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Managing carbon in livestock systems: modelling options for net carbon balance (Victorian DPI)

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Abstract

A desktop study that involved assessing the baseline greenhouse gas emissions of a case study farm located in south-west Victoria and testing the feasibility of the use of nitrification inhibitors and feeding oil supplements to dairy cows to reduce emissions was conducted.

Emissions attributable to farm businesses are methane and nitrous oxide. On the farm analysed, the combined methane and nitrous oxide emissions were 1494 tonnes of carbon dioxide equivalents (t CO_2-e). Methane emissions were 76% of this. The nitrification inhibitor strategy tested reduced nitrous oxide emissions by 63 t CO_2-e and when cows were fed an oil supplement in place of some of the grain supplement they were already consuming, methane emissions were reduced by up to 22 t CO_2-e.

As the expected carbon price is \$25/t CO_2-e or less, the economic opportunity to dairy and other livestock farmers under the Carbon Farming Initiative is currently limited. The best way forward for industry is to continue to focus on productivity. As farms increase their efficiency of production, they will reduce their emissions intensity which is a good outcome for Australian agriculture.

Executive summary

Farming, particularly businesses operating in the livestock industries generate greenhouse gas emissions. Unlike some other sectors of the economy, direct agricultural emissions are currently exempt from a ‘carbon tax.’ However, farm businesses may experience higher input costs and possibly processor ‘pass-backs’ from other sectors. Whilst this may not seem good news for Victoria’s food and fibre producers, there may be opportunities for farmers to generate saleable carbon credits under the Federal Government’s Carbon Farming Initiative.

This analysis was conducted to quantify the economic opportunities for dairy farmers adopting specific emissions reduction strategies on-farm. The two strategies examined were the use of nitrification inhibitors on pastures to reduce nitrous oxide emissions and feeding oil supplements to cows to reduce methane emissions. The case study farm used was a dairy farm, however, the mitigation strategies tested could be applied to other livestock industries in cases where nitrogen fertilisers are used or where grain is being fed.

The greenhouse gas emissions for the dairy farm were estimated using “DGas”. DGas is a program developed to estimate annual greenhouse gas emissions from dairy farms. Similar programs such as FarmGas are available for other industries such as beef and lamb.

Emissions attributable to the farm business are methane and nitrous oxide. On the farm analysed, the combined methane and nitrous oxide emissions were 1494 tonnes of carbon dioxide equivalents (t CO_2-e). Methane emissions were 76% of this total. The nitrification inhibitor strategy tested reduced nitrous oxide emissions by 63 t CO_2-e and when cows were fed an oil supplement in place of some of the grain supplement they were already consuming, methane emissions were reduced by up to 22 t CO_2-e.

Whilst reductions in emissions are environmentally desirable and are in the Government’s interest to meet its emissions reduction targets, based on this analysis it is unlikely that a commercial farm would apply these strategies for economic reasons. At best, the estimated income for the case study farm from the sale of carbon credits when feeding an oil supplement was $550. The estimated income from using a nitrification inhibitor was $1575. This is extremely small when considered alongside the main income streams. As an example, the milk income over a 5 year period was valued between $559,000 and $996,000 per annum, for the case study farm. There would also be costs associated with participating in the Carbon Farming Initiative not analysed here that would need to be considered by farmers.

As new technologies for reducing agricultural emissions become available, there might be greater opportunities for farmers under the Carbon Farming Initiative. For example, commercial research is currently being undertaken on different modes of applying nitrification inhibitors including coated fertiliser products and delivery of the inhibitor via the animal. When these occur, farmers will need to critically assess whether these are a good choice in their particular circumstances. As well as assessing the economics of a particular strategy, farmers are encouraged to examine the effects on production to ensure there are no production losses as a result.

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Background

The Commonwealth's Reducing Emissions from Livestock Research Program aims, through an integrated Research, Development and Demonstration program, to achieve Australia's farming future outcome: "Primary producers are equipped with the knowledge, tools and strategies to manage their emissions including the ability to respond to the commercial imperatives arising from Emissions Trading."

Under this program, demonstration projects for on-farm practical methane management strategies were conducted. In Victoria, two sites were used as a focal point to engage with industry (sheep and dairy). Field days were conducted at these sites as part of project B.CCH.1034.

