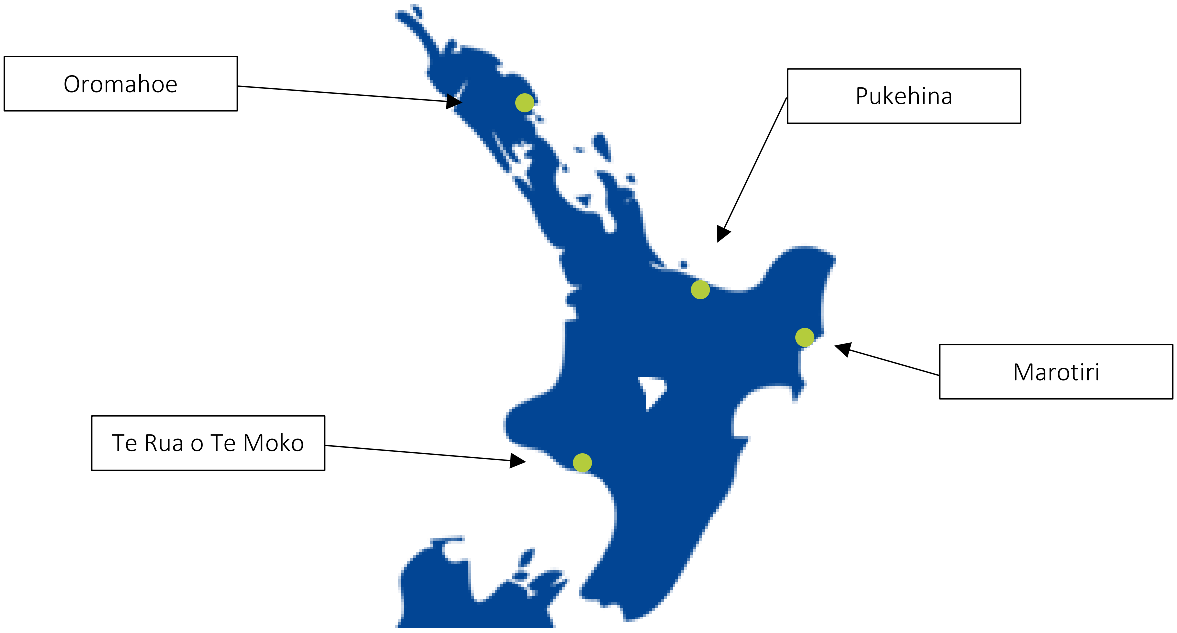
(v) Climate: This is linked to the geographic spread, but the intent was to look for farms in differing climate zones.

(vi) Able to benchmark current GHG emissions.

(vii) Farm governance and management are agreeable to be a focus farm and to allow scrutiny via the discussion groups and the wider public.

(viii) The farm needed to have a consultant working with it, who was capable of using Farmax and Overseer.

Figure 6: Location of Focus Farms



9.0 SUMMARY DESCRIPTION OF THE FOUR FOCUS FARMS

Marotiri

Marotiri is a 3,999 hectare sheep and beef farm near Gisborne. The farm is made up of three main blocks - the proprietors of Mangahauini 7 and other adjoining blocks, the proprietors of Tokomaru K5B, and Pararaki Trust. Of the 3,999 hectare property, 1,941 hectares is effective, with large areas of the property in scrub, and 150 hectares in pines. The majority of the property is on very steep hill country with 152 hectares of flat land used as a finishing block. The soils on the property are sedimentary, with sandy clay loams predominantly on the hills and silt loams on the finishing flats. Sheep (7,229 RSU) are grazed on the property. These consist of breeding ewes, replacements, breeding rams, hogget's and lambs. The farm supports 10,216 RSU of cattle, consisting of breeding cows, replacements, weaners, bull beef and breeding bulls. No supplements are imported or made on the property.

Oromahoe

Oromahoe is a 1,079 hectare sheep and beef finishing farm in Northland. The effective area is 765 hectares and in addition, the property has 38 hectares in pines, 140 hectares in native bush and 136 hectares as wetlands. The contour of the property is flat to rolling with some easy hill country. The predominant soil orders are Podzols, Brown, Allophanic and Ultic. In total 2,163 revised stock units (RSU*) of Texel sheep are present on farm, including breeding ewes, replacements, breeding rams and prime lambs for slaughter. In addition, 4,388 RSU of beef animals are run on the property. These are mainly Friesian bulls for finishing, although there are some Friesian steers and Friesian weaned bull calves.

*An RSU is defined as 6000 MJ ME intake which is the new standard stock unit.

Pukehina

The Pukehina dairy farm is located near Pukehina in the Bay of Plenty, southeast of Tauranga. It has multiple Māori owners, and is administered by Te Tumu Paeroa. The property has a flat to rolling contour, mainly on Peat and Pumice soils. At peak, 450 Friesian x Jersey cows are milked over 153 hectares producing 135,052 kgMS. This equates to 883 kgMS/ha and 300.1 kgMS/cow. Dairy replacements are brought onto the property in May, two months before they are due to calve. 100 tonne (DM) of pasture silage and hay (15 T) is purchased in, with additional hay and pasture silage made on the property. Maize and turnips are grown and fed out over March and February and 33 T of palm kernel extract (PKE) is brought and fed to the milking herd.

Te Rua o Te Moko

The Te Rua o Te Moko dairy farm is located in Taranaki, north of Hawera. It encompasses four blocks of land that were owned by four Ahu whenua trusts that have formed a farming company, plus also encompasses a treaty settlement block, is administered by Te Tumu Paeroa, and was awarded the Ahu Whenua Māori Farmer of the Year in 2014. The property has an effective area of 170 hectares, with a further 16 hectares fenced off in trees and scrub. The property has a flat contour with Allophanic soils. At peak, 506 Friesian x Jersey cows are milked, producing 185,871 kgMS/year. This equates to 1,093 kgMS/ha and 367.3 kgMS/cow. Turnips, maize and fodder beet are grown on the property and 100 T of silage is made on the property. PKE (220 T) is imported to be fed to the milking herd. No replacements are grazed on farm.

9.1 Comparison of Focus Farms with regional averages

The following tables show the focus farm statistics relative to regional averages.

Table 8: Dairy focus farm comparisons

	Effective area (ha)	Cows Wintered	Stocking rate (Cows/ha)	Total Production (kgMS)	Production/ha (kgMS)
Pukehina	153	450	2.9	136,872	895
BoP average	119	336	2.85	121,947	1,028
Te Rua o Te Moko	170	506	3.0	188,005	1,106
Taranaki average	102	291	2.85	114,965	1,124

Statistics from Dairy Statistics 2014-15.

Table 9: Sheep and Beef focus farm comparisons

	Effective area (ha)	Total Stock Units	Stocking rate (SU/ha)	Sheep:Cattle ratio	Lambing %	Total Production (kg/ha)
Marotiri	1,941	17,445	9.0	41:59	121	135
East Coast Average	**549**	**4,775**	**8.7**	**64:36**	**125**	**194**
Oromahoe	765	6,551	8.6	33:67	140	214
Northland Average	**345**	**3,385**	**9.8**	**46:52**	**126**	**212**

Statistics from Beef + Lamb NZ.

Note: The 'East Coast Average' covers Gisborne + Hawke's Bay + Wairarapa, while the 'Northland Average' covers Northland + Auckland + Waikato. This makes comparisons with the focus farms somewhat problematic.

10.0 GHG AND LEACHING PROFILES FOR THE FOCUS FARMS

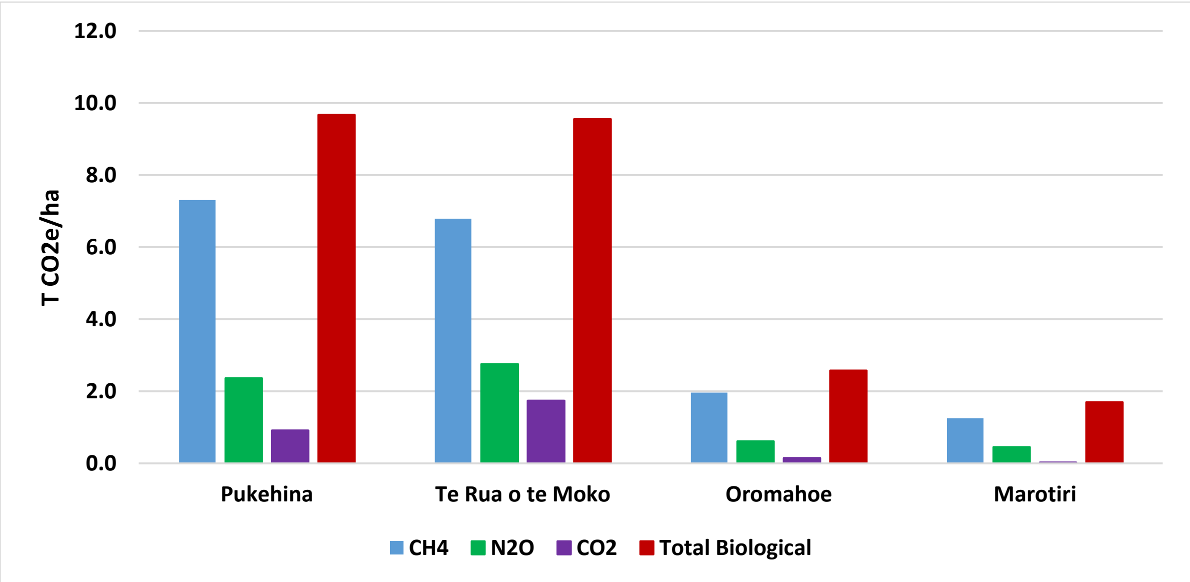
The following Tables and Figures show the base GHG emissions and nutrient losses for the four focus farms.

Table 10: Focus Farm GHG emissions (Tonnes CO_2 equiv.) and Nutrient Losses (kg/ha)

	Methane	N_2O	CO_2	Total Biological		Nitrogen	Phosphorous
Te Rua o Te Moko	6.8	2.4	1.7	9.2		26	0.5
Pukehina	7.3	5.0	0.9	12.5		29	3.4
Marotiri	1.3	0.7	0.0	2.0		7	0.8
Oromahoe	2.0	0.5	0.1	2.7		7	1.5

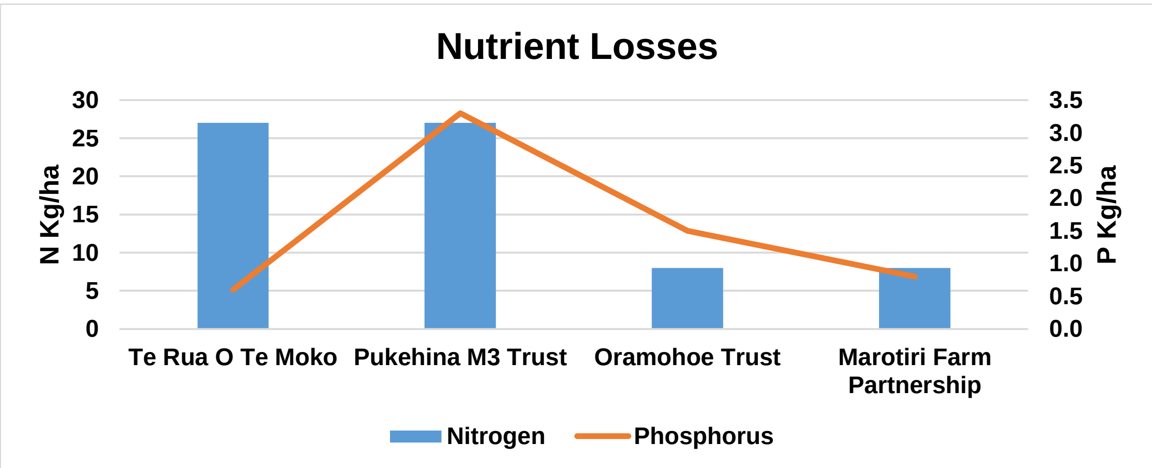
This is shown in graphical form, below.

Figure 7: GHG Emissions (Tonnes CO2 equivalent/ha)



Note: Te Rua o Te Moko, Pukehina = dairy farms, Oromahoe, Marotiri = sheep and beef farms

Figure 8: Nutrient losses (kg/ha)



10.1 Governance Structure

The governance structure of the Focus Farms is shown in Table 9.

Table 11: Governance Structure of Focus Farms

Farm	Type	Governance Structure
Pukehina M3	Dairy	Trust
Te Rua O Te Moko	Dairy	Trust
Marotiri Farm	S&B	Partnership
Oromahoe	S&B	Trust

While it was desirable to get a mix of governance structure amongst the focus farms, in the event other selection criteria took precedence.

10.2 Comment

(i) The emissions from the four focus farms are within expectation, being around or below the group average.

(ii) Nutrient losses are well within expectation, with the exception of the phosphorous loss from Pukehina, which is slightly high. This loss is consistent over the whole farm, from both soil types - peat, and pumice.

(iii) The above factors are directly related to the initial modelling scenarios (discussed below), where each farm is looking at factors that would help mitigate losses relative to the issues they face.

(iv) While the farmers were interested in GHG emission levels, they are not regarded as significant issues at this point in time. Currently, nutrient discharge levels are of far more interest to the dairy farms given the expectation of nutrient discharge limits.

(v) There are a number of Māori cultural and economic factors which create tensions around GHG mitigations. These include:

- Matauranga Māori framework. From a Māori perspective, the management of land (and water) is a blend of cultural norms and modern practices. This includes balancing the productive aspect of land management with an environmental stewardship ethic.

- Māori land is owned by multiple owners, with often many shareholders per title. This ownership, usually based on a genealogical connection to the land, means that Māori land cannot, or won't ever, be sold. While this can present a variety of challenges, it does mean that Māori often take a very long-term view of issues, which can assist with GHG emissions around forestry development.

- The politics of Māori land in New Zealand, coupled with recent Treaty settlements, has often resulted in a combination of an under-utilisation of that land, and/or a strong desire to improve the productivity/profitability from that land.

Overall therefore, there are some inherent tensions around potential GHG mitigations, and the intense pressure governance bodies are under to improve financial returns. Within the focus farms, the latter is certainly a dominant factor.

The intensity of emissions (based on actual production levels) are:

Table 12: Focus farm emission intensity

Farm	Hectares	Total Biological kg/ha CO_2 e	Production (kgMS)	Intensity: kg CO_2/kgMS
Pukehina M3 Trust	153	9,672	135,052	10.95
Te Rua O Te Moko	186	9,554	185,871	8.7

Farm	Hectares	Total Biological kg/ha CO_2 e	Production (kg meat & wool sold/ha)	Intensity: kg CO_2/kg Production
Oromahoe Trust	1,042	2,579	156.2	16.5
Marotiri Farm Partnership	3,973	1,699	135.1	12.6

11.0 SCENARIO MODELLING

The simulation models used to analyse the farms are OverseerFM® Nutrient Budgets Model (Overseer) and Farmax. Overseer provides information about the nutrient inputs and outputs (losses) from a farm system and Farmax provides information about the biological feasibility of the farm system. The baseline GHG emissions as determine by Overseer are then reported for each of the case study farms. This is followed by an analysis of the mitigation scenarios proposed and their impact on total GHG emissions, and the financial implications of incorporating the mitigation strategies on the farm system.

On completion of the initial modelling, the results are then adjusted for carbon sequestration (which is not accounted for within Overseer) and the financial returns from forestry, which are not accounted for within Farmax. The Radiata Pine calculator (Scion) was used to calculate the forestry economics, and the whole property GHGs, nitrate, and integrated economics has been analysed in spreadsheets.

The scenarios modelled were determined in discussion with the individual focus farms. These were modelled as separate scenarios. Once completed, they were then discussed with the owners/managers/advisors of the farms, and a second round of scenarios were then determined for further modelling.

12.0 MODELLING TOOLS

12.1 Introduction to FARMAX modelling

Farmax Pro is a computer based farm system and economic simulation model developed to improve the transfer of information about alternative livestock policies to New Zealand sheep and beef farmers. The model indicates the biological feasibility of a livestock system and allows users to evaluate the economics of alternative livestock policies. The model platform was developed in 1991 as the Stockpol model, and has since been refined, updated and tested against scientific data. The model calculates the required feed demand for a modelled livestock system within the restraints of input pasture growth rates and animal performance data.

12.2 Introduction to OverseerFM® modelling

Overseer allows nutrient budgets to be created for a large range of farm systems in New Zealand, from dairy farms to arable cropping and some horticultural operations. Overseer was developed with a set of key ground rules that are necessary to provide comparable results over time. For example, Overseer assumes the farm management system is constant, good management is practiced and the information entered into the model is reasonable and accurate.

One of the key features of Overseer is that it is based largely on information that farmers have or that can be readily obtained. Where this is not the case, suitable defaults are generally available. Overseer requires information about the farm at two scales - the farm scale and management block scale. At the farm scale the type of information required includes location, types of enterprise (stock), structures present (feed-pads etc.) and feed supplements imported. Splitting the farm into management blocks is an essential part of correctly setting up the model. Management blocks within a farm system are defined as the sum of areas of the farm that are managed differently (e.g. irrigated, cropped, effluent applied), have different soil types, topography, fertiliser application rates or soil test values. At the management block scale, the type of information Overseer requires includes topography, climate conditions, soil type, pasture type, supplements used, fertiliser applied, irrigation applied or effluent management system. The nature of the information required will vary depending on the block type, i.e. pastoral block or crop block.

A key development focus for Overseer has been to incorporate a wide range of possible on-farm management practices including many that can be used to enhance nutrient use efficiency and/or mitigate environmental impacts. This ability to model different practices enables decisions to be made for farm management planning purposes.

Overseer is one of the few tools widely used by farmers and their advisors which allow farm-specific GHG emissions to be estimated.

12.3 Carbon sequestration modelling

This was included via Excel spreadsheeting, including forestry and carbon returns as per the Scion Radiata Calculator Pro Version 4.0.

Calculators for Radiata Pine and other species have been developed for the farm forester and are available via the NZFFA web site[7].

This modelling system is driven by the productivity of the site through indices for volume (300 Index) and height growth (Site Index). It allows the forest tending regime to be input and simulated the growth

[7]http://www.nzffa.org.nz/farm-forestry-model/resource-centre/tree-grower-articles/tree-grower-may-2005/version-2-calculators-upgrading-the-business-of-farm-forestry/

of 1 hectare of plantation forest to harvest. It then estimates harvested volume by log grade and combined costs and prices to run discounted cash flow and calculated a range of economic metrics such as NPV, LEV, IRR.

It has been built to answer the following questions:

- What is the profitability of your proposed forestry investment?
- What quantity and quality of wood will you get at harvest?
- When is the best time to do your pruning and thinning?
- What is the most profitable silvicultural regime?
- What is the most profitable way around certain limitations, such as available labour or finance?
- What are the environmental consequences of a forestry scheme?

An important factor to remember with forestry mitigation strategies is that the mitigation only lasts as long as the first forestry rotation. Once this is complete, a further area would be required to be planted in order to continue the offset.

12.4 Introduction to MyLand Modelling

MyLand is an integrated decision support system (DSS) to assist land managers in taking a long-term holistic approach to integrated land-use decisions. It involves meta-modelling calibrated off-productivity surfaces for spatial application, a decision tree for selecting options, multiple land-use analysis, multiple outputs and a mapping interface deployed over the Web.

Techniques to solve forestry modelling challenges have been generalised and applied in modelling pastoral and forestry land-use types. Forestry yield modelling is accommodated by a two-stage approach of spatial modelling of a productivity index followed by meta-modelling output from forest stand growth models. Livestock farming is modelled using the property owner's estimates of livestock carrying capacity of land management units in a whole property stock reconciliation model. The environmental performance of the property is calculated from the land-use type and management regime.

13.0 GREENHOUSE GASES – METHANE (CH_4) AND NITROUS OXIDE (N_2O)

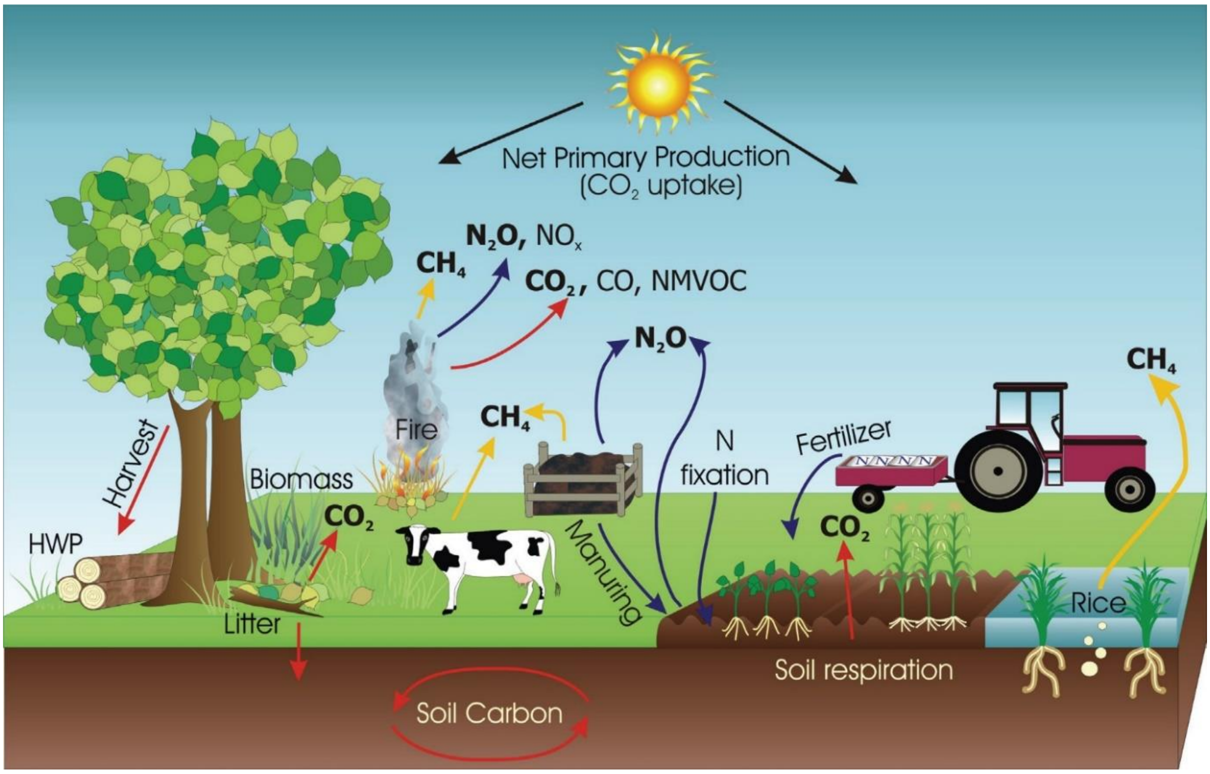
13.1 Methane

Methane is the primary component of natural gas. In the atmosphere it absorbs the sun's heat, warming the atmosphere, and for this reason it is considered a GHG, like carbon dioxide. It has a global warming potential of 25 times that of carbon dioxide based on a 100-year timeframe, although its longevity in the atmosphere is measured in tens of years rather than hundreds of years for CO_2.

