Independent
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Network

Final Report – GHG costs and benefits on different land classes

Prepared for the Interim Climate Change Committee

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1.0 CONTEXT

The Interim Climate Change Committee is considering mechanisms for the agricultural sector to address its emissions. This work considers a range of different policy options as well as mechanisms to support policy solutions. Different policy options could influence different parts of the agricultural sector in different ways. To support the policy analysis, this report considers *whether the costs and benefits of options to reduce emissions differ fundamentally between land classes.*

To be able to consider the research question, it is important to understand some context around land use in New Zealand agriculture. A brief overview of this context is outlined below.

1.1 Profitability

Within all farm systems and land classes there is a significant range in profitability per hectare. For example, the profit per hectare across all sheep and beef farms in the Beef + Lamb New Zealand Economic Survey (2016/17) ranges from a $450/ha loss through to greater than $1050/ha profit. The DairyNZ Economic Survey (2016/17) shows a range of $554/ha through to $3184/ha operating profit. While the land type or class and the use of that land will influence the potential for profitability, this is largely driven by management. When looking more closely at the data within regions, and land classes, there is also a significant range in profitability e.g. two sheep and beef breeding properties on the same class of land can have markedly different levels of profitability. Thus, mitigation options that may be financially beneficial to one farmer, could be detrimental to another of the same land use and land type or class. This is particularly the case with the current mitigation options available to farmers which are largely related to system changes and therefore rely on the ability of the farmer to maximise the benefit and minimise the cost.

1.2 Decision making around land use

As discussed in the report on farmer decision making with regard to climate change[1], there are a range of factors which will influence the uptake of specific mitigation options including:

- Relative advantage and perceived advantage
- Ease of implementation and complexity
- Compatibility with existing system
- Observability of results

These are also influenced by a range of individual and community social factors. It is important to understand these, because decisions made on-farm are not solely based on the most profitable option or financial implications.

A price incentive to mitigate is likely to achieve changes if it provides encouragement (via added cost, or gain) to farmers for mitigation investment or system change but may not be sufficient motivation for some farmers.

1.3 Land class as a proxy for land use

Land Use Capability (LUC) or land class is used as a proxy for the productive capacity or potential stock carrying capacity of the land. This connection needs to be made with caution due to the following:

[1] https://www.mpi.govt.nz/dmsdocument/32137-farm-behaviour-ghg-literature-review-final-dec-2018

- LUC is a *'systematic arrangement of different kinds of land according to those properties that determine its capacity for long-term sustained production.'* Assessment of the land is based on an interpretation of the physical information observed which requires specialist expertise, and while there is consistency in approach across the country, it is somewhat subjective in nature. The whole of New Zealand has been mapped (in the 1970's – 80's) at a scale of 1:50,000 which is suitable for making decisions at a district/regional scale, but not at a farm scale. The farm scale mapping is usually done between 1:10,000 and 1:15,000 scale (less for more intensive systems), and this is appropriate for informing land use and land management decisions.
- LUC combines a range of different factors to provide an indication of use and of risk, but it is only an indication. Land use and management decisions are made by people, and there are numerous examples across New Zealand of farmers who are using their land for something other than what the LUC indicates is 'best use'. Refer to the Analysis of Drivers and Barriers to Land Use Change Report[2] for more information. A good example would be in the Mackenzie Basin which has a LUC of 6 and a soil limitation, yet this land is irrigated and farming dairy cattle which you may otherwise associate with typically more productive LUC classes (i.e. 1 to 4).

1.4 Practice change or system change?

There is some debate around terminology and impact of different mitigation options on farm practices and/or farm systems. From a farmer's perspective, talking about 'farm practice change' can sound or appear like less of a task than 'farm system change'. However, one could argue that practice changes are likely to alter the system in some form, and that is probably the point of making them in the first place. Implementing changes in a business will lead to different degrees of change to the overall system (e.g. Halting the application of nitrogen may be considered a 'practice change'. However, this will result in less feed being produced and therefore system changes are likely to be needed to manage the overall performance of the business such as bringing in feed, reducing stock performance, or reducing stock numbers. Conversely, changing from dairy to bull beef is a large system change made up of multiple 'practice changes' and an obvious change to the system). Thus, it is difficult to make a clear distinction between the two terms. Discussing 'mitigation options' may therefore be more appropriate and less confusing or subjective.

2.0 METHODOLOGY

Using farm systems knowledge, and referencing existing modelling work, a hypothetical case study approach has been used based on the major land uses on the relevant, different classes of land (Class I to VIII) as a proxy for land use. A base 'farm system' has been established for six case studies which relate to different intensity of land use and relate to land use classification. The range of known mitigation options for farm systems have been considered and then applied to the relevant land use. The farm systems have then been modelled using Farmax (version 7.2.1.82 sheep, beef and deer, and version 7.1.2.31 dairy), Overseer (version 6.3.1) and Forestry Look-up tables[3] (where relevant). Estimates of the cost of implementing mitigation options have been considered. Modelled data on the relative change in emissions,

[2] https://www.mpi.govt.nz/dmsdocument/23056-analysis-of-drivers-and-barriers-to-land-use-change
[3] https://www.mpi.govt.nz/dmsdocument/31695/send

and a modelled financial impact on the farm system is presented along with the financial impact of different free allocation methodologies. The analysis is based on farm level emissions and obligations. Analysis of the implications of a processor level obligation have not been included.

A brief description of the land and general system for each of the case study farms is provided in Table 1 below. Appendix 1.0 has more detailed information about each base farm including stock numbers, supplements, nitrogen fertiliser and stock policies. Note, the LUC given is at regional scale and therefore provides an approximate characterisation of the land only.

