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Prepared by: Dr Brendan Cullen
Dr Kithsiri Dassanayake
Dr. T. Ramilan

University of Melbourne

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Modelling of selected CFI offset options

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Abstract

The impact of four potential Carbon Farming Initiative (CFI) methodologies on total methane and nitrous oxide emissions per hectare and per unit of production was modelled, and the financial gain to the farmer estimated. In the wheat-sheep zone, earlier finishing of lambs by feedlotting compared to grazing on annual pastures showed potential to reduce total emissions and emissions intensity but predicted CFI income was low. In south-west Victoria, increasing forage quality by incorporating lucerne into the farm did not reduce emissions from a lamb production enterprise. Improving weaning rates from 50 to 80% in northern beef herds has substantial potential to reduce total emissions by 40%, with potential CFI income estimated at 10% of gross farm income. Modelling of a beef supply chain in south west Victoria indicated that the emissions associated with growing a steer to 500 kg liveweight were 4.76 t carbon dioxide equivalents (CO_2-e) per head, with 61, 24 and 15% of total emissions breeding, backgrounding and feedlot systems respectively. Substantial reductions in emissions will require integration of a suite of management, feeding and breeding options.

Executive summary

The impact of four potential Carbon Farming Initiative (CFI) methodologies on total methane and nitrous oxide emissions per hectare and per unit of production was modelled, and the financial gain to the farmer estimated. The methodologies focussed on earlier finishing of livestock, increasing forage quality, increasing reproductive performance and an investigation of emissions from a beef supply chain.

The general approach used to assess the four methodologies in this project was firstly to identify a baseline scenario for each of the issues examined and then applying the most suitable modelling tools to the analysis. The 'baseline' scenario for each of the methodologies defined the essential details of the modelling to be conducted including location, soil and pasture types, and livestock production system including stocking rates and calving dates. In each case the baseline scenario was formed from existing case studies and/or regional farm benchmarking data. The CFI methodologies were then investigated as increments of changes in management to the baseline system. In this project a modelling approach utilising a combination of daily time step biophysical systems models (eg. Grassgro and SGS Pasture model) and spreadsheet calculators based on greenhouse gas accounting approaches (eg. Farmgas) was developed to estimate the productivity and greenhouse gas (GHG) emissions from these animal production systems. There is currently no biophysical model that can simulate both the animal management systems and greenhouses gases (methane and nitrous oxide) within the one simulation framework. GHG emissions of methane and nitrous oxide only were considered in this analysis, in line with the rules of the CFI.

In the 'wheat-sheep' zone at Birchip, lamb finishing systems that primarily relied on pasture had the lowest total meat sold, highest total emissions per hectare and the highest emissions intensity of all five systems. The proportional gains of feedlotting lambs relative to the baseline, pasture finishing system were greater for emissions intensity (≈8% for feedlotting wether lambs only and ≈14% for feedlotting all lambs) than for total emissions (4-5% for all feedlotting scenarios). If the farmer was paid \$20/t CO_2-e, these reductions in total emissions would lead to a payment equivalent to \$1.00-1.40/ha. Under the meat price and supplementary prices used in this analysis, feedlotting lambs was more profitable than the pasture finishing system, however this result is highly sensitive to meat and supplementary feed prices and would not be profitable in all years.

Incorporating lucerne into the farm to improve forage quality on a lamb production enterprise at Hamilton was not effective at reducing emissions or increasing production. The simulated monthly growth patterns of ryegrass and lucerne at Hamilton indicated that lucerne did produce more forage over summer and autumn but less during the winter and spring. Overall there was little difference between the systems in GHG emissions per hectare or emissions intensity. Lower emissions were only predicted with lucerne when the 27% reduction in stock grazing lucerne between the months November and April (Phillips 2011) was applied. Under these conditions, total emissions per ha from the farm with 30% lucerne were 4.03 t CO_2-e/ha compared to 4.13 t CO_2-e/ha on the baseline farm. At a price of $20 pet t CO_2-e this would be worth $2.00 per ha to the farmer. However further work is required to verify the emissions reductions from stock grazing lucerne as the report by Phillips (2011) was a preliminary study.

