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MITIGATION OF ON-FARM GREENHOUSE GAS EMISSIONS

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Background

This paper discusses the results from a range of modelling studies carried out for the NZ Greenhouse Gas Research Centre (NZAGRC), the Biological Emissions Reference Group (BERG), and individual private farms.

The aim of the modelling was to investigate the impact of changes in the farm system, and/or offsetting via forestry, or averaging across the inclusion of a horticultural block. These impacts were measured as the change in farm profitability, as measured by EBITDA[1], relative to the change in biological greenhouse gas[2] (GHG) emissions.

The modelling was done via a range of approaches:

(i) The farm system modelling was done with FARMAX[3], a farm management decision support model, where the base farm was set up within Farmax, and changes made to the farm system depending on the scenario, with Farmax showing (a) when the system was biologically feasible, and (b) the change in farm profitability.

(ii) The data was then transferred to Overseer[4], a nutrient budget model, which would show any nutrient (phosphorus, nitrogen) losses, as well as the GHG emissions.

(iii) For forestry, the rotation cashflow (very largely based on *pinus radiata*) was set up in an Excel spreadsheet, discounted back to a NPV, which in turn was converted to an annuity so as to line up with the farm EBITDA. Carbon sequestration rates were based on the MPI Look-up tables (MPI 2017).

(iv) This information was then collated in an Excel spreadsheet, so as to directly compare the scenarios side by side.

In many respects the aim was to endeavour to identify farm systems which reduced GHG emissions relative to the status quo, and had minimal impact on the farm profitability, or at best, improved it.

Biological GHG Emissions

[1] Earnings before Interest, Tax, Depreciation, and Amortisation.
[2] Biological GHG = methane + nitrous oxide.

[3] www.farmax.co.nz
[4] www.overseer.org.nz

Methane is produced by ruminant animals. When the pasture is digested within the rumen, hydrogen is a by-product of this; methanogen microbes within the rumen scavenge this hydrogen, along with CO_2, to produce methane, which is then very largely burped out by the animal. Essentially its is natures way of removing the hydrogen from the rumen, as it would become poisonous if allowed to build up. Once in the atmosphere the methane then breaks down to CO_2 and H_2O.

Nitrous oxide is a direct product from the nitrogen excreted in the urine onto the ground (as a result of protein digestion), as well as from nitrogen fertilisers applied.

There is a direct relationship between methane produced and forage eaten: approximately 21 grams of methane per kilogram of dry matter intake (NZAGRC 2016). Nitrous oxide emissions vary more, depending much more on soil types and rainfall.

While some feeds (e.g. forage rape, cereal grain, plantain, fodder beet) have been shown to reduce methane emissions, they have to be fed at a significant level of the diet, often more than 30%, to have any effect.

Average farm GHG emissions

Industry studies, based on Overseer modelling, of a nationally stratified sample, have shown the average farm GHG emissions are:

Table 1: Average farm biological GHG emissions (tonnes CO_2e/ha)

	Average (TCO_2e/ha)	Range (TCO_2e/ha)
Dairy	9.6	3.1 – 18.8
Sheep & Beef	2.8	0.4 – 6.5

The range shown in Table 1 is very much driven by the intensity of the farm system. For the average farm, 78% of emissions are methane, and 22% nitrous oxide.

The intensity of GHG emissions - the amount of CO_2e per kilogram of product is often raised, inasmuch as New Zealand pastoral farming is very efficient, and the intensity of our emissions are among the best in the world. Indeed, the improvement in efficiency over recent decades means that New Zealand's absolute emissions are much less than they would have been without the improvement.

The main point though is that all the international agreements, and internal emission targets, are based on absolute emissions.

On-Farm Modelling

As discussed earlier, the base farms were set up in Farmax and Overseer, with the changed farm system scenario then modelled to determine the impact on farm profitability and GHG emissions.

A summary of some of this modelling is outlined below.