Table 1 Summary of base farm systems used in analysis

Base farm	**Description**
Canterbury Dairy (239ha effective)	The farm is predominantly LUC 3 with some areas of LUC 2. The farm is flat, well-drained, and irrigated. 766 cows are milked with replacements grazed off-farm and half of the cows grazed-off over winter. Supplements are imported. It is running 3.2 cows/ha.
Bay of Plenty Dairy (153ha effective)	The farm is flat and includes areas of LUC 2 and 3. The areas defined as LUC 2 are well drained pumice soils. The areas defined as LUC 3 are poorly-drained, peat soils. 445 cows are milked, and replacements are grazed off-farm. Crops are grown on-farm and supplements are imported. It is running 2.8 cows/ha.
Taranaki Dairy (170ha effective)	The farm is predominantly LUC 1. This land is flat with freely draining fertile soils. There are areas of sloping land that is classified as LUC 3 and 4. These areas include a number of waterways/small gullies that run through the farm. The gully areas are fenced to exclude livestock. 506 cows are milked and replacements grazed off-farm. Crops are grown on the farm and supplements are imported. It is running 3 cows/ha.
East Coast Sheep and Beef (1,941ha effective)	The property is predominantly steep hill country which is LUC 7. There are some moderate hills that are LUC 6 and some flat to rolling land that is LUC 3. Sheep and beef breeding farm finishing 90% of lambs with majority of cattle finished (excluding replacements). Weaner bulls purchased and finished. The stocking rate is 4.5SU/ha.
Central North Island Sheep and Beef (1,153ha effective)	The property is predominantly LUC 6. The majority of the farm is moderate to steep hills with some rolling country. The soils are moderately well drained. Sheep and beef breeding farm finishing 75% of lambs and 100% cattle (excluding replacements). The stocking rate is 6.85SU/ha.
Otago Sheep, Beef and Deer (6,800ha effective)	The farm includes flat to rolling land which is classified as LUC 3 and LUC 4 with some irrigation on this land. The predominant area is moderate hills that are LUC 6 and hard hills which are classified as LUC 7. The LUC 7 land is unimproved native tussock, and about half of the LUC 6 has been improved via over-sowing and top-dressing. It is a breeding/finishing property with 70% of lambs, most of the cattle and most of the deer, other than replacements, finished with some sold store depending on the season. The stocking rate is 1.2SU/ha.

2.1 Mitigation options

Mitigation options considered in the modelling are summarised in Table 2 below. More detail of each scenario and the base farm system is included in Appendix 1.0.

Table 2 Mitigation options assessed for dairy, and sheep, beef and deer case study farms.

Mitigation	**Dairy**	**Sheep, beef and deer**
Reduce or remove nitrogen fertiliser	✓	✓
Lower nitrogen content feed	✓	
Reduce stocking rate: maintain overall production	✓	✓
Reduce stocking rate: decrease overall production	✓	✓
Convert dairy to beef	✓	
Retire land to forestry/native	✓	✓
Increase sheep:cattle		✓

Note: Once-a-day milking is also a known mitigation option in some situations. It was not analysed due to time-constraints with the modelling and the variability in effectiveness seen in other analysis. Replacing breeding cattle for younger, growing males is also a known mitigation practice which due to time constraints was not modelled.

It is also worth considering the implications of different types of land in relation to the different mitigation options. This has been broadly characterised in Table 3 below and overleaf.

Table 3 Implications of land on different mitigation options.

Mitigation	**Implications of land type/class and use**
Reduce or remove nitrogen fertiliser	Nitrogen fertiliser can be applied on all land types, it is used to grow more feed. Generally, the more intensive the system, the more that is used, so on more challenging land (e.g. steep), it is likely less nitrogen fertiliser is used than on flat land (the cost of application is much greater on hill country as requires aerial application). Many hill country farmers do not use it, and some only use it as a buffer in challenging conditions (e.g. following drought). Thus, it is only a viable mitigation for properties which use it, and the reduction or removal may only make a small difference to total emissions.
Lower nitrogen content feed	The majority of supplementary feed used is on flat to rolling land due to the practicality of delivery (it generally requires a tractor). It is common on dairy farms, and sheep, beef and deer finishing farms, and rare on hill country sheep, beef and/or deer farms. However, many hill country farms have 'flatter' areas which are often used in winter (particularly in the Southern South Island), and supplementary feed use is common as pasture production is close to zero through this period. As a mitigation practice it more broadly applies to dairy, but could be considered for sheep, beef and deer where supplements are used.
Reduce stocking rate: maintain overall production	This option is largely not constrained by land type/class but is constrained by management ability. To maintain the overall production with less animals, the animals need to consume the same amount and quality of feed. While some of this may occur from reduced competition (i.e. less animals competing for same amount of feed), it usually requires additional management (e.g. improved grazing management, increased supplementary feed provided). Harder hill country may be climate constrained or constrained by vegetation cover which even the best managers may not be able to overcome.

Mitigation	**Implications of land type/class and use**
Reduce stocking rate: decrease overall production	This option is not constrained by land type/class. In the absence of management effort, overall production often declines with a decreased stocking rate. If animals are being underfed prior to this change occurring, a decrease in production may not eventuate.
Convert dairy to beef	While this option is not technically constrained by land type/class, it is only going to occur when a dairy farm system exists. Thus, it is more likely to apply on land class 4 or below.
Retire land to forestry/native	Retiring land for plantation/carbon forestry or into native via planting or regeneration is not constrained by land type/class. However, it is more likely to occur when returns per hectare for the current land use are less than under forestry or are very low (if anything); therefore, retiring land is unlikely to influence overall profitability. Thus, it is more likely to occur on less intensive land uses (or moderate to steep land, e.g. class 7 and 8), than on easier land which is suitable for dairy, lamb and beef finishing, or horticultural use.
Increase sheep:cattle	There are a range of factors which influence the ratio of sheep to cattle on sheep and beef farms including, but not limited to, climate (largely relating to animal disease e.g. Facial eczema), topography, geology, personal preference, and local markets (e.g. proximity to processor). Thus, land class will influence the ability for this mitigation to occur. Cattle (particularly breeding cows), are often used to control pasture quality in summer and removing them or reducing them in some systems may compromise pasture quality, leading to reduced performance of the sheep. The ability to implement this mitigation effectively may therefore decline as land class increases (but not in all cases).

2.2 Free allocation and obligation

The free allocation and obligation scenarios for a farm-level obligation have been calculated based on analysis from the ICCC. All free allocation scenarios exclude nitrous oxide emissions from nitrogen fertiliser (it is likely that it will be proposed that this remain at processor level). The free allocation methodology options are:

- Proportional (95% of total emissions)
- Land (95% of effective area multiplied by an allocation factor)
- Output (95% of output multiplied by an allocation factor)
- Hybrid – land and output (half of allocation from output and half from land – based on above)

The allocation factors are based on the national annual average emissions per ha of effective farm area for 'Land', and the national annual average emissions per unit of product for 'Output'. These are specific to each stock type or output (i.e. sheep, cattle, deer, or milk solids).