Increasing weaning rates in the beef herds in south west Queensland showed significant potential to reduce total emissions and provide income to farmers through the CFI. Breeding herd size at the different weaning rates were determined to maintain the number of calves weaned at the same level as in the 50% weaning rate (Baseline) scenario. Total farm emissions declined at higher weaning rates in line with reduction in breeding herd size, by over 40% at the highest weaning rate compared to the baseline (3432 and 2006 t CO_2-e/farm for the baseline and 80% weaning rates respectively). There a substantial reduction in emissions intensity of weaner meat production from 100 to 35 kg CO_2-e/kg CWT for the 50 and 80% weaning rates. Additional farm income from a CFI project moving from 50 to 60, 70 or 80% weaning rates was estimated at $13,320, $22,260 and $28,520 per farm (4.2, 7.9 and 10.3% of gross farm income respectively).

The modelled emissions from growing a 500 kg liveweight steer through the cow-calf, backgrounding and feedlot systems were 4.76 t carbon dioxide equivalents (CO_2-e) per head with 61, 24 and 15% of total emissions for cow-calf breeding, backgrounding and feedlot systems respectively. On an intensity basis the emissions per kg liveweight gain were 15.0, 7.5 and 4.8 for the cow-calf breeding, backgrounding and feedlot systems respectively with a lifetime value of 9.52 kg CO_2-e/kg liveweight gain. This analysis allows definition of where CFI projects may be targeted. For example, improving reproductive performance will assist in reducing emissions from the cow-calf system and options for backgrounding include use of higher quality forages to reduce the time spent on pasture before entering the feedlot.

Reductions in GHG emissions will require an integrated suite of options including faster turnoff of livestock for slaughter, increasing reproductive efficiency, and selection of more efficient animals. In many cases individual technologies or management options will not be capable of achieving large emissions reductions per farm, so the potential for CFI projects to generate much income for farmers is low. However there is still a benefit to the industry of improving the efficiency of production. Emissions intensity is an important metric in this respect.

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1 Background

The CFI allows farmers to earn carbon credits by reducing greenhouse emissions. The development of CFI projects that land managers may take up requires explicit documentation of the rules under which a CFI credit may be obtained, including a description of the project activities and how it will reduce emissions, instructions on determining a baseline for the project, and procedures for estimating abatement and reporting requirements. Together these rules describe the CFI 'methodology' (http://www.climatechange.gov.au/government/initiatives/carbon-farming-initiative/handbook/).

The "Reducing Emissions from Livestock Research Program" (RELRP) identified 18 possible methodologies for reducing methane emissions from livestock production systems. These options cover a range of technologies including use of feed additives, improving forage quality, animal breeding and adaptation of grazing systems management. While each of these options has the potential to reduce methane emissions on a per hectare and/or an emissions intensity basis, there is a need to assess the whole farm impact of the technology from both an emissions (methane and nitrous oxide) and economic viewpoint. For example, earlier finishing in feedlots will involve the transfer of animals from farms to feedlots at an earlier age with expected higher growth rates and earlier finishing in feedlot systems leading to reduced methane emissions per animal. The whole farm analysis will also consider the options for the grazier to respond to the earlier removal of animals to the feedlot, for example by examining the trade-offs between reduced emissions and increasing stock rate to utilise the remaining forage.

Prior to development of CFI methodologies an assessment is needed of the viability of options, including estimates of the GHG emissions reductions per unit area and per unit of production, and an assessment of the potential income derived from a CFI project. In the project reported here, biophysical and economic modelling tools were used to assess the viability of four potential CFI methodologies.

2 Project objectives

Outputs The whole farm methane and nitrous oxide emissions from offset methodologies quantified on a per hectare and emissions intensity basis using biophysical and economic modelling tools for four strategies.