Table 2: Dairy Modelling Results

		Change in GHG	Change in EBIT
Reduce stocking rate by 10%	Farm 1	-6%	12%
	Farm 2	-7%	-4%
	Farm 3	-8%	-3%
	Farm 4	-3%	14%
Replace N fertiliser with bought-in feed		-11%	-18%
In-shed feeding with increased cow numbers		11%	12%
In-shed feeding, no increase in cows		10%	9%
Grow maize instead of buying in PK		-4%	0%
Limit N fertiliser to 100kgN/ha		-5%	-12%
Shift to once-a-day milking		3%	21%
Remove all bought in supplement/reduce N fertiliser 60%		-20%	-10%

Table 3: Sheep & Beef modelling results

		Change in GHG	Change in EBIT
All male progeny as bulls		-6%	12%
Convert to deer (finishing weaners)		0%	-19%
Shift to 50:50 sheep: beef		-10%	13%
Increase sheep : cattle ratio	Farm 1	-1%	0%
	Farm 2	1%	10%
	Farm 3	-1%	-20%
	Farm 4	0%	19%
Intensive lamb finishing		7%	22%
Increase lambing % (135 to 160)		0%	12%
Develop 100 ha techno beef unit		9%	33%
Replace breeding cows with finishing bulls & heifers		-8%	78%
Convert to dairy sheep		17%	68%

There are two main lessons to be learned from this modelling:

(i) The variation in response, both with respect to GHG emissions and farm profitability, from similar farm system changes on different farms. The main factor affecting this is the intensity of the farming system at the outset, and, in the real world, the ability of the farmer to implement the change

(ii) As a result, there are no ready recipes; it is not possible to say to a farmer "if you do x, you'll achieve y". Because basically each farm is different.

As a generalisation, the modelling showed that changing farm systems could reduce GHG emissions by 0 -10 %, with varying impacts on farm profitability.

Multi Enterprise Modelling

This involved modelling two businesses with multi-enterprise operations; forestry, sheep & beef, and several dairy farms. The idea was to look at different mitigation approaches on the different farms, and then "mix and match" these across the whole enterprise.

Examples of this are:

Table 4: Impact of modelling scenarios across whole farming enterprise

	Change in GHG	Change in EBIT
Reduce SR, increase per cow to 400kgMS/cow on dairy farms + all male progeny kept as bulls on S&B farm, + plant 348ha forestry on S&B farm	-45%	14%
Lower SR 10% on dairy farms + grow maize instead of buying PK + all male progeny kept as bulls on S&B farm, + plant 348ha forestry on S&B farm	-45%	4%
Restrict N fertiliser to 100kgN/ha on dairy farms + all male progeny kept as bulls on S&B farm, + plant 348ha forestry on S&B farm	-46%	-10%
Reduce SR 10% on dairy farms + 129.5ha forestry on S&B farm	-24%	-1%
Reduce SR 10% on all dairy farms + 129.5ha forestry & 34.5 ha manuka on S&B farm	-27%	-4%

Note that in these examples, the biggest impact in reducing GHG emissions was planting forestry areas to act as an offset.

Permanent Horticulture

Permanent horticulture (i.e. trees and vines) is also an option as a low carbon emitting land use, with average emissions in the order of 0.1-0.2 tonnes CO_2e/ha – as nitrous oxide, directly related to nitrogen fertiliser use.

While this could be an option, it also depends on soil types and local microclimates, and while potentially very profitable, also usually has high up-front capital costs and a delay of several years before profitability is achieved.

In essence the inclusion of such a horticultural crop means that the farming enterprise can then average down its total emissions. As a hypothetical example; assume a 100ha dairy farm, emitting 9.6 tonnes CO_2e/ha, or 960 tonnes in total. If 5 ha of kiwifruit (emitting 0.1 tonne CO_2e/ha) is grown, then the total GHG emission reduces down to 912.5 tonnes CO_2e (95ha x 9.6 + 5 ha x 0.1), which equates to a 5% reduction.

Some modelling work on tree crops (in this case chestnuts) in the central North Island, where an area on the farm was taken out in order to grow the crop, showed the following results:

Table 5: Impact of a permanent horticultural crop

	Change in GHG	Change in EBIT
Dairy Farm (133ha)		
10ha Horticulture	-5%	96%
40ha Horticulture	-24%	346%
Sheep & Beef Farm (908ha)		
10ha Horticulture	-1%	14%
40ha Horticulture	-3%	61%

While the impact in reducing GHG's is significant within the area involved in horticulture, this can be reduced when considered across the larger area of farms, as is the case with the sheep and beef farm modelled above.

Arable and Vegetable Cropping

Inasmuch as no animals are involved in these production systems, then obviously no methane is produced. Which means the main/sole biological emission from these systems is nitrous oxide. This is directly related to nitrogen fertiliser use and affected by soil type and rainfall.

The only option to reduce nitrous oxide emissions therefore is to reduce nitrogen fertiliser inputs, which has complications of its own. The use of nitrogen fertiliser in the arable and vegetable sectors has a number of advantages, namely for both it provides the ability to grow a greater range of crops continuously and at a much higher yield, and provides a greater range of fresh vegetables to the NZ consumer at an affordable price. In the absence of using nitrogen fertiliser all these factors would be adversely affected.