Key assumptions for the free allocation are:

- Overseer values scaled to align with inventory (based on standard percentage for dairy and sheep, beef and deer respectively)
- Allocation factors provided by the ICCC

- Carbon price of $25/tonne
- Free allocation to the total agriculture sector of 95% assumed (obligation is therefore 5%); individual farmers may face a greater or lower level depending on the free allocation method.
- Emissions calculated in Overseer and related back to effective area (Overseer based on total)
- Stock units as calculated in Overseer
- Stock numbers consistent between Farmax and Overseer
- Sheep and beef – based on opening numbers (July)
- Dairy – based on cow numbers at peak milk (September)

2.3 Forestry

Comparison of annual income between forestry and agriculture is complicated by the long timeframe until first income is received from forestry (in the absence of carbon sales) compared to the annual cash flows generally associated with agriculture. To overcome this complexity, the approached used in this project was to calculate a Net Present Value (NPV) at a given discount rate (5%) and then convert this figure by the assumed harvest timeframe of 28 years to produce an annual payment (annuity) that could be used to compare the annual EFS from the status quo and revised livestock systems.

Carbon sales are not included in the analysis of Economic Farm Surplus (EFS)/ha as they are presented as an off-set in the relevant scenarios. In the scenarios which include forestry, the free allocation has been applied to the agricultural emissions modelled with the land retirement for the forestry area which accounts for lower stocking rates and/or inputs, but not the carbon reduction sequestered by the forestry. A greenhouse gas reduction from forestry has been calculated by using the 'averaging' method. A table of sequestration rates per hectare is presented in Appendix 2.0. The 'averaging' method is based on half of the annualised carbon sequestration rates from the Look-Up tables by region over 28 years for pine and 50 years for native. This can only be applied in the first rotation of a forestry crop.

Aspects of terrain, access, scale, transport distance etc have a major impact on the economics of a particular forestry operation. These can vary markedly from property to property. In calculating a generalised annual income from forestry for the properties, assumptions have been made about costs (detailed in Appendix 2.0).

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

3.0 RESULTS AND DISCUSSION

The costs and benefits of mitigation options to reduce greenhouse gas emissions will differ between farms and this is likely to have a greater influence on the outcomes than the land class per se (see above). Differences in the costs and benefits will occur both between and within land uses and land type/class. A range of land classes have been analysed, but with only 6 case studies, quantitative conclusions are not able to be drawn. The farms modelled are specific farms with specific assumptions which may or may not be applicable to similar farms.

A summary of the analysis is presented in Table 4 below. The table shows each of the base farm systems in relation to modelled mitigation practices. It shows mitigation reductions, and the subsequent impact on EFS (Economic Farm Surplus). It also shows the impact of different free allocation methodologies on EFS/ha based on the mitigations applied and obligation at \$25/tonne CO_2-e. It should be noted, that the data presented in the table is based on effective area, which has been maintained (even if land retired) to compare scenarios against each other. This also ensures data presented from Overseer and Farmax is consistent. The methodology for a land-based free allocation in relation to how retired land will impact on land area (effective or ineffective) is yet to be determined and subject to ongoing work.

Forestry profitability and a total GHG reduction from forestry has been presented. The EFS/ha accounts for forestry an estimated forestry revenue but not carbon sales. The free allocation and subsequent total obligation for different scenarios has been included in Appendix 3.0. This free allocation is for methane and nitrous oxide emissions (excluding fertiliser) only and is applied before accounting for sequestration from forestry.

The one-off costs and benefits presented in the table are estimates only based on Farmax long-term stock prices, and standard costing. The capital costs are for infrastructure only, primarily fencing, with yards for the dairy to bull beef scenario. The costs of stock purchases have been netted from the sales of capital stock. In reality, farmers would choose the timing of stock sales to maximise returns and may use natural increase or decrease in numbers from breeding stock rather than facing a cash purchase on one date.

In general, as the land type/class became more limiting, the EFS/ha declined both within and between land use. This could suggest that any additional costs imposed on the systems will have a greater influence on land which is 'harder' than 'easier' land. The free allocation methodology can be used to influence this. In the analysis, the majority of sheep and beef scenarios received a rebate under the allocation methodologies applied which would benefit their EFS/ha. These farms are on harder land than the dairy farms analysed.

The impact of different mitigation options in relation to EFS/ha was highly variable, with some demonstrating improved EFS/ha and others resulting in a decline in EFS/ha relative to the base. This was not necessarily driven by the land per se but is discussed further in the topic sections below. Again, the different free allocation methodology influenced the outcome of these in relation to the net EFS/ha.

The percentage greenhouse gas reduction ranged from 1.1% to 57.4% with the range covered across all land types/classes and use. The percentage change in EFS/ha ranged from -54% to 33%, again, with the range covered across all land types/classes and use. The effectiveness of a mitigation strategy on the EFS/ha is highly dependent on the ability of a farmer to implement the strategy, and this ability will be influenced by physical constraints (e.g. soils, climate, topography). The less physical constraints, the more options that are available to the farmer to maximise the strategy implemented.

Table 4 Summary of Farmax, Overseer and Look-Up table analysis including obligation and estimates of one-off costs/benefits to implement – all per hectare data is based on effective area.

