GREENHOUSE GAS ISSUES AND OTHER STUFF

Phil Journeaux
AgFirst Waikato
phil.journeaux@agfirst.co.nz

Tanira Kingi
Tanira Kingi Ltd
tanira@kokiri.net.nz

Abstract

Several years of on-farm modelling is discussed as to the impact of farm system change, and land use change (forestry, horticulture) on the reduction of greenhouse gas (GHG) emissions and impact on farm profitability. It also indicates the amount of the of the GHG levy, based on the He Waka Eke Noa (HWEN) indicative pricing, for a number of case study farms, and the implication of this on farm profitability. It also shows the value of forestry offsetting on the levy. The use of shadow pricing in developing abatement curves is discussed, as well as discussing issues around native forestry for carbon farming.

Key words: greenhouse gas emissions, profitability, offsetting, shadow prices

Background

Over the last 7 years a methodology for modelling mitigation and/or offsetting of on-farm GHG emissions has been developed, via working with 32 case study farms spread around the North Island (17 sheep & beef farms, 15 dairy farms). This work has been funded by the NZ Agricultural Greenhouse Gas Research Centre, with the current programme, Takahuri Whenua (the changing land) currently in progress. At a general level, this methodology involves:

- Meeting with the owners/managers, with discussion around climate change and greenhouse gas issues, along with collection of information on the farm, and a farm inspection
- The farm is then set up in Farmax (www.farmax.co.nz) so as to model the farm system and any changes to this. This shows any changes in production levels and profitability.
- Data is then transferred into OverseerFM (www.overseer.org.nz) in order to calculate the GHG emissions and nitrogen leaching levels. This was done initially, but with Farmax now calculating GHG emissions, Overseer is used only if nutrient leaching is also an issue (which is often the case)
- A farm inspection is carried out to identify areas on the farm for any afforestation, and/or horticultural development, as a land use change option. These options are then discussed by forestry and horticultural members of the team[1].
- Forestry scenario modelling is set up in Forecaster (www.scionresearch.com) to determine the level of timber returns (excluding carbon)
- A spatial model is set up for each farm using ArcGIS with relevant spatial layers added to support the presentation of the land use change scenarios with the governance and management teams
- Data outputs from all models is then collated within an Excel spreadsheet, to show the impacts of the various scenarios on any changes in GHG emissions, farm profitability, nitrogen leaching, and the level of the proposed carbon levy.
- The results of the modelling are then reported back and discussed with the farm owners/managers

For farm system change, the three key drivers of GHG emissions are:

- The amount of dry matter (DM) eaten by the livestock,
- The amount of protein in the diet, and
- The amount of nitrogen fertiliser used.

Of these, usually the most important by far is the amount of DM eaten. This has a direct correlation with methane emissions, and a strong correlation with nitrous oxide emissions. The amount of protein in the diet is difficult to manipulate with a pasture-only diet but can be done so if supplementary feeds are being provided. Nitrogen fertiliser emits some nitrous oxide and CO_2 emissions as it dissolves, but it's main impact is that it is used to grow more DM.

[1] Groundtruth Ltd and Fruition Horticulture

It is these aspects which are looked to be manipulated when considering farm system changes, with the general aim of reducing GHG emissions while at the same time maintaining the profitability of the farm system. Generally, if forestry for offsetting is considered, areas planted would be on the lesser pasture productive areas of the farm in order to lessen the impact on the pastoral operation. Areas considered for horticulture were on the best soil types, which were often the most productive pasture areas.

