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in farm profitability but also gains in GHG efficiency. If greater gains in improving GHG efficiency are desired then the Intensity and DPE indexes would help achieve this. The DPE index captures a significant proportion (80%) of the GHG benefits of the Intensity index, with a relatively minor impact of less than a 1% reduction on the rate of genetic progress for farm profitability. As such, it is likely to have appeal to progressive sheep farmers supplying meat companies targeting premium markets with environmentally conscious consumers. With an efficient emissions trading scheme incorporating a farmer point of obligation, this may become the economic optimum index. In the meantime, it is only slightly sub-optimal from the perspective of improving profit. Further acceleration of the rate of improvement in GHG emissions efficiency could result from better selection criteria developed for GHG efficiency improving traits, and new genomic technologies hold significant promise in this regard (P.R. Amer, Unpublished data).

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Modelling farm management scenarios that illustrate opportunities farmers have to reduce greenhouse gas emissions while maintaining profitability

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ASBTRACT

Farmer focus groups have been involved in a range of learning exercises and farm system modelling exercises to determine the effect that alternative farm management scenarios would have on greenhouse gas (GHG) emission profiles on-farm. Annual GHG emissions from the current livestock farming policies for the sheep and beef property were estimated to be 4.91 tonnes of carbon dioxide equivalents per hectare (t CO_2-e/ha) or 14.3 kg CO_2-e per kg of meat and fibre produced. All of the alternative farm management options had a small impact on total GHG emissions, ranging from a reduction of 0.67 t CO_2-e/ha to an increase in 0.42 t CO_2-e/ha (-13% and + 8% of the whole farm emissions per hectare, respectively). Most exposed the business to greater risk due to market and climate variability. The Canterbury dairy farm annual GHG emissions from the current farm were estimated to be 13.1 t CO_2-e/ha or 9.9 kg CO_2-e per kg of milk solids. Across the mitigation scenarios investigated total GHG emissions were up to 14% lower than the baseline farm while emissions intensity ranged from 33% higher to 9% lower than the baseline farm. Opportunities which decreased emissions intensity and increased profit were identified; these require consideration of multiple risks around climate and market variability.

Keywords: greenhouse gas; farm management; sheep; dairy.

INTRODUCTION

New Zealand farmers remain uncertain about the importance of climate change and greenhouse gas (GHG) emissions to their businesses (T.G. Parminter, Personal communication). Despite this uncertainty, managing and growing their farm businesses will increasingly involve balancing the demands of export markets, regional and national regulators, and non-agricultural New Zealand stakeholders. Agriculture is included in the New Zealand emissions trading scheme (NZETS) and from 2,015 farmers will potentially be levied for a portion of their farm emissions. This levy would be deducted by the processor, who is the current point of obligation. The levy would be based on the quantity of meat and milk processed.

To help farmers develop a greater understanding of GHG emissions on-farm, several farmer focus groups have been involved in a range of learning exercises and farm system modelling exercises to determine the effect that alternative farm management scenarios would have on GHG

TABLE 1: Greenhouse gas (GHG) mitigation scenarios tested on the King Country sheep and beef farm.

Scenario	Description
Dicyandiamide (DCD)	Nitrification inhibitor (DCD) applied to pasture in autumn and early winter.
More ewes instead of cows	Increase to 3,800 ewes, 960 yearling ewes and 35 cows from 3,300 ewes, 800 yearling ewes and 120 cows.
Younger breeding flock	Mate replacement yearling ewes, requiring mixed aged ewe numbers to be reduced to 2,400 and replaced with an additional 550 yearling ewes.
More trading cattle	Entire breeding cow herd replaced with 280 additional 2-year steers.
Once-bred heifers	Cattle policy simplified to only purchasing 675 in-calf heifers in winter and selling everything in autumn.
Deer enterprise	Replacing yearling trading cattle with 470 breeding hinds and finishing all non-replacement progeny.
Summer fallow	Summer fallowing 10% of the farm's effective grazing area, with a reduction of 1,100 SU.