A significant source of CH_4 is from ruminant animals (cattle, sheep), where the breakdown of cellulose in the stomach produces methane (a process called enteric fermentation). Some 10 per cent of livestock methane is produced from anaerobic manure storage, with still smaller emissions from animal manure deposited directly onto soils by grazing animals.

13.2 Nitrous Oxide

N_2O is a potent GHG with a long-term global warming potential 298 times that of carbon dioxide over a 100-year timeframe. In agriculture, it is mostly produced by microbial action within the soil, feeding on manure, mostly urine and fertilisers. Some indirect emissions also come from nitrogen leaching, wetlands, and run-off.



Source: IPCC

14.0 BASELINE GHG AND NUTRIENT LOSSES

GHG emissions for the case study farms were determined via Overseer for the case study farms. Figure 9 shows the average GHG emissions for methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2) for each of the case study farms, based on CO_2 equivalents (kg/ha/yr). The two dairy farms, Pukehina and Te Rua o Te Moko, generally have higher GHG emissions than the two sheep and beef farms.

Figure 9: Baseline GHG emissions from the four case study farms. Based on total farm area (CO_2 equivalents (kg/ha)).

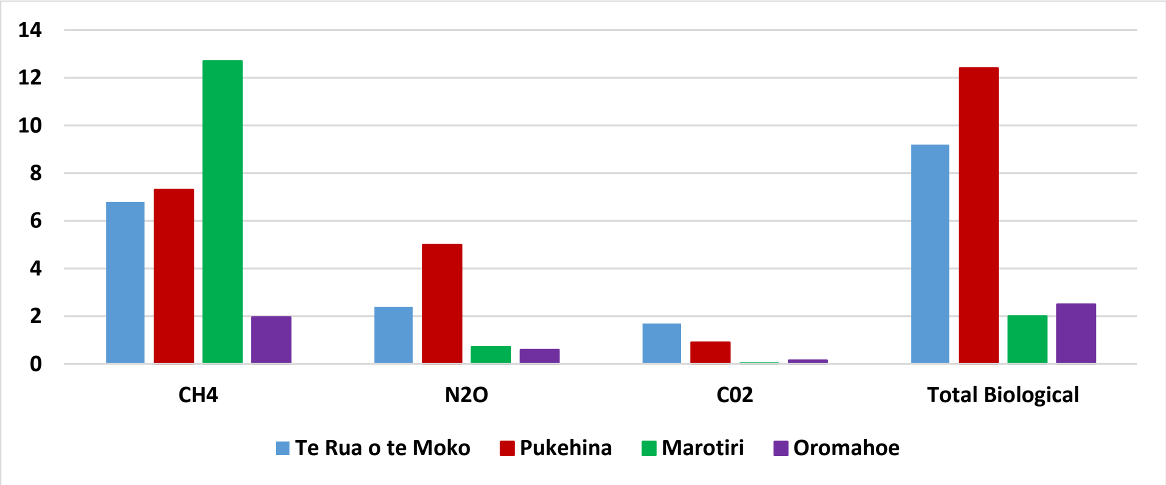


Table 13 shows the origin of each emission. Excreta was the main contributor to N_2O emissions on all farms. As expected, the majority of CH_4 emissions originate from the ruminant livestock on farm. CO_2 emissions on the two dairy farms mainly originate from the use of N fertiliser and imported supplements. CO_2 emissions on the sheep and beef farm were negligible compared to the dairy farms. The use of lime contributed the most to CO_2 emissions on Oromahoe while at Marotiri they came mainly from the use of fuel.

Table 13: Overseer GHG report. Based on total farm area (CO_2 equivalents (kg/ha/yr)).

	Pukehina	Te Rua o Te Moko	Oromahoe	Marotiri
Total GHG emissions	**10583**	**11298**	**2720**	**1724**
CH_4 emissions	**7306**	**6796**	**1956**	**1249**
Enteric	7206	6595	1932	1235
Dung	74	65	23	14
Effluent	25	135	0	0
N_2O emissions	**2366**	**2758**	**614**	**450**
Excreta paddock	1361	1296	442	313
Excreta effluent	117	117	0	0
N fertiliser	330	809	14	8
Crops	5	3	0	0
In Direct	553	537	158	130
CO_2 emissions	**911**	**1744**	**150**	**25**
Electricity	130	120	2	1
Fuel	90	85	22	14
N fertiliser	302	663	15	7
Fertiliser and organic inputs	111	204	40	1
Lime	3	54	70	0
Supplements	169	446	0	0
Animal transport	3	0	0	1
Other	104	154	1	0

Note: The CO_2 emissions shown above are embedded emissions, not direct emissions from the farming operation. They are excluded from the farm level analyses, and discussed further in Section 15.

14.1 Baseline Nitrogen and Phosphorus losses

Nitrogen is essential for plant growth and function and is the nutrient most in demand. However, excess N in the soil pool is easily leached from the soil profile and can have negative impacts on the environment if not managed correctly (Cameron et al., 2013). Phosphorus, like N is essential for plant growth. Excess P in the soil, like N, can have negative impacts on the environment if not managed correctly. Unlike N, P is not very mobile in the soil and the major pathway for P loss is through surface runoff and eroding soils.

Nitrogen losses from the two dairy farms (Pukehina and Te Rua o Te Moko) were similar (Table 14). N loss was much less on the sheep and beef farms, with both losing 8.0 kgN/ha/yr.

Table 14: Nitrogen and Phosphorus losses (kg/ha/yr)

	Pukehina	Te Rua o Te Moko	Oromahoe	Marotiri
P Loss to water	3.3	0.6	1.5	0.8
N Loss to water	27	27	8	8

15.0 Results of Mitigation Scenarios

A number of mitigation scenarios had been discussed and agreed with each of the four case study farms. This was a two-step process whereby an initial number of scenarios were discussed and modelled, and then reported back to the Focus Farms, at which stage a number of further scenarios were identified and subsequently modelled. A further meeting was then held with the Focus Farms to report on all scenarios modelled.

The process for modelling these scenarios was firstly to capture the scenario in Farmax. By utilising Farmax it ensured that the scenario and associated changes required of the farm were feasible. Once the scenario was modelled in Farmax, the changes that had been applied to the farm in Farmax were reflected in Overseer. The results of the effectiveness of the mitigation scenarios at reducing GHG emissions are discussed in the following sections. The appendix provides further breakdown of the results. Each mitigation scenario was modelled against the base farm file (i.e. mitigation scenarios are not cumulative).

Note the following discussion is based on the Overseer results; a further section discusses the impact of carbon sequestration. Also, all forestry plantations are assumed to be intensively managed *Pinus Radiata* (Radiata pine) unless otherwise stated.

15.1 Pukehina

A total of six mitigation scenarios were modelled for the Pukehina dairy farm.

Table 15: Pukehina Mitigation Scenarios

Scenario	Description
S1: Remove summer and autumn crops and replace with supplements	Summer and autumn crops (maize and turnips) were removed and replaced with imported PKE. Annual milk production was increased but animal numbers were unaffected (same as base farm).
S2: Partial wintering facilities	A feed pad is used year round except in November and December. The feed pad was used for three hours a day and was predominantly required for feeding rather than standing off in wet conditions. Cows were fed 2-5 kgDM/cow/day of maize, grass silage or PKE.
S3: In-shed feeding with increased cow numbers	The concentrate, Ingham TopCow seasonal, was brought in and fed in the milking shed throughout the season. This increased annual milk production. Cow numbers increased by 30 cows.
S4: In-shed feeding system, with young stock kept on the milking platform	Milking cow numbers were reduced to allow young stock to be run on the farm all year, with in-shed feeding of concentrates used to help maintain milk production.
S5: Reduce stocking rate	Cow numbers were reduced by 10%, with the intent to hold per cow production levels via better feeding.
S6: Retire marginal land	3 ha of marginal land was retired and put into Radiata pine. Milk production decreased due to the reduction in pasture production.

The impact of the scenarios on GHG emissions as calculated by Overseer for Pukehina showed:

Table 16: GHG emissions from modelled scenarios (kg CO_2 equivalents/ha/year)

	CH_4	N_2O	Total CO_2 equiv.*	% Change CH_4	% Change N_2O	% change Total CO_2 equiv.
Base	7,306	2,366	9,672			
S 1	7,380	2,388	9,768	1%	1%	1%
S 2	7,358	2,385	9,743	1%	1%	1%
S 3	8,210	2,502	10,712	12%	6%	11%
S 4	7,918	3,283	11,201	8%	39%	16%
S 5	7,352	2,368	9,720	1%	0%	0%
S 6	7,277	2,352	9,196	0%	-1%	-5%

*Includes sequestered CO_2 within forestry

The impact of the scenarios on GHG emissions (Figure 10 and Table 16) for Pukehina showed:

- All mitigation scenarios apart from planting the marginal area in forestry increased CH_4 emissions.
- S1, S2, S3 and S4 resulted in GHG emissions increasing; the main reason being the increase in stock numbers and increased bought-in supplements.
- S6 shows the largest drop in total CO_2e as a result of the carbon sequestration from the forestry planting.

Figure 10: GHG emissions for each mitigation scenario compared to emissions on the base farm

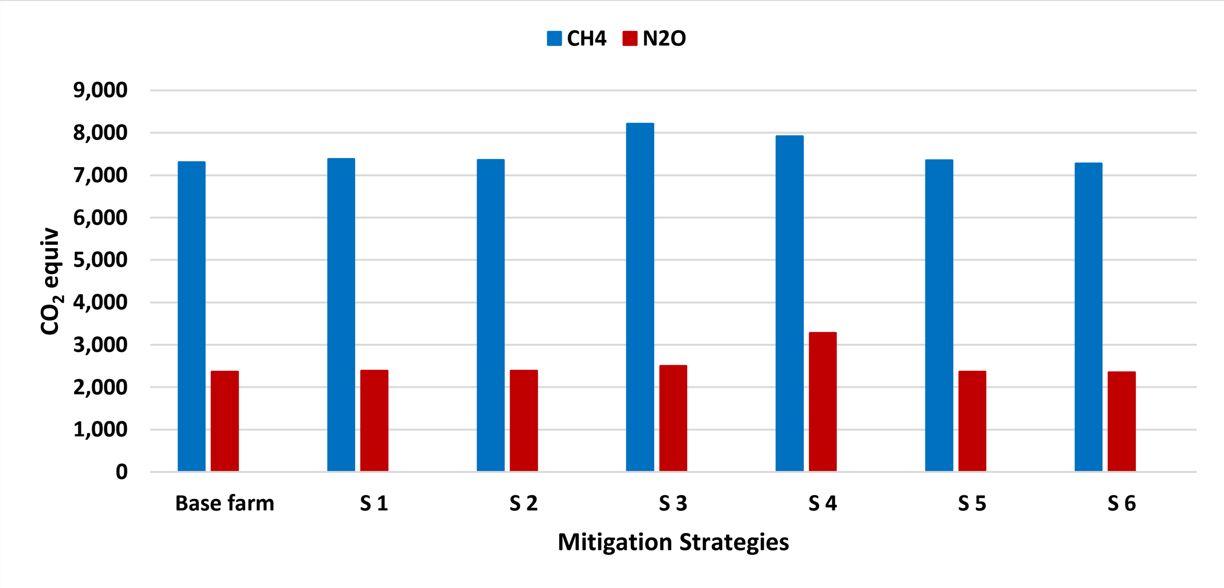
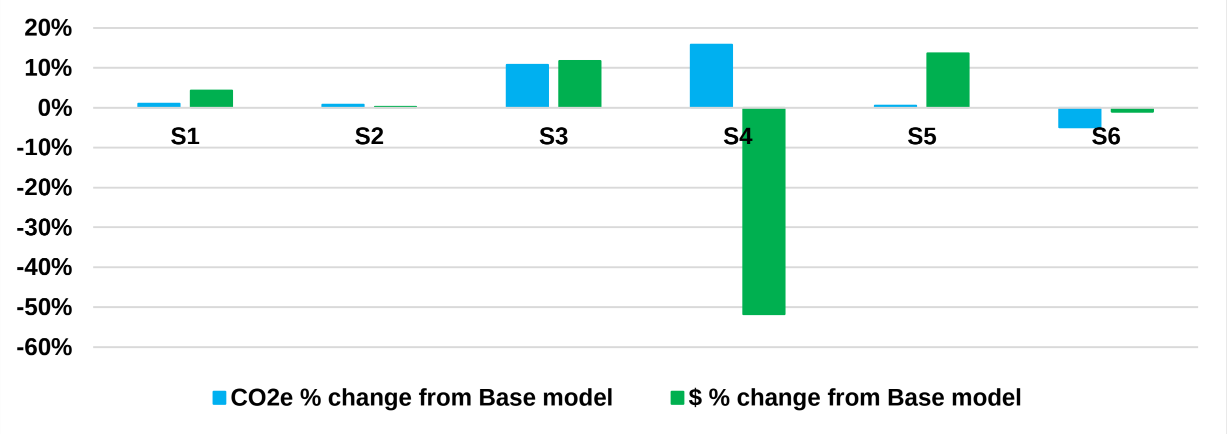


Figure 11: Change in profitability relative to change in CO_2e emissions



This shows:

- A (slight) increase in total CO_2e for S2 and S5, with accompanying increase in profitability, significantly so for S5 (reduced stocking rate). In this scenario, milking cow numbers were reduced by 10%, but production held as a result of better feeding; in essence, an improvement in efficiency.

  This is an important issue, as at face value there is a direct win-win situation – GHG emissions have decreased, whereas profitability has increased. To some degree this is an artefact of the model; the scenario saw cow numbers reduced, and bought-in supplementary feed reduced. In achieving the same level of production as per the base situation, the model has assumed that pasture quality has not deteriorated, and that grazing efficiency is either similar to previous, or better. In effect efficiency has improved, because the model is a perfect farmer.

  In practice, things are more complicated. A number of farmers would be able to maintain pasture quality and grazing efficiency (i.e. pasture utilisation) with reduced stock numbers, and hence achieve the win-win, which has been achieved on a number of farms looking to reduce nutrient discharges. But many farmers would struggle to maintain pasture quality at a lower stocking rate, and the very high likelihood is that this would then result in lower production and lower profitability.

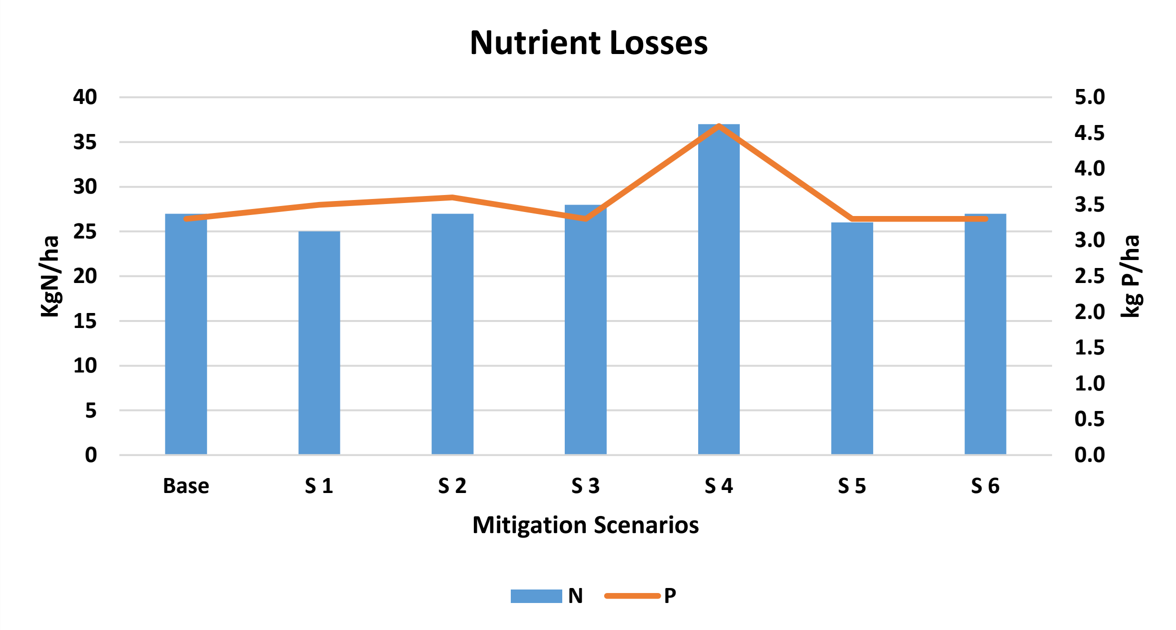
  Interpreting the results of the model therefore needs to be done with caution as it could lead to a false positive.

  Essentially the model has realigned its marginal benefit with marginal cost; at the payout and farm costs used, the extra supplementary feed and cows run (in the base model) meant that marginal cost was higher than marginal benefit. The issue that arises is that this MR/MC 'sweet spot' varies with payout and costs (obviously), and hence a different result would be obtained with a different payout/cost structure, which in turn, out on the farm, makes it difficult for the farmer to consistently operate around this 'sweet spot', especially as costs and returns are often not known with certainty until well into the season.

- For S1 (replace cropping with supplements) and S3 (in-shed feeding with increased cows), profitability has improved, but at the expense of higher CO_2e emissions.

- For S4 (in-shed feeding and with young stock on the milking platform), CO_2e emissions have increased while profitability has decreased.

Figure 12: Nitrogen and phosphorous loss for each mitigation scenario compared to losses on the base farm. Note P loss is shown on the right axis.



The impact of the scenarios on N and P loss for Pukehina is shown in Figure 12 and Table 17. The results show that overall N and P loss are not dramatically changed for most of the mitigation scenarios. The exceptions are the two in-shed feeding (S3, S4) with increased stock number scenarios.

Table 17: Changes in N and P losses for each mitigation scenario compared to losses on the base farm.

	N loss to water (kg N/ha/yr)	P loss to water (kg P/ha/yr)
Base Farm	27	3.3
S1	25	3.5
S2	27	3.6
S3	28	3.3
S4	37	4.6
S 5	26	3.3
S 6	27	3.3

To understand the impact of GHG, emission intensity is often referred to. Emission intensity is defined as kg of GHG emitted per kg of product sold. For the Pukehina farm this is total farm CO_2 equivalents divided by total milk solid plus beef production (Table 18).

Table 18: Pukehina Emission Intensity

	Total CO_2 equivalents (kg) (Farm only)	Kg of product sold (milk solids + beef kg/yr)*	Emission Intensity (kg CO2 equivalent/kg product)	Percentage change in intensity relative to base
Base Farm	1,479,816	153,762	9.6	
S1	1,494,504	157,116	9.5	-1%
S2	1,490,679	155,202	9.6	0%
S3	1,638,936	186,227	8.8	-9%
S4	1,713,753	158,955	10.8	12%
S5	1,487,160	165,281	9.0	-7%
S6	1,444,350	152,604	9.5	-2%

Note that for the dairy focus farms, total 'production' incorporated milksolids and beef produced.

As reflected in Table 18, the reduced stocking rate (S5) and in-shed feeding with increased stock (S3) have reduced the emission intensity, while in-shed feeding with young stock on the farm (S4) has increased intensity, and other scenarios have seen little movement in emission intensity.

The effects of these changes on the Pukehina farm profit per hectare are shown below (Table 19). Economic analysis as taken from Farmax did not include infrastructure costs of the scenarios such as feed pads, in-shed feed systems or planting/fencing of retired land (discussed in Section 17).

Table 19: Economic analysis of mitigation scenarios for Pukehina (net profit/ha) - includes CO_2 costs and returns.

Scenario	Nil CO_2e Cost	% difference from base	\$10 T CO_2e Cost	% difference from nil cost base	\$25 T CO_2e Cost	% difference from nil cost base
Base Farm				-8%		-20%
S1: Remove summer and autumn crops and replace with supplements		4%		-4%		-16%
S2: Partial wintering facilities		0%		-8%		-20%
S3: In-shed feeding with increased cow numbers		12%		3%		-10%
S4: In-shed feeding system, with young stock on the milking platform		-52%		-61%		-75%
S5: Reduce stocking rate		14%		6%		-6%
S6: Retire marginal land*		-1%		-9%		-20%

Note: Actual $ net profit/ha figures are confidential

*per hectare results for the marginal land scenario includes the hectare of marginal land for comparison with other scenarios. Other scenarios only include effective grazed hectares as modelled in Farmax.