The results of this modelling on a selected number of farms is indicated below

Summary of Results

Table 1: Dairy Farm System Change Impacts

	Farm 1			Farm 2			Farm 3			Farm 4			Farm 5		
Scenario	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)
Reduce stocking numbers by 10%, no improvement in productivity	-10%	-17%	-11%	-8%	-18%	-7%	-10%	-14%	-9%	-9%	-17%	-8%	-9%	-20%	-8%
Reduce SR 10%, Increase per cow production	-4%	0%	-5%	-3%	10%	-3%	-4%	5%	-5%	-5%	4%	-6%	-2%	19%	-3%
½ Nitrogen fertiliser	-3%	-1%	-8%	-4%	-3%	-7%	-8%	-5%	-11%	-8%	-2%	-19%	-6%	-2%	-10%
No Bought-in Supplement	-6%	-1%	0%	-7%	4%	-3%	-9%	-10%	-7%	-11%	-6%	-3%	-9%	5%	-2%
Replace Palm Kernel with Maize Silage	0%	0%	-3%	2%	0%	-3%	0%	-2%	-4%	1%	1%	-11%	0%	0%	-2%
Forestry - 10% of effective area in pines	-26%	-8%	-14%	-27%	-1%	-3%	-26%	-5%	-4%	8%	-1%	0%	-31%	-6%	-2%
Forestry - 10% of effective area in natives	-16%	-11%	-14%	-11%	-6%	-3%	-11%	-7%	-4%	8%	-5%	0%	-13%	-12%	-2%
Arable - 10ha Oats	-6%	-2%	-3%	-2%	-5%	-3%	-4%	-6%	-2%	2%	-6%	0%	-1%	-6%	2%
Horticulture - 10 ha*	-6%	142%	-5%	-2%	2%	0%	-4%	5%	0%	2%	224%	-3%	-2%	8%	2%

*A number of horticultural crops were considered; a very high lift in EBITDA is based on growing kiwifruit

Table 2: Sheep & Beef farm System Change Impacts

	Farm 1			Farm 2			Farm 3			Farm 4		Farm 5	
Scenario	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in N Leaching (%)	Change in GHGs (%)	Change in EBITDA (%)	Change in GHGs (%)	Change in EBITDA (%)
Reduce stock numbers by 10%, no improvement in productivity	-7%	-43%	0%	-10%	-18%	-6%	-9%	-15%	-4%	-10%	2%	-12%	-10%
Reduce stock numbers by 10% Increase Productivity	-4%	2%	0%	-2%	-5%	-6%	-8%	-5%	-4%	-6%	9%	-7%	19%
Swap breeding beef herd for finishing bulls	-2%	44%	0%	6%	52%	0%				-3%	13%	0%	-22%
Reduce Breeding Ewes 20%, Increase Lambing from 130% to 160%							-3%	8%	0%			-5%	66%
Forestry - 10% of effective area in pines	-69%	5%	-5%	-55%	-7%	-6%	-53%	13%	0%	-34%	3%	-30%	-3%
Forestry - 10% of effective area in natives	-23%	-50%	-5%	-25%	-31%	-6%	-17%	-10%	0%	-7%	-6%	-7%	-14%
Arable - 50/100ha*	0%	9%	5%	-7%	2%	12%	0%	5%	9%	-1%	6%	-1%	9%
Horticulture - 20/40 ha*	0%	67%	0%	-4%	54%	0%	1%	26%	4%	-1%	79%	-1%	33%

*The area planted varied, relative to the size of the property

Discussion

(i) The “reduce stocking rate, no change in productivity” scenario illustrates the impact of reducing the amount of DM eaten; GHG emissions reduce almost linearly, but there is a relatively significant negative impact on farm profitability. The “reduce stocking rate, improve productivity” scenario meant that the per animal production level was increased in the remaining animals. This resulted in a smaller GHG reduction, as to increase productivity, more DM needs to be eaten. But the increase in productivity meant that farm profitability was maintained or improved in many cases. On some farms the change in profitability was still negative, but much less so than in the absence of any productivity improvement.

(ii) For dairy farms, reducing or removing inputs such as nitrogen fertiliser or supplementary feed reduced GHG emissions, as well as reducing farm profitability. The overall impact on both these factors depended on the relative amount of nitrogen fertiliser and/or supplementary feed being inputted into the system. Changing the amount of a relatively moderate protein feed (palm kernel) for a low protein feed (maize silage) generally had a minor impact – again it depended on the amount of the supplement in the diet. While in some cases nitrous oxide emissions dropped by 1-2%, often methane emissions rose slightly & negated the overall impact.