Outcome By August 2012, the grazing industries will be better informed of the viability of developing four abatement options into CFI offset methodologies. This proposal will utilise biophysical and economic modelling tools to evaluate the greenhouse gas emissions and economic outcomes from adopting four different offset methodologies. Four strategies will be selected from the list for analysis in consultation with MLA.

Four potential Carbon Farming Initiative (CFI) methodologies were selected for investigation, in consultation with MLA. These were:

(1) earlier lamb finishing in feedlots (north-west Victoria),
(2) improving forage quality by adding lucerne to farm (south west Victoria),
(3) lower protein diets in finishing rations, and
(4) increased maternal efficiency in northern beef herds (south west Queensland).

In discussions between the project leader and MLA during the course of the project it was agreed that the investigation of lower protein diets in finishing rations (methodology 3 above) would be replaced by an assessment of emissions from a beef supply chain (cow-calf, backgrounding and feedlot) in southern Australia. The purpose of this study was to identify which parts of the beef supply chain contribute most to total emissions from the system, with a view to determining the most appropriate points in the supply chain to target CFI methodologies.

3 Methodology

General approach

The general approach used to assess the four methodologies in this project was firstly to identify a baseline scenario for each of the issues examined and then applying the most suitable modelling tools to the analysis. The 'baseline' scenario for each of the methodologies defined the essential details of the modelling to be conducted including location, soil and pasture types, and livestock production system including stocking rates and calving dates. In each case the baseline scenario was formed from existing case studies and/or regional farm benchmarking data. The CFI methodologies were then investigated as increments of changes in management to the baseline system. The assumptions underlying the modelling of the systems are reported for each of the methodologies in later sections of the Material and Methods.

When the farm systems to be simulated were clearly defined the most appropriate modelling tools were selected to investigate the effects on production and GHG emissions (methane and nitrous oxide). Each of the methodologies investigated involved changes in livestock management and/or diet for all or part of the year. Where possible daily time step biophysical models were used to estimate production and emissions from the systems so that changes to animal management could be realistically simulated (eg. lambs sold were sold when their growth rates slow) and the influence of variable climates were taken into account. These effects can be realistically implemented in biophysical models but cannot be fully captured using inventory approaches.

In this project a modelling approach utilising a combination of daily time step biophysical systems models (eg. Grassgro and SGS Pasture model) and spreadsheet calculators based on greenhouse gas accounting approaches (eg. Farmgas) was developed to estimate the productivity and greenhouse gas (GHG) emissions from these animal production systems. There is currently no biophysical model that can simulate both the animal management systems and greenhouses gases (methane and nitrous oxide) within the one simulation framework.

Due to the importance of animal management in the lamb and beef production systems simulated in this project, Grassgro was selected as the biophysical model to use. Production and methane emissions were modelled in Grassgro, and emissions of nitrous oxide were estimated by inputting the required date from Grassgro into the Farmgas model or GHG inventory spreadsheets. In regions where Grassgro was not suited, ie. in the beef production system in southern Queensland, emissions were estimated using FarmGas alone. This approach was considered to be the most suitable at the present time.

GHG emissions of methane and nitrous oxide only were considered in this analysis, in line with the rules of the CFI.

Grain finishing to reduce emissions from lamb production systems in northern Victoria.

On mixed cropping-livestock farms there is an opportunity to feed grain to lambs to increase lamb growth rates and achieve higher lamb liveweights in less time compared to finishing lambs on pasture only. Such lamb finishing systems also have potential to reduce the GHG emissions from lamb production. The objective of this study was to quantify meat production (kg carcass weight (CWT)/ha), total GHG emissions (t CO_2-e/ha) and emissions intensity (t CO_2-e/t CWT) of pasture and grain finishing systems. An assessment of potential income from changing from pasture to grain finishing systems as a Carbon Farming Initiative (CFI) methodology was also made.