							Obligation per ha (calculated on emissions excluding forestry sequestration)				Total EFS and % difference from base (incl obligation and forestry)									
	Emissions (kg CO_2-e /ha)	GHG reduction (kg CO_2-e/ha)	Sequestered (kg CO_2-e /ha)	Total reduction (kg CO_2-e /ha)	% reduction	EFS/ha	Proportional	Land	Output	Hybrid (land + output)	Proportional	%	Land	%	Output	%	Hybrid (land + output)	%	Capital cost (Total)	One-off net benefit (Total)
Base - Canterbury dairy (239 effective ha, 3.2 cows/ha)	12,930					$ 1,142	$ 14	$ 25	-$ 38	-$ 7	$ 1,128	-1%	$ 1,117	-2%	$ 1,180	3%	$ 1,149	1%		
Scenario: PKE swapped for maize	12,615	315			2.4%	$ 1,177	$ 13	$ 18	-$ 45	-$ 13	$ 1,164	2%	$ 1,159	1%	$ 1,222	7%	$ 1,190	4%		
Scenario: Reduced stocking rate	11,998	932			7.2%	$ 1,215	$ 13	$ 3	-$ 28	-$ 12	$ 1,202	5%	$ 1,212	6%	$ 1,243	9%	$ 1,227	7%		$ 144,900
Base - Bay of Plenty dairy (153 effective ha, 2.8 cows/ha)	10,109					$ 1,353	$ 12	-$ 19	-$ 2	-$ 10	$ 1,341	-1%	$ 1,372	1%	$ 1,355	0%	$ 1,363	1%		
Scenario: Reduced stocking rate	9,647	462			4.6%	$ 1,798	$ 11	-$ 30	-$ 13	-$ 21	$ 1,787	32%	$ 1,828	35%	$ 1,811	34%	$ 1,819	34%		$ 82,300
Scenario: Retire 8.5ha to pines	9,167	942	700	1,642	16.0%	$ 1,247	$ 10	-$ 41	$ -	-$ 21	$ 1,237	-9%	$ 1,288	-5%	$ 1,247	-8%	$ 1,268	-6%	$ 6,900	$ 82,300
Base - Taranaki dairy (170 effective ha, 3 cows/ha)	11,535					$ 2,111	$ 12	-$ 20	-$ 32	-$ 26	$ 2,099	-1%	$ 2,131	1%	$ 2,143	2%	$ 2,137	1%		
Scenario: Replace urea with low N feed	10,328	1,207			10.5%	$ 1,826	$ 11	-$ 30	-$ 42	-$ 36	$ 1,815	-14%	$ 1,856	-12%	$ 1,868	-12%	$ 1,862	-12%		
Scenario: Remove urea	8,896	2,639			22.9%	$ 1,656	$ 9	-$ 61	-$ 35	-$ 48	$ 1,647	-22%	$ 1,717	-19%	$ 1,691	-20%	$ 1,704	-19%		
Scenario: Retire 2ha to pines	11,426	109	167	276	2.4%	$ 2,136	$ 11	-$ 23	-$ 35	-$ 29	$ 2,125	1%	$ 2,159	2%	$ 2,171	3%	$ 2,165	3%	$ 3,420	
Scenario: Convert to bull beef	9,477	2,058			17.8%	$ 973	$ 7	$ 103	-$ 18	$ 43	$ 966	-54%	$ 870	-59%	$ 991	-53%	$ 930	-56%	$ 20,000	$ 811,200
Base - East Coast sheep and beef (1,941 effective ha, 4.5SU/ha)	3,408					$ 215	$ 2	-$ 15	-$ 43	-$ 40	$ 213	-1%	$ 230	7%	$ 258	20%	$ 255	19%		
Scenario: Remove nitrogen fertiliser	3,369	39			1.1%	$ 219	$ 2	-$ 15	-$ 43	-$ 40	$ 217	1%	$ 234	9%	$ 262	22%	$ 259	20%		
Scenario: 50:50 sheep and beef	3,362	45			1.3%	$ 214	$ 2	-$ 15	-$ 44	-$ 42	$ 212	-1%	$ 229	7%	$ 258	20%	$ 256	19%		$ 187,120
Scenario: 60:40 sheep and beef	3,243	165			4.8%	$ 209	$ 1	-$ 16	-$ 46	-$ 44	$ 208	-3%	$ 225	5%	$ 255	19%	$ 253	18%		$ 564,440
Scenario: Retire 50ha to pines	3,369	39	371	410	12.0%	$ 230	$ 2	-$ 15	-$ 40	-$ 40	$ 228	6%	$ 245	14%	$ 270	26%	$ 270	26%	$ 45,000	$ 25,170
Base - Central North Island sheep and beef (1,153 effective ha, 6.9SU/ha)	3,998					$ 409	$ 3	$ 14	-$ 30	-$ 10	$ 406	-1%	$ 395	-3%	$ 439	7%	$ 419	2%		
Scenario: Retire 145ha to pines	3,488	510	1,786	2,296	57.4%	$ 412	$ 3	$ 6	-$ 27	-$ 11	$ 409	0%	$ 406	-1%	$ 439	7%	$ 423	3%	$ 75,000	$ 244,670
Scenario: 80:20 sheep and beef	3,909	89			2.2%	$ 422	$ 3	$ 12	-$ 33	-$ 12	$ 419	2%	$ 410	0%	$ 455	11%	$ 434	6%		$ 160,000
Base - Otago sheep, beef and deer (6,800 effective ha, 1.2SU/ha)	709					$ 80	$ 0.4	-$ 37	-$ 8	-$ 22	$ 80	-1%	$ 117	47%	$ 88	10%	$ 102	28%		
Scenario: Retire 2,815ha to native (20% woody)	645	64	265	329	46.4%	$ 73	$ 0.4	-$ 38	-$ 8	-$ 22	$ 73	-9%	$ 111	39%	$ 81	1%	$ 95	19%	$ 200,000	$ 67,000

Notes:

- All costs are based on effective area
- Capital costs are for infrastructure – fencing for retiring to pines, and yards for the conversion to bull beef. These are estimates only.
- One-off net benefit is the value of stock sold less purchased at the end of a financial year to transition to a different system based on long-term stock values in Farmax. These are estimates only.
- Allocation factors used for calculating obligation are based on national average emissions per hectare and per unit of output for land and output based obligation methodology respectively.

3.1 Results and discussion for dairy farms

It should be noted that the data on which the three dairy case studies were built meant they were above average national emissions per kilogram of milk solids. The output and hybrid allocation methodologies therefore result in a benefit for these farms which would not occur if they were below average.

Analysis of scenarios was consistent with previous modelling work. For the Canterbury dairy farm, swapping the PKE for maize silage reduced emissions by 2.4% and increased EFS/ha by 3.1%. Reducing stocking rate by 10% while maintaining per cow production reduced emissions by 7.2% and increased EFS/ha by 6.4% as a result of lower costs and improved efficiency. Similarly, reducing stocking rate and imported feed on the Bay of Plenty dairy farm resulted in a reduction of emissions of 4.6%, and an increase of 32.9% EFS/ha[4] due to increased per cow production. This increase in EFS/ha for both scenarios was still positive regardless of the free allocation methodology. Reducing stocking rate means a 'sale' of stock which could generate a short-term cash benefit, although would decrease the asset value for overall farm profitability.

These mitigation strategies are not constrained by the land, although the ability to supplementary feed is more limited on rolling dairy land, than flat, and therefore, generally more costly. To achieve a positive outcome from reducing stocking rate, the feed quantity and quality needs to be maintained which can be more challenging as the limiting factors of the land such as soils, climate and topography increase. The improved EFS/ha on the Bay of Plenty property suggests the farm was not performing efficiently in the base.