On 31st July 2011, the work detailed in this report (project B.CCH.1034 "Managing carbon in livestock systems: modelling options for net carbon balance (Victorian DPI") was commissioned as a subset of project B.CCH.1081. The work primarily involved assessing the baseline emissions of a case study farm and testing the feasibility of practical strategies to reduce emissions in a farming systems context.

Project Objectives

This work contributed to the following objectives under the Reducing Emissions from Livestock Research Program (RELRP):

1. A range of modelling frameworks to evaluate mitigation options will be evaluated using the RELRP Demonstration sites.
2. A report (in confidence) to the Commonwealth determining efficacy, boundaries of operation and confidence of modelling approaches used to develop CFI methodologies within the boundary of the RELRP demonstration sites.

Methodology

This project was a desktop study that involved assessing the baseline greenhouse gas emissions of a case study farm and testing the feasibility of the use of nitrification inhibitors and feeding oil supplements to dairy cows to reduce emissions.

Details of the production system for the case study farm

The case study farm used in this analysis was based on a scaled-up version of a dairy farmlet established in 2005 on DemoDairy in Terang, south-west Victoria (38°14'S, 142°54'E). The farmlet was established as part of Project 3030, which aimed to increase profit by 30% through consuming 30% more home-grown feed. The farmlet represented a model of a farm operating a well-managed perennial pasture-based system.

The scaled up version of the farmlet (herein referred to as the farm) was initially proposed by Ozkan *et al.* (2011)[1] and was considered by these authors to be representative of farms in the region. Our analysis used the same scaling as Ozkan *et al.* (2011)[1] and additional information from the 3030 project to estimate the greenhouse gas emissions from the farm. Further information on assumptions and data used to estimate emissions are detailed in Appendix 1.

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[1] Özkan Ş, Farquharson B, Hill J, Malcolm B (2011) Effect of carbon price on farm profitability on rainfed dairy farms in south west Victoria: a first look. Proceedings of the Australian Agricultural and Resource Economics Society 55th Annual Conference.

Estimation of greenhouse gas emissions

The greenhouse gas emissions for the dairy farm were estimated using “DGas”. DGas is a program developed to estimate annual greenhouse gas emissions from dairy farms and is freely available to industry via the Dairy Australia website. It uses the methodologies, algorithms and emissions factors used by the Department of Climate Change to estimate Australia’s National Greenhouse Gas emissions as part of the Kyoto Protocol and United Nations Framework Convention on Climate Change. Version 1.4 of DGas (Advisor) was used for the analysis reported here.

DGas estimates 4 sources of greenhouse gases:

- Methane (CH_4): from dairy cows as a result of digestive processes in the animal (enteric fermentation) and from effluent management.
- Nitrous oxide (N_2O) from animal waste and fertilisers. DGas accounts for both the direct emissions (those occurring on-farm) and indirect emissions (those lost through leaching, runoff and volatilisation).
- Carbon dioxide (CO_2) from consumption of electricity and fuels on farm.
- Carbon dioxide associated with the production of key farm inputs including grain/concentrates, forage supplements and fertilisers (pre-farm embedded emissions).

Of these, only methane and nitrous oxide are directly attributable to the farm business.

As greenhouse gases differ in their global warming potential, they are converted to carbon dioxide equivalents (CO_2-e). Compared to CO_2, CH_4 is 21 and N_2O is 310 times more potent. This means that actual emissions of CH_4 and N_2O are multiplied by 21 and 310 respectively to get a CO_2-e value. All results reported in this report are expressed in terms of CO_2-e.

The Carbon Farming Initiative

It was assumed that the mitigation strategies tested could become eligible activities under the Carbon Farming Initiative, and hence farmers could earn income through adopting the strategies described. However, as this initiative is in its infancy, methodologies have not yet been developed for the mitigation strategies tested. It is also unclear at this point in time what the cost will be to farmers for participating in the initiative.

Testing mitigation strategies

The underlying assumption for the mitigation modelling was that dairy farming will remain the land use. The strategies selected are currently available to farmers. There are other strategies currently being researched that may offer significant potential to reduce farm greenhouse gas emissions, but these are not yet fully developed or commercially available.