An autumn-lambing prime lamb production system was modelled at Birchip in northern Victoria using Grassgro (eg. Freer *et al.* 1997). The pasture was based on annual ryegrass and medic species, and stocked at 4 first cross ewes per ha. Ewes were fed supplementary feed if required to maintain body condition score at 1.5 throughout most the year, and 2.5 in the last month of gestation and first month of lactation (May-June inclusive). Five lamb finishing systems were simulated with different management and feeding systems applied between weaning on 1 October and selling of lambs off the farm:

A. Baseline system. Pasture only – ewe lambs sold in spring or summer at a target live weight of 45 kg or earlier if the average daily weight gain was less than 100 g/day for more than 14 days, and wether lambs fed to maintain condition score 2 over summer then sold on 1 April. This was termed the 'baseline' finishing system. This baseline system was based on practice documented by Birchip Cropping Group (recommended calendar of operations for ewe nutrition; http://www.bcg.org.au/cb_pages/files/Tim%20Hewitt%20Fact%20Sheet%20-%20FINAL.pdf) .
B. Wether lambs fed in feedlot – ewe lambs managed as in A, with wether lambs entering a feedlot after weaning on 1 October where they were fed to achieve a target liveweight of 45 kg on 1 January then sold.

C. Wether lambs fed in paddock – management as for B, except that wether lambs were also given access to pasture if available.
D. All lambs fed in feedlot – ewe and wether lambs fed in feedlot from weaning on 1 October to reach target liveweight of 45 kg on 1 January.
E. All lambs fed in paddock – management as for D, except that lambs were also given access to pasture if available.

A schematic diagram of the lamb management systems is provided in Figure 1.

Scenario	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
A	Wether lambs on pasture				on pasture							
	Ewe lambs on pasture				on pasture							
B	Wether lambs on pasture				fed in feedlot							
	Ewe lambs on pasture				on pasture							
C	Wether lambs on pasture				fed on paddock							
	Ewe lambs on pasture				on pasture							
D	Wether lambs on pasture				fed in feedlot							
	Ewe lambs on pasture				fed in feedlot							
E	Wether lambs on pasture				fed on paddock							
	Ewe lambs on pasture				fed on paddock							

Figure 1. Diagram of wether and ewe lamb management in the five scenarios at Birchip, indicating times of year that lambs are on farm and whether they are grazing pasture of being fed in feedlot or on the paddock (with access to pasture).

Animal production and enteric methane emissions were estimated using the approach of Blaxter and Clapperton (1965), as implemented in Grassgro, with nitrous oxide emissions estimated using inventory approaches (Browne *et al.* 2011). A farm gross margin analysis was conducted (see Appendix 1 for details) including an investigation of the potential income from a CFI project that changed management from scenario A, based on a price of $20 per t CO_2-e.

Improving forage quality by adding lucerne to the farm.

An August-lambing prime lamb production system was modelled at Hamilton in south-west Victoria using Grassgro (eg. Freer *et al.* 1997). The pasture was based on perennial ryegrass and sub clover species, and stocked at 10 first cross (Merino x Border Leicester) ewes per ha. Ewes were fed supplementary feed if required to maintain body condition score at 1.5 throughout most the year, and 2.5 in the last month of gestation and first month of lactation (mid July to mid September inclusive).

Six different lamb finishing systems were simulated:

A. Pasture only – lambs sold between late spring and early winter at a target live weight of 45 kg or earlier if the average daily weight gain was less than 100 g/day for more than 14 days. This was termed the 'baseline' system. The characteristics of this system were based on management of top 20% producers from the Department of Primary Industries Victoria Farm Monitor report.
B. 20% farm area sown to lucerne – lambs were managed as in A.
C. 30% farm area sown to lucerne – lambs were managed as in A.
D. Pasture only but lambs production fed in paddock – all lambs fed in feedlot from weaning on 15 November to reach target liveweight of 45 kg on 20 Febraury. This scenario was included to provide a contrast in management.
E. As for B, but incorporating 27% lower methane emissions from stock grazing lucerne compared to perennial ryegrass in months December to April based on the report by Phillips (2011).
F. As for C, but incorporating 27% lower methane emissions from stock grazing lucerne compared to perennial ryegrass in months December to April based on the report by Phillips (2011).