Conversely, reductions in emissions ranged from 10.5 to 22.9% for the options in the Taranaki dairy farm including replacing urea with low N feed, removing urea and converting to bull beef. However, these scenarios all resulted in decreases in EFS/ha by 13.5% for replacing urea with low N feed, 21.6% for removing urea, and 53.9% for converting to bull beef. These reductions are not likely to be influenced by the land as it is unconstrained. The farm was also operating efficiently, where changes that reduced feed availability also decreased EFS/ha.

Retiring 8.5ha to pines on the Bay of Plenty dairy farm reduced emissions by 9.3%, and decreased EFS/ha by 7.8%. Whereas on the Taranaki dairy farm, retiring 2ha of pines decreased emissions by 2.4% and increased EFS/ha by 1.2% due to decreased feed costs over slightly fewer cows. The calculations used may underestimate the cost of forestry for such a small area as a standard cost per hectare was applied in all scenarios.

Capital costs would be experienced for retiring areas to pines in the form of fencing, and the bull beef scenario would require new, more substantive yards.

A land-based free allocation methodology resulted in a credit for all of the scenarios in Bay of Plenty dairy and Taranaki dairy. All of the dairy farms were performing better than average which resulted in a credit (rather than obligation) when the free allocation was based on milk production or the hybrid of land and milk.

[4] When stock numbers are reduced, GHG emissions also reduce. If per animal production then increases, GHG emissions will start to increase again. Whether a reduction in stocking rate is profitable depends very much on the farmers' ability to maintain pasture quality. There is also a limit to the degree of stocking rate reduction before the whole system is unprofitable.

Dairy farmers have more farm system mitigation options compared with sheep & beef farms, as well as the opportunity for land use change into permanent horticulture. But they have very limited scope to retire land into forestry as an offset. In addition, due to dairy cows being milked at least once a day, usually twice, there are options for emerging technologies such as feed additives or vaccines which are more difficult in sheep, beef and deer systems where stock are not handled on a daily basis through a shed. However, the capital required for a dairy farm is significant, and mitigation options which result in land use change to a less intensive land use are likely to come at a significant opportunity cost as shown in previous work.

While there have not been enough scenarios analysed to make quantitative conclusions, this analysis demonstrates some of the complexity of making system changes to reduce greenhouse gas emissions on dairy farms. These properties are all relatively highly performing compared to national averages in terms of EFS/ha, yet there was still opportunity to make gains for emissions and EFS/ha, and many of the free allocation methodologies also resulted in a net benefit for the farm, or obligations were reduced with mitigation while still providing a positive benefit on EFS/ha. The land type was likely to have less of an influence on these farms than other factors such as the efficiency of the existing operation and ability to manage reductions in stock numbers with better feeding. These options decline as physical limitations of the land increase.

3.2 Results and discussion for sheep, beef and deer farms

Analysis of the scenarios was consistent with previous modelling work. Emission reductions ranged from 1.1% to 57% with a range of impacts on EFS/ha from increasing by 7% to a reduction of 8.8%.

Increasing the sheep to cattle ratio was used on East Coast sheep and beef, and the Central North Island sheep and beef. This resulted in a decrease in EFS/ha for the East Coast farms, and an increase in the Central North Island. Market drivers have a strong influence on returns and there are fluctuations over-time where sheep may be performing better than cattle and vice versa. Regional differences can influence this also depending on the proportion of animals sold store. The store market is largely driven by feed availability which can distort prices across regions. The climate, soils and topography of land will have a strong influence on how much feed is grown in any given season and will therefore influence the effectiveness of this scenario. It is likely to be more difficult to maximise variable markets as physical constraints increase. Thus, shifting policies to increase or decrease the overall ratio can be risky, and variable in its impact.

Retiring land to pines on the East Coast farm and the Central North Island farm reduced emissions, by 12% for East Coast, and 57% for Central North Island. However, it increased East Coast EFS/ha by 7%, and Central North Island by only 0.7% due to the underlying base profitability of the farm. Retirement to natives was also modelled on the Otago farm which reduced emissions by 46%, but also reduced EFS/ha by 8.8%. The more challenging the land, the less likely good returns will be experienced from forestry, like pastures, pines will grow better on better soils, topography and in a better climate. There was no accommodation made for this in the modelling, a standard approach was used. However, it needs to be considered. Practical constraints such as distance to port, infrastructure, and access to labour for planting, management and harvest are also likely to be increased on harder landscapes.

It should be noted that the use of forestry for mitigation is complex, particularly if planting plantation forestry in a single-age stand. In this modelling there is no cash-benefit from carbon, because it has been used as an 'off-set' for emissions. However, under the current rules, approximately 80% of the value of the off-set needs to be paid back when trees are harvested, and the forest area needs to be replanted. An alternative approach of 'averaging' is currently proposed which has been used for this modelling, but this only applies in the first rotation.

The free allocation methodology has a mixed impact on the mitigation options considered. For East Coast and Otago, the land, output, and hybrid all result in credits. Central North Island still faces a liability under the land-based free allocation. The credit paid in some cases makes a significant, positive difference to EFS/ha.

Capital costs for fencing off retired areas would be faced by sheep and beef farmers in these case studies.

Sheep, beef and deer farmers have relatively fewer farm system options available to them, particularly in very extensive, low-input systems, but more scope with land for retiring areas or planting into forestry which results in more significant emissions reductions than other mitigation options. These options are limited in the harsher climates (e.g. South Island High Country) where regeneration of natives or planted forestry can be very slow. The opportunity cost of this is also generally lower due to lower land values and less capital outlay for these farming systems. Although it can still be substantial, as the land value for steep, pastoral hill country is circa $6,000-7,000/ha, compared with circa $1,000-2,000/ha under forestry.

3.3 Mitigation options

Mitigation options currently available to New Zealand farmers are limited to farm system changes and land use change. Therefore, the costs of applying these options varies significantly from minimal to substantial. Many of the costs of implementation are included in the calculation for EFS/ha. As mentioned above, an estimate of the costs and benefits of making the change (where relevant) are presented.

The mitigation options which have shown greenhouse gas reductions in other modelling work were used, and as many as resulted in reductions are presented. Some options were discarded as they resulted in an increase in emissions. These are presented in Table 5 below. This highlights the complexity associated with modelling, and also the potential practical challenges farmers will face in assessing the options available to them to reduce emissions when there are regulations and/or a market mechanism to do so.