(iii) For the sheep & beef farms, removing breeding cows (a relatively inefficient stock type) for bull beef (a much more efficient stock type) resulted in a small reduction in GHG emissions, and (generally, but not always) an improvement in farm profitability. This raises an important issue. As it is stocking rate, rather than stock type, which drives GHG emissions. So changing, for example, sheep to cattle ratios, will have minimal impact on GHG emissions if the "after" stocking rate is the same as the "before" stocking rate. If changing a less efficient stock type for a more efficient stock type, this then opens the possibility of reducing the stocking rate, thereby gaining some reduction in GHG emissions, while maintaining farm profitability. At an industry level, analysis has shown that replacing beef calves with calves from the dairy herd will reduce GHG emissions in aggregate[2]Finishing stock more quickly will also reduce GHG emissions. For example, assume the farm is finishing cattle to 300 kg carcass weight at 24 months. If they are finished to 300kg CW at 20 months, this then saves on 4 months of maintenance feeding, thereby reducing GHG emissions. Plus will be more profitable, given the time-value of money.

(iv) The addition of forestry on the case study farms provides the opportunity to offset farm emissions with carbon sequestered by the trees. This is illustrated in Tables 1 and 2, where 10% of the effective area of the farms was planted, resulting in significant reductions in net GHG emissions. For the dairy farms this also resulted in a reduction in profitability, given the returns from the forest were much less than from dairying. For the sheep & beef farms, the profitability impact was more variable. The intent was to plant the trees on the less productive areas of the farm, hence for a number of the farms the returns from forestry were greater than from the pastoral farming operation, giving an overall financial boost to the farm business.

Note that the financial situation excludes the value of carbon, as this has all been used for offsetting. The sequestration rates used are based on the 2017 MPI Look-up Tables, and the much greater value of the pines in offsetting is due to their much faster growth rates leading to higher sequestration relative to the slower growing natives. The (sometimes) positive impact of pines on farm profitability is also in direct contrast to the universal reduction in profitability from natives[3].

(v) Land use change into horticultural or arable options had a relatively minor impact in reducing GHG emissions. The key aspect here is that the inclusion of a horticultural or arable option results in an "averaging down" in GHG emissions, whereby the farm is replacing a higher GHG emitting operation (the pastoral operation), with a lower GHG emitting operation (horticulture/arable). From a GHG perspective therefore, diversification into alternative land uses such as horticulture or arable can be worthwhile, but only if it is done on sufficient scale.

On the profitability side, the horticultural operation lifted farm profitability on both dairy and sheep & beef farms, whereas the arable options improved the sheep & beef farm profitability, but not the dairy farms. For some of the horticultural/arable options modelled, value chains do not yet exist – something that would need to be rectified before any crops were grown.

The other issue that arose is that the advent of the arable cropping on free draining soils often increased the level of nitrogen leching.

(vi) Overall, the modelling has shown:

- That farm system changes can reduce GHG emissions, but only to around a 5-6% reduction, while still maintaining the profitability of the business
- Significant reductions in net emissions, i.e. above 10%, were only readily obtainable via planting forests for offsetting
- Land use change into horticulture or arable options has to be at scale to have a significant impact on GHG emissions

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[2] Reducing greenhouse gas emissions of New Zealand beef through better integration of dairy and beef production. van Selm et al, 2021.

[3] The current MPI carbon look-up Tables for natives is accurate only for naturally regenerating kanuka/manuka shrubland (6.5tCO_2e ha/yr) mean annual increment (MAI) over 50 years. This compares to 21-27tCO_2 ha/yr at age 50 years for pinus radiata. Unpublished research shows that managed native plantations of totara, kauri, kahikatea, rimu and other conifers can produce an MIA over 50yrs of 10 to 16.4 https://pureadvantage.org/carbon-sequestration-by-native-forest-setting-the-record-straight/

- The farm systems modelled would require a significant lift in farm management in order to achieve GHG reductions. Maintaining pasture quality is more difficult at a lower stocking rate, and therefore grazing management would need to step up in order to maintain such quality. Modelling where the metabolisable energy value of the pasture was reduced as a proxy for reduced pasture quality showed a rapid deterioration in the productivity of the farm. Other options, such as the "reducing breeding ewes, significantly improve lambing %", while possible, would require a 5-10 year programme to achieve this. In other words, most farm system changes are not necessarily going to be achieved overnight.
- The intensity and efficiency of the farm also has a big bearing on the results obtained, with a key lesson being; each farm is different.