Animal production and enteric methane emissions were estimated using the approach of Blaxter and Clapperton (1965), as implemented in Grassgro. Nitrous oxide emissions were estimated using inventory approaches (Browne *et al.* 2011). A farm gross margin was also calculated using the costs and prices documented in Appendix 1.

Improving maternal efficiency in northern beef herds.

A self-replacing beef herd was modelled in south-west Queensland with increasing conception rates designed to achieve weaning rates 50, 60 70 and 80%. A suitable biophysical model was not available so assumptions were based on farm benchmark information. The weaning rates selected were based on preliminary results from the 'Cash Cow' project indicating that the percentage of mature breeders pregnant four months ranged from approximately 30 to 90% in the Southern Forest region. Using this data, the weaning rates modelled (50 to 80%) represented a range from what would be expected on the on a farm in the lowest 25% weaning rate to one with weaning rates in the top 30%.

The general approach was to model the herd structures for the 50% weaning rate (the baseline scenario) based on a breeding herd of 995 cows and calculate the farm gross margin for meat production. Breeding herd size for the 60, 70 and 80% weaning rates were set so that the number of cows weaned on the farm was maintained. Heifers were kept as replacement breeding stock as required to replace cows culled because they were non-pregnant or cast for age. At low weaning rates all heifers were kept and additional heifers were purchased from off-farm to maintain the breeding herd, whereas at high weaning rates surplus heifers were sold.

There was no biophysical modelling approach available for predicting pasture and animal production from this region, so assumptions were made about animal liveweights based on data from beef weaner production on native pastures collated by NSW Department of Primary Industries (http://www.dpi.nsw.gov.au/__data/assets/pdf_file/0007/175534/14-Inland-store-weaners.pdf, accessed August 2012). The key assumptions are documented in Table 1.

Emissions from the four scenarios were estimated using FarmGas. A farm gross margin was calculated based on the costs and prices documented in Appendix 2, with an analysis of CFI income based on a price of $20 per t CO_2-e.

Table 1. Production assumptions for the beef breeding enterprise in south-west Queensland.

Parameter	Assumption
Cow weight (average)	440 kg liveweight
Steer weight at sale (9 months)	260 kg liveweight
Heifer weight at sale (9 months)	230 kg liveweight
Bull weight at sale	700 kg liveweight
Dressing percentage (all stock)	52%

Emissions from a beef supply chain in southern Australia

Production, GHG emissions and profitability was simulated from a cow-calf, background and feedlot system at Hamilton in south west Victoria. The cow-calf and backgrounding systems were both based on perennial ryegrass and sub clover pastures. A self-replacing cow-calf system stocked at 2.2 Angus (500 kg mature weight) cows per ha was simulated, where steers and excess heifers were sold at five months of age. Steers were purchased by a backgrounding operation in the same region at an average liveweight of 175 kg, stocked a 4 steers/ha and grown to 350 kg liveweight. At this weight the steers entered a feedlot and were grown to 500 kg over 100 days. The supply chain together with a timeline is shown in Figure 2.

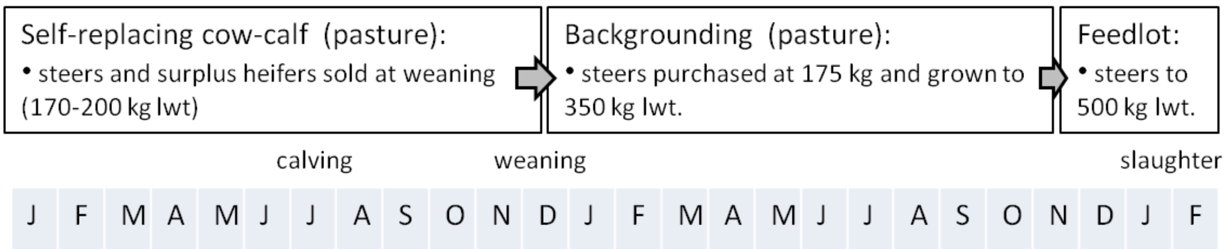


Figure 2. Flow chart of the beef supply chain indicating the months that the steers are in each of the cow-calf, backgrounding and feedlot systems, and the liveweight change in each of the systems.