Table 5 Mitigation options which *increased* emissions in the Overseer modelling

Farm	**Potential mitigations that increased GHG emissions**
Canterbury Dairy	None
Taranaki Dairy	- Replace maize with fodder beet - Remove crops - In shed feeding
BOP Dairy	- Remove crops - Install feed pad - In-shed feeding
Otago SBD	- Removing deer and replace with sheep - Increasing sheep numbers and reduce cattle numbers
Central NI SB	- Change male cattle to all bulls rather than mix of steers and bulls
East Coast SB	None

Additionally, some of the mitigation options available are long-term and can 'lock-in' landowners to these options with a high cost to reverse this. Forestry is an example of this, where it takes decades to achieve the whole financial benefit, albeit there can be some carbon income in the meantime, so changing the system prior to an appropriate harvest time means losing out on the full-worth of the crop.

Overseer modelling has been used across a number of projects to consider mitigations and their applicability to land use. A report on on-farm mitigation options to reduce agricultural GHG emissions in New Zealand[5] concludes that the range of options modelled showed a moderate reduction in GHG emissions and production without reducing profitability, but to achieve greater emission reductions, this came with a significant impact on production and profitability. As mentioned above – the impact on profitability to individual farmers will be highly variable depending on where they sit currently and their ability to manage new systems.

The report referenced above on on-farm mitigation options, found a reduction of between 2 and 10% for dairy farms (other than forestry) and 1 to 5% for sheep, beef and deer. In the report, forestry could reduce emissions by more than this but had a significant impact on profitability (with implied carbon costs of mitigation well in excess of \$100/tCO_2-e for dairy and \$10-\$45/tCO_2-e for sheep and beef). The present report found greater reductions in dairy systems and similar ranges in sheep and beef.

As outlined earlier, decisions around what mitigation options to apply will be driven by a range of factors including economic drivers. Anecdotally, a lot of changes to a farm business occur with a generational change and/or farm sale (i.e. new management/ownership). It is therefore difficult to say whether a poor performing sheep and beef farm is more or less likely to convert to forestry, they may be more likely to sell to someone else who would presumably weigh up the options of different land use in relation to the price paid for land.

3.4 Land use change

In general, moving from a higher intensity land use to a lower intensity land use will reduce greenhouse gas emissions. The impact on profitability is variable depending on a range of factors, although generally will also reduce profitability, and can come at a significant

[5] https://www.mpi.govt.nz/dmsdocument/32158-berg-current-mitigaiton-potential-final

opportunity cost in the form of stranded capital and ongoing income generation. The case studies consider retiring areas into forestry/native which has greater application (generally) to sheep, beef and deer farmers as land values are generally lower and there is usually land which would be suitable for forestry/retirement without impacting on current stocking rates substantially. The scale and type of land going into forestry/native will have a big influence on whether stocking rates need to reduce, and whether it can be planted in plantation forestry or planted or retired into native.

3.5 Impact of emission reductions on different land use

3.5.1 Stranded Assets

More intensive land uses are generally producing more greenhouse gas emissions and are on higher priced land with higher cost infrastructure. Those operating in this way are doing so within the acceptable rules and regulations of the day and make or have made long-term investment decisions on the basis that they will be able to operate a level of intensity which will enable them to generate a return on this investment. The impact of a cost on emissions will depend on the free allocation methodology and the ability of the farmer to respond. Where farms are performing above average, under the output-based obligation, they received a credit (which was the case for all the case study farms). If farms are performing below average, this will result in a greater liability. Where a farm needs to reduce the intensity of production, this could leave them with stranded assets (e.g. decreased stocking rate under irrigation where per cow performance is not able to be maintained, may reduce the economic return and value of the irrigation). The free allocation of 95% of emissions to the total agricultural sector is partly being made to negate this risk.

3.5.2 Cost-benefits in isolation

Other regulatory or market drivers may/will change the relative economics of options. Factors such as water regulations or animal welfare regulations are likely to impact these. A range of mitigation options may be required to meet water quality or quantity limits, as has happened in many parts of New Zealand. Likewise, a ban on bobby calves will change the relative economics of bull beef systems. The analysis can only consider what is known today, but a range of regulations are pending which may alter the relative advantage or disadvantages of different approaches and should be considered. Market opportunities may also develop as a result of substantive changes to New Zealand farm systems.

4.0 CONCLUSION

The costs and benefits of mitigation options to reduce greenhouse gas emissions will differ between farms and this is likely to have a greater influence on the outcomes than the land class per se (see above). Differences in the costs and benefits will occur between and within land uses. The ability to implement mitigation strategies will to some extent be constrained by the physical limitations of the land such as soils, climate and topography, as well as the ability of the farmer. Therefore, as physical limitations of land increase, the opportunity to a) implement mitigation strategies, and b) maximise the benefit of them, declines. However, the proposed free allocation methodologies are generally more positive than negative for these farms.

While there are mitigation options currently available to most farmers, as demonstrated by a range of work completed in New Zealand and the present research, these will have a varying impact on emissions reductions and the profitability of these farms.

It is not possible to draw quantitative conclusions from the case study analysis of 6 farms. However, there are mitigation options which reduce emissions and improve EFS/ha. Similarly, a number of options which reduced emissions also reduced EFS/ha. The magnitude of benefits were greater in the dairy case studies considered than the sheep and beef, although greater benefits were realised on the sheep and beef properties from most of the free allocation methodologies.

Mitigation options were more limited on sheep and beef farms than dairy and these options may expose farmers to greater market volatility (e.g. moving production systems to more sheep if sheep market declines which can occur on a regional basis as well as nationally). This can be countered to some extent with the appropriate free allocation methodology.