As can be seen from Table 19, the addition of a cost for CO_2e significantly affects the farm EBIT; for the base farm, a $10/T cost reduces the EBIT by 8%, and a $25/T cost reduces it by 20%. While the value of sequested carbon is added to the 'retire marginal land' scenario, the area in question is too small to have any material affect.

Carbon Neutral

This is the point where carbon emissions from the farming activity would be totally mitigated by carbon sequestration for the next 25 years (i.e. the rotation of the forest). Within the project, this was modelled by increasing the area planted in forestry (Radiata) until the net GHG emission was essentially zero. The approach taken in the CO_2 sequestration modelling has been conservative in that it uses the MPI ETS Carbon stock look-up tables and takes half the annualised table amount (for specified tree age and region) to assume a long term average and avoid issues around liability at harvest. This approach may be changed in future modelling if a Field Measurement Approach is thought to be beneficial to the farmer.

For Pukehina, this occurred when 67 hectares of land was planted in forestry. This only holds given the assumption that the remaining 86 hectares of dairying continued at the current level of intensity.

Obviously this level of forestry planting would have a significant impact on the overall profitability of the farming enterprise, with the remaining area in dairying likely to be marginal as a standalone commercial unit.

It should also be noted that planting of forestry as a mitigation strategy is only valid for the first rotation of the forestry block – once this rotation has been completed, then (a) the block needs to be replanted; and (b) a further area of forestry needs to be planted in order to continue the mitigation.

Carbon breakeven price

This is the price of carbon whereby both the (current) returns from forestry plus carbon equal the current profitability level from dairying on Pukehina. The assumption here is that the current profitability of both forestry and dairying stays constant. For Pukehina, the breakeven price of carbon is $50.50/tonne.

Carbon crossover point

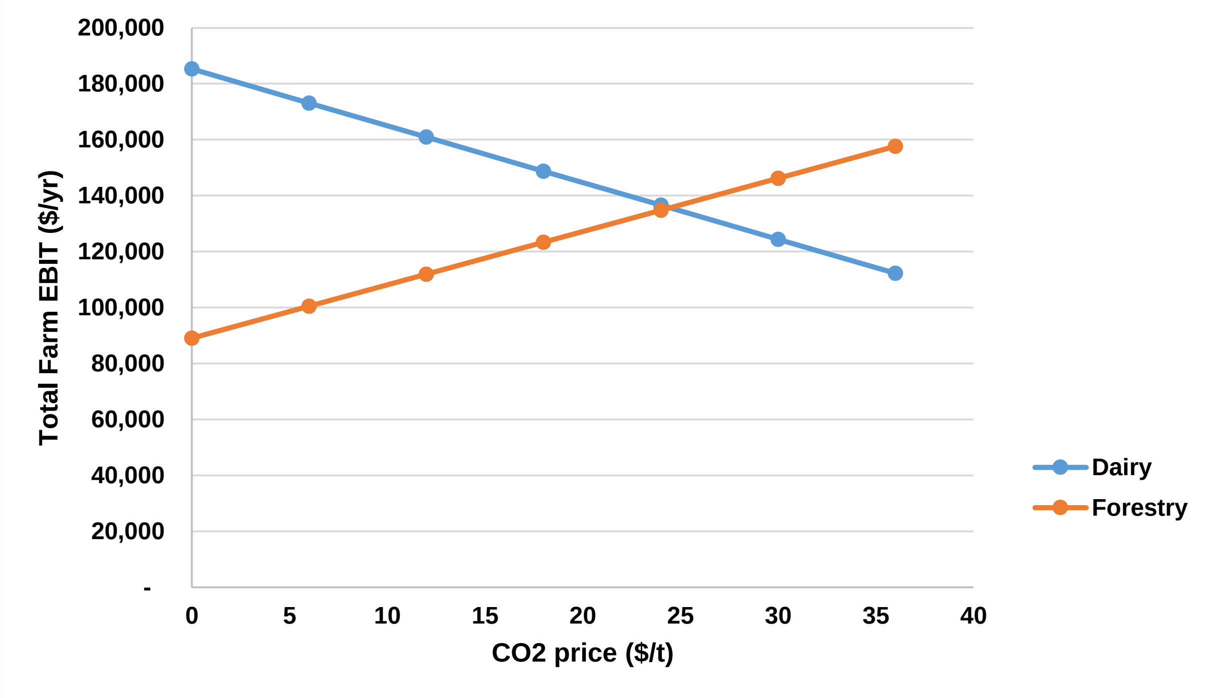
Under the assumption that a carbon charge is payable by the farm, and no mitigations are carried out, this is the point at which the profitability of dairying (which would decline under an increasing carbon cost) crosses over the profitability of forestry (which would increase under an increasing carbon return). As can be seen from the figure below, this crossover point occurs at a carbon price of $24.50/tonne.

Just to clarify:

1. **Carbon Neutral** point is the area of forestry (Radiata pine) required to offset the farm CO_2e emissions.
2. **Carbon Breakeven Price** is the price of carbon at which, when added to the forestry returns, would provide the same profitability as the current farm (without forestry).
3. **Carbon Crossover Point** is the price of carbon, when (a) added to forestry returns; and (b) deducted from the farm as a cost, the profitability of forestry equates to the profitability of farming.

These three factors are different, although (2) and (3) may well lead to (1). These factors were introduced by the researchers as a means of discussing issues around carbon tax and carbon neutrality.

Figure 13: CO_2 Crossover Point for Pukehina



Summary

Six mitigation scenarios were modelled for the Pukehina dairy farm using Farmax to model the farm systems, Overseer to model the nutrient and GHG discharges, and Radiata Calculator Pro/spreadsheeting to incorporate the carbon sequestration.

A summary of the results show:

Table 20: Pukehina Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base Model			9.7		9.6		27	
S1: Remove summer and autumn crops and replace with supplements		4%	9.8	1%	9.5	-1%	25	-7%
S2: Partial wintering facilities		0%	9.7	1%	9.6	0%	27	0%
S3: In-shed feeding with increased cow numbers		12%	10.7	11%	8.8	-9%	28	4%
S4: In-shed feeding with young stock on the milking platform		-52%	11.2	16%	10.8	12%	37	37%
S5: Lower stocking rate		14%	9.7	0%	9.0	-7%	26	-4%
S6: Plant 3 ha forest		-1%	9.2	-5%	9.5	-2%	27	0%

Note: Actual $ net profit/ha figures are confidential.

15.2 Te Rua o Te Moko

Six mitigation scenarios were modelled for the Te Rua o Te Moko dairy farm (Table 21).

Table 21: Te Rua o Te Moko mitigation scenarios

Scenario	Description
S1: Replace maize	Replace maize crops with a larger area of fodder beet crop.
S2: Replace N fertiliser	N fertiliser removed and maize silage brought in to make up for the loss of pasture production. Animal numbers and milk production remained the same.
S3: Eliminate N fertiliser	N fertiliser removed and animal numbers were reduced to match the decrease in pasture production.
S4: Remove crops	Summer and autumn crops were removed and replaced with brought in maize silage and PKE.
S5: Retire land	2 hectares of marginal land was retired and put into Radiata pine. Animal numbers were unchanged but milk production was decreased to match the loss of pasture production.
S6: In-shed feeding	In-shed feeding system installed and cow numbers increased

The impact of the scenarios on GHG emissions as calculated by Overseer for Te Rua o Te Moko showed:

Table 22: GHG emissions from modelled scenarios (kg CO_2 equivalents/ha/year)

	CH_4	N_2O	Total CO_2 equiv.*	% Change CH_4	% Change N_2O	% change Total CO_2 equiv.
Base	6796	2758	9,007			
S1	6854	2783	9,088	1%	1%	1%
S2	6853	1685	8,014	1%	-39%	-11%
S3	5751	1594	6,849	-15%	-42%	-24%
S4	7010	2807	9,264	3%	2%	3%
S5	6770	2753	8,703	0%	0%	-3%
S6	7133	3327	9,892	5%	21%	10%

*Includes sequested carbon from forestry area

- As can be seen from the table, eliminating nitrogen fertiliser (S3) has the largest impact in reducing all GHGs relative to the base farm. This was likely due to the reduction in stock numbers and N fertiliser – less enteric CH_4 emissions and N_2O from fertiliser.
- S2 (replacing nitrogen fertiliser with maize silage) also showed large reductions in N_2O, but with a slight increase in CH_4 emissions.
- S1, S4 had only relatively minor effects on total GHG emissions.
- S5 (planting trees on marginal land) resulted in a marginal decrease increase in total CO_2e as a result of running the same stock numbers on a smaller area.
- S6 (in-shed feeding system) saw a significant increase in all GHGs as a result of higher cow numbers and increased feeding levels.

Figure 14: GHG emissions for each mitigation scenario compared to emissions on the base farm

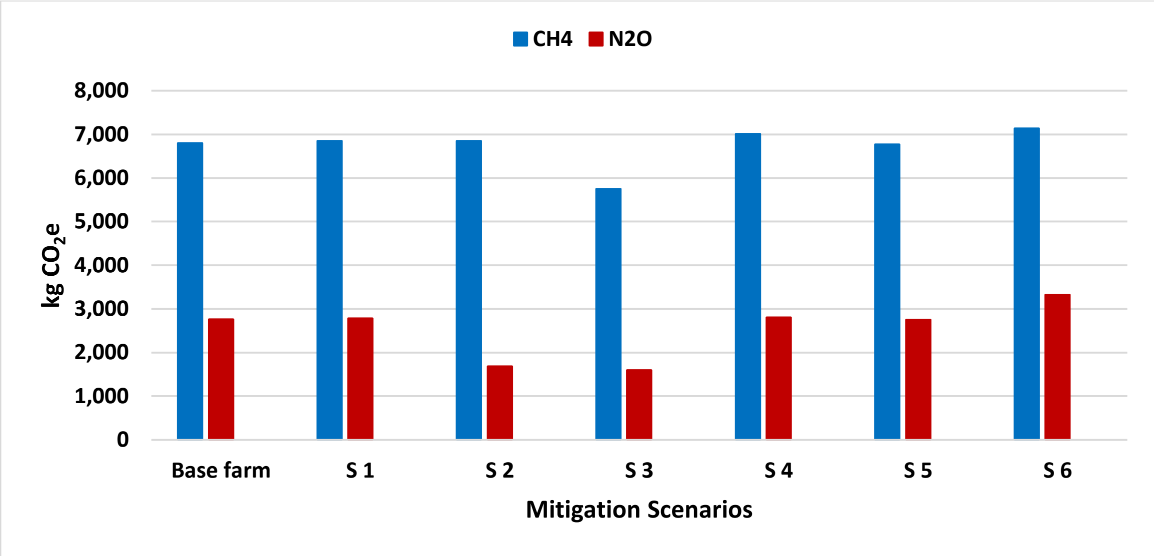
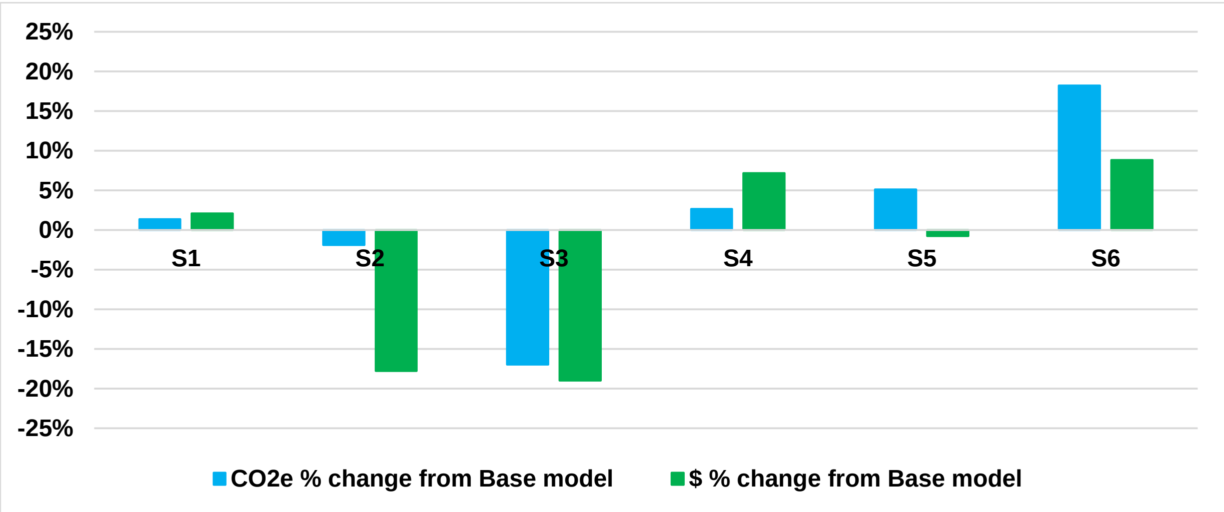


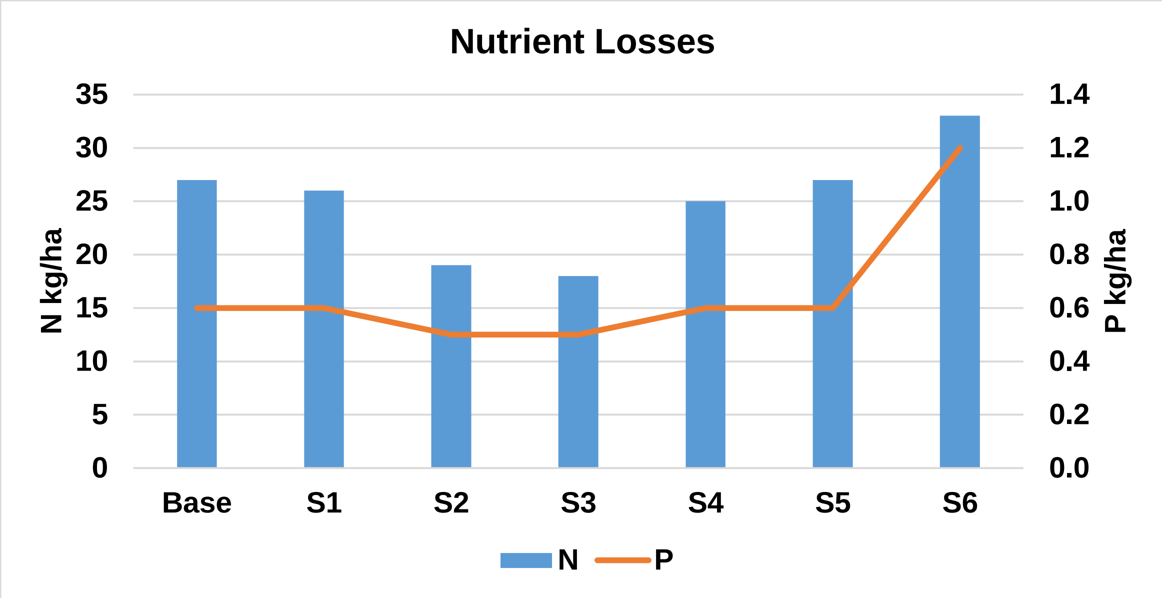
Figure 15: Change in profitability relative to change in CO_2e emissions



This shows:

- A reduction in GHG emissions with the reduction/elimination of nitrogen fertiliser (S2, S3), but at a significant cost to farm profitability.
- In most of the other scenarios an increase in profitability is accompanied by an increase in CO_2e emissions, apart from the afforestation scenarios where CO_2e has increased slightly (same cows on lesser area) accompanied by a decrease in profitability.

Figure 16: Nitrogen and phosphorous loss for each mitigation scenario compared to losses on the base farm. Note P loss is shown on the right axis.



The impact of the scenarios on N and P loss for Te Rua o Te Moko is shown in Figure 16 and Table 23. P loss was largely unaffected by each mitigation option, apart from S6 (in-shed feeding/more cows). N loss was affected to varying degrees, particularly via the reduced/eliminated nitrogen fertiliser scenarios. The reduction in N loss here was a result of the removal of N fertiliser and either the subsequent reduction in stock numbers or low N input feed being brought in. The in-shed feeding scenario increased N losses, due to increased stock numbers and increased supplementary feeding.

Table 23: Changes in N and P losses for each mitigation scenario compared to losses on the base farm.

	N loss to water (kg N/ha/yr)	P loss to water (kg P/ha/yr)
Base Farm	27	0.6
S1	26	0.6
S2	19	0.5
S3	18	0.5
S4	25	0.6
S5	27	0.6
S6	33	1.2

The intensity of CO_2e production (gross CO_2e divided by gross milk plus beef production) for Te Rua o Te Moko is outlined below.

Table 24: Intensity of CO2e production for Te Rua o Te Moko

	Total CO_2 equivalents (kg) (farm only)	Kg of product sold (milk solids + beef kg/yr)	Emission Intensity (kg CO_2 equivalent/kg product)	Percentage change in intensity relative to base
Base Farm	1,624,180	210,538	7.7	
S1	1,638,290	211,072	7.8	1%
S2	1,451,460	210,098	6.9	-10%
S3	1,248,650	180,493	6.9	-10%
S4	1,668,890	210,497	7.9	3%
S5	1,599,864	209,131	7.7	-1%
S6	1,778,200	233,005	7.6	-1%

This shows:

- For the two reduce/eliminate nitrogen scenarios (S2, S3) absolute emissions have decreased, along with reduced production, leading to an improvement in emission intensity;
- For S1 (less maize more fodder beet) the increase in total emissions is not quite offset by an increase in production;
- For S4 (no crop) total emissions have increased while production has decreased;
- For S5 (forestry on marginal area) total emissions have decreased, offset by decreased production, giving the same level of intensity; and
- For S6 (in-shed feeding), while production has increased significantly this is more than offset by an increase in total emissions.

The effects of these changes on the Te Rua o Te Moko farm profit per are shown below (Table 25). As noted earlier, economic analysis as taken from Farmax did not include infrastructure costs of the scenarios such as feed pads, in-shed feed systems or planting/fencing of retired land.

Table 25: Economic analysis of mitigation scenarios for Te Rua o Te Moko (net profit/ha) – includes CO_2 costs and returns

Scenario	Nil CO_2 Cost	% difference from base	$10 T CO_2e Cost	% difference from nil cost base	$25 T CO_2e Cost	% difference from nil cost base
Base Farm	$2,021		$1,931	-4%	$1,796	-11%
S1: Replace maize	$2,058	2%	$1,968	-3%	$1,831	-9%
S2: Replace N fertiliser	$1,663	-18%	$1,583	-22%	$1,462	-28%
S3: Eliminate N fertiliser	$1,629	-19%	$1,561	-23%	$1,458	-28%
S4: Remove crops	$2,160	7%	$2,067	2%	$1,928	-5%
S5: Plant 2 ha forest	$2,004	-1%	$1,917	-5%	$1,786	-12%
S6: In-shed feeding	$2,203	9%	$2,104	4%	$1,956	-3%

Similar to Pukehina, the imposition of a carbon cost has reduced the farm EBIT; for the base farm scenario, it decreases by 4% under a $10/T CO_2e cost and by 11% under a $25/T CO_2e cost. These reductions are much smaller relative to Pukehina due to the lower total CO_2e emissions from Te Rua o Te Moko.

Again while the value of carbon sequestration has been added to the 'retire land' scenario, the area is too small to have a material impact.

Carbon Neutral

This is the point where carbon emissions from the farming activity would be totally mitigated by carbon sequestration. Within the project, this was modelled by increasing the area planted in forestry (Radiata) until the net GHG emission was essentially zero.

For Te Rua o Te Moko, this occurred when 70 hectares was planted in forestry, leaving 104 hectares remaining in dairying, given the assumption that the remaining area of dairying continued at the current level of intensity.

Again this level of planting would have a major impact on the viability of the remaining dairying unit, and again forestry as a mitigation strategy would only last for the first rotation; after this a further area would need to be planted.

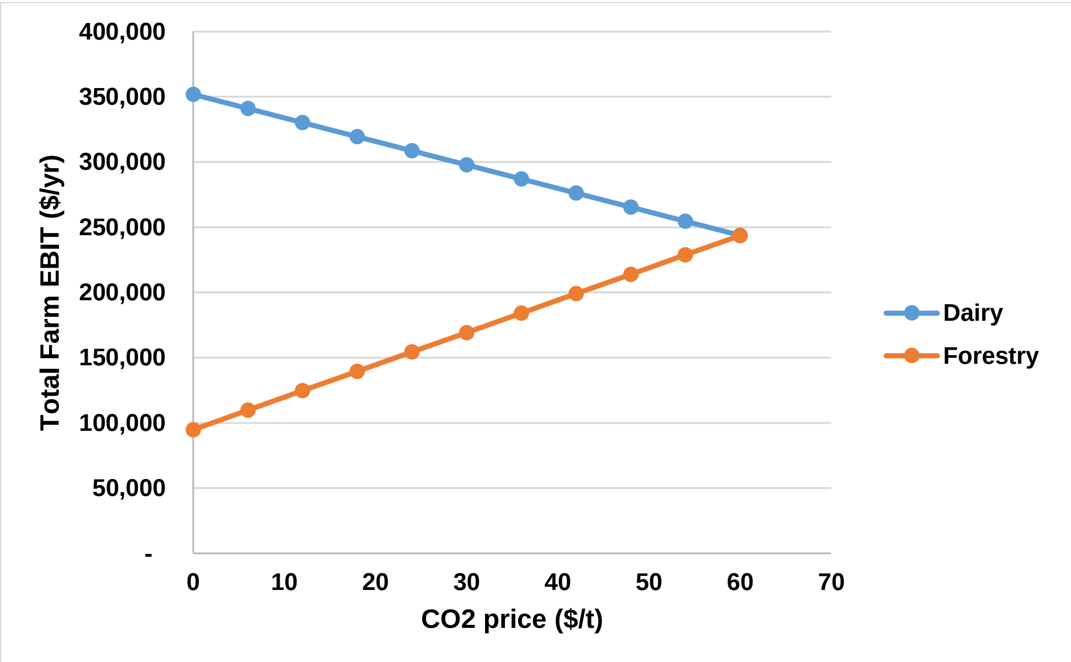
Carbon breakeven price

This is the price of carbon whereby both the (current) returns from forestry plus carbon equal the current profitability level from dairying on Te Rua o Te Moko. The assumption here is that the current profitability of both forestry and dairying stays constant. For Te Rua o Te Moko, the breakeven price of carbon is $103/tonne.