In the cow calf and backgrounding systems the cattle were fed pasture only, except if the body condition score of animal dropped below 2.5 for mature females and 3 for weaners in which case they were fed a maintenance diet. In the feedlot the steers were fed *ad libitum* an 80:20 mix of crushed sorghum and cottonseed meal (80% dry matter digestibility, 12.6 MJ ME/kg DM, 17% crude protein and 75% rumen degradable protein).

Enteric methane emissions were estimated using the approach of Blaxter and Clapperton (1965), as implemented in Grassgro. Nitrous oxide emissions were estimated using inventory approaches. Key assumptions about the cost and prices used in the economic analysis of the cow-calf and backgrounding systems are documented in Appendix 3.

4 Results and discussion

Grain finishing to reduce emissions from lamb production systems in northern Victoria.

The baseline lamb finishing systems that primarily relied on pasture (system A) had the lowest total meat sold (on average 93 kg carcass weight/ha, Figure 3a), highest total emissions per hectare (1.36 t CO_2-e/ha, Figure 4a) and the highest emissions intensity of all five systems (14.7 kg CO_2-e/kg carcass weight, Figure 4b). Across the lamb finishing systems simulated methane contributed 90% and nitrous oxide 10% of total GHG emissions expressed at CO_2-e.

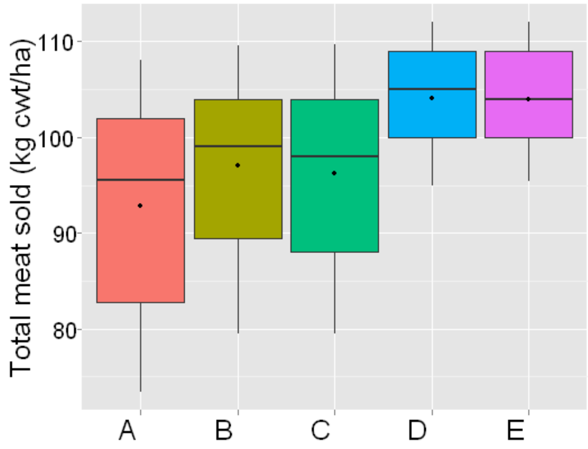
Earlier finishing of wether lambs by feeding in a feedlot (B) or in the paddock (C) increased meat production with lower total emissions, leading to a 7-8% reduction in emissions intensity. When all lambs where fed in the feedlot (D) or in the paddock (E) there were further increases in meat sold, and this meat was produced with lower emissions intensity. These increases in production and production efficiency were achieved by finishing lambs earlier and more consistently to the target weight by replacing a poor quality pasture diet (50% dry matter digestibility) with a supplementary feed ration (80% dry matter digestibility) for lambs over the summer months.

Under the meat price and supplementary prices used in this analysis (Appendix 1), feedlotting lambs was more profitable than the pasture finishing system (Figure 3b). However this result is highly sensitive to meat and supplementary feed prices. The sensitivity analysis presented in Table 2 indicates that if meat price declined by 25% or if supplementary feed price increased by 25% the feeding of grain to livestock would not be profitable. This indicates that it would not be profitable to feedlot lambs in all years.

Total emissions were reduced in the production feeding systems (B-E) by 50-70 kg CO_2-e/ha compared to the pasture finishing system (A). If scenario A is considered to be the baseline management in a CFI methodology, and the farmer was paid \$20/t CO_2-e, these reductions would lead to a payment equivalent to \$1.00-1.40/ha. This income would be considered modest, contributing less than 2% to the gross margin of these production systems.