1.0 APPENDIX 1 – DETAIL OF CASE STUDY FARMS AND MITIGATION APPLIED

1.1 Base: Case Study 1 – Canterbury Dairy Farm

- 245ha total, 239ha effective
- 766 cows (peak), 312,000kgMS/year, replacement stock grazed off-farm, 400 cows grazed-off over winter
- 180 replacements
- 8ha winter crop
- Imported feed
    - 200tDM maize silage
    - 400tDM PKE
    - 200tDM barley grain
    - 200tDM wheat grain

1.1.1 Mitigation Scenario 1 – Increased use of maize

- Imported PKE replaced with additional 205tDM imported maize silage and 20ha of maize silage grown on farm
    - Total maize silage imported now 405tDM
    - Total maize silage harvested 480tDM
- Approximately 1 tonne less urea
- Cow numbers and production maintained

1.1.2 Mitigation Scenario 2 – Reduced stocking rate

- Stocking rate reduced by 10% (689 cows, 162 replacements) (400 cows grazed-off in winter)
- Per cow production maintained, overall reduced (280,665kgMS/year)
- 400tDM PKE no longer imported

1.2 Base: Case Study 2 – Bay of Plenty Dairy Farm

- 153ha total, 153ha effective
- 445 cows (peak), 148,500kgMS/year, replacement stock grazed off-farm
- 80 replacements
- 13ha turnips
- 6ha maize
- Imported feed
    - 176tDM PKE
    - 9tDM hay

1.2.1 Mitigation Scenario 1 – Reduced stocking rate

- Stocking rate reduced by 10% (400 cows, 72 replacements)
- Per cow production increases, total milk production stays the same (148,500kgMS/year)
- Imported feed
    - 31tDM PKE
    - 9tDM hay

1.2.2 *Mitigation Scenario 2 – Retiring land into pines*

- 8.5ha retired and planted in pines
- Stocking rate reduced (400 cows, 72 replacements)
- Per cow production maintained, total reduced (133,650kgMS/year)
- Imported feed
  - 31tDM PKE
  - 9tDM hay
- Approximately 1 tonne less urea

1.3 Base: Case Study 3 – Taranaki Dairy Farm

- 186ha total, 170ha effective
- 506 cows (peak), 185,871kgMS/year, replacements grazed off-farm
- 112 replacements
- 14ha turnips
- 9.1ha maize
- 1ha fodder beet
- 220tDM PKE
- 62t urea

1.3.1 *Mitigation Scenario 1 – Replace urea with low N feed*

- All urea applications removed
- 332tDM maize silage imported
- Cow numbers and production remain the same
- Crops and PKE remain the same

1.3.2 *Mitigation Scenario 2 – No urea applied*

- All urea applications removed
- Cow numbers reduced (429 cows, 95 replacements)
- Per cow production maintained, total production reduced (158,914kgMS/year)
- Crops and supplements remain the same

1.3.3 *Mitigation Scenario 3 – Retire land to pines*

- 2ha retired from grazing and planted in pines
- Cow numbers reduced (501 cows, 111 replacements)
- Per cow production maintained, total production reduced (184,059kgMS/year)
- All other inputs remain the same

1.3.4 *Mitigation Scenario 4 – Convert from dairy to bull beef*

- Converted from dairy to bull beef finishing
- 240 weaner bulls purchased at 5 months old and finished from 20-26-months old
- 240 bulls purchased at 15-months old, and finished from 21-26 months old
- No cropping
- No imported feed
- 62t of urea applied, slight reduction in other fertiliser due to removal of crops.

1.4 Base: Case Study 4 – East Coast Sheep and Beef

- 3,999ha total, 1,941ha grazed, 1,880ha trees and scrub, 150ha pines, 28ha non-effective
- 40:60 sheep:cattle
- 3,500 ewes, 1,063 replacements, 120% lambing, all lambs sold by July
- 662 MA breeding cows, 158 replacements, 83% calving. All progeny retained, non-replacement females sold store and to the works, all male progeny finished to the works. An additional 106 weaner bulls are purchased
- 15t of urea applied to flats

1.4.1 Mitigation Scenario 1 – No Nitrogen Fertiliser

- 15t urea removed
- 10 less bull calves purchased
- Sheep and breeding cattle numbers and performance remain unchanged

1.4.2 Mitigation Scenario 2 – Increasing sheep ratio to 50:50 with cattle

- Sheep numbers increased (4,364 MA ewes, 1,328 replacements)
- Cattle numbers decreased (554 breeding cows, 132 replacements, 85 weaner bulls purchased)
- Stock performance and policies remain unchanged

1.4.3 Mitigation Scenario 3 – Increasing sheep ratio to 60:40 with cattle

- Sheep numbers increased (5,284 MA ewes, 1,606 replacements)
- Cattle numbers decreased (437 breeding cows, 103 replacements, 71 weaner bulls purchased)
- Stock performance and policies remain unchanged

1.4.4 Mitigation Scenario 4 – Retiring marginal land

- 50ha of marginal (effective) area retired and planted in pines
- Sheep numbers decreased (3,464 ewes, 1,052 replacements)
- Cattle numbers decreased (655 breeding cows, 157 replacements)
- Stock performance and policies remain unchanged

1.5 Base: Case Study 5 – Central North Island Sheep and Beef

- 1,445ha total, 1,153ha grazed, 57ha pines (not ETS registered), 220ha natives, 15ha non-effective
- Sheep:cattle 64:36
- 3,800MA ewes, 1545 replacements. 145% lambing. Non-replacement lambs sold before winter
- 270 MA breeding cows, 50 replacements, 94% calving
- 25ha winter fodder crop for cattle

1.5.1 Mitigation Scenario 1 – Retire marginal land

- 145ha retired and planted in pines

- Sheep numbers decreased (3,347 ewes, 1,234 replacements)
- Cattle numbers decreased (238 breeding cows, 44 replacements)
- Stock performance and policies remain unchanged

1.5.2 Mitigation Scenario 2 – Increase sheep ratio to 80:20 with cattle

- Sheep numbers decreased (4,783 ewes, 1,764 replacements)
- Cattle numbers decreased (154 breeding cows, 27 replacements)
- Stock performance and policies remain unchanged

1.6 Base: Case Study 6 – Otago Sheep, Beef and Deer Farm (High Country)

- 10,436ha total, 6,800ha effective, 4ha forestry, 3,621ha native (primarily tussock), 10ha non-productive
- 5,725 ewes, 130% lambing, 1,925 replacements, all non-replacement lambs sold by March
- 135 breeding cows, 16 replacements, non-replacement calves finished at 20-months of age
- 155 breeding hinds, 20 replacements, remaining hinds sold store or finished at 20 months of age, half stags finished at 20 months of age, half as replacements for velveting stags
- 170 velveting stags
- 67ha winter fodder crops
- 22ha grain and cereal feed crops
- 100ha lucerne

1.6.1 Mitigation Scenario 1 – Retiring marginal land

- 2,815ha of marginal hill country (only grazed by cattle) retired
- Half of the retired area is pre-1990 and half was grazing land in 1990
- Assumed 20% would be able to sequester carbon (i.e. 563ha)
- Cow numbers reduced (68 cows, 10 replacements)
- Sheep and deer numbers remain
- Policies unchanged

2.0 APPENDIX 2 – FORESTRY ASSUMPTIONS

2.1 Silviculture costs

A clearwood regime was assumed for the radiata pine scenarios. Genetically improved tree stock and timely management was assumed to mean this regime could be achieved with two pruning operations. Table 6 below sets out the generalised regime used and cost assumptions.