Carbon Crossover Point

Under the assumption that a carbon charge is payable by the farm, and no mitigations are carried out, this is the point at which the profitability of dairying (which would decline under an increasing carbon cost) crosses over the profitability of forestry (which would increase under an increasing carbon return). As can be seen from the figure below, this crossover point occurs at a carbon price of $60/tonne.

Figure 17: CO_2 Cross-Over Point for Te Rua o Te Moko



Summary

Six mitigation scenarios were modelled for the Te Rua o Te Moko dairy farm using Farmax to model the farm systems, OVERSEER to model the nutrient and GHG discharges, and Radiata Calculator Pro/spreadsheeting to incorporate the carbon sequestration.

A summary of the results show:

Table 26: Te Rua o Te Moko Modelling results (relative to base scenario)

	Per ha net profit incl CO_2 costs or revenues	% change from Base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	$2,021		9.0		7.7		27	
S1: Replace maize with fodder beet	$2,058	2%	9.1	1%	7.8	1%	26	-4%
S2: Replace N fertiliser with bought-in feed	$1,663	-18%	8.0	-11%	6.9	-10%	19	-30%
S3: Eliminate N Fertiliser	$1,629	-19%	6.8	-24%	6.9	-10%	18	-33%
S4: Remove crops	$2,160	7%	9.3	3%	7.9	3%	25	-7%
S5: Plant 2 ha forest	$2,004	-1%	8.7	-3%	7.7	-1%	27	0%
S6: In-shed feeding	$2,203	9%	9.9	10%	7.6	-1%	33	22%

15.3 Marotiri

Seven mitigation scenarios were modelled for the Marotiri sheep and beef farm (Table 27).

Table 27: Marotiri Mitigation Scenarios

Scenario	Description
S1: Eliminate N fertiliser	N fertiliser removed and animal numbers were reduced across all stock classes to match feed demand with the decrease in pasture production.
S2: 50 sheep:50 beef	The number of sheep to beef animals was increased to 50:50 without changing the proportion of animals in each mob.
S3: 60 sheep:40 beef	The number of sheep to beef animals was increased to 60:40 without changing the proportion of animals in each mob.
S4: Retire land into Pines	50 hectares of marginal land was retired and planted with pine trees. Stock numbers were scaled back to match the decrease in pasture production.
S5: Intensify 100 ha into a lamb finishing block	Capital fertiliser was applied to 100 hectares to improve fertility, with the block then used to finish lambs ready for slaughter.
S6: Retire land into Lusitanica	50 hectares of marginal land was retired and planted with Lusitanica trees. Stock numbers were scaled back to match the decrease in pasture production.
S7: Retire land into Manuka	50 hectares of marginal land was retired and planted with Manuka for Manuka honey. Stock numbers were scaled back to match the decrease in pasture production.

The impact of the scenarios on GHG emissions as calculated by Overseer for Marotiri showed:

Table 28: GHG emissions from modelled scenarios (kg CO_2 equivalents/ha/year – farm only)

	CH_4	N_2O	Total CO_2 equiv.	% Change CH_4	% Change N_2O	% change Total CO_2 equiv.
Base	1,249	450	1,699			
S 1	1,243	441	1,684	0%	-2%	-1%
S 2	1,249	409	1,658	0%	-9%	-2%
S 3	1,228	402	1,630	-2%	-11%	-4%
S 4	1,242	447	1,689	-1%	-1%	-1%
S 5	1,270	459	1,729	2%	2%	2%
S 6	1,242	402	1,644	-1%	-1%	-1%
S 7	1,242	402	1,644	-1%	-1%	-1%

The impact of the scenarios on GHG emissions (Figure 10 and Table 28) for Marotiri showed relatively minor changes for most scenarios, particularly for changes in total CO_2e. N_2O decreased in S2 and S3 (increasing sheep numbers relative to cattle).

Figure 18: GHG emissions for each mitigation scenario compared to emissions on the base farm

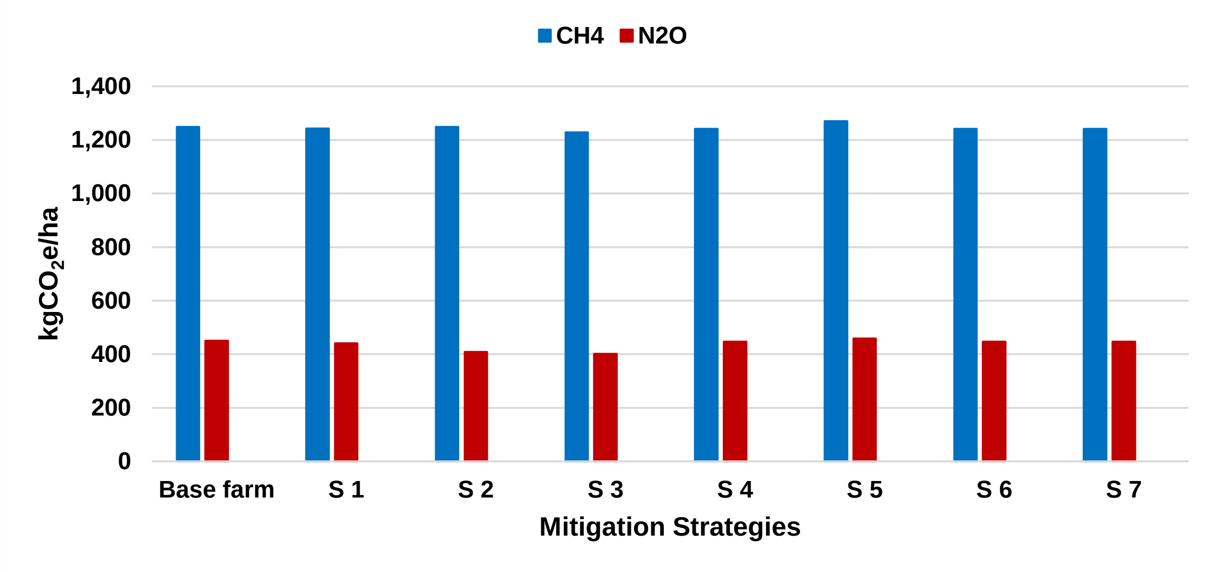
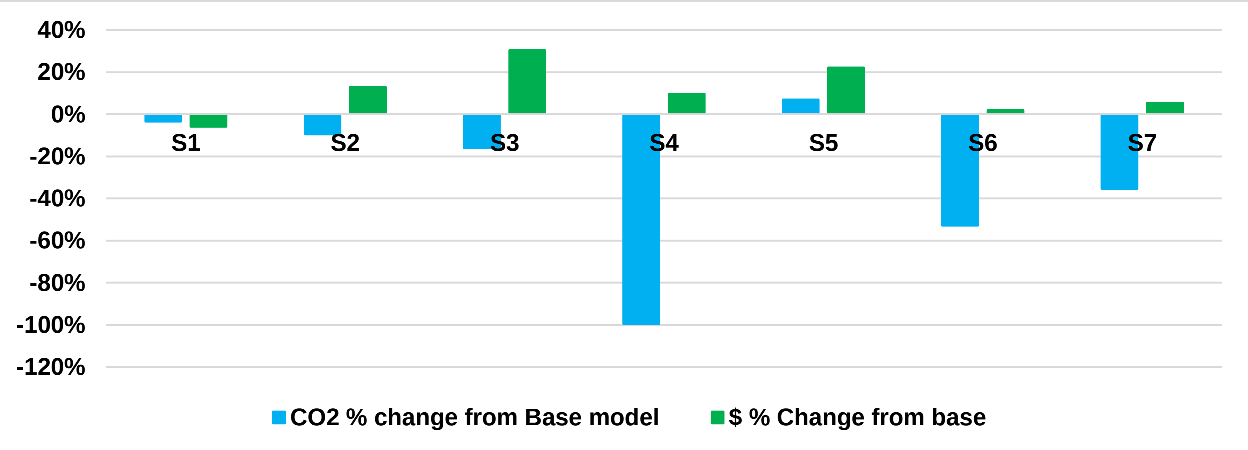


Figure 19: Change in profitability relative to change in CO_2e emissions*



*Includes forestry

This shows a win-win from all scenarios apart from S1 (eliminate N fertiliser); while CO_2e has decreased, so has profitability), and S5 (increase lamb finishing); while profitability has increased so has CO_2e (slightly). In all others increasing sheep ratios, and planting of trees has decreased CO_2e emissions and improved profitability. An issue that arises is that the current profitability of the farming enterprise is less than the current profitability of forestry.

Inclusion of Carbon Sequestration, and value of Forestry returns

As noted earlier, Overseer does not account for carbon sequestration by trees, and Farmax does not include forestry costs and returns. These have been included separately, building on the results from the Overseer and Farmax modelling.

The results of this are shown in the following tables:

Table 29: Marotiri net carbon emissions

Marotiri Farm Partnership						Overseer							
Pastoral Area	Plantation Forest	Scrub & Native (eligible for ETS)	Curtilage & Roads	Total property	Scenario	CH_4 emissions	N_2O emissions	Total	CO_2 sequestered/ha		Net CO_2		
ha	ha	ha	ha	ha		(CO_2 equivalents kg/ha)			from Radiata pine plantations	from Indigenous forest	Total property net CO_2 (kg)	Net Tonnes CO_2e/ha	% change from Base model
1941	150	100	28	2219	Base model	1,249	450	1,699	14,450	3,000	830,259	0.4	0%
1941	150	100	28	2219	S1: Eliminate N fertiliser	1,243	441	1,684	14,450	3,000	801,144	0.4	-4%
1941	150	100	28	2219	S2: 50 sheep :50 beef	1,249	409	1,658	14,450	3,000	750,678	0.4	-10%
1941	150	100	28	2219	S3: 60 sheep :40 beef	1,228	402	1,630	14,450	3,000	696,330	0.3	-16%
1891	200	100	28	2219	S4: Plant 50 ha forest	1,242	447	1,689	14,450	3,000	3,899	0.0	-100%
1941	150	100	28	2219	S5: Intensify 100ha in lamb production	1,270	459	1,729	14,450	3,000	888,489	0.4	7%
1891	200	100	28	2219	S6: Plant 50 ha Lusitanica	1,242	447	1,689	12,513	3,000	391,399	0.2	-53%
1891	200	100	28	2219	S7: Plant 50 ha Manuka	1,242	447	1,689	11,788	3,000	536,399	0.3	-35%

Table 30: Marotiri net financial returns

Marotiri Farm Partnership	Farmax Pro		Radiata Calc	Whole property					
Scenario	Pastoral		Forestry	Total enterprise net profit incl. forestry	Per ha net profit incl. forestry	Total enterprise net profit (incl. GHG costs)		Per ha net profit incl. CO_2 costs or revenues	
	EBIT ($ ha/yr)	Gross margin per ha /yr	Annuity ($/ha/yr)	EBIT + Annuity ($/ha/yr)	EBIT ($ effective ha/yr)	EBIT + Annuity ($/ha/yr)	CO_2 cost or revenue ($/ property)	EBIT ($ effective ha/yr)	% change from Base model
Base model	56	379	379	165,546	79	165,546	0	79	0%
S1: Eliminate N fertiliser	51	375	379	155,841	75	155,841	0	75	-6%
S2: 50 sheep :50 beef	67	392	379	186,897	89	186,897	0	89	13%
S3: 60 sheep :40 beef	82	409	379	216,012	103	216,012	0	103	30%
S4: Plant 50 ha forest	56	379	379	181,696	87	181,696	0	87	10%
S5: Intensify 100 ha in lamb production	75	397	379	202,425	97	202,425	0	97	22%
S6: Plant 50 ha Lusitanica	56	379	314	168,746	81	168,746	0	81	2%
S7: Plant 50 ha Manuka	56	379	344	174,746	84	174,746	0	84	6%

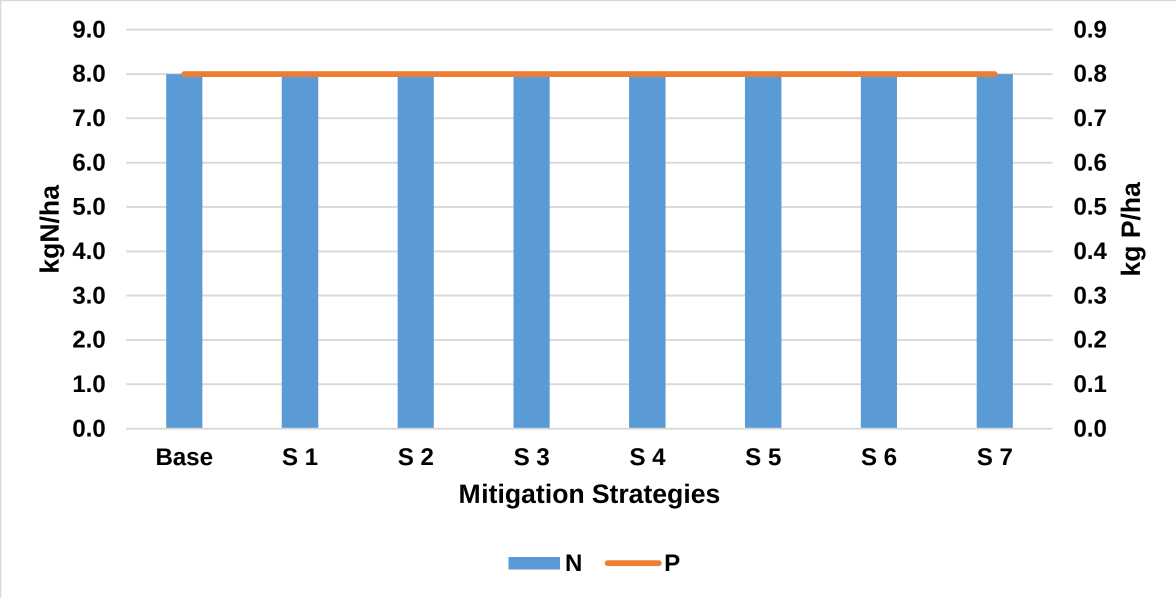
This analysis indicates:

(i) The most profitable scenario is the 60 sheep:40 beef scenario, which increased profitability by 30%, and also decreased GHG emissions by 16%.

(ii) The scenario which decreases GHG emissions the most is via retiring 50 hectares of marginal land; GHG emissions decrease by almost 100%, while profitability increases by 10%. Planting 50 hectares into Lusitanica or Manuka show similar trends, albeit at a lower level.

(iii) Given the annuity from forestry is higher than the current EBIT, the effective breakeven price for carbon is zero.

Figure 20: Nitrogen and phosphorous loss for each mitigation scenario compared to losses on the base farm. Note P loss is shown on the right axis.



The impact of the scenarios on N and P loss for Pukehina is shown in Figure 20 and Table 31. Starting at a low base, these show no effective change in either P or N losses relative to each scenario.

Table 31: Changes in N and P losses for each mitigation scenario compared to losses on the base farm.

	N loss to water (kg N/ha/yr)	P loss to water (kg P/ha/yr)
Base farm	8	0.8
S1	8	0.8
S2	8	0.8
S3	8	0.8
S4	8	0.8
S 5	8	0.8
S 6	8	0.8
S 7	8	0.8

The intensity of CO_2e production (gross CO_2e divided by meat & wool production) for Marotiri is outlined below.

Table 32: Intensity of CO2e production for Marotiri

	Total CO_2 equivalents (kg) (farm only)	Kg of product sold (kg/yr)	Emission Intensity (kg CO_2 equivalent /kg product)	Percentage change in Intensity relative to base
Base farm	3,297,759	262,152	12.6	
S1	3,268,644	259,754	12.6	0%
S2	3,218,178	266,815	12.1	-4%
S3	3,163,830	272,994	11.6	-8%
S4	3,193,899	258,782	12.3	-2%
S5	3,355,989	270,682	12.4	-1%
S6	3,193,899	258,782	12.3	-2%
S7	3,193,899	258,782	12.3	-2%

This shows that emission intensity has improved (i.e. decreased) across all the scenarios apart from eliminate N fertiliser (1). In all other scenarios total emissions have decreased, as has total production, but to a lesser degree. The largest improvement in emission intensity (S3) is as a result of a much-increased number of sheep and decreased cattle numbers.

The impact of the scenarios along with carbon charges of $10/$25 T CO_2e on Marotiri farm profit per are shown below (Table 33).

Table 33: Economic analysis of mitigation scenarios for Marotiri (net profit/ha) – includes CO_2 costs and returns

Scenario	Nil CO_2 Cost	% difference from base	$10 T CO_2e Cost	% difference from nil cost base	$25 T CO_2e Cost	% difference from nil cost base
Base model	$79		$75	-5%	$69	-12%
S1: Eliminate N fertiliser	$75	-6%	$71	-11%	$65	-18%
S2: 50 sheep :50 beef	$89	13%	$86	9%	$80	2%
S3: 60 sheep :40 beef	$103	30%	$100	27%	$95	20%
S4: Plant 50 ha forest	$87	10%	$87	10%	$87	10%
S5: Intensify 100 ha in lamb production	$97	22%	$93	17%	$86	9%
S6: Plant 50 ha Lusitanica	$81	2%	$79	0%	$76	-4%
S7: Plant 50 ha Manuka	$84	6%	$81	3%	$77	-2%

As can be seen from this table, the imposition of a carbon cost has a material impact on farm profitability in the absence of any mitigation strategies.

Carbon Neutral

This is the point where carbon emissions from the farming activity would be totally mitigated by carbon sequestration. Within the project, this was modelled by increasing the area planted in forestry (Radiata pine) until the net GHG emission was essentially zero.

Marotiri currently has 150 hectares of pine plantation, and 100 hectares of reverting scrub which would qualify under the ETS for carbon sequestration (along with 1,780 hectares of native forest and scrub which would not quality).

In order to be carbon neutral, Marotiri would need to plant up a further 51 hectares for forestry (pines).

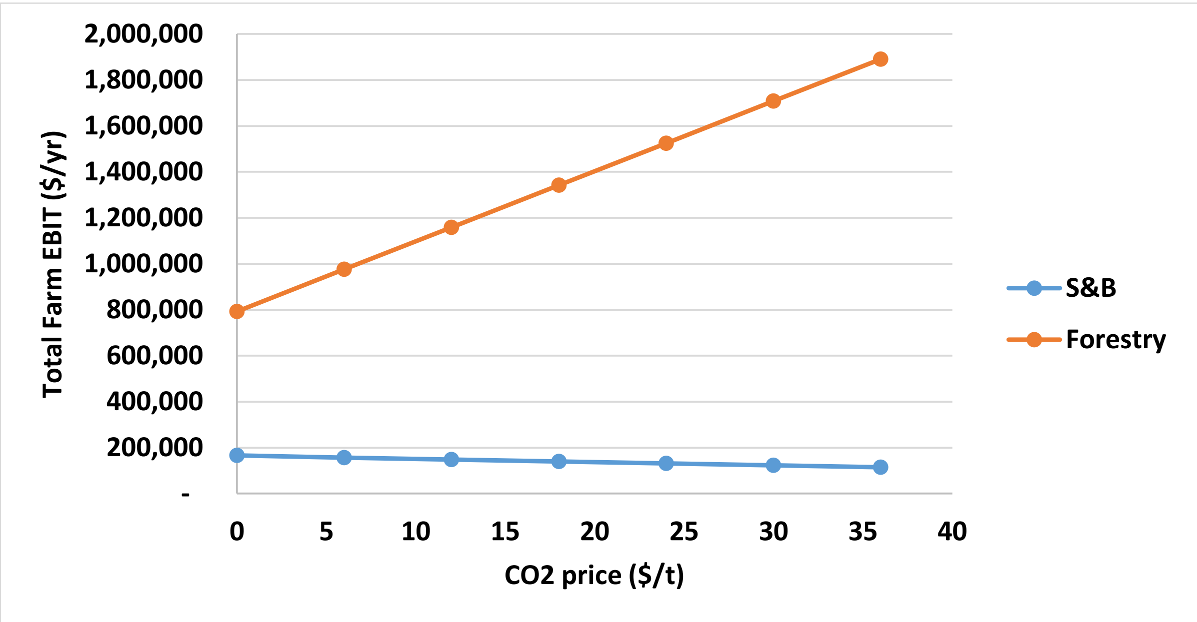
Carbon breakeven price

This is the price of carbon whereby both the (current) returns from forestry plus carbon equal the current profitability level from dairying on Marotiri. For Marotiri, this is somewhat hypothetical, given that the current forestry returns are greater than the farm returns.

Carbon Crossover Point

Under the assumption that a carbon charge is payable by the farm, and no mitigations are carried out, this is the point at which the profitability of sheep and beef (which would decline under an increasing carbon cost) crosses over the profitability of forestry (which would increase under an increasing carbon return). As shown in the figure below, a crossover point does not occur, given that the annuity + carbon return from forestry is greater than the current farm EBIT.

Figure 21: CO_2 Crossover Point for Marotiri



Summary

Seven mitigation scenarios were modelled for the Marotiri sheep and beef farm using Farmax to model the farm systems, Overseer to model the nutrient and GHG discharges, and Radiata Calculator Pro/spreadsheeting to incorporate the carbon sequestration.