Applying a nitrification inhibitor to pasture

An excel spreadsheet model was developed to test the feasibility of nitrification inhibitors on nitrous oxide emissions. Data on the nitrous oxide emissions from the farm estimated by the DGas program were used in the spreadsheet.

In the analysis it was assumed that:

- the inhibitor was applied as a spray to pastures twice per year
- the cost of the chemical and application was $165/ha/year
- the reduction in emissions were achieved for 75 days per year
- the reduction in nitrous oxide emissions during the period of the inhibitor's effectiveness was 35%
- emissions from fertiliser and animal waste were included
- all nitrogen fertiliser was applied at a time when the inhibitor was effective
- any extra pasture yield was valued on a cents per megajoule of metabolisable energy basis.
- income was earned from extra pasture dry matter (DM) production (if achieved) and sale of carbon offsets from reduced emissions.

Feeding cows dietary oil supplements

On the case study farm, the estimated intake of the cows in the summer period was 19.6 kg DM/cow/day. On average, this represented 3.7% of live weight. It is unlikely that intake could be increased to amounts much higher than this. Even if the oil supplement was believed to be 'added' to the diet, it is likely there would be substitution, whereby the intake of another dietary component reduces to account for the new supplement. For the analysis it was therefore assumed that the oil supplement replaced an existing grain supplement in the cows' diet.

Initially it was assumed that the metabolisable energy and therefore the digestibility of the oil supplement was the same as the supplement being replaced. As there can be considerable variation in the digestibility value of ruminant feeds, some sensitivity analysis around the digestibility value was conducted. The scenarios of assuming a digestibility value of the oil supplement at 5% and 10% lower digestibility than the grain supplement were tested. As the grain supplement already fed to the cows had a high digestibility (85.6%), no scenarios where the digestibility of the oil supplement was higher were tested, as it was considered unlikely that the oil supplement would be higher in digestibility than the grain already being fed. Other reasons for not running a scenario where a supplement with a higher digestibility was fed were the nutritional issues of decreases in digestibility with increasing intake, and associative effects whereby the digestibility of the diet is lower than the sum of the digestibility values of dietary components. The significance of these nutritional issues is such that perceived improvements in digestibility are not likely to be achieved in a commercial farm situation.

DGas was used to estimate the reduction in methane emissions when the cows were fed an oil supplement. When selecting the fats and oils strategy in the DGas program, a 10.5% reduction in emissions was entered for summer only. This value was derived from research that has demonstrated for every 1% additional fat/oil in the diet, there is a 3.5% reduction in methane emissions. The daily grain intake in summer was reduced by 2.7 kg DM and 2.7 kg DM of the oil supplement added in the herd input screen of DGas. The digestibility values were also modified as required by the scenario being tested on this screen.

Other assumptions underlying this strategy were:

- a maximum of 6% oil (total) in the cows' diet was possible
- the strategy could be applied for 3 months only (in summer) when levels of oil in pasture were at their lowest
- no changes in fatty acid composition of the milk were included – as they will not affect price
- any effects on supplement palatability were not significant at the amounts fed
- cows could consume the supplement in the same amount of time as in existing system
- no change to feed delivery system was required
- the inhibitory effect on methane persisted for as long as the oil supplement was fed
- changes in the crude protein of the diet were not considered.
- the cost of the oil supplement was the same as the grain supplement it was replacing

Results

Farm Emissions profile

The emissions profile for the farm as estimated by DGas is shown in Figure 1. An estimated total (including pre-farm emissions and carbon dioxide emissions for the use of electricity and fuel on-farm) of 2018 t CO_2-e are associated with this farm. Of these, only the methane and nitrous oxide emissions are directly attributable to the farm business.

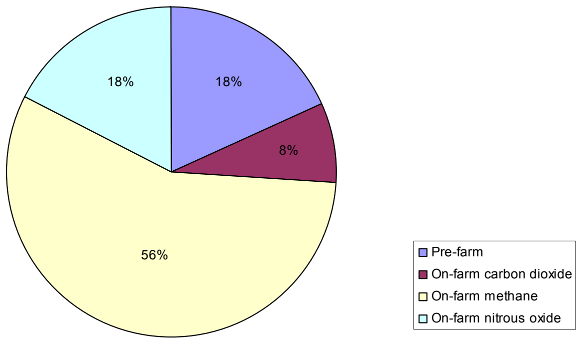

Figure 1. Emissions profile of the case study farm.