Impact of the Carbon Levy

A key component of the He Waka Eke Noa workstream is to develop an on-farm pricing system as to the carbon levy farmers will be paying from 2025 onwards.

The pricing formula promulgated is A + B – I – C, where:
A= methane, priced in kg methane
B = nitrous oxide + CO_2 from nitrogen fertiliser, priced in \$/tonne CO_2e
I = value of innovations (i.e. new technologies when they come available)
C = value of sequestered carbon

Each component is determined in dollar terms, and then netted off.

The indicative prices suggested by HWEN are:
- Methane: 11c/kg in 2025, rising to 17-35c/kg in 2030
- Nitrous oxide: \$4.25/T CO_2e in 2025, rising to \$13.80/T in 2030

This pricing approach has been applied to the case study farms, with the table below illustrating the amount of the gross levy and the proportion of this relative to the farms' EBITDA.

Table 3: Gross Carbon Levy as a Proportion of EBITDA

Dairy	2025 Levy	2030 Levy	2025 levy as a proportion of EBITDA	2030 levy as a proportion of EBITDA
Farm 1	$8,613	$27,966	1%	4%
Farm 2	$20,635	$67,004	2%	5%
Farm 3	$7,664	$24,887	1%	3%
Farm 4	$7,484	$24,302	1%	5%
Farm 5	$11,404	$37,028	2%	6%
Sheep & Beef				
Farm 1	$35,212	$114,336	6%	20%
Farm 2	$35,682	$115,862	13%	41%
Farm 3	$50,168	$162,900	5%	17%
Farm 4	$56,554	$183,635	2%	8%
Farm 5	$22,242	$72,220	4%	14%

The key issue here is not so much the amount of the levy, but the proportion of the EBITDA it takes to cover this. This is particularly so for the sheep & beef farms. While the per hectare biological GHG emission from the average sheep & beef farm is 37.5% of that of the average dairy farm, the average sheep & beef farm is 4.5 times larger in area. This means the total emissions from the average sheep & beef farm are greater than from the average dairy farm, and therefore the amount of levy payable is higher. This is then compounded by the lower overall profitability of sheep & beef farms relative to dairy farms. As Table 3 illustrates, there is some variability between farms, and for sheep & beef farms, the levy takes up a much higher proportion of their available cash.

This obviously provides a direct incentive to mitigate or offset emissions. As this paper notes, mitigation options are limited, which then pushes the farmer towards offsetting. The impact of the modelled mitigation/offset scenario has on the overall levy is illustrated via one of the sheep & beef farms modelled.

Table 4: Impact of Mitigation/Offsetting Scenarios on the Carbon Levy: S&B farm example

			Forestry credit		**Net Levy**		**Levy as a % of EBITDA**	
	2025 Levy	**2030 Levy**	**2025**	**2030**	**2025**	**2030**	**2025**	**2030**
Base	$35,212	$114,336			$35,212	$114,336	6%	20%
Reduce stock numbers by 10%	$32,684	$106,128			$32,684	$106,128	10%	33%
Reduce stock numbers by 10% Increase Productivity	$33,830	$109,848			$33,830	$109,848	6%	19%
Swap breeding beef herd for finishing bulls	$34,403	$111,707			$34,403	$111,707	4%	14%
Swap breeding beef herd for finishing prime beef	$33,534	$108,886			$33,534	$108,886	4%	15%
Plant 10% forest - Pines	$33,731	$109,527	$552,279	$896,641	-$518,548	-$787,114	-89%	-134%
Plant 10% forest - Other Exotic Softwood	$33,731	$109,527	$319,872	$519,322	-$286,141	-$409,795	-54%	-77%
Plant 10% forest - Natives	$33,731	$109,527	$162,435	$263,718	-$128,704	-$154,191	-46%	-55%
Cropping - 100ha Oats	$35,200	$114,297			$35,200	$114,297	6%	19%
Horticulture - 40ha Chestnuts	$35,015	$113,695			$35,015	$113,695	4%	12%

As can be seen in Table 4, the farm system change scenarios have some impact on the overall levy relative to the base farm, but in most cases the impact is small. Similarly with the arable/horticulture scenarios, although at least the horticulture scenario is providing a higher profitability, so the proportion of EBITDA is reduced. The one scenario which has the biggest impact is forestry; if all of the credits generated are sold, this then pushes the farm into a significant surplus situation. In reality, the farm would be best to just sell sufficient credits to pay the levy, pushing the remaining credits into the future, in order to maximise the benefit well past the period when credits would be available under the new averaging scheme. The table also illustrates the sequestration advantage of pines.