A summary of the results show:

Table 34: Marotiri Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	79		0.4		12.6		8	
S1: Eliminate N fertiliser	75	-6%	0.4	-4%	12.6	0%	8	0%
S2: 50 sheep:50 beef	89	13%	0.4	-10%	12.1	-4%	8	0%
S3: 60 sheep:40 beef	103	30%	0.3	-16%	11.6	-8%	8	0%
S4: Plant 50 ha forest	87	10%	0.0	-100%	12.3	-2%	8	0%
S5: Intensify 100 ha in lamb production	97	22%	0.4	7%	12.4	-1%	8	0%
S6: Plant 50 ha Lusitanica	81	2%	0.2	-53%	12.3	-2%	8	0%
S7: Plant 50 ha Manuka	84	6%	0.3	-35%	12.3	-2%	8	0%

15.4 Oromahoe

Six mitigation scenarios were modelled for the Oromahoe sheep and beef farm (Table 35).

Table 35: Oromahoe Mitigation Scenarios

Scenario	Description
S1: Techno system	Adjusted stock numbers and removed 100 ha from the Hupra block for the Techno system to which 40 kgN/ha was applied in August. Increased pasture quality and amount grown on the Techno block and increased the efficiency of cattle. Scaled the current cattle system into the Techno system.
S2: Retire land	30 ha of marginal land was retired and put into pine trees. Stock numbers were scaled back to match feed demand with the decrease in pasture production.
S3: Increase Techno beef area + plant 30 ha in pines	Increase the Techno beef area to 200 hectares, plus plant 30 hectares into pines.
S4: Winter Lambs	500 stock unit equivalents of finishing cattle were replaced with store lambs to be finished for winter/spring slaughter.
S5: Increase Lambing percentage	Lambing percentage was increased from 135% to 160%. This was achieved by increasing ewe weight and autumn weight gain. Lamb losses were reduced and time from lambing to weaning was decreased.
S6: Plant 30 ha in Manuka	30 hectares of marginal land was retired and put into Manuka. Stock numbers were scaled back to match feed demand with the decrease in pasture production.

Table 36: GHG emissions from modelled scenarios (kg CO_2 equivalents/ha/year – farm only)

	CH_4	N_2O	Total CO_2 equiv.	% Change CH_4	% Change N_2O	% change Total CO_2 equiv.
Base	1,965	614	2,579			
S1	2,079	667	2,746	6%	9%	6%
S2	1,917	599	2,516	-2%	-2%	-2%
S3	2,095	706	2,801	7%	15%	9%
S4	1,970	623	2,593	0%	1%	1%
S5	1,958	617	2,575	0%	0%	0%
S6	1,917	599	2,516	-2%	-2%	-2%

The impact of the scenarios on GHG emissions (Figure 14 and Table 36) for Oromahoe shows:

- An increase in GHG emissions as a result of the Techno beef systems.
- A decrease from retiring land; and
- Relatively neutral for wintering more lambs/increasing lambing percentage.

Figure 22: GHG emissions for each mitigation scenario compared to emissions on the base farm.

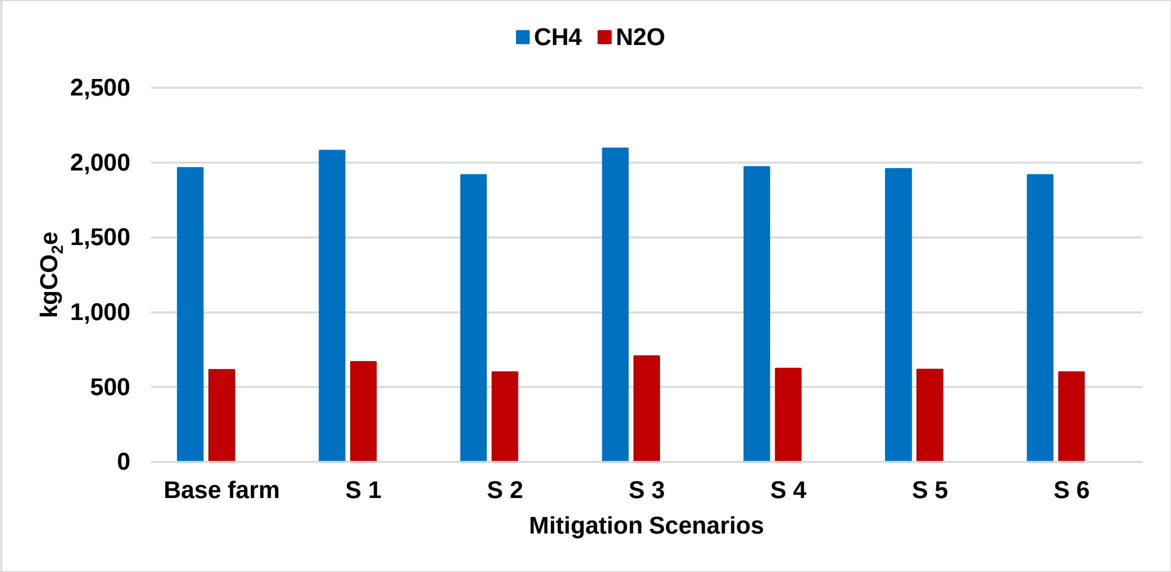
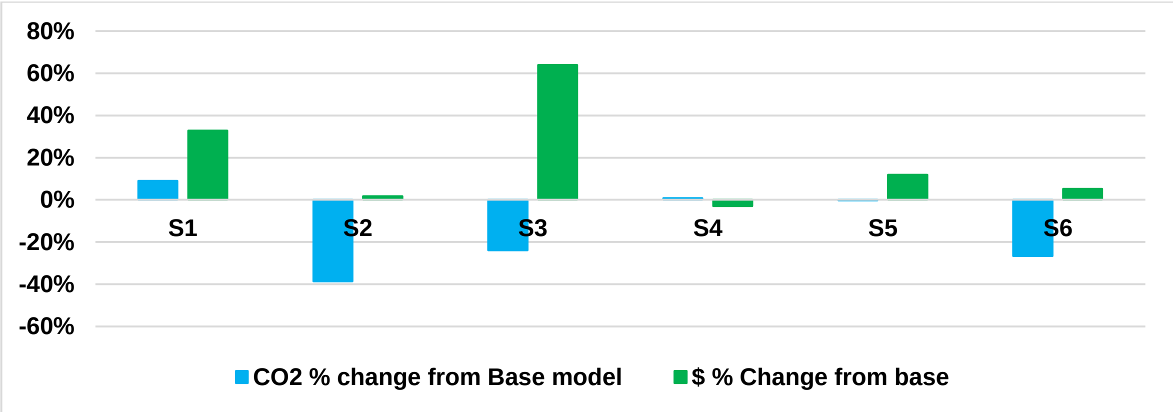


Figure 23: Change in profitability relative to change in CO_2e emissions*



*Includes forestry

This shows that while the Techno beef scenario (S1) has increased both profitability and GHG emissions, doubling the Techno area while at the same time retiring 30 hectares into forestry (S3) has significantly increased profitability while at the same time decreasing GHG emissions.

Retiring land into forestry (S2) or Manuka (S6) has also boosted profitability while reducing GHG emissions (noting that the forestry annuity is very similar to the farm EBIT, and Manuka returns are higher than the farm EBIT).

The wintering lambs' scenario (S4) resulted in a marginal decrease in profitability and a marginal increase in GHG emissions. Increasing the lambing percentage (S5) increased profitability, with a slight decrease in CO_2e emissions.

Inclusion of Carbon Sequestration, and value of Forestry returns

As noted earlier, Overseer does not account for carbon sequestration by trees, and Farmax does not include forestry costs and returns. These have been included separately, building on the results from the Overseer and Farmax modelling.

The results of this are shown in the following tables:

Table 37: Oromahoe net carbon emissions

Oramohoe Trust						Overseer							
Pastoral Area	Plantation Forest	Scrub & Native (eligible for ETS)	Curtilage & Roads	Total property	Scenario	CH_4 emissions	N_2O emissions	Total	CO_2 sequestered/ha		Net CO_2		
						CO_2 equivalents kg/ha			from Radiata pine plantations	from Indigenous forest	Total property net CO_2 (kg)	Net Tonnes CO_2e/ha	% change from Base model
ha	ha	ha	ha	ha									
765	38		136	1,079	Base model	1,965	614	2,579	14,300	0	1,429,535	1.8	
765	38		136	1,079	S1: Techno system (100ha)	2,079	667	2,746	14,300	0	1,557,290	1.9	9%
735	68		136	1,079	S2: Plant 30 ha forest	1,917	599	2,516	14,300	0	876,860	1.1	-39%
735	68		136	1,079	S3: Increase Techno area + plant 30ha forest	2,095	706	2,801	14,300	0	1,086,335	1.4	-24%
765	38		136	1,079	S4: Winter Lambs	1,970	623	2,593	14,300	0	1,440,245	1.8	1%
765	38		136	1,079	S5: Increase Lambing percentage	1,958	617	2,575	14,300	0	1,426,475	1.8	0%
735	68		136	1,079	S6 Plant 30ha manuka	1,917	599	2,516	11,788	0	1,047,676	1.3	-27%

Table 38: Oromahoe net financial returns

Oramohoe Trust	Farmax Pro		Radiata Calc	Whole property					
Scenario	Pastoral		Forestry	Total enterprise net profit incl. forestry	Per ha net profit incl. forestry	Total enterprise net profit (incl. GHG costs)		Per ha net profit incl. CO_2 costs or revenues	
	EBIT ($ ha/yr)	Gross margin per ha /yr	Annuity ($/ha/yr)	EBIT + Annuity ($/ha/yr)	EBIT ($ effective ha/yr)	EBIT + Annuity ($/ha/yr)	CO_2 cost or revenue ($/ property)	EBIT ($ effective ha/yr)	% change from Base model
Base model	222	663	251	179,368	223	179,368	0	223	
S1: Techno system (100 ha)	299	743	251	238,273	297	238,273	0	297	33%
S2: Plant 30 ha forest	225	675	251	182,443	227	182,443	0	227	2%
S3: Increase Techno area + plant 30 ha forest	377	835	251	294,163	366	294,163	0	366	64%
S4: Winter Lambs	215	657	251	174,013	217	174,013	0	217	-3%
S5: Increase Lambing percentage	250	692	251	200,788	250	200,788	0	250	12%
S6 Plant 30 ha Manuka	225	0	344	188,767	235	188,767	0	235	5%

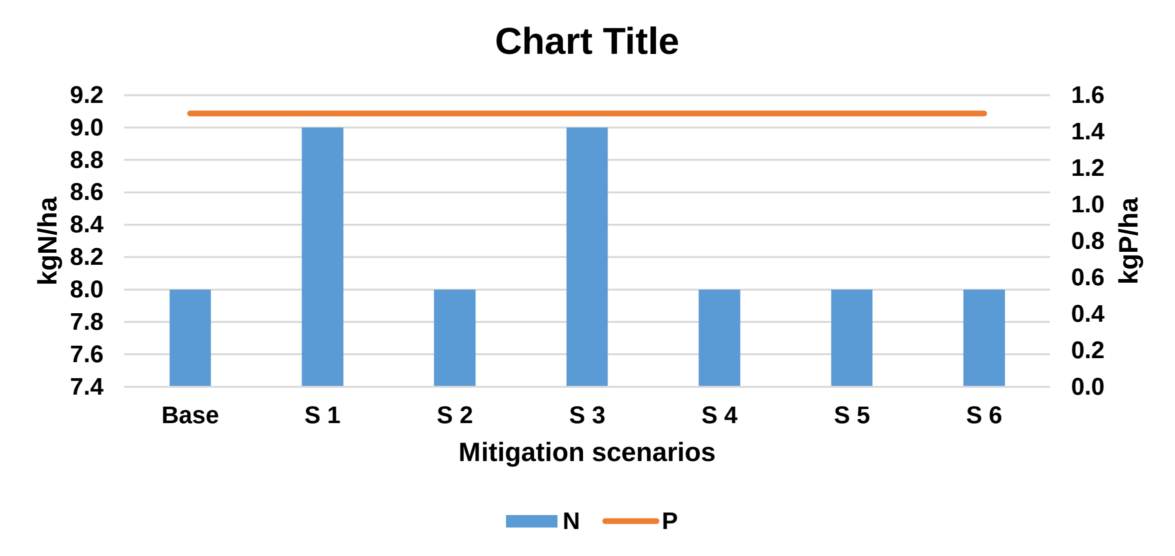
This analysis indicates:

(i) The most profitable scenario is the double Techno beef system (+64% over the base profitability situation), and the inclusion of the 30 hectares of forest results in a -24% decrease in GHG emissions.

(ii) Scenario 2 (plant 30 hectares in trees) has the greatest impact in reducing GHG emissions (39% reduction), but increases profitability by only 2%.

(iii) Given that in the base situation, the annuity from forestry is higher than the current EFS, the effective breakeven price for carbon is zero.

Figure 24: Nitrogen and phosphorous loss for each mitigation scenario compared to losses on the base farm. Note P loss is shown on the right axis.



The impact of the scenarios on N and P loss for Oromahoe is shown in Figure 24 and Table 39. As can be seen, nitrogen losses increased under the techno beef systems, but remained the same for the other scenarios. Meanwhile the phosphorus losses did not vary between scenarios. P loss is relatively high, given that the main soil type on Oromahoe is a Podzol.

Table 39: Changes in N and P losses for each mitigation scenario compared to losses on the base farm.

	N loss to water (kg N/ha/yr)	P loss to water (kg P/ha/yr)
Base farm	8	1.5
S1	9	1.5
S2	8	1.5
S3	9	1.5
S4	8	1.5
S5	8	1.5
S6	8	1.5

The intensity of CO_2e production (gross CO_2e divided by meat and wool production) for Oromahoe is outlined below.

Table 40: Intensity of CO_2e production for Oromahoe

	Total CO_2 equivalents (kg) (farm only)	Kg of product sold (kg/yr)	Emission Intensity (kg CO2 equivalent/kg product)	Percentage change in Intensity relative to base
Base farm	1,972,935	160,900	12.3	
S1	2,100,690	173,064	12.1	-1%
S2	1,849,260	157,764	11.7	-4%
S3	2,058,735	181,702	11.3	-8%
S4	1,983,645	158,547	12.5	2%
S5	1,969,875	163,150	12.1	-2%
S6	1,849,260	157,764	11.7	-4%

This shows that emission intensity has improved (i.e. decreased) across all the scenarios except for the winter lamb scenario. The largest improvement in emission intensity (S2, S3, S6) are where areas have been planted in forestry/Manuka.

While the double Techno beef area (S3) resulted in an increase in emissions as a result of the increased cattle numbers, this has been well offset by the increased level of production.

The impact of the scenarios along with carbon charges of \$10/\$25 T CO_2e on Oromahoe farm profit per hectare are shown below (Table 31).

Table 41: Economic analysis of mitigation scenarios for Oromahoe (net profit/ha) – includes CO_2 costs and returns

Scenario	Nil CO_2 Cost	% difference from base	\$10 T CO_2e Cost	% difference from nil cost base	\$25 T CO_2e Cost	% difference from nil cost base
Base model	\$223		\$206	-8%	\$179	-20%
S1: 100 ha Techno beef system	\$297	33%	\$277	24%	\$248	11%
S2: Plant 30 ha forest	\$227	2%	\$216	-3%	\$200	-10%
S3: Increase Techno area (200 ha) + plant 30 ha forest	\$366	64%	\$353	58%	\$333	49%
S4: Winter Lambs	\$217	-3%	\$199	-11%	\$172	-23%
S5: Increase Lambing percentage	\$250	12%	\$232	4%	\$206	-8%
S6: Plant 30 ha Manuka	\$235	5%	\$222	0%	\$202	-9%

Again the carbon cost has some impact of farm profitability in the absence of any mitigation strategies, with the forestry/Manuka options directly buffering the impact in those scenarios.

Carbon Neutral

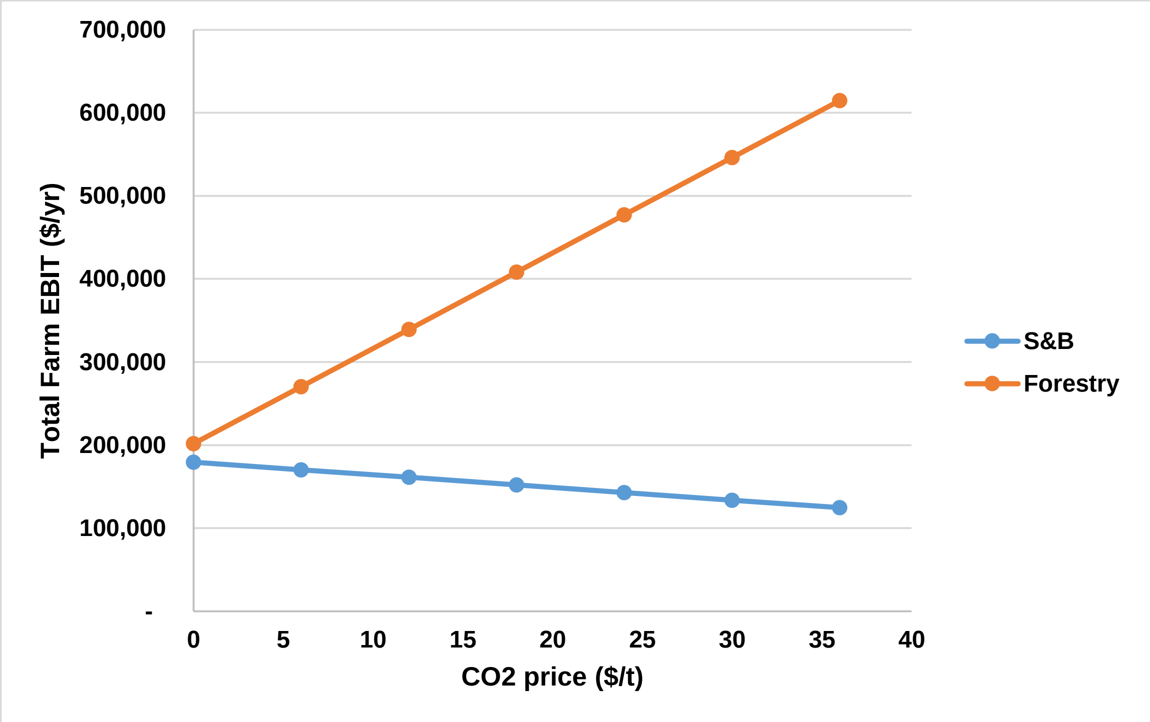
This is the point where carbon emissions from the farming activity would be totally mitigated by carbon sequestration. Within the project, this was modelled by increasing the area planted in forestry (Radiata) until the net GHG emission was essentially zero.

For Oromahoe, the area required to be planted to achieve carbon neutrality would be 123 hectares. Currently they have 38 hectares in pine forest, which means an extra 85 hectares would need to be planted. Note Oromahoe has 140 hectares in scrub and native forest, but none of this qualifies under the ETS.

Carbon Crossover Point

Under the assumption that a carbon charge is payable by the farm, and no mitigations are carried out, this is the point at which the profitability of sheep and beef (which would decline under an increasing carbon cost) crosses over the profitability of forestry (which would increase under an increasing carbon return). As shown in the figure below, a crossover point does not occur, given that the annuity + carbon return from forestry is greater than the current farm EBIT.

Figure 25: CO_2 Crossover Point for Oromahoe



Summary

Six mitigation scenarios were modelled for the Oromahoe sheep and beef farm using Farmax to model the farm systems, Overseer to model the nutrient and GHG discharges, and Radiata Calculator Pro/spreadsheeting to incorporate the carbon sequestration.

A summary of the results show:

Table 42: Oromahoe Modelling results (relative to base scenario)

	Per ha net profit incl. CO_2 costs or revenues	% change from base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	$223		1.8		12.3		8	
S1: 100 ha Techno beef system	$297	33%	1.9	9%	12.1	-1%	9	13%
S2: Plant 30 ha forest	$227	2%	1.1	-39%	11.7	-4%	8	0%
S3: Increase Techno area (200 ha) + plant 30 ha forest	$366	64%	1.4	-24%	11.3	-8%	9	13%
S4: Winter lambs	$217	-3%	1.8	1%	12.5	2%	8	0%
S5: Increase lambing percentage	$250	12%	1.8	0%	12.1	-2%	8	0%
S6: Plant 30 ha Manuka	$235	5%	1.3	-27%	11.7	-4%	8	0%

16.0 EMBEDDED CO_2E

16.1 Embedded CO_2e calculated within Overseer

Within Overseer, a range of embedded CO_2 emissions are calculated, as illustrated earlier in Table 43. These are reproduced below.

Table 43: Embedded CO_2 emissions as calculated within Overseer.

	Pukehina	Te Rua o Te Moko	Oromahoe	Marotiri
Total CO_2 emissions	**911**	**1744**	**150**	**26**
Electricity	130	120	2	1
Fuel	90	85	22	15
N fertiliser	302	663	15	7
Fertiliser and organic inputs	111	204	40	1
Lime	3	54	70	0
Supplements	169	464	0	0
Animal transport	3	0	0	2
Other	104	154	1	0

16.2 Embedded CO_2e in Supplementary Feed

In a number of the dairy farm system scenarios, either extra or much less supplementary feed was brought into the farm as a result of the changes in the farm system. This supplementary feed would include 'embedded CO_2' within it, which, although the farmers are not liable for this under the ETS, needs to be included if a wider Life Cycle Analysis (LCA) approach is taken to give a truer picture of the wider GHG emissions involved in the farming system. This is particularly so given that some of the CO_2e calculations within Overseer include embedded CO_2 in energy and fertiliser.

The embedded CO_2e within the various feeds is shown in the table below.