The combined methane and nitrous oxide emissions are 1494 t CO_2-e (Table 1) and represent a significant proportion of the total profile (74%; Figure 1).

Table 1. Methane and nitrous oxide emissions from the case study farm.

Emissions	t CO_2-e/farm	t CO_2-e/t milk solids
CH_4 enteric	1046.4	8.3
CH_4 manure	92.1	0.7
CH_4 TOTAL	**1138.5**	**9.0**
N_2O – N fertiliser	61.7	0.5
N_2O – effluent pond	1.1	<0.05
N_2O – dung, urine and spread	95.4	0.8
N_2O – indirect fertiliser	73.2	0.6
N_2O – indirect animal waste	124.2	1.0
N_2O TOTAL	**355.5**	**2.9**
CH_4 and N_2O TOTAL	**1494**	**11.9**

Estimated reduction in emissions

Applying a nitrification inhibitor to pasture

When a nitrification inhibitor was applied to the pasture, the farm-level reduction in emissions using the assumptions outlined previously was estimated to be 63 t CO_2-e (Table 2) or 17.7% of nitrous oxide emissions.

Table 2. Estimated farm nitrous oxide emissions before and after the inhibitor was applied.

Nitrous oxide emission source	Emissions prior to use of inhibitor (t CO_2-e)	Emissions when inhibitor is applied (t CO_2-e)
Nitrogen fertiliser (direct)	61.7	40.1
Effluent ponds	1	1
Dung, urine, spread	95.4	88.5
Fertiliser (indirect)	73.2	47.6
Waste (indirect)	124.2	115.3
TOTAL	355.5	292.5

Feeding cows dietary oil supplements

The estimated herd-level reduction in methane when an oil supplement of the same or lower digestibility was fed is shown in Table 3. Prior to feeding the oil supplement, the total farm methane emissions were 1139 t CO_2-e. Therefore farm methane emissions would be reduced by approximately 2% when this strategy is applied.

Table 3. Reduction in methane emissions (t CO_2-e) when feeding an oil supplement in place of a grain supplement with the same or lower digestibility

Oil and grain supplement with the same digestibility	Oil supplement with digestibility 5% lower than grain supplement being replaced	Oil supplement with digestibility 10% lower than grain supplement being replaced
22	21	19

Economic feasibility of mitigation strategy

Applying a nitrification inhibitor to pasture

The total cost of applying the nitrification inhibitor on this farm was estimated to be $29,205. Depending on the carbon price, the potential income from the sale of carbon credit units was $630 to $1575 for the farm (Table 4). If an increase in pasture yield through use of the nitrification inhibitor was possible, this income would be higher, although this still would be insufficient to cover the costs of applying the inhibitor.

It was estimated that the price of carbon would have to be $400-$500/t CO_2-e to make this strategy viable under these conditions. This is unlikely, as the carbon price proposed by the Australian Government for 2012/13 is $23/t CO_2-e, increasing to $25.40/t CO_2-e in 2014/15. It could be expected that the price of carbon offsets will be less than this.

Table 4. Combined income ($) for the farm from carbon offsets sold and additional pasture production resulting from application of nitrification inhibitor.

Pasture yield increase (%)	Carbon price $/t CO_2-e			
	10	15	20	25
0	630	945	1260	1575
5	1029	1344	1659	1974
10	1428	1743	2058	2373
20	2226	2541	2856	3172
30	3024	3340	3655	3970
40	3823	4138	4453	4768

Feeding cows dietary oil supplements

The potential income from the sale of carbon credit units through applying this supplementary feeding strategy is modest (Table 5). Whilst the decreases in the digestibility of the supplement did not result in much of a decrease in potential income from the sale of carbon credits, decreases in digestibility have potential to decrease milk production. For an individual cow on a particular day this may be small, however, when multiplied over the herd across summer, the impact on farm milk production would become significant.