TABLE 2: Greenhouse gas (GHG) mitigation scenarios tested on the Canterbury dairy farm.

Scenario	Description
50% less N fertiliser.	Nitrogen (N) fertiliser use halved.
Increase breeding worth by100 and decrease stocking rate.	Breeding worth of cows increased from $75to $1,175, with a decrease in stocking rate (SR) from3.8 cows/ha to 3.5 cows/ha.
Dicyandiamide (DCD).	Nitrification inhibitor (DCD) applied to pasture in autumn and spring.

emission profiles on-farm (Ministry of Agriculture and Forestry, 2011). Using existing tools, including Farmax® (Bryant *et al*, 2010a) and OVERSEER® (Wheeler *et al*, 2003), a range of different farming systems, including dairy, sheep and beef and deer farms, have been modelled throughout New Zealand. This paper will specifically focus on a dairy and sheep and beef farm, which has been modelled together with several alternative farm management scenarios, which have the potential to change the total or intensity of GHG emissions on-farm.

MATERIALS AND METHODS

King Country sheep and beef farm

A highly productive King Country sheep and beef farm, achieving higher than average per animal and hectare performance for the region, was modelled. The farm consisted of 840 ha of hill land (700 ha grazed and 140 ha in trees and native bush). In total, 8,800 stock units (SU) (12.6 SU/ha) were run on the property at a sheep to cattle ratio of 53:47. The sheep enterprise contained a high performance breeding flock of 3,200 ewes, retaining 800 replacements, and finishing a high proportion of lambs with an average lamb carcass weight of 15.4 kg. All finishing lambs were sold by the end of April. There was a mixed cattle enterprise with a herd of 120 dairy-cross breeding cows, with all progeny finishing by 18 months of age. No replacements were kept with an annual purchase of all replacements. In addition, 380 Friesian bulls were purchased as 100 kg weaners and finished by 18-20 months of age. Other cattle trading included: yearling steers purchased in July and sold in March and 2-year steers purchased in August and sold in January. The annual livestock feed demand on the farm was 6,916 kg dry matter (DM)/ha and farm production per hectare was 343 kg carcass weight equivalent (carcass + wool weight).

Alternative farm management scenarios modelled included, the use of a nitrification inhibitor dicyandiamide (DCD), changing sheep and cattle policies, and the use of a summer fallow for a portion of the farm were modelled A detailed description of these scenarios is given in Table 1.

Mid-Canterbury dairy farm

The second farm modelled was a highly productive dairy farm in Mid-Canterbury. The flat land farm receives about 800 mm rainfall per year, with all remaining soil moisture requirements met through irrigation. All dry-stock are grazed off the milking platform (farm, or area wihin a farm, grazed exclusively by milking cows), as is the milking herd for eight weeks over winter. Summer and winter crops are grown on the milking platform and 0.7 t DM/cow (2.1 t DM/ha) is brought in as supplements and nitrogen fertiliser used across the platform (206 kgN/ha). The dairy enterprise produces 1,320 kg MS/ha from 3.8 cows/ha (344 kg MS/cow). Annually, 15.6 t DM/ha is consumed by the milking herd, of which 0.4 t DM/ha is imported. This does not include feed eaten by animals grazing off the milking platform.

Alternative farm management scenarios modelled included, reduced N fertiliser use, increased cow genetic merit and a lower stocking rate, and the use of DCD as a nitrification inhibitor. The effects of not wintering the milking herd off the

TABLE 3: Livestock greenhouse gas (GHG) emissions for case study King country sheep and beef farm.