Table 44: Embedded CO_2e within various supplementary feeds (kg CO_2e/kgDM)

Palm Kernel Expeller (PKE)	1.20
Maize silage	0.19
Compound feed	0.35
Pasture Silage	0.20
Barley grain	0.35

Source: S Ledgard, AgResearch, pers comm.

The above figures extend from the seed used for sowing through to harvesting and transport to farm. It also includes the nitrous oxide (N_2O) emissions from the harvested crop residues. Inventory for this partial LCA includes the upstream processes, i.e. the production, transportation and application of inputs (seeds, pesticides, fertilisers and diesel) as well as the emissions from the use of these inputs.

For Palm Kernel Expeller (PKE), it includes land use change (deforestation), plus shipping and processing emissions, with total GHG emissions partitioned between palm oil and PKE.

Based on the figures in Tables 45 and 46, the effect of the embedded CO_2e for the differing scenarios for the Pukehina and Te Rua o Te Moko dairy farms, are shown below.

Table 45: Pukehina: Effect of embedded CO_2e (T/ha)

	Base CO_2e Emissions T/ha	% change	Embedded CO_2e as calculated in Overseer (T/ha)	Embedded CO_2e in bought in supplementary feed (T/ha)	Total emissions including embedded CO_2e (T/ha)	% change from new base
Base model	9.7		0.9	0.3	10.9	12%
S1: Remove summer and autumn crops and replace with supplements	9.8	1%	1.4	1.3	12.5	15%
S2: Partial wintering facilities	9.7	1%	0.9	0.5	11.1	2%
S3: In-shed feeding with increased cow numbers	10.7	11%	1.2	1	12.9	19%
S4: In-shed feeding with young stock on milking platform	11.2	16%	1.1	0.7	13.0	20%
S5: Lower stocking rate	9.7	0%	0.8	0	10.5	-3%
S6: Plant 3 ha forest	9.2	-5%	0.9	0.3	10.4	-4%

Table 46: Te Rua o Te Moko: Effect of embedded CO_2e (T/ha)

	Base CO_2e Emissions T/ha	% change	Embedded CO_2e as calculated in Overseer (T/ha)	Embedded CO_2e in bought in supplementary feed (T/ha)	Total emissions including embedded CO_2e (T/ha)	% change from new base
Base model	9.0		1.7	1.6	12.3	37%
S1: Replace maize	9.1	1%	1.7	1.6	12.4	1%
S2: Replace N fertiliser	8.0	-11%	1.5	1.9	11.4	-7%
S3: Eliminate N fertiliser	6.9	-24%	1.1	1.6	9.5	-22%
S4: Remove crops	9.3	3%	1.7	1.7	12.7	3%
S5: Plant 2 ha forest	8.7	-3%	1.7	1.6	12.0	-2%
S6: In-shed feeding	9.9	10%	2	2.4	14.3	16%

These show:

(i) An (obvious) increase in total CO_2e emissions from the farms.

(ii) A general increase in the proportional differences for the Pukehina scenarios, mainly due to very little bought-in supplementary feed in the base farming situation.

(iii) Relatively small proportional changes for Te Rua o Te Moko for most of the scenarios given relatively small changes in the amount of bought-in feed between the scenarios, with the exception of the 'in-shed feeding' scenario where significant amounts of extra bought-in feed has occurred.

Table 47: Marotiri: Effect of embedded CO_2e (T/ha)

	Base CO_2e Emissions T/ha	% change	Embedded CO_2e as calculated in Overseer (T/ha)	Embedded CO_2e in bought in supplementary feed (T/ha)	Total emissions including embedded CO_2e (T/ha)	% change from new base
Base model	0.4		0.03	0	0.43	8%
S1: Eliminate N fertiliser	0.4	0%	0.02	0	0.42	-2%
S2: 50 sheep:50 beef	0.4	0%	0.03	0	0.43	0%
S3: 60 sheep:40 beef	0.3	-25%	0.03	0	0.33	-23%
S4: Plant 50 ha forest	0.0	-100%	0.03	0	0.03	-93%
S5: Intensify 100 ha in lamb production	0.4	0%	0.03	0	0.43	0%
S6: Plant 50 ha Lusitanica	0.2	-50%	0.03	0	0.23	-47%
S7: Plant 50 ha Manuka	0.3	-25%	0.03	0	0.33	-23%

Table 48: Oromahoe: Effect of embedded CO_2e (T/ha)

	Base CO_2e Emissions T/ha	% change	Embedded CO_2e as calculated in Overseer (T/ha)	Embedded CO_2e in bought in supplementary feed (T/ha)	Total emissions including embedded CO_2e (T/ha)	% change from new base
Base model	1.8		0.15	0	2.0	8%
S1: Techno system (100 ha)	1.9	6%	0.17	0	2.1	6%
S2: Plant 30 ha forest	1.1	-39%	0.15	0	1.3	-36%
S3: Increase Techno area (200 ha) + plant 30 ha forest	1.4	-22%	0.19	0	1.6	-18%
S4: Winter lambs	1.8	0%	0.15	0	2.0	0%
S5: Increase lambing percentage	1.8	0%	0.15	0	2.0	0%
S6: Plant 30 ha Manuka	1.3	-28%	0.15	0	1.5	-26%

These show:

(i) Again an increase in the total CO_2e emissions.

(ii) Relatively minor proportional changes between the scenarios and the base figures. Oromahoe changes tend to be larger due to the effect of greater levels of fertiliser and lime applied compared with Marotiri.

17.0 FINANCIAL CAPITAL CONSIDERATIONS

As noted earlier, the requirement for extra capital or the release of capital, as a result of the scenarios, has not been included within the impact on EBIT.

Nevertheless, capital considerations could play a significant part in whether the focus farms looked to adopt the scenario in question, particularly those requiring significant additional capital. Given the scenarios are changes in farm systems, the changes in capital are very largely related to changes in livestock numbers, and the establishment costs for afforestation and Manuka.

The capital costs involved for the focus farms have been calculated as follows.

Assumptions

(i) Changes in stock numbers were valued at the 2016 IRD Herd Scheme tax values.

(ii) A feed pad was allowed for on Pukehina. The cost of such structures can vary widely, depending on such aspects as the degree of earth works required, flooring arrangements (e.g. concrete, sawdust), and effluent requirements. Typical costs vary from $300 - $1,000/cow. For the purposes of this analysis a mid-point cost of $650/cow was used.

More sophisticated structures (aka wintering barns) plus in-shed feeding systems could easily cost $2,000 - $3,000/cow.

(iii) In-shed feeding systems cost between $800 and $1,000 per set of cups within the milking shed. For the purposes of this analysis a mid-point cost of $900/set of cups was used.

(iv) Afforestation establishment costs were based on the costs provided by Scion:

Site prep	$400
Planting	$800
Spot release spray	$220
Total	**$1420/ha**

(v) The costs for establishing Manuka were based on the ANZ October 2015 report on Manuka honey (ANZ 2015) which estimated establishment costs at $1,600 - $2,500/ha. A mid-point of $2,050 was assumed in this analysis.

The results show:

Table 49: Estimated capital requirements/capital released for the mitigation scenarios

Scenario	Pukehina	Te Rua o Te Moko	Marotiri	Oromahoe
S1	$0	$0	$22,954	$138,410
S2	$292,500	$0	$138,837	$58,999
S3	$31,500	-$115,308	$361,977	$160,282
S4	$72,180	$0	$32,801	-$23,559
S5	-$65,790	$2,840	$31,350	$16,923
S6	$4,260	$60,460	$103,801	$77,899
S7			$135,301	

As can be seen from the above table, capital costs vary widely depending on the scenarios. For the dairy farms, the higher costs are more associated with provision of infrastructure, e.g. feed pads or in-shed feeding systems, whereas for the sheep and beef farms the higher costs are associated with forestry/Manuka development, or the provision of infrastructure, e.g. the fencing etc. for the Techno beef systems, or capital fertiliser inputs.

In some instances, there is a release of capital as stock numbers are reduced.

The above capital costs have been translated into a cost of carbon mitigation relative to the scenarios modelled, using a 5% interest rate, as outlined below.

Table 50: Capital carbon mitigation costs ($/T CO_2e/yr)

Scenario	Pukehina	Te Rua o Te Moko	Marotiri	Oromahoe
S1	$0.00	$0.00	$1.49	$5.08
S2	$9.79	$0.00	$9.33	$1.99
S3	$1.06	-$4.23	$25.97	$9.59
S4	$2.20	$0.00	$2.54	-$1.14
S5	-$1.92	$0.09	$433.09	$0.62
S6	$0.14	$2.04	$6.29	$2.87
S7			$18.62	

18.0 COMPARISON OF THE COST OF CO_{2E} EMISSIONS RELATIVE TO EMISSION FACTOR CALCULATION

Emission factors have been specified in the Climate Change Response (Emissions Trading and Other Matters) Amendment Act 2012. These were developed for the purpose of reporting and surrendering obligations under the New Zealand ETS, using a methodology that yields consistency with New Zealand's Greenhouse Gas Inventory (Ministry for Primary Industries, 2012)[8].

Table 51: Emission factors in agriculture

Activity	Tonnes CO_2e
Livestock Slaughter	
Per tonne carcass weight cattle	12.70
Per tonne carcass weight sheep	12.70
Dairy processing of milk	
Per tonne milksolids	8.50
Synthetic fertiliser use	
Per tonne nitrogen	5.72

These factors have been used to calculate the cost of CO_2e emissions from the focus farms, relative to those calculated via Overseer, using a carbon cost of \$10/T CO_2e.

The key assumption is that the total CO_2e emissions from the focus farms is the CH_4 + N_2O produced from animals, over the area in pasture. All embedded CO_2 has been removed.

The results show (detail in Appendix 2):

[8] Ministry for Primary Industries. 2012. "Updating the Regulations for Agriculture in the New Zealand Emissions Trading Scheme," MPI Discussion Paper No: 2012/12, Ministry for Primary Industries, Wellington.

Table 52: Cost per hectare between the calculated CO_2e emission cost using the emission factors, and a direct carbon cost based on the emissions calculated by OVERSEER

	$10/TCO₂e				$25/TCO₂e				$50/TCO₂e			
	Direct Application ($/ha)	Via Emission factor ($/ha)	Difference ($/ha)	Difference (%)	Direct Application ($/ha)	Via Emission factor ($/ha)	Difference ($/ha)	Difference (%)	Direct Application ($/ha)	Via Emission factor ($/ha)	Difference ($/ha)	Difference (%)
Pukehina	$97.00	$84.64	-$12.36	-13%	$242.50	$211.61	-$30.89	-13%	$485.00	$423.21	-$61.79	-13%
Te Rua o te Moko	$95.00	$118.21	$23.21	24%	237.5	$295.52	$58.02	24%	$475.00	$591.03	$116.03	24%
Marotiri	$17.00	$17.35	$0.35	2%	$42.50	$43.39	$0.89	2%	$85.00	$86.77	$1.77	2%
Oromahoe	$26.00	$27.18	$1.18	5%	$65.00	$67.96	$2.96	5%	$130.00	$135.91	$5.91	5%

As can be seen from this table, the absolute cost/ha varies with increasing CO_2e costs, while the percentage difference remains the same.

19.0 EFFECT OF MĀORI FARM STRUCTURE ON CO_2E EMISSIONS

The four focus farms were selected as representative entities of the 29 entities in the network. Selection of these farms was based on three simple criteria: (i) farm type (ii) structure; and (iii) location. Two dairy farms needed to be selected located in four regions of the North Island with high proportion of Māori land (see table below).

Table 53: Focus farms; Farm Type, Structure and Location

Entity	Farm Type	Structure	Location
Rua te Moko Ltd	Dairy	Limited liability company	Taranaki/Whanganui
Pukehina M3 Trust	Dairy	Ahu Whenua Trust	Bay of Plenty/Waiariki
Oromahoe Trust	S&B	Ahu Whenua Trust	Northland/Taitokerau
Marotiri Partnership	S&B	Partnership	East Coast/Tairawhiti

The three ownership structures chosen were a compromise, but the selection proved to be representative of the main structures in the pastoral sector. Ahu whenua trusts are the dominant structure and so it was appropriate that two out of the four were these structures. Companies have become more common in recent years, especially as a vehicle established under treaty settlements or a collaboration among landowning hapu, and partnerships have also increased in use. The Marotiri partnership represents Ahu whenua trusts and incorporations.

While ownership structure is often assumed to be a key driver in the decision-making behaviour of the governing boards, the level of influence is often affected more by three key factors:

(i) Legislation governing the entity

(ii) Ownership of the entity

(iii) Governance characteristics

Each of the farms have farm consultants.

RUA O TE MOKO

Five directors appointed to the company including the accountant for Parinihi ki Waitotara, and a very experienced research scientist. The company structure enables the directors to focus on the commercial priorities of the owners - four hapu landowning groups. Administration of the entity is carried out by Te Tumu Paeroa (Māori Trustee).

PUKEHINA M3

Trust administration carried out by Te Tumu Paeroa. Owner representatives are advisory trustees but the control of the entity lies with TTP.

OROMAHOE TRUST

Ahu Whenua Trust with seven trustees that maintain very good communication with the owners and have strong leadership from the chair.

Marotiri Partnership
Governance is made up of representatives of the landowning entities. Governance capability has a relatively high reliance on their farm consultants, AgFirst Gisborne.

The focus farms share a number of characteristics with Māori land owning entities around the country. The main attribute is that they have representative owners that are charged with making strategic decisions on the direction of the organisation.

Applying the results of this work to other Māori entities around the country will be similar to applying the results of any trial research in the pastoral sector to the wider farming community. The pastoral sector has a huge range of farm types, structures, scale etc. The Māori sector is no different.

What is important is that the research is relevant, and that the results are communicated using tools and media formats that ensure maximum exposure. One of the reasons for partnering with Te Tumu Paeroa is that they have a national network of farms and have become more influential in recent years within the Māori agribusiness sector.

Typology Criteria
Given the specific focus on greenhouse gas emissions and mitigation, there is a need to understand the key drivers for emissions and likely mitigation options. However, it was decided that this information should not be part of the typology criteria, but information to be collected later in the research programme.

The selection of Māori farms from within these three categories relies on access to databases with Māori farms located across the country. Because much of the information needed to identify and contact farming entities is held privately and is confidential, the typology matrix required access to information that is not in the public arena. This meant that the identification of farms would not follow any rules of statistical sampling and therefore could not be considered to be a representative sample. Instead they were identified using the existing networks of Māori land entity collectives and knowledge of the sector from advisors and consultants working in the Māori pastoral agriculture sector.

The matrix used to guide the selection of 30 representative Māori farms was based essentially on three components: (i) geographic spread of the farms (based on the Māori Land Court regions), (ii) farming enterprise (based on the two main pastoral agricultural systems, (i.e. beef and lamb, and dairy); and (iii) ownership structure.

Geographic Spread
Māori land under the Te Ture Whenua Māori Act is managed under seven Māori Land Court districts and outlined in several papers. Given the uneven spread of Māori land across the seven districts the number of entities selected were consistent with this distribution, i.e. a higher number of entities were selected in Taitokerau, Tairawhiti and Waiariki districts.

Farming Enterprise
The entities were selected on their main land use or business enterprise, i.e. dairy or sheep and beef. This may be an oversimplified description of these organisations given that some have exotic forestry interests, indigenous forests and other land uses including horticulture. Many of these alternative land uses will contribute to the sequestering of carbon thereby lowering the total carbon footprint. Given however, that the key research objective is the effectiveness of mitigation strategies that reduce both total carbon emissions for the property as well as the efficiency of the farming operation to reduce the

volume of carbon per unit of output, the decision was to identify standard pastoral agriculture properties that produce the highest levels of carbon, i.e. dairy and sheep and beef.

Ownership Structures

Defining Māori farmers is often done using one of two approaches (or a combination of both), (i) the ethnicity of the owner of the farm; and/or (ii) the tenure status of the land. However, defining Māori farmers as a 'person of Māori ethnicity that owns a farm and produces farm produce' is problematic. Many industries do not record the ethnicity of farmers. More consistent and less problematic, although there are issues, is to define Māori farmers as entities that own Māori land under the Te Ture Whenua Māori Act (Māori Land Act) 1993, or land that is owned by an iwi authority or post (Treaty) settlement governance entities (PSGEs).

The Post-Settlement Governance Entity (or PSGE) has emerged in recent years through the ongoing Treaty Settlement process. This type of entity may be entirely new or built on previous entities, notably Māori Trust Boards or 'Mandated Iwi Organisation' (MIO), with the latter being the primary recipients of fisheries quota assets allocated via the Treaty fisheries settlement. In addition, numerous iwi and hapu entities have established businesses as providers of social services, notably health, education and welfare. The net result is a diverse range of Māori organisations in addition to the land-owning trusts and incorporations under the Te Ture Whenua Māori Act.

These new iwi-hapu entities have a wider mandate from their tribal constituents and many are leading investment into new technologies and land use change that the more conservative trust and incorporations would not contemplate. Several recent Treaty settlements have involved the transfer of government-owned farms to iwi as part of the settlement process. These purchases or transfers to iwi are likely to continue into the future and as such the number of large scale farms that are owned by Māori will increase over time.

19.1 Categorising Māori farms according to scale, diversity and ownership

The categorisation of Māori farming adopted applied a combination of the ethnicity of the owners in combination with the legal status of the land. For the purposes of developing the kāhui these criteria provide a useful guideline that acknowledges the diversity of tenure and governance structures:

A. Entities that own or manage pastoral land that is defined as Māori land under Te Ture Whenua Māori Act 1993 (e.g. Māori Incorporations and Trusts).

B. Organisations that administer land defined as General Land where these organisations are owned by Māori (e.g. PSGEs).

C. Individual Māori that own or manage pastoral land.

Within these three ownership categories, Māori farming activity could vary significantly. The main categories of farming activity, scale and organisational complexity can be represented as:

Category 1 - Multiple farms, multiple enterprise, multiple structures (TTWMA) plus limited liability company/companies;

Category 2 - Multiple farms, multiple enterprise, single governance structure;

Category 3 - Single farm, multiple enterprise, single governance structure;

Category 4 - Single farm, single enterprise; and

Category 5 - Owner operator

An earlier section outlined the large areas of land that are either governed by small entities or they do not have a governance structure at all. For many of these properties there are issues that currently take precedence over GHG mitigation and it was therefore pragmatic to select farms that employed a consultant, advisor or other individual to assist with the compilation of data. Criteria for selection and invitation into the programme therefore include:

(a) Farms need to fall into one of the categories (1-5) outlined above.

(b) Farms need to fall into one of the groups (A, B or C) outlined above.

(c) Pastoral agriculture, e.g. dairy or sheep and beef should be the dominant enterprise in the farm business.

(d) Scale or size of the farm is not critical but the farm should be at least the minimum size for an economic unit, i.e. able to support full-time management staff, and a range of sizes was targeted.

(e) Geographical spread across tribal regions is preferable.

More dairy farms were selected relative to their proportion of total Māori farms because of the recent trend in dairy conversions and their higher level of GHG emissions. Varying proportions of effective farm area and existing forestry area were also desirable given their effect on farm mitigation potential. It was hoped that the selection criteria would be sufficient to result in a broad range of farm emissions (GHG intensity and total property GHG) as well as identifying a range of feasible mitigation options.

It should be noted that 'cultural values' were not used to differentiate farms or as a basis for selection, and farms were not surveyed for values/aspirations/objectives. This will be carried out in a later stage of the research. A description of a range generic values, as outlined in this section, was given to provide the cultural context that these organisations function within, and the cultural influences on investment decisions and management practices will vary across the group of 29 organisations/farms.

Summary

As can be seen from the results in this report, and the analysis of the remaining 25 profile farms, there is no direct correlation between farm typology and GHG emissions. Overall, farm performance is very much more driven by the capability of governance and management than by the structure of the business.

20.0 MODELLING CONCLUSIONS/DISCUSSION

The impact of the various mitigation scenarios had a widely varying impact on CO_2e emissions. While many had a relatively small impact (0-10%), a number had a more significant effect.

The relationship between changes in profitability and change in GHG emissions varied somewhat. As a generalisation if the change in farm system improved profitability, often GHG emissions also increased, and if GHG emissions decreased, then often profitability decreased.