It should also be noted that cultivation of the land in preparation of these crops can often result in significant release of CO_2, as organic matter within the soil oxidises when exposed to the air. Given the difficulties in measuring and monitoring such losses, this is aspect of GHG emission is currently not included within the Emissions Trading System.

Economic Impact

The cost at the farm level, based on the average emissions, and in the absence of any mitigations or offsetting, as shown in Table 1 is:

Table 6: Cost for the average dairy farm ($/ha)

	Price of carbon ($/t CO2e)			
% Liability	$25	$30	$50	$100
5%	$12	$14	$24	$48
10%	$24	$29	$48	$96
50%	$120	$144	$240	$480
100%	$240	$288	$480	$960

Table 7: Cost for the average sheep & beef farm ($/ha)

	Price of carbon ($/t CO2e)			
% Liability	$25	$30	$50	$100
5%	$3.60	$4.30	$7	$14
10%	$7	$9	$14	$29
50%	$36	$43	$71	$143
100%	$71	$86	$143	$286

Note that the "% Liability" relates to the proportion of GHG emissions that must be paid for. Currently the government is proposing a 5% liability on the sector, with the remaining 95% a "free" allocation. How this free allocation will be actually allocated remains to be determined, as well as whether it will abate over time.

These tables illustrate the varying potential as to the financial impact at an on-farm level. If the price remains at $25/tonne CO2e, and the % liability remains at 5%, then for most farmers the easiest/least cost approach would be to simply pay the tax. If the cost starts to fall into the bottom right-hand quadrants of the tables, then the cost will be (a) significant, and (b) provide an incentive to mitigate or offset!

Forestry

Land use change into forestry can result in significant reductions in GHG emissions, on the basis that the carbon sequestered by the trees is used to offset the GHG emissions from the farming operation.

Using forestry as an offset is a complex area, which is outside the scope of this paper. Perhaps the main recommendation for farmers considering forestry offsets is to seek expert advice.

The financial impact varies, depending on the annuity received from the forest, relative to the profitability of the farm. As a generalisation, most dairy farms would be much more profitable than forestry, whereas for sheep & beef farming, this can vary considerably; in some instances forestry is more profitable, in others less profitable. Which reinforces the need to consider the option at an individual farm level.

The amount of forestry required to offset the average farm is shown below:

Table 8: Area of forestry required to offset the average farm (ha)

% Offset:	5%		10%		50%		100%	
Offsetting Regime	Total	Average	Total	Average	Total	Average	Total	Average
151 ha dairy farm	2.9	3.3	5.8	6.6	29.0	33.0	58.0	66.0
640 ha sheep & beef farm	3.6	4.1	7.2	8.2	35.8	40.8	71.7	81.6

Note:

(i) The forestry regime is based on pinus radiata, which has varying sequestration rates in different regions of New Zealand. Other tree species will also have differing figures

(ii) The % Offset is based on the percent liability farmers will face. Currently the government has indicated there will be an initial 95% free allocation – how this is achieved is yet to be determined

(iii) The Offsetting Regime relates to the carbon credits claimed. "Total" indicates that all carbon sequestered over the harvest cycle is claimed, whereas "Average" relates to the latest ETS scheme whereby the average amount of carbon can be claimed in the first rotation, without the need to repay this. The "total" regime would give 28 years coverage, whereas the "average" scheme gives 16-18 years coverage.

(iv) Assumes no other GHG mitigation is undertaken

(v) Assumes both methane and nitrous oxide are offset

Under the Zero-Carbon legislation, methane can not be directly offset by forestry. It can still be achieved though via the medium of money; carbon credits obtained via forestry sequestration can be sold, and the money then used to pay the carbon tax relating to methane.

Perhaps the main issue with using forestry as an offset is that it is not a permanent solution. A hypothetical example to illustrate this;

Assume 100ha is sufficient to offset the GHG emissions from the farming operation. When the forest is harvested, the carbon sequestered is deemed to be lost. This means that the 100ha must be replanted, to continue to offset the farm emissions that have occurred over the forestry rotation – in a sense the replanted forest is necessary to offset backwards. A further 100ha is then needed to be planted to cover the farm emissions going forward for the next rotation. At the end of the next rotation the 200ha is harvested, which again means the sequestered carbon is gone. The 200ha must then be replanted, in order to continue the (backwards) offset. But assuming the farming continues, then a further 100ha needs to be planted to cover the emissions going forward. And so on. The main use of forestry as an offset therefore essentially gives 16-18 years (assuming the main specie planted is radiata, and assuming the new averaging scheme is used) in order to come up with a permanent solution.