Scenario	Livestock emissions ($t CO_2$-e/ha)			Emission intensity (kg CO_2-e/kg of meat and fibre)
	Methane (CH_4)	Nitrous oxide (N_20)	Total	
Baseline	3.41	1.51	4.91	14.3
DCD	3.41	1.46	4.86	14.1
More ewes - less cows	3.53	1.38	4.91	14.4
Younger breeding flock	3.51	1.37	4.87	14.5
More trading cattle	3.83	1.50	5.33	14.5
Once-bred heifers	3.03	1.21	4.24	16.6
Deer enterprise	3.32	1.32	4.64	17.7
Summer fallow	3.17	1.24	4.41	12.9
1990 estimate	2.63	1.03	5.68	17.8

milking platform or grazing all of the dry-stock on the milking platform were also investigated (Table 2).

RESULTS

King Country sheep and beef farm

Annual GHG emissions from the current livestock farming policies were estimated to be 4.91 tonnes of carbon dioxide equivalents per hectare ($t CO_2$-e/ha) or 14.3 kg CO_2-e per kg of meat and fibre produced (Table3). This level of intensity of emissions appears to be low when compared with other farms involved in the focus groups. This may have been caused by the farm's high level of flock reproductive efficiency (0.70 kg live weight weaned/kg ewe live weight mated) and high rates of liveweight gain in lambs and young cattle (weighted average daily live weight gain of 1.11 kg to slaughter at 286 kg carcass weight and 502 days of age). All of the alternative farm management options had a small impact on total GHG emissions, ranging from a reduction of 0.67 t CO_2-e/ha to an increase in 0.42 t CO_2-e/ha (-13% and + 8% of the whole farm emissions per hectare, respectively; Table 3). Each of these scenarios posed potential challenges and risk to the farm business, including the very high cost of nitrification inhibitors ($100/ha) and the high sensitivity of any stock policies to purchase and sale prices.

Both the use of DCD and summer fallowing reduced the farm's GHG emission intensity (Table 3). However, both also reduced farm profitability (Table 4). The most profitable options were either to replace the breeding cow herd with more trading cattle or to replace part of the latter with a deer breeding and finishing enterprise (Table 4). Total GHG emissions would decrease 6% with the switch to deer (Table 3). While replacing the breeding cows with two year-old steers would increase total GHG emissions and the intensity of emissions (Table 3), the extra profit made from this policy change would more than offset any additional costs imposed by the GHG emission levy when at $25/tonne CO_2-e (Table 4). However, a steer trading policy changes the nature and level of financial risk the business is exposed to. Spring cattle prices are impacted by a variable combination of market outlook, beef schedule and grass market factors.

Over the last two decades the GHG emission intensity of the current farm has decreased by about 20% compared to estimated 1990 levels (Table 3). This likely reflects significant gains in: flock lambing performance of 142% compared with 109% and 0.70 kg live

TABLE 4: Production and profit information and potential financial impact of greenhouse gas (GHG) emissions costs for the case study King Country sheep and beef farm. DCD = Use of dicyandiamide as a nitrification inhibitor.

Scenario	Farm production (kg meat and fibre)	Economic farm surplus (EFS)[1] ($)	Net EFS with full $25/ t CO_2-e emissions cost[2] ($)	Net EFS with 10% $25/ t CO_2-e emission cost ($)
Baseline	343	313	189	301
DCD	343	113	25	101
More ewes- less cows	342	339	216	327
Younger breeding flock	337	255	133	242
More trading cattle	367	373	239	359
Once-bred heifers	255	206	100	196
Deer enterprise	262	344	228	333
Summer fallow	341	225	115	214

[1] Economic farm surplus or earnings before interest and tax, is calculated as: Net cash income, plus change in livestock values, less farm working expenses, less depreciation, less wages of management.

[2] Net farm profitability after meeting the cost of GHG emissions at indicated cost. Values are indicative only. Final cost will be dependent on climate change response (Emissions Trading Amendment Act (2008) and any subsequent setting of the baseline).

TABLE 5: Livestock Greenhouse (GHG) emissions for the case study Canterbury dairy farm. CO_2-e = CO_2 equivalent; MS = Milksolids; BW = Breeding worth; SR = Stocking rate; DCD = Use of dicyandiamide as a nitrification inhibitor.