The effect on CO_2e emissions and profitability are summarised in the following tables:

Table 54: Summary of Pukehina modelling

	Per ha net profit incl. CO_2 costs or revenues	% change from Base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base Model			9.7		9.6		27	
S1: Remove summer and autumn crops and replace with supplements		4%	9.8	1%	9.5	-1%	25	-7%
S2: Partial wintering facilities		0%	9.7	1%	9.6	0%	27	0%
S3: In-shed feeding with increased cow numbers		12%	10.7	11%	8.8	-9%	28	4%
S4: In-shed feeding with young stock on the milking platform		-52%	11.2	16%	10.8	12%	37	37%
S5: Lower stocking rate		14%	9.7	0%	9.0	-7%	26	-4%
S6: Plant 3 ha forest		-1%	9.2	-5%	9.5	-2%	27	0%

Note: Actual $ net profit/ha figures are confidential

Table 55: Summary of Te Rua o Te Moko modelling

	Per ha net profit incl. CO_2 costs or revenues	% change from Base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	$2,021		9.0		7.7		27	
S1: Replace maize with fodder beet	$2,058	2%	9.1	1%	7.8	1%	26	-4%
S2: Replace N fertiliser with bought-in feed	$1,663	-18%	8.0	-11%	6.9	-10%	19	-30%
S3: Eliminate N Fertiliser	$1,629	-19%	6.8	-24%	6.9	-10%	18	-33%
S4: Remove crops	$2,160	7%	9.3	3%	7.9	3%	25	-7%
S5: Plant 2 ha forest	$2,004	-1%	8.7	-3%	7.7	-1%	27	0%
S6: In-shed feeding	$2,203	9%	9.9	10%	7.6	-1%	33	22%

Table 56: Summary of Marotiri Modelling

	Per ha net profit incl. CO_2 costs or revenues	% change from Base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	79		0.4		12.6		8	
S1: Eliminate N fertiliser	75	-6%	0.4	-4%	12.6	0%	8	0%
S2: 50 sheep:50 beef	89	13%	0.4	-10%	12.1	-4%	8	0%
S3: 60 sheep:40 beef	103	30%	0.3	-16%	11.6	-8%	8	0%
S4: Plant 50 ha forest	87	10%	0.0	-100%	12.3	-2%	8	0%
S5: Intensify 100 ha in lamb production	97	22%	0.4	7%	12.4	-1%	8	0%
S6: Plant 50 ha Lusitanica	81	2%	0.2	-53%	12.3	-2%	8	0%
S7: Plant 50 ha Manuka	84	6%	0.3	-35%	12.3	-2%	8	0%

Table 57: Summary of Oromahoe modelling

	Per ha net profit incl. CO_2 costs or revenues	% change from Base model	Total property net CO_2e (T/ha)	% change from base model	Emission Intensity (kg CO_2e/kg product)	% change from base model	N Leaching (kgN/ha/yr)	% change from base model
Base model	$223		1.8		12.3		8	
S1: 100 ha Techno beef system	$297	33%	1.9	9%	12.1	-1%	9	13%
S2: Plant 30 ha forest	$227	2%	1.1	-39%	11.7	-4%	8	0%
S3: Increase Techno area (200 ha) + plant 30 ha forest	$366	64%	1.4	-24%	11.3	-8%	9	13%
S4: Winter lambs	$217	-3%	1.8	1%	12.5	2%	8	0%
S5: Increase lambing percentage	$250	12%	1.8	0%	12.1	-2%	8	0%
S6: Plant 30 ha Manuka	$235	5%	1.3	-27%	11.7	-4%	8	0%

There is some difference in intensity of GHG emissions, mainly between the two dairy farms, whereas the two sheep and beef farms are reasonably similar, as illustrated below.

Table 58: Intensity of production; base farming systems.

	Intensity of GHG emissions (kg CO_2e/kg produced)
Pukehina	9.6
Te Rua o Te Moko	7.7
Oromahoe	12.3
Marotiri	12.6

The difference between the two dairy farms is because Te Rua o Te Moko is run more intensively.

The difference between the two sheep and beef farms is mainly due to the more intensive production level (per hectare) from Oromahoe.

As can be seen from Tables 54-57, the relationship between total CO_2e emission and the corresponding intensity of emission across the different scenarios for each farm is variable.

The correlation between absolute and intensity of emissions is shown below. This relates to the change in absolute emissions versus the corresponding change in intensity, across the different scenarios for each farm.

Table 59: Correlation between absolute emissions compared with intensity of emissions

Farm	Correlation
Pukehina	0.43
Te Rua o Te Moko	0.83
Marotiri	0.02
Oromahoe	0.77

Often the intensity of GHG emissions decreased if the farming intensity increased; the increase in production was greater than the increase (usually) in GHG emissions, meaning overall intensity decreased. Overall, the correlation between absolute and intensity is (a) poor, and (b) very variable.
The impact of planting an area up in trees was limited on the dairy farms, given the very limited area available for such a strategy. If carbon prices are low (e.g. <$10 tonne), then it would be cheaper for the farms just to pay this, whereas if carbon prices rise, then the option of buying land elsewhere and planting trees on this as a carbon sink is a possibility.

For the sheep and beef farms the situation is different - both had significant areas that could be planted in trees. As the analysis showed, Oromahoe would be carbon neutral if a further 80.5 hectares was planted in trees, and Marotiri would be carbon neutral if a further 104 hectares was planted in trees (at least for the first rotation of the trees).

In subsequent discussions with the focus farm trustees, while they were interested in reducing GHG emissions, they were loath to do this at any significant cost to profitability. Oromahoe trustees were very interested in the combination of developing a 200 hectare Techno beef system, which would significantly enhance profitability, combined with planting up 30 hectares of trees, which would mitigate the increased CO_2e emissions. Marotiri trustees were very interested in expanding their area in Manuka, mainly for profitability reasons, but with the added bonus of creating carbon credits.

The advent of a carbon cost for farm-level emissions would directly impact on farm profitability, as summarised below.

Table 60: Summary of the impact of a carbon cost on farm profitability, assuming no mitigation strategies; % change in farm EBIT.

Farm	$10/T CO_2e	$25/T CO_2e
Pukehina	-8%	-20%
Te Rua o Te Moko	-4%	-11%
Marotiri	-5%	-12%
Oromahoe	-8%	-20%

Note: This reflects the full impost of the carbon cost – under the current ETS rules the cost would be imposed gradually.

The impact of Māori farm typology was minimal – farm performance is very much more driven by the capability of governance and management than by the structure of the business.

21.0 INTEGRATION OF A MODELLING FRAMEWORK

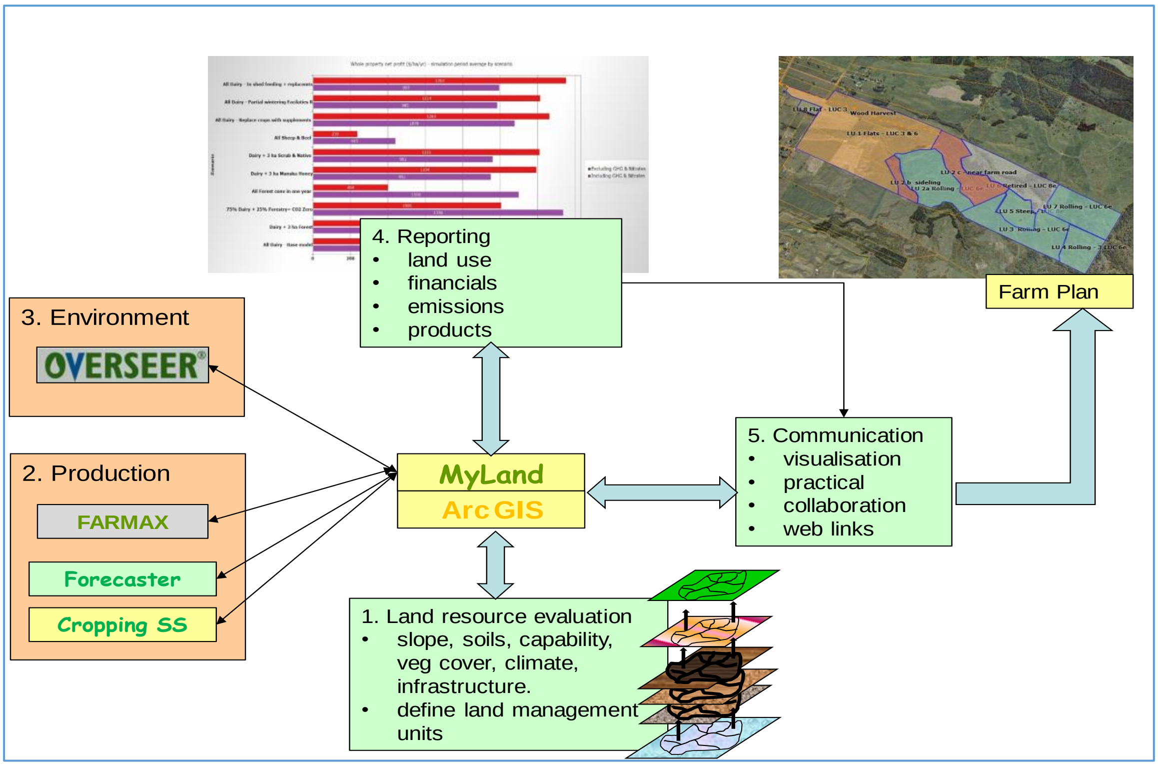
As outlined, the modelling process involved a range of models - Farmax for farm systems and farm economics, OverseerFM® for GHG and nutrient emissions, Radiata Pine Calculator for forestry economics and carbon sequestration levels, all of which was pulled together and summarised/integrated for each farm within an Excel spreadsheet.

This involved a lot of manual transfer of information, particularly from Farmax into Overseer, and from all models into the spreadsheet. In discussion with the focus farms, and other farmers at the field days (discussed below), they were looking for information and mitigations at a whole farm level, i.e. how the mitigation impacted the farm system, and how it might affect the farm spatially.

In order to achieve a better integration as well as geospatial capability, the project decided to use and enhance the MyLand programme, developed by Scion. MyLand is a web based framework that uses geospatial information (property boundaries, infrastructure, soils, slope, productivity, etc.) to determine management units and apply scenario analysis (with costs and prices) with resultant whole property cashflows, environmental impacts, and associated economic metrics for long term planning.

MyLand was enhanced to accept output from Overseer and Farmax and to include these values into a whole property cash flow and environmental footprint which incorporated a carbon balance and nitrate loss to ground water. Figure 26 below provides a schematic of how the integration works and how this leads to a farm plan.

Figure 26: Structure of the MyLand System



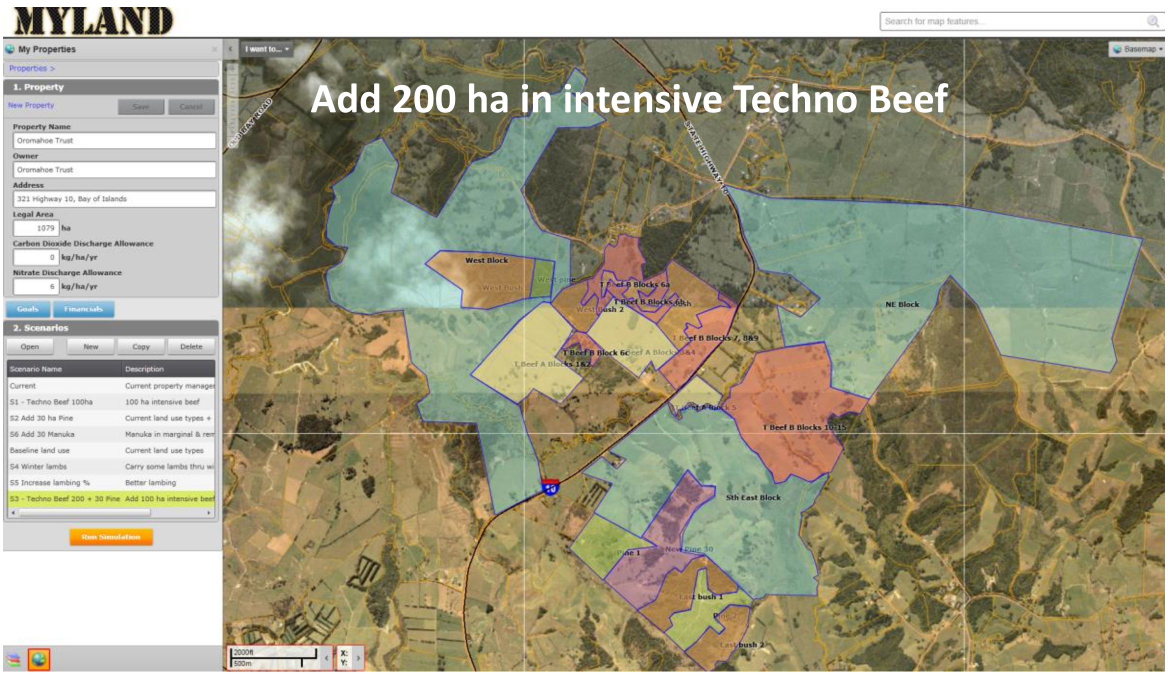
The integration system starts with the user defining the farm and management unit boundaries in MyLand. Using the GIS capability, land resource evaluation can then occur with multiple underlying surfaces like terrain, soils, productive capacity. Production by land use type is then modelled and input into MyLand. Environmental outputs are modelled separately in Overseer and passed to MyLand. Similarly, farm economics are modelled via Farmax and again input into MyLand.

For a given farm property area (defined by component land use types) with inputs on costs and prices, MyLand then simulates whole property economic metrics using discounted cashflow analysis for a defined period of simulation. Results are provided in a number of tables or graphs. Once the baseline information is thoroughly checked, scenarios can be developed to examine ways to improve profitability and mitigate environmental emissions.

Costs and/or prices to buy/sell carbon credits or nitrogen allowances are also built into the model to allow for calculation of the costs/benefits of this if required.

The spatial nature of the model is illustrated below.

Figure 27: Farm plan for Oromahoe showing Techno beef scenario.



Output from the model is shown below.

Figure 28: Whole property economic analysis for Oromahoe for different scenarios.

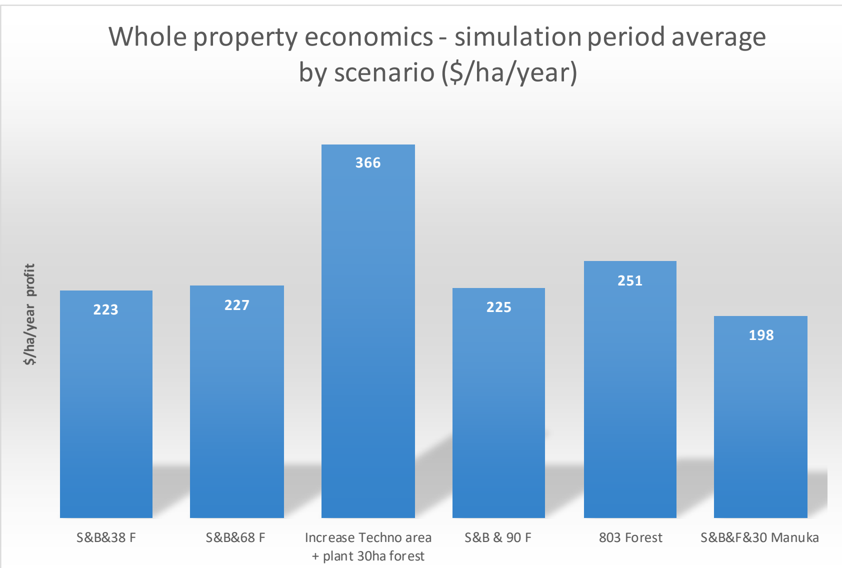


Figure 29: Changes in emissions for Oromahoe based on scenarios.

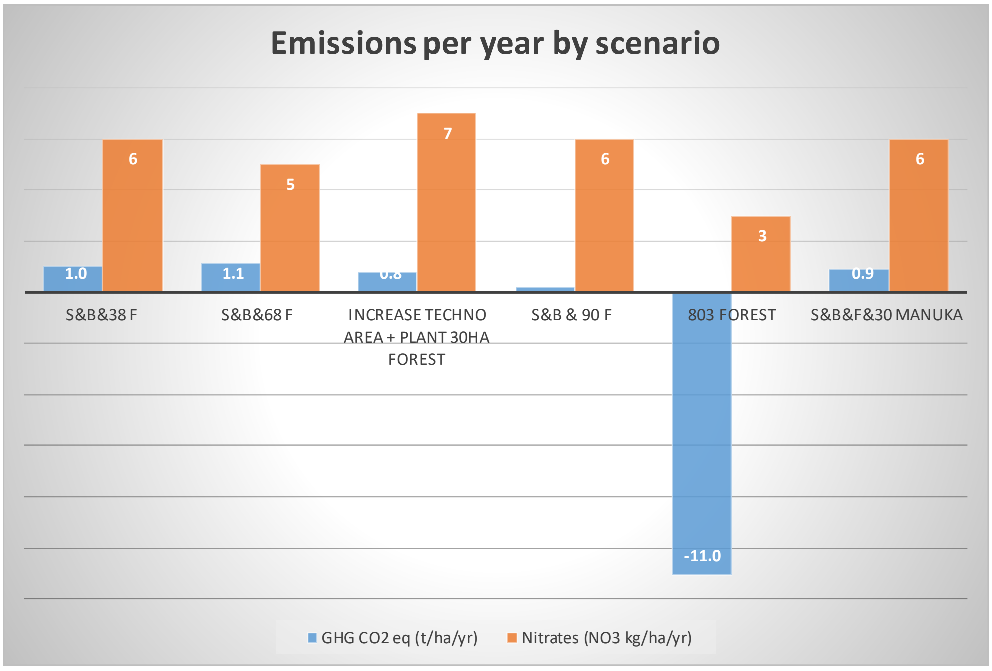
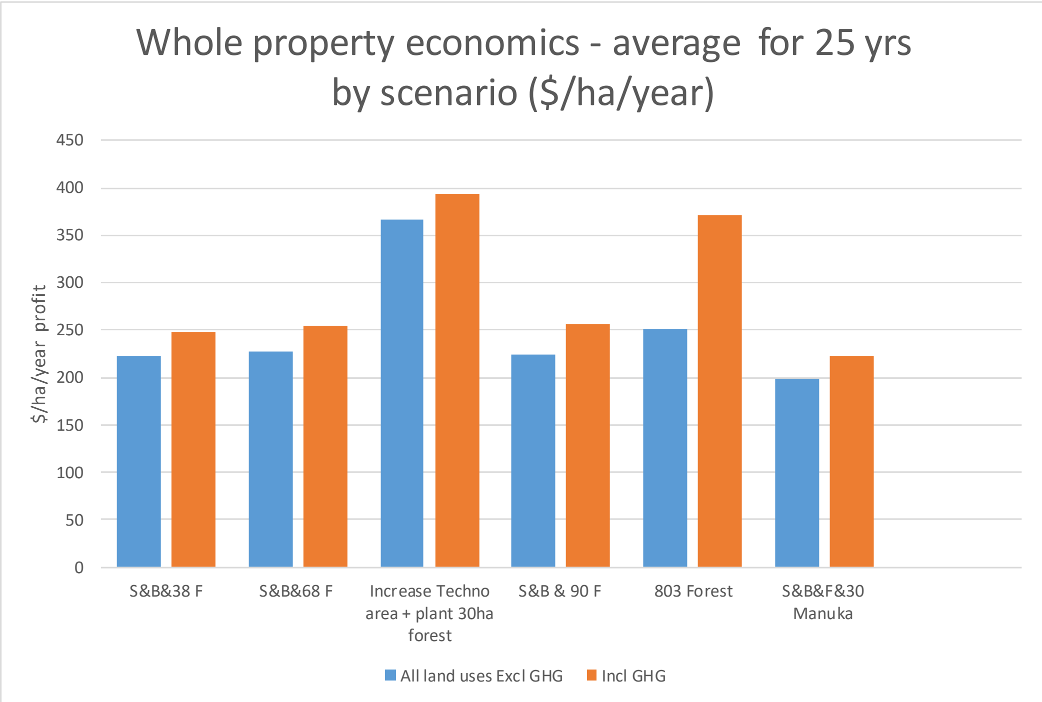


Figure 30: Whole property economics for Oromahoe based on 25-year scenario.



The reaction to the MyLand information from farmers was quite positive, particularly in illustrating the spatial effects of land use change. This allowed the focus farm management to much more readily visualise where the land use change would occur on-farm, and from this understand better the implications, particularly for farm management, which directly illustrates the usefulness of having such an integrated modelling tool.

21.1 Mitigation Matrix Calculator

One of the original intents of the project was to develop a 'Mitigation Matrix', which would allow consultants and farmers to readily understand the implications of changes in farm systems or land use on GHG emissions and profitability.

To this end a spreadsheet calculator has been developed which incorporates the basic concepts developed via this project. The intention is to make the farmer aware of the basic drivers of emissions and allow scenarios of land use and system modification to be tested with a one or two-page interface.

While farmers were interested in the Mitigation Matrix calculator, it still requires a reasonable amount of information to be entered, and the initial reaction was that it is still probably a 'consultancy' tool, albeit one that could be used to readily indicate implications around changes in enterprise mix and/or land use change.

Baseline information on emissions would still need to come from other models such as Overseer and financials would need to come from Farmax, or the farm accounts. The calculator involves three pages, 1. Instructions, 2. Set up, and 3. Scenarios and Results.

Data is entered as to the enterprise/land use mix on the property (as percentages), and then multiple scenarios can be entered as to changes to the original enterprise/land use. These essentially combine to form the Mitigation Matrix. The calculator then readily calculates the impact of any changes, and displays these as a series of graphs. If need be, the Excel solver can be run to find a quick optimum solution, but this is likely to be complicated for the average user. The interface is illustrated below.