Table 5. Potential income ($) for the farm from the sale of carbon credit units when a grain supplement in the cows' diet is replaced by an oil supplement with the same or lower digestibility.

Carbon price ($/t CO_2-e)	Oil and grain supplement with the same digestibility	Oil supplement with digestibility 5% lower than grain supplement being replaced	Oil supplement with digestibility 10% lower than grain supplement being replaced
10	220	210	190
15	330	315	285
20	440	420	380
25	550	525	475

Discussion / Conclusion

The mitigation strategies tested are amongst the few currently available to farmers that have potential to be eligible projects under the Carbon Farming Initiative. In the farming system described, farm methane emissions were reduced from 1139 t CO_2-e to 1117 t CO_2-e when the oil supplement had the same digestibility as the grain supplement it was replacing. The nitrous oxide emissions were decreased from 356 to 293 t CO_2-e. If both strategies were applied, farm emissions would be reduced from 1494 t CO_2-e to 1409 t CO_2-e.

Whilst reductions in emissions are environmentally desirable, based on this analysis it is unlikely that a commercial farm would apply these strategies for economic reasons.

Using the average milk prices over a 5 year period at the time the baseline data was collected on this farm (2005/06-2009/10), the estimated farm milk income ranged from $559,411 to $996,451 per annum. When considering this, the estimated additional income from the sale of carbon credits is extremely small. At best, the estimated income from the sale of carbon credits for feeding an oil supplement was $550 and $1575 for the use of a nitrification inhibitor.

The scenario tested where nitrification inhibitor was applied to pasture as a spray was chosen as the inhibitor would be effective on the cow urine and faeces voided onto pasture and the fertiliser applied at the time the inhibitor is effective. Commercial research is currently being undertaken on different modes of applying the inhibitor to pasture including coated fertiliser products and delivery of the inhibitor via the animal. As more information and products become available, the use of nitrification inhibitors, depending on the cost, may be more viable on commercial farms in the future. In this analysis, the economic return from additional pasture grown was also tested. However, recent research in Victoria suggests there may not be any detectable yield increase with the use of nitrification inhibitors. Pasture yield response depends on soil type and, based on local research is unlikely to be high at the case study farm analysed.

In the analysis conducted, methane emissions of the herd were reduced by 20 t CO_2-e per year when an oil supplement was fed during summer in place of some of the grain supplement. When using this type of strategy, producers and their nutritional advisors need to consider the overall farm feeding system and potential nutritional issues. If the cows' intake is high, as it was for this case study farm, it cannot be assumed the oil can be added to what the cow is already consuming. If it is 'added,' the cows will decrease their intake of other dietary components, which may result in the cows not receiving the nutrients they require. Also there is the issue of associative effects where the digestibility of the diet is lower than what's estimated by adding together the digestibility values of the dietary components. Both these could have detrimental effects on milk production and income. If the dry matter intakes of the cows are a lot lower than what's possible, there may be benefits of additional supplementation. In this case, there could be increased milk production. Additionally, in instances where the energy density of the cows' diet is low, the daily metabolisable energy intake of the cows may be increased through use of an oil supplement. In commercial situations, producers could capture a benefit (cost savings) from feeding an oil supplement if they can source it for a lower price than the grain supplement its replacing. With the volatility of grain prices, this cost saving will not always be possible and so was not assumed in the analysis conducted here.

As Carbon Farming Initiative methodologies applicable to the southern livestock industries become available, it may be possible to combine strategies to achieve increased reduction in greenhouse gas emissions. Also, although outside this study, farms that continually improve their efficiency of production (eg. feed conversion efficiency of livestock) and follow current "best management" practice when applying fertilisers for example, can also achieve emissions reductions. However, anything that is considered 'normal' farm practice may not be an eligible 'project' under the Carbon Farming Initiative, and hence there would be no ability for farmer to sell carbon credits.

From a commercial perspective, the production and economic benefits of improving productivity may be greater than the potential income from the sale of carbon credits. This very much will depend on the individual farm and how it's currently performing.