Another issue which arises with offsetting is that under the Carbon Zero Act (2019), methane cannot be directly offset by sequestered carbon. This is readily got around via the pricing mechanism discussed earlier (A+B-I-C) where everything is denominated in dollars. If this monetary manoeuvre was thwarted, then farmers would be in a very difficult position, as methane makes up around 80% of a farm's biological GHG emissions, and options to mitigate emissions are currently very limited.

Shadow Prices

Within the modelling, shadow prices have been calculated as: change in farm profitability, divided by change in biological GHG emissions. This gives an indication of what price carbon needs to be to restore profitability back to the base situation.

An indication of these prices are:

Table 5: Average Shadow Prices (\$/T CO_2e)

	S&B	Dairy
Reduce stock numbers by 10%	\$91	\$562
Reduce stock numbers by 10% Increase Productivity	-\$348	-\$746
Plant 10% pines	-\$2	\$56
Plant 10% natives	\$180	\$225
50% N Fertiliser		\$145
No bought in supplement		\$90

Caution is needed in interpreting these prices, as they are averages based on a small sample. Nevertheless, they give an indication of several factors:

- The sheep & beef prices are much lower than for dairy, an indication of the relative level of profitability
- The negative figures for the "reduce stocking rate/improve profitability" show the gains that can be made by improving on-farm efficiency
- For both farm types, pine forestry is the cheapest option. The negative price for pines for sheep & beef again indicate that planting some of the area on the farm for forestry will strengthen the farm business.
- There is a significant difference between pines and natives, again a reflection of the much higher profitability and carbon sequestration of pines.

The caution required in using these averages, is that there is a very wide distribution around these figures, again reinforcing that every farm is different. This can be illustrated by graphing the relationship between shadow prices and the level of GHG reductions being achieved.