Figure 31: Mitigation Matrix set-up

1

Property description	
Owner	Fred Dagg
Property Name	Twin Creeks
Area (ha)	153
Land type & terrain	Flats and rolling hill
Region	BOP
Climate risk	Mild Autumn Drought
Scenario driver	Switch to beef

2

Per ha Target Goals & Caps		
Factor	per ha	Total for Property
N Cap (kg/	35	5,355
P Cap (kg/	2	306
GHG cap (kg CO_2^e/yr)	5,000	765,000
EBIT ($)	$ 1,250	$ 191,250

3

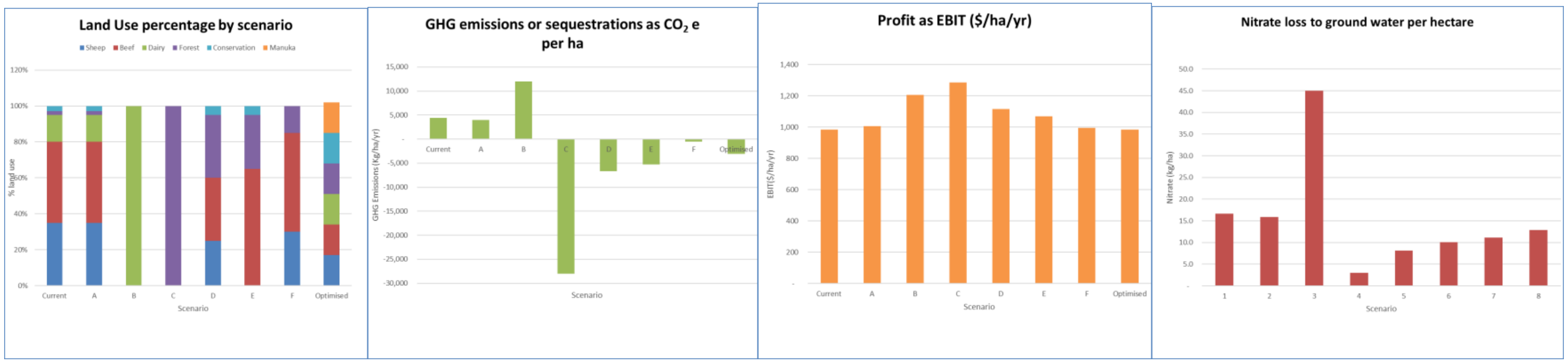
Property settings by Land use	Financials		Emmissions				Cost of		
Land use type	Costs	EBIT	CO_2^e	NO_3	P lost	DM	Capital & loans	NO_3	CO_2
	$/ha/yr	$/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr	kg/ha/yr		$/kg	$/t
Sheep	950	400	3,000	10.0	2.0	8,000	8%	210	18
Beef	1,200	650	5,000	14.0	5.0	10,000			
Dairy or Dairy grazers	5,100	1,500	12,000	45.0	3.0	14,000			
Forest	620	450	-28,000	3.0	1.0	12,000			
Conservation	20	0	-3,000	2.0	0.5	500			
Honey	80	180	-7,000	2.0	0.5	600			

Figure 32: Mitigation matrix calculator

MITGATION MATRIX CALCULATOR

Scenario	Mitigation Matrix: Land Use (percentage of total property)						Mitigation Matrix: System change impact (+/-%)			Outcomes: Total farm expenses	Property Net Profit (excluding envionment costs)	Net profit /ha (excl enviro costs)	Nitrate lost to ground water per ha	Nitrate lost to ground water for property	kg Dry Matter/kg N lost	P lost	N traded	Sale or purchase of N credits	$ profit /kg N	**GHG emmisions or sequestration**	Sale or purchase of CO_2 units	Whole System Profit /ha (incl emissions sales or costs)	Sum check on land use total % (should = 100)
	Sheep	**Beef**	**Dairy**	**Forest**	**Conservation**	**Manuka**	**on GHG**	**on Nitrate**	**on EBIT**	$/yr	$/yr	EBIT $/ha/yr	NO_3 Kg/ha	kg	/ha	P Kg/ha	kg/ha	Annuity $/ha	$/kg N	kg/ha/yr CO_2 e	Annuity $/ha	$/ha	
Current	35%	45%	15%	2%	3%		0%	0%	0%	252,496	$101,975	667	16.7	2551	579	3.4	18.3	307.9	40.0	4450	9.9	984	100%
A	35%	45%	15%	2%	3%		-10%	-5%	0%	252,496	$101,975	667	15.8	2423	610	3.4	19.2	321.9	42.1	4005	17.9	1,006	100%
B	0%	0%	100%	0%	0%		0%	0%	0%	780,300	$229,500	1,500	45.0	6885	311	3.0	- 10.0	-168.0	33.3	12,000	- 126.0	1,206	100%
C	0%		0%	100%	0%		0%	0%	0%	97,920	$68,850	450	3.0	459	4,000	1.0	32.0	537.6	150.0	-28000	297.0	1,285	100%
D	25%	35%	0%	35%	5%		-10%	-5%	15%	134,870	$85,336	558	8.1	1243	1,197	2.6	26.9	451.5	68.7	-6705	105.3	1,115	100%
E		65%		30%	5%	0%	0%	0%	0%	148,716	$85,298	558	10.1	1545	1,002	3.6	24.9	418.3	55.2	-5300	92.7	1,069	100%
F	30%	55%		15%	0%		0%	0%	0%	159,273	$83,385	545	11.2	1706	870	3.5	23.9	400.7	48.9	-550	50.0	996	100%
Optimised	17%	17%	17%	17%	17%	17%	0%	0%	0%	207,300	$82,712	541	12.9	1977	593	2.0	22.1	370.9	41.8	-3060	72.5	984	102%

Figure 33: Mitigation Matrix Output



22.0 FARMER REACTION

At the start of the project most of the farmers interacted with, including the profile farms, the focus farms, and farmers attending the field days, had very limited understanding of greenhouse gas emissions, mitigations around these, and the implications of any mitigation scenarios.

As the project progressed and the impact of the differing scenarios were demonstrated, understanding around both GHG emissions and implications of these increased significantly. The modelling generated interest at two levels:

(i) Changes in farm systems and/or land use and the implications of this at a farm productivity/profitability level irrespective of GHG or nutrient discharges; and

(ii) The implications of such changes in impacting on GHG emissions or nutrient discharges.

This latter factor was very much driven by:

(i) The push over recent years around improving water quality and subsequent Regional Council rules restricting nutrient discharges; and

(ii) The potential for a cost on carbon and the need to mitigate GHG emissions.

At the end of the project the focus farms were very much aware of the GHG issue, and cognisant of a range of potential mitigation strategies. All expressed some interest in implementing some mitigation strategies, but the extent to which this happens remains to be seen. As noted earlier in this report, all the farms were driven by a strong profitability motive coupled with their custodial (kaitiakitanga) responsibilities to their owners.

At the concluding field days a question was raised to both the focus farms and outside farmers attending; “what scenarios do you see as most attractive, and which least attractive”?

The response was universal across all the focus farms and outside farmers. They were definitely interested in strategies which improved farm profitability, particularly if GHG emissions decreased, or even if they increased slightly. In this latter case, the reasoning was that any increase in GHG tended to be marginal relative to the increase in profitability, and hence the improvement in profitability would assist in paying any carbon cost if it is imposed.

They were not interested in strategies that decreased GHG emissions if it had a negative effect on profitability. This highlighted two factors that we recommend for further exploration:

- The effect of multiple mitigation options bundled into a scenario.
- The effect of multiple farms under the control of a single entity.

The first factor responds to requests from the farm case studies themselves where they saw combinations of system changes, e.g. reducing stocking rate or stocking policy, changing fertiliser inputs, changing cropping regimes or pasture composition as more practicable and realistic within their farming system.

The second factor also came out of discussions with entities in the wider network that had multiple farm properties across multiple sectors, i.e. mixed livestock, dairy, forestry and horticulture. The choices that entities had in selecting both farm systems mitigation strategies (to improve emission intensity) along with land diversification options (to reduce total or absolute emissions) is often an important characteristic of Māori agribusinesses.

23.0 APPENDIX ONE: MODELLING ASSUMPTIONS

Note: Scenarios were modelled in Farmax first and then the appropriate changes mirrored in OverseerFM®.

Pukehina Dairy Farm

Scenario 1: Remove summer and autumn crops and replace with supplements

Scenario 1a: Same milk production - not reported but used as an interim model

Supplements were used to replace crops and fed in the same quantities (by energy intake) in the same months. Crops were removed which increased available pasture. Purchased supplements were reduced to utilise the extra grown feed keeping monthly milk production locked to the same amount. This resulted in a different herbage accumulation profile and less utilised feed. The cost of buying feed compared to growing crops made this scenario less profitable than base.

Modelling steps:

(i) Remove crops - no additional N fertiliser on pasture (Farmax doesn't model crop fertiliser).

(ii) Buy in Maize feed: 21.6 T and 33.4 T to dry cows in April and May.

(iii) Feed the maize feed at 5.5 T, 20.5 T and 19 T to milkers in July, August and September.

(iv) Buy in PKE feed: 29.5 T, 37.7 T and 40.2 T to milkers in January, February and March.

(v) Milk production remains the same.

Scenario 1b: Increased milk production - this is the scenario used for the report

Without changing the supplements fed in Scenario 1a above, the pasture intake was increased to utilise the additional feed earlier in the spring. Milk production was increased by utilising the feed grown without crops to make the Net Herbage Accumulation profile more closely match the profile in the base model. This offset the value of buying in feed and made the scenario more profitable than the base model.

Modelling steps:

(i) Changes around bought in feed as above (Scenario 1a).

(ii) Milk production increases occurred in October, November, December and February.

(iii) Total annual MS production 138,751 kgMS.

Scenario 2: Partial wintering facilities (on/off)

Modelling steps:

(i) Feed pad used by 100% of the cows for three hours per day (except in November and December) to feed the supplements.

(ii) Additional PKE (29 T) was imported for use on the feed pad.

(iii) Only minor changes to the feeding regime occurred, which resulted in some additional MS production in January.

(iv) Total annual MS production 136,471 kgMS.

(v) No incorporation of capital costs in the finances.

Scenario 3: In-shed feeding system

Feed concentrates in-shed (dairy shed meal TopCow seasonal feed). No incorporation of capital cost or any cost of feeding/maintenance/depreciation etc. Based on Inghams TopCow seasonal (DM 90%; Energy 12.2; Utilisation 100%; Digestibility 80; NDF 31 and Cost $450/T).

Modelling steps:

(i) Increased cow numbers by 30 cows at start of year equating to an increase in peak milked by 29.

(ii) Bring in 312 T Inghams TopCow.

(iii) Required 19.5 ha of pasture silage yielding 49 T DM for the dry cows.

(iv) Moved silage forward TWO weeks (shut up on 30 November). Pasture silage not fed to milkers.

(v) Fed less grass/cow.

(vi) Total annual MS production increased to 167,243 kgMS.

Scenario 4: In-shed feeding with young stock on the milking platform

Feed concentrates as per Scenario 3.

Modelling steps:

(i) Incorporate young stock all year round.

(ii) Reduce cow numbers (by 30 cows) to adjust to feasible system.

(iii) Buy in 228 tonne Inghams TopCow.

(iv) Production reduced to 142,020 kgMS.

Scenario 5: Reduce stocking rate

Reduce cow numbers so that no bought-in supplement is required.

Modelling steps:

(i) Eliminate all bought-in supplements.

(ii) Reduce cow numbers (by 45) to ensure feasible model.

(iii) Production reduced to 149,920 kgMS.

Scenario 6: Retire marginal land and increase forest plantings (3 hectares on dry area, currently 50% *relative productivity)*

First step - Rearranged base file:

Add marginal block that has come out of the dry block 3 hectares – pasture production 5725 kgDM/ha.

Modelling steps:

(i) Reduce size of dry block and increase pasture production to compensate.

(ii) Removed dry marginal block from Farmax (Farmax only deals with effective hectares).

(iii) Reduced pasture intake to make model feasible. Resulted in reduced milk production.

(iv) November N application to original dry block was to whole block (except crop) so kept an N application in the marginal block in Farmax. No other N was applied to the marginal block. No N applied to marginal block in Overseer.

(v) In Overseer 3 hectares was added as a trees and scrub block, planted in pines.

(vi) Total annual milk production reduced to 133,902 kgMS.

Te Rua o Te Moko Dairy Farm

Develop a base file (this was required to make the farm feasible prior to scenario analysis).

(i) Develop a base file by reducing pasture growth to make the farm just feasible.

(ii) Take 2 hectares off the main block and add a marginal block with the same properties.

(iii) Keep all crops and N application on the main block.

(iv) Reduce marginal block pasture production to 60% the value of main block.

(v) Increase main block pasture production to compensate for pasture loss.

(vi) Overall the changes resulted in the same total pasture production and same animal performance.

Scenario 1: Replace maize with fodder beet

(i) Replaced 9 hectares of maize with 9 hectares of fodder beet.

(ii) Fodder beet inputs were the same as on the current fodder beet crop.

(iii) Pasture was reduced slightly in spring because a longer crop period meant that autumn sowing of new pasture was not possible.

(iv) More DM and energy was provided by the fodder beet option giving an increase in total MS.

(v) Fodder beet was fed at the same time of the year as the maize silage.

Scenario 2: Replace N fertiliser with low N feed (maize silage)

(i) Animal numbers and milk production remained the same.

(ii) Removed all N applications. Loss of pasture production calculated at 3.6 million MJ ME which requires 332 T maize to replace feed energy. Utilisation was not taken into account, which is modelled higher in Farmax for pasture than maize silage on average.

(iii) Offered (fed) an average of 2 kgDM/head/day to both dry cows and milkers with rates from 0 kg to 3 kg in some months. A total of 332 T of bought maize silage was fed.

Scenario 3: Eliminate N fertiliser

(i) Removed all N fertiliser application to pasture.

(ii) Reduced animal numbers to match pasture supply using modify function in Farmax - 429 peak number of cows in milk and production of 158,914 kgMS.

Scenario 4: Remove summer and autumn crops and replace with supplements (maize silage/PKE)

(i) As for the Pukehina model, crops were removed and purchased maize silage and PKE were used to replace the feed provided.

(ii) Maize silage was replaced kg for kg.

(iii) PKE replaced turnips on an energy basis.

(iv) Bought supplements were reduced to eat additional pasture grown without the crops on the farm.

(v) Milk production was kept the same but less supplements were fed overall.

Scenario 5: Retire marginal land and increase forest plantings (2 hectares on farm block – 60% relative productivity)

(i) Remove marginal block from Farmax model.

(ii) Reduced milk production (184,597 kgMS) and live weights using modify tool to compensate for loss of pasture.

Scenario 6: Install in-shed feeding system

(i) Increase cow numbers by 15.

(ii) Buy in an extra 62 T PKE, Plus 206 T maize grain.

(iii) Production increased to 209,706 kgMS.

Oromahoe Sheep and Beef Farm

Scenario 1: Impact of 100 hectare Techno system for bull beef

Rearranged blocks to give a 100 hectare block to be used for Techno grazing. This came from a good block so the pasture was increased over the main block. This was done as per the relative productivity ratios in the Overseer files. Set pasture production to zero on 100 hectare block and reduced bull beef enterprise to match pasture available. This gave the reinstated Techno graze block. Increased efficiencies as per Ogle and Tither 2000 (NZGA paper on Techno graze in Farmax). Increased pasture production by 35%. Increased animal mature weight by 10% on new bull beef enterprise. Increased pasture quality from medium to high. Duplicated the current bull beef system to form a new bull beef (Techno) enterprise and scaled to suit the pasture production from the Techno graze block.

Scenario 2: Retire 30 hectares marginal land for forest plantings - Pinus or Totara.

First step - Rearranged base file:

(i) The model has a large pasture buffer, i.e. the supply is always greater than the demand by a large margin. Pasture growth was reduced to make the model just feasible. This is a necessary step prior to scenario building.

(ii) Add a 30 hectare marginal block, reduce the main block from 750 hectares to 720 hectares.

(iii) Halve the growth rate on the marginal block to make it marginal *[assumption].*

(iv) Increase the pasture grown on the main block to meet demand (same as starting point).

Modelling steps:

(i) The 30 hectare block was removed from the Farmax model.

(ii) The 30 hectare block in Overseer was changed to a trees and scrub block, and planted in Pines.

(iii) The stock numbers in all enterprises were scaled back to match the feed demand with the available pasture.

Scenario 3: Increase the Techno beef area to 200 hectares plus include a 30 hectares block of forestry

(i) As per Scenarios 1 and 2, increase the Techno area to 100 hectares, plus include the 30 hectares of forestry (pines).

(ii) Sheep numbers held as per base.

(iii) Cattle numbers reduced slightly (2.5%), but performance lifted by 10%.

Scenario 4: Replace 500 stock unit equivalents of finishing cattle with store lambs for finishing for winter/spring slaughter.

(i) Purchased 800 store lambs in January to March and sell them from May to September.

(ii) Reduced the steers in the finishing prime enterprise using reduce stock numbers in modify tool.

Scenario 5: Improve lambing percentage from 135% to 160%

(i) Increased ewe start weight up to 79 kg.

(ii) Increased autumn weight gain to keep ewe weights high.

(iii) Reduced losses to tailing from 24% to 20%. Justification: better feeding reduces many issues causing lamb death.

(iv) Kept losses from tailing to weaning low (2%).

(v) Moved back lambing date 10 days, kept tailing and weaning dates the same.

(vi) Did not modify lamb growth rates or selling dates although weaning weight was increased with heavier ewes.

(vii) Reduced sheep enterprise numbers to match feed supply.

Scenario 6: Plant 30 hectares in Manuka

(i) As per Scenario 2, except substitute Manuka for Pines.

Marotiri Sheep and Beef Farm

Develop base file:

(i) Reduce pasture growth to make model just feasible

(ii) Add 50 hectare marginal Mangahauini block by adding 50 hectare block reducing Mangahauini block by 50 hectare. Setting marginal block to 40% of pasture growth and increasing main Mangahauini block to compensate for loss in growth. Overall no change in pasture growth.

(iii) Mangahauini block 5363 kgDM/ha.

(iv) Mangahauini marginal 2143 kgDM/ha.

Scenario 1: Eliminate N fertiliser

(i) Removed N fertiliser on 152 hectares of Hikuwai block.

(ii) Scaled back all stock classes using the 'reduce stock numbers' function in Farmax.

Scenario 2: Increase sheep to beef ratio; (currently 44% sheep, 56% cattle – change to (a) 50/50; (b) 60/40).

(i) For both scenarios above, modified ratio using 'increase/reduce stock numbers' function in Farmax to scale stock numbers without changing the proportion of mobs weights and sales within an enterprise.

Scenario 3: Retire marginal land and increase forest plantings. 50 hectares on Mangahauini block, currently 40% productivity cf rest of block.

(i) 50 hectares on Mangahauini block, currently 40% productivity cf rest of block.

(ii) Removed 50 hectare marginal block from model scaled down all stock numbers

Scenario 4: Intensify 100 hectares into lamb finishing area

(i) Apply 100 T superphosphate (within Overseer) as capital dressing.

(ii) Stock numbers held as per base model.

(iii) Lambs finished to 17.7 kgCWT cf 16 kg in base.

Scenario 5: Plant 50 hectares in Lusitanica/Manuka

(i) As per Scenario 3.

24.0 APPENDIX TWO: COMPARISON OF DIRECT CARBON CHARGE COMPARED WITH EMISSION FACTOR CALCULATION

Note: Emissions are only CH_4 and N_2O

Carbon Charge = \$10/T CO_2e

Pukehina

Table 61: Base Pukehina emission and production data

Total CO_2e emissions (T/ha)	9.7	
		/ha
Milksolids (kg)	135,052	794
Beef (kg)	16,890	99
Nitrogen use (kg N)	13,370	79
EBIT (\$/ha)	1,211	

Table 62: Pukehina: Comparison of direct carbon cost cf emission factor calculation

Straight application of carbon cost to farm			
Carbon charge =		\$97.00	/ha
new EBIT =		\$1,114.00	/ha
Application via emission factors			
Milksolids			
EF/kg =	0.0085		
Carbon cost =		\$67.53	/ha
Beef			
EF/kg =	0.0127		
Carbon cost =		\$12.62	/ha
Nitrogen			
EF/kg =	0.00572		
Carbon cost =		\$4.50	/ha
Total carbon cost =		\$84.64	/ha
new EBIT =		\$1,126.36	/ha

Te Rua o Te Moko

Table 63: Base Te Rua o Te Moko emission and production data

Total CO_2e emissions (T/ha)	9.5	
		/ha
Milksolids (kg)	185,871	1,106
Beef (kg)	22,533	134
Nitrogen use (kg N)	20,944	125
EBIT ($/ha)	2,056	

Table 64: Te Rua o Te Moko: Comparison of direct carbon cost cf emission factor calculation

Straight application of carbon cost to farm			
Carbon charge =		$95.00	/ha
new EBIT =		$1,961.00	/ha
Application via processing cost			
Milksolids			
EF/kg =	0.0085		
Carbon cost =		$94.04	/ha
Beef			
EF/kg =	0.0127		
Carbon cost =		$17.03	/ha
Nitrogen			
EF/kg =	0.00572		
Carbon cost =		$7.13	/ha
Total carbon cost =		$118.21	/ha
new EBIT =		$1,937.79	/ha

Marotiri

Table 65: Base Marotiri emission and production data

Total CO_2e emissions (T/ha)	1.7	
		/ha
Beef (kg)	138,014	71
Sheep Meat + Wool (kg)	124,138	64
Nitrogen use (kg N)	6,840	4
EBIT ($/ha)	72	

Table 66: Marotiri: Comparison of direct carbon cost cf emission factor calculation

Straight application of carbon cost to farm			
Carbon charge =		$17.00	/ha
new EBIT =		$55.00	/ha
Application via processing cost			
Beef			
EF/kg =	0.0127		
Carbon cost =		$9.03	/ha
Sheep Meat			
EF/kg =	0.0127		
Carbon cost =		$8.12	/ha
Nitrogen			
EF/kg =	0.00572		
Carbon cost =		$0.20	/ha
Total carbon cost =		$17.35	/ha
new EBIT =		$54.65	/ha

Oromahoe

Table 67: Base Oromahoe emission and production data

Total CO_2e emissions (T/ha)	2.6	
		/ha
Beef (kg)	121,614	159
Sheep Meat + Wool (kg)	39,285	51
Nitrogen use (kg N)	6,300	8
EBIT ($/ha)	205	

Table 68: Oromahoe: Comparison of direct carbon cost cf emission factor calculation

Straight application of carbon cost to farm			
Carbon charge =		$26.00	/ha
new EBIT =		$179.00	/ha
Application via processing cost			
Beef			
EF/kg =	0.0127		
Carbon cost =		$20.19	/ha
Sheep Meat			
EF/kg =	0.0127		
Carbon cost =		$6.52	/ha
Nitrogen			
EF/kg =	0.00572		
Carbon cost =		$0.47	/ha
Total carbon cost =		$27.18	/ha
new EBIT =		$177.82	/ha