At this point in time, there doesn't appear to be substantial opportunities for pasture-based dairy farmers under the Carbon Farming Initiative. There does appear to be considerable interest by the service provider sector in seeking out information as shown by the evaluation of field days conducted under project B.CCH.1034. As new information, technology and policy changes relating to farm greenhouse gas emissions are introduced, the service provider sector will be an important target audience.

Appendix 1 – Data entered into DGas to estimate emissions

In our analysis it was assumed that young stock and bulls grazed the milking area. Assumptions on electricity and diesel usage were made using the 2008/09 Dairy Farm Monitor data (Department of Primary Industries, 2009).

Table A1. General farm information used as inputs into the DGas calculator

Input required	Data entered
State	Victoria
Rainfall (mm)	High (>700)
Manure system	MMS-1 Pasture; default state-based figures
Tree plantings after 1990 (ha)	0
Total farm area (ha)	177
Irrigated pasture (ha)	0
Dryland pasture (ha)	177
Irrigated crops (ha)	0
Dryland crops (ha)	0
Fertiliser inputs (kg/ha)	
N	179
P	17.5
K	38.2
S	21.4
Lime	0
Electricity (kWh)	87981
Electricity source	Coal
Diesel (L)	9968
Purchased feed inputs (t DM/annum)	
Pasture hay	231
Cereal/Maize silage	51
Lucerne Hay	91
Grain/concentrate	457

Table A2. Milk production information used as inputs in the DGas calculator

Input required	Data entered
Farm milksolids (t/year)	125.7
Average lactation (days)	305
Average production (L/cow/day)	19.9

Table A3. Herd information used as inputs in the DGas calculator

	Milkers	Heifers 0-1	Heifers 1-2	Young bulls	Mature bulls
Number	288	80	72	0	4
Weight (kg)	535	182	401		800
Weight gain (kg/cow/day)	n/a	0.7	0.7		n/a

The whole farm modelling by Ozkan *et al.* (2011), assumed that 208 calves were sold. Therefore, in our analysis it was assumed 80 calves were raised as replacements, and 72 heifers retained as rising 2 year olds to allow for a 25% replacement rate. The weight gains for the young stock were estimated assuming the weight reported for the 0-1 and 1-2 year old heifers were the weights at 6 and 18 months, respectively. It was assumed heifers were 34% and 75% of mature age at 6 and 18 months respectively.

Table A4. Dry matter digestibility (DMD), crude protein and quantities of feeds consumed by the milking herd and used as inputs in the DGas calculator

Feed	Measure	Spring	Summer	Autumn	Winter
Pasture	Amount consumed (kg DM/cow/day)	14.1	9.6	1.5	10.9
	DMD (%)	78.2	71.8	75.3	76.5
	CP (%)	17.7	12.6	17.8	23.1
Concentrate	Amount consumed (kg/ DM cow/day)	4.6	4.7	2.7	5.4
	DMD (%)	85.6	85.6	85.6	85.6
	CP (%)	13.1	13.1	13.1	13.1
Silage	Amount consumed (kg/cow/day)	0.3	2.7	2	1.7
	DMD (%)	67.4	67.4	66.2	64.3
	CP (%)	18.2	18.2	16.2	13
Hay	Amount consumed (kg/cow/day)	0.2	1.2	0.6	0.9
	DMD (%)	65	65	65	65
	CP (%)	12.8	12.8	12.8	12.8
Other – lower quality hay	Amount consumed (kg/cow/day)	0.2	1.4	5.7	0
	DMD (%)	61.7	61.7	61.7	61.7
	CP (%)	8.8	8.8	8.8	8.8

It was assumed heifers and bulls consumed pasture only and in the following amounts: 5.5, 9.3 and 9.7 kg DM/animal/day for heifers less than 1 year old, heifers greater than 1 year old and bulls, respectively.

Bibliography

Department of Primary Industries (2009) Dairy Industry Farm Monitor Project: Summary of Results 2008/2009. (Department of Primary Industries: Victoria).

Özkan Ş, Farquharson B, Hill J, Malcolm B (2011) Effect of carbon price on farm profitability on rainfed dairy farms in south west Victoria: a first look. Proceedings of the Australian Agricultural and Resource Economics Society 55th Annual Conference, Melbourne, Australia.