Reducing Methane and Nitrous Oxide emissions

As noted earlier, there is a direct relationship between dry matter eaten and methane emissions, and the level of protein in the diet directly relates to nitrous oxide emissions.

Boiled down to the essentials therefore, the following are the two key aspects for reducing biological GHG emissions:

(i) To reduce methane, reduce the level of dry matter intake.

(ii) To reduce nitrous oxide, reduce the amount of protein in the diet, and/or reduce the amount of nitrogen fertiliser applied.

To achieve a 10% reduction in methane therefore, a simplistic approach would be to reduce the amount of dry mater fed by 10%. This is not a recommended farm management approach, so the corollary is to reduce stocking rates. Another approach is to increase per animal production, in that, at the margin, less dry matter is required per kilogramme of product, as the maintenance requirements of the animal have already been met.

A hypothetical example to illustrate this. Assume a 400-cow dairy farm, producing 160,000 kg milksolids. If cow numbers and production are reduced by 10% to 360 cows/144,000 kgMS, overall GHG emissions drop 10% - both methane and nitrous oxide emissions drop 10%. But the drop in production could also have a somewhat deleterious impact on farm profitability.

Now let's assume that because we have surplus feed available, due to the reduction in stocking rate, we can increase per cow production up to the point where total production is back to 160,000 kgMS. This means an increase in per cow production from 400kg/cow to 444/cow. It also means an increase in methane and nitrous oxide emission, because there is more dry matter being eaten.

But not back up to the same level as the base farm. The 360 cows/160,000 kgMS are emitting 5% less than the original base – approximately 2% of this is due to the forgone maintenance cost of the cows removed, and approximately 3% is due to the improvement in the efficiency in the use of the dry matter eaten; at the margin they are eating less dry matter per kilogramme of milksolids. So overall the cows are eating less dry matter relative to the original base herd, hence the drop in GHG emissions. The lesser number of cows but same production relative to the base also means the farm is likely to be more profitable (although in noting this it is very dependent on the marginal cost of the feed relative to the marginal benefit received).

While this sounds very good, there is also a caution; in the real world a reduction in stocking rate often means that, at least initially on most farm, there will be surplus pasture available. Which means that farmer skill and expertise in maintaining pasture quality becomes very important. If pasture quality deteriorates, then production will drop further, directly impacting farm profitability.

Altering the protein level in the diet for a predominantly pasture-fed system is problematic. One of the advantages of New Zealand pasture is that it is relatively high in protein, resulting in good growth rates and levels of production. The disadvantage is that it means the level of nitrogen in urine is high, exacerbating nitrate and nitrous oxide losses.

Where high levels of supplement are being fed, the diet can be altered to reduce the amount of protein. For example, on a dairy farm palm kernel (with moderate protein) can be substituted for with maize silage (low protein). The degree to which this impacts on total emissions depends very much on the proportion of the diet is being supplemented. For sheep & beef farms, with relatively minor levels of supplementation, this option is somewhat limited.

On-Farm versus Sector Reductions

Under the zero-carbon legislation, the targets are:

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

These are national targets, and inasmuch as the vast bulk of methane and nitrous oxide come from pastoral farming, they could be considered sector targets. While the discussion in this paper is all around on-farm GHG reduction, the degree to which they are necessary will depend very much what happens at the wider sector level.

A recent report from NZX (NZX, 2019), forecasts a reduction of around 500,000 cows and 200,000 hectares of dairying land, by 2025. Part of this reduction is land going out of dairy and into a range of other land uses, some of which will still be livestock based, and reduction in cow number on the remaining dairy farms.

The advent of carbon farming has meant a significant improvement in the returns from forestry, particularly relative to sheep & beef farming, and over the last 6 months there has been considerable interest in buying sheep & beef farms (mainly hill country) for planting up into forestry[5]. This has a double impact on GHG emissions, by (a) reducing livestock numbers, and (b) increasing the area in forestry and hence increasing carbon sequestration.

Assuming that these sector-level trends continue/come to pass, it may well mean that the individual farmer well need to do less to reduce GHG emissions relative to the targets indicated.

So watch this space.

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[5] From 1 June -31 October the OIO has approved the purchase by overseas buyers of approximately 32,500ha of S&B land for forestry conversion. To which must be added farms purchased by New Zealand investors.