The proportional gains relative to the baseline, pasture finishing system (A) were greater for emissions intensity (≈8% for B and C, ≈14% for D and E) than for total emissions (4-5% for B-E). Nevertheless, this analysis demonstrates that production feeding of lambs with grain can achieve both increased meat production and reduced emissions per ha, leading to significant gains in emissions intensity.

(a)



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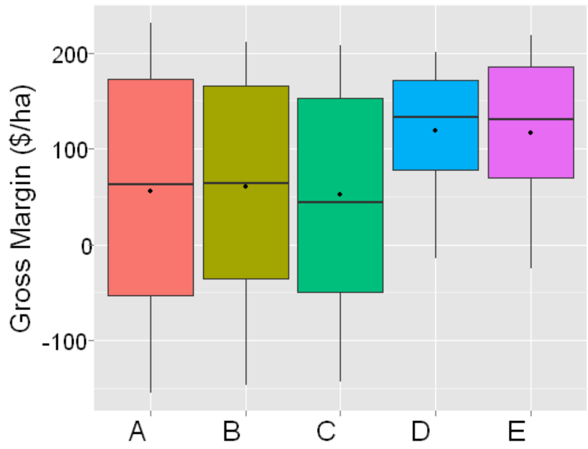
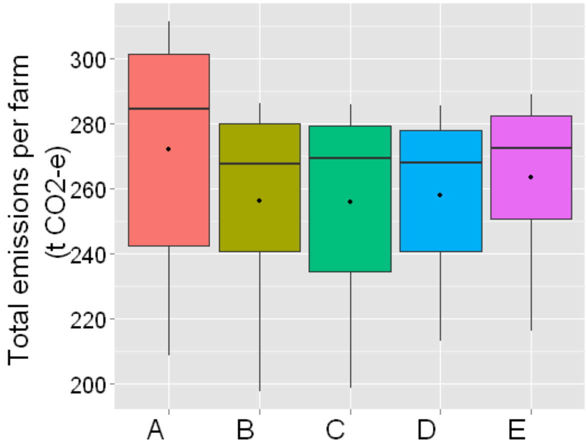


Figure 3. (a) Annual meat sold (kg carcass weight (cwt)/ha) and (b) gross margin ($/ha) for the pasture and feeding lambs finishing systems, as described in Figure 1. Box-plots indicate variation over 40 years (1960-2009) showing minimum, 25, 50, 75th percentiles and the maximum, with the dot indicating the mean.

(a)



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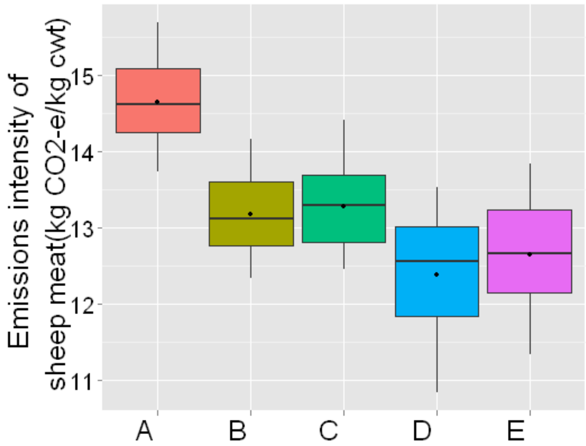


Figure 4. (a) Annual total emissions (t CO_2-e) per 200 ha farm and (b) emissions intensity of sheep meat production (kg CO_2-e/kg carcass weight) for the pasture and feeding lambs finishing systems, as described in Figure 1. Box-plots indicate variation over 40 years (1960-2009) showing minimum, 25, 50, 75th percentiles and the maximum. The dot indicates the mean.

Brief description of lamb finishing systems at Birchip (see Figure 1 for details):

A. Baseline system. Pasture only.
B. Wether lambs fed in feedlot.
C. Wether lambs fed in paddock.
D. All lambs fed in feedlot.
E. All lambs fed in paddock.