Table 6 Silviculture costs for *Pinus radiata*

Operation	Year	Cost /ha
Tree stocks, planting and releasing	0	$1,070
Prune 1	5	$750
Prune 2	8	$900

2.2 Yield tables

National Exotic Forest Description (NEFD) 2017 regional yield tables published by MPI were used to generate a generalised split of grades. Post 1989 pruned stand tables were used. These yield tables give volumes per hectare in the general grade mixes of pruned, unpruned saw-log and pulp. General assumption on the split of these grades was made in Table 7 as follows:

Table 7 Yield assumptions for forestry analysis

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

2.3 Log prices

Log prices are from MPI Indicative New Zealand Radiata Pine Log Prices by Quarter[6]. The weighted average from June 2017 to December 2018 was used (note that log prices have been particularly high over the past 18-months, a longer-term average would reduce these).

Composite prices for the pruned, unpruned, and pulp were calculated based on the assumed grade composition above. Export JAS fob log prices were reduced by $\$18/m^3$ to allow for wharfage and JAS conversion. Composite prices used are set out in Table 8 below.

Table 8 Log price based on yield composition

NEFD Composite log grade	$/m³ at mill or wharf gate
Pruned saw-log	$171.5
Unpruned saw-log	$147.1
Pulp	$56

[6] https://www.teururakau.govt.nz/news-and-resources/open-data-and-forecasting/forestry/wood-product-markets/

2.4 Harvesting costs

Harvesting costs were based on general industry knowledge and expectations of the type of land and likely broad location where forests might be established. The assumptions are presented in Table 9 below.

Table 9 Harvesting cost assumptions

Operation	Cost/m³
Road & skid construction	$4
Logging & loading	$26.5
Management	$4
Contingency / RMA	$1
Transport	$21.5
Total harvest costs	$57

2.5 Annual costs

The annual cost of $50/ha has been used to cover general admin and insurance.

2.6 Carbon sequestration assumptions

Carbon sequestration for the five scenarios which had retiring areas are outlined in Table 10 below. An 'averaging' approach was used which was based on half of the annual average sequestered over 28-years for pines and 50-years for native.

Table 10 Carbon sequestration rates by region under 'averaging' policy

Region	Carbon sequestered per ha using 'averaging' (tonnes CO_2-e/ha)
Gisborne	14.4
Southern North Island	14.2
Bay of Plenty	12.6
Native (national)	3.2

3.0 APPENDIX 3 – FREE ALLOCATION RESULTS

Table 11 Free allocation in tonnes CO_2-e for different allocation methodologies and obligation based on $25/tonne CO_2-e for each allocation methodology

Mitigation	**Emissions (kg CO_2-e/eff ha)**	**GHG reduction (kg CO_2-e/eff ha)**	**Free allocation (tonnes CO_2-e total)**				**Net obligation (Total $)**			
			Proportional	**Land**	**Output**	**Hybrid (land + output)**	**Proportional**	**Land**	**Output**	**Hybrid (land + output)**
Base - Canterbury dairy	12,930		2499	2393	2996	2695	$ 3,288	$ 5,920	-$ 9,139	-$ 1,609
Scenario: PKE swapped for maize	12,615	315	2438	2393	2996	2695	$ 3,208	$ 4,326	-$ 10,733	-$ 3,203
Scenario: Reduced stocking rate	11,998	932	2303	2393	2695	2544	$ 3,031	$ 782	-$ 6,755	-$ 2,986
Base - Bay of Plenty dairy	10,109		1344	1532	1426	1479	$ 1,769	-$ 2,922	-$ 265	-$ 1,594
Scenario: Reduced stocking rate	9,647	462	1281	1532	1426	1479	$ 1,685	-$ 4,594	-$ 1,937	-$ 3,265
Scenario: Retire 8.5ha to pines	9,167	942	1217	1532	1283	1408	$ 1,602	-$ 6,273	-$ 51	-$ 3,162
Base - Taranaki dairy	11,535		1487	1702	1785	1744	$ 1,957	-$ 3,424	-$ 5,481	-$ 4,452
Scenario: Replace urea with low N feed	10,328	1,207	1423	1702	1785	1744	$ 1,873	-$ 5,108	-$ 7,166	-$ 6,137
Scenario: Remove urea	8,896	2,639	1223	1702	1526	1614	$ 1,609	-$ 10,371	-$ 5,958	-$ 8,164
Scenario: Retire 2ha to pines	11,426	109	1455	1682	1767	1725	$ 1,914	-$ 3,781	-$ 5,904	-$ 4,842
Scenario: Convert to bull beef	9,477	2,058	962	312	1135	723	$ 1,266	$ 17,504	-$ 3,054	$ 7,225
Base - East Coast sheep and beef	3,408		2285	3565	5733	4553	$ 3,007	-$ 28,988	-$ 78,386	-$53,687
Scenario: Remove nitrogen fertiliser	3,369	39	2270	3565	5698	4536	$ 2,987	-$ 29,390	-$ 77,942	-$53,666
Scenario: 50:50 sheep and beef	3,362	45	2255	3565	5790	4590	$ 2,967	-$ 29,792	-$ 81,038	-$55,415
Scenario: 60:40 sheep and beef	3,243	165	2174	3565	5867	4643	$ 2,861	-$ 31,911	-$ 85,812	-$58,861
Scenario: Retire 50ha to pines	3,369	39	2259	3565	5678	4520	$ 2,972	-$ 29,682	-$ 77,394	-$53,538
Base - Central North Island sheep and beef	3,998		2613	2118	4140	3214	$ 3,438	$ 15,816	-$ 38,976	-$ 11,580
Scenario: Retire 145ha to pines	3,488	510	2278	2118	3643	2925	$ 2,997	$ 7,004	-$ 33,378	-$ 13,187
Scenario: 80:20 sheep and beef	3,909	89	2555	2118	4189	3266	$ 3,362	$ 14,297	-$ 43,110	-$ 14,407
Base - Otago sheep, beef and deer	709		2233	12490	4572	8209	$ 2,938	-$253,502	-$ 39,411	-$146,456
Scenario: Retire 2,815ha to native (20% woody)	645	64	2028	12490	4325	8097	$ 2,669	-$258,879	-$ 39,188	-$149,033

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