Scenario	Livestock emissions (t CO_2-e per hectare)			Emissions intensity (kg CO_2-e/kg MS)	Emissions charge (\$/ha)[1]
	Methane (CH_4)	Nitrous oxide (N_2O)	Total		
Base	7.2	4.4	13.1	9.9	327
50% less N fertiliser	6.6	3.5	11.3	9.3	283
Increase BW 100 + Decrease SR	6.9	4.3	12.7	9.6	317
DCD	7.4	3.9	12.9	9.3	322
Increase BW 100 + Decrease SR + DCD	7.3	3.8	12.6	9	316
Base, cows wintered at home	6.8	4.3	12.6	11.1	315
Base, cows home, young stock off	6.5	4.1	12.1	13.2	303

[1] At \$25/t CO_2 equivalents. Proposed that in 2015, farms will only be charged 10% of this cost.

TABLE 6: Input, production and profit information for the case study Canterbury dairy farm. MS = Milksolids; BW = Breeding worth; SR = Stocking rate; DCD = Use of dicyandiamide as a nitrification inhibitor.

Scenario	Stocking rate (cows/ha)[1]	Production (kg MS/cow)	Imported feed (t DM/cow)[1]	N fertiliser (kg/ha)	Profit (\$/ha)
Base	3.8	344	0.1	206	2759
50% less N fertiliser	3.5	342	0.1	103	2432
Increase BW 100 + Decrease SR	3.5	378	0.1	206	3023
DCD	3.9	352	0.1	206	2902
Increase BW 100 + Decrease SR + DCD	3.7	378	0.1	206	3047
Base, cows wintered at home	3.2	349	0	206	2561
Base, cows home, young stock off	2.6	351	0	206	2093

[1] Per cows milked in November.

weight weaned/kg ewe live weight mated compared with 0.57 respectively; better ewe nutrition; heavier lamb weaning weights; and improved young cattle feeding, resulting in similar bull slaughter weights at 18-20 months of age, in contrast to 30-months of age in 1990 (340 compared with 319 kg meat and fibre carcass weight equivalents/hectare).

Mid-Canterbury dairy farm

Annual GHG emissions from the current farm were estimated to be 13.1 t CO_2-e/ha or 9.9 kg CO_2-e per kg of milk solids (MS; Table 5). Across the mitigation scenarios investigated total GHG emissions were up to 14% lower than the baseline farm. However, the change in emissions intensity caused by the mitigation scenarios was much more varied, ranging from 33% higher to 9% lower than the baseline farm. Overall, the results indicate that reductions in total emissions and emissions intensity (Table 5) can be compatible with higher profit and generally are associated with farming systems that increase per cow production, excluding use of imported feed, which was not tested (Table 6). The two scenarios at the bottom of Tables 5 and 6 indicate the size of the GHG "exporting" effort, of running dry-stock and wintering dairy cows off the dairy milking platform. The results also show that the emissions levy at \$25/t CO_2-e (Table 5) has no impact on the profitability ranking of the alternative systems tested (Table 6) and that the proposed charge in 2015 is about 1% of expected profit. Figure 1 reflects the comments above, indicating that systems that achieve a virtuous combination of emissions efficiency and high profit are possible, across the reasonably narrow range of emissions efficiency values achieved.

DISCUSSION

This case study modelling shows farmers have options that can change both the intensity of GHG emissions and the total level of livestock GHG emissions, and that these outputs can be independent. The opportunity within these options will depend on the GHG emission efficiency of the current system relative to potential alternative systems. For sheep and beef systems, the potential for alternative systems is driven by the combination of the total pasture production, seasonal pasture production, feed utilisation and willingness to alter the system, relative animal performance and livestock type and class. For example growing young lambs faster will decrease intensity of emissions but requires a system with sufficient high quality feed in summer-autumn to achieve high growth rates. The potential of sheep and beef systems to maximise pasture production may be limited by nutrient availability, temperature and rainfall. Managers can manipulate fertiliser inputs (Suckling, 1976) but not the impacts of slope and aspect (Radcliffe *et al.,* 1973) on pasture production.