Figure 1: Sheep & Beef Farms: Reduction in stocking rate by 10%

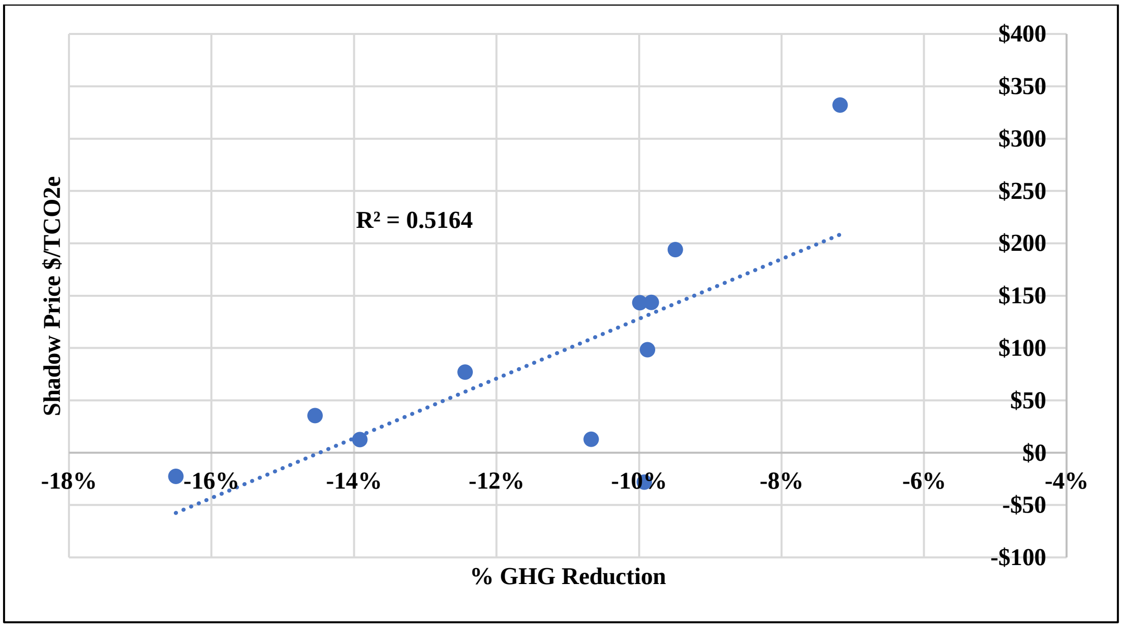


Figure 2: Sheep & Beef Farms: Planting 10% in Pines

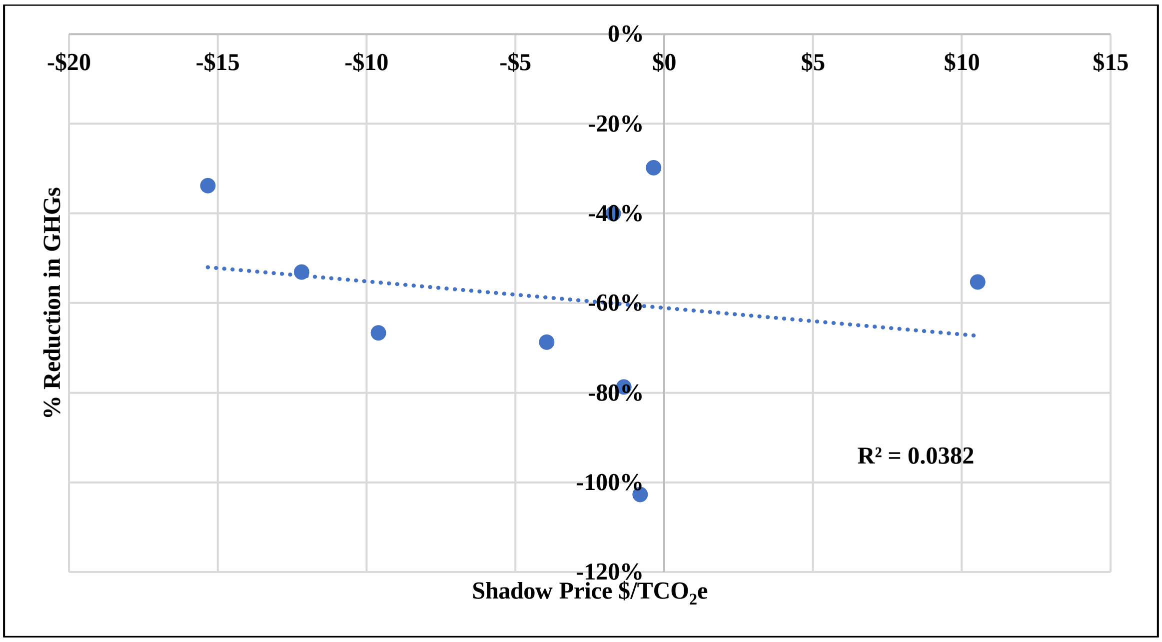
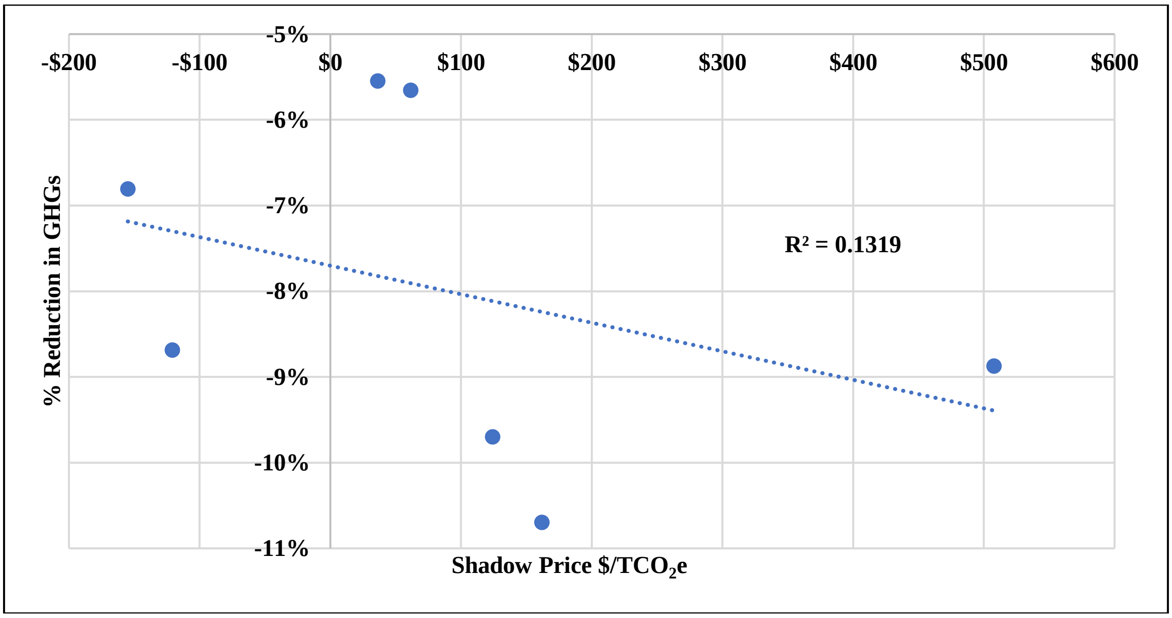


Figure 3: Dairy Farms: Remove Bought-In Supplements



These scatter graphs also illustrate the danger of endeavouring to develop abatement curves in the face of (a) scarce data, and (b) what data that does exist indicates almost no relationship between shadow prices and GHG reductions.

Native Forest for Carbon Farming

Many farmers have expressed the desire to plant native rather than exotics, especially pines, and the Climate Change Commission has estimated the need to plant 300,000 hectares of natives by 2035, as part of their recommendations to Government.

The issue that arises, especially from an investment perspective with planting natives for carbon sequestration, is the high up-front cost of establishing natives, and their relatively low sequestration rate. The current cost of establishing natives can vary between $10,000 - $45,000 per hectare, with a median cost around $13,000/ha. This compares with the cost of planting pines of around $2,500 - $3,000/ha. This higher cost is due to the much higher planting density for natives (3,000-5,000 stems/ha) and the limited supply of seedlings from nurseries driving up the cost. Forestry scientists believe the costs can be reduced down to around $8,000/ha, based on a lower planting rate (2,5000 seedlings/ha) accompanied by a good releasing regime (G West, pers com).

The second factor is the relatively low sequestration rate; pines sequester 20-25 tonnes CO_2e/ha/yr depending on the region, whereas natives average 6.5 tonnes CO_2e/ha (both rates based on the MPI Look-up Tables), or around 30% of the rate of pines. As noted earlier, there is an issue in that the sequestration rate for native trees in the look-up tables is very conservative.

From an investment perspective therefore, natives suffer two distinct drawbacks; a high up-front cost, and a relatively low cashflow.

An investment analysis based on a 50-year sequestration period shows:

Table 6: Native Forest Investment Returns from Carbon Sequestration

Establishment ($/ha)	Carbon Price ($/T)	NPV@5%	IRR
$13,000	$75	-$4,963	2.6%
$8,000	$75	$37	5.0%
$13,000	$100	-$1,865	4.2%
$8,000	$100	$3,135	6.9%
$13,000	$200	$10,528	8.7%
$8,000	$200	$15,528	12.4%

Note: The analysis does not include any land values

While Table 6 shows that natives can be profitable at the current price of carbon (~$75/t) in the sense that the IRR is positive, it is not covering its cost of capital. These returns obviously improve in the face of lower establishment/higher carbon prices. The issue is that the current return on pines is in the order of 30-35% IRR; in other words, pines are around 15 times more cost effective for carbon sequestration than natives.

This means that further work is required; breeding of faster growing natives, planting natives with timber production as part of the regime, better analysis of the sequestration rates of different native species, development of biodiversity credits, and for nurseries to gear up to provide plants in volume at a lower cost. Or, if the government wants large areas planted in natives, then subsidies perhaps need to be under consideration.

Summary

The current toolbox available for farmers to mitigate GHG emissions is quite small. While farm system change can reduce GHG emissions, the overall impact is small, especially if the farm is to remain financially viable. Diversification into horticultural or arable options can reduce emissions, but this is only significant if done at scale. Currently the option that has the greatest effect in offsetting (not mitigating) GHG emissions, and the carbon levy, is forestry, which also tends to be the cheapest option as well.