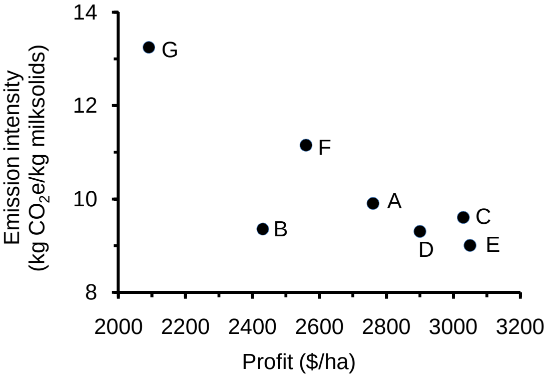
Dairy farmers have the potential to increase productivity through reductions in, and the balance between cow stocking rate, improved genetic merit, use of nitrification inhibitors and imported feed. The benefits of the latter two items are dependent on the biological response of pasture grown and milk production, and cost effectiveness. In addition, anecdotal evidence indicates that low stocked farm systems require a high level of managerial skill to be run successfully. The costs of inferior management can be very high due to loss of pasture quality and per cow performance.

The dairy farm results indicated that profit/hectare varied far more than either total GHG emissions or GHG emissions intensity and farmers should place greater emphasis on profit in deciding on the system best suited to their farm. Fortuitously, assuming one wants to reduce GHG emissions, selecting dairy farm systems based on increased net profit will normally have a correlated beneficial impact on GHG emissions.

The modelled case study sheep and beef farm has had a dramatic improvement in its intensity of emissions compared to its estimated levels in 1990. This is a feature common to many sheep and beef farms, and also dairy farms, partly at least due to improvements in the genetic merit of many livestock classes. This has resulted in a higher percentage of feed eaten going into liveweight gain or milk production compared to meeting maintenance requirements. Increases in production efficiency have included: increases in lamb carcass weight gain per day, lambing percentages, and milk production/kg cow live weight. The capacity for sheep, beef cattle and dairy farms to repeat these gains into the future is unknown but is likely to be considerable (Carter *et al.*, 1990; Baker *et al.*, 1991).

Increasing the production of saleable product of meat and fibre per hectare was negatively correlated with the intensity of livestock GHG emission per kg of meat and fibre (Tables 3 and 4). It resulted in reduced intensity of emissions and increased profitability. The management response to increasing efficiency will determine the impact on total emissions from the farm. If stocking rate is increased total emissions are likely to increase even where intensity of emissions is reduced.

FIGURE 1: Greenhouse gas (GHG) emissions intensity (kg CO_2-e/kg MS) versus profit ($/ha) for the case study Canterbury dairy farm. A = Base; B = 50% less fertilizer; C = Increase breeding worth and decrease stocking rate; D = Application of dicyandiamide (DCD) as a nitrification inhibitor; E = Increase breeding worth and decrease stocking rate and apply DCD; F = Base with cows wintered at home; G = Base with cows wintered at home and young stock on the milking platform.



The impact of changes in livestock policies and management systems was evaluated using OVERSEER®. However, farmer liability under the NZETS will be determined using the Climate Change (Agriculture Sector) Regulations 2010 and any subsequent regulations. These regulations do not differentiate product coming from low or high intensity emission farms. The consequence is that businesses that produce with low emission intensity invariably will face the highest level of liability under the current NZETS.

Farm modelling provides a one year snapshot and does not capture the complexity of farming systems when spanning several years of production. The results have also not included the capital costs of changing from one system to another. When considering a farm system change, multiple impacts must be considered, not only impacts on profitability and GHG emissions, but also market and climatic risk, management complexity, impacts on feed quality, and personal attitudes to new or different systems.

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