Table 2. Sensitivity of farm gross margin ($/ha) to percentage changes in meat and supplementary feed prices for system B (wether lambs fed in feedlot) at Birchip. In the zero change scenarios the meat prices were $4.11/kg cwt for lamb and $2.78/kg cwt for ewes, while the supplementary feed price was $178.8/ tonne.

		Percent change in meat prices				
		-25%	-10%	0%	10%	25%
Percent change in supplement price	-25%	$46	$103	$142	$180	$238
	-10%	-$3	$55	$93	$132	$189
	0%	-$36	$22	$61	$99	$157
	10%	-$68	-$10	$28	$67	$125
	25%	-$117	-$59	-$20	$18	$76

Improving forage quality by adding lucerne to the farm.

The simulated monthly growth patterns of ryegrass and lucerne at Hamilton indicated that lucerne did produce more forage over summer and autumn but less during the winter and spring (Figure 5). The changes in seasonal pattern of pasture production led to some changes in meat produced, with lower production when 20 or 30% of the farm are was sown to lucenre compared to the perennial ryegrass based pasture, while the feedlotting option (Scenario D) produced a small increase in meat production (Figure 6a). These production patterns were reflected in the farm gross margins (Figure 6b).

Overall there was little difference between the systems in GHG emissions per hectare (averages of 4.03-4.22 t CO_2-e/ha, Figure 7a) or emissions intensity (14.1-15.9 kg CO_2-e/kg carcass weight, Figure 7b) across the farm systems simulated. Methane contributed 83% of total farm CO_2-e emissions. The inclusion of lucerne on the farm provided a higher quality feed over the summer and autumn months but its growth rate was not always higher than the perennial pasture. In some years, this resulted in the lambs being kept on the farm longer through summer with little weight gain, leading to higher methane emissions. Lower emissions were only predicted with lucerne when the 27% reduction in stock grazing lucerne between the months November and April (Phillips 2011) was applied. Under these conditions, total emissions per ha from the farm with 30% lucerne were 4.03 t CO_2-e/ha compared to 4.13 t CO_2-e/ha on the baseline farm. At a price of $20 pet t CO_2-e this would be worth $2.00 per ha to the farmer. This income is equivalent to 0.25% of the gross margin of the baseline farm.

Further work is required to verify the emissions reductions from stock grazing lucerne as the report by Phillips (2011) was a preliminary study.

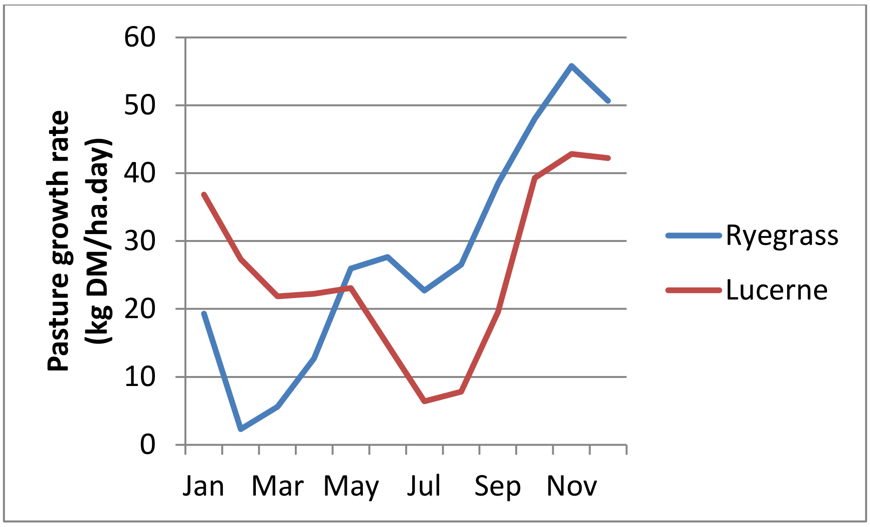


Figure 5. Simulated long-term (1961-2009) average monthly growth rates (kg DM/ha.day) of perennial ryegrass and lucerne pastures in rain-fed conditions at Hamilton, south-west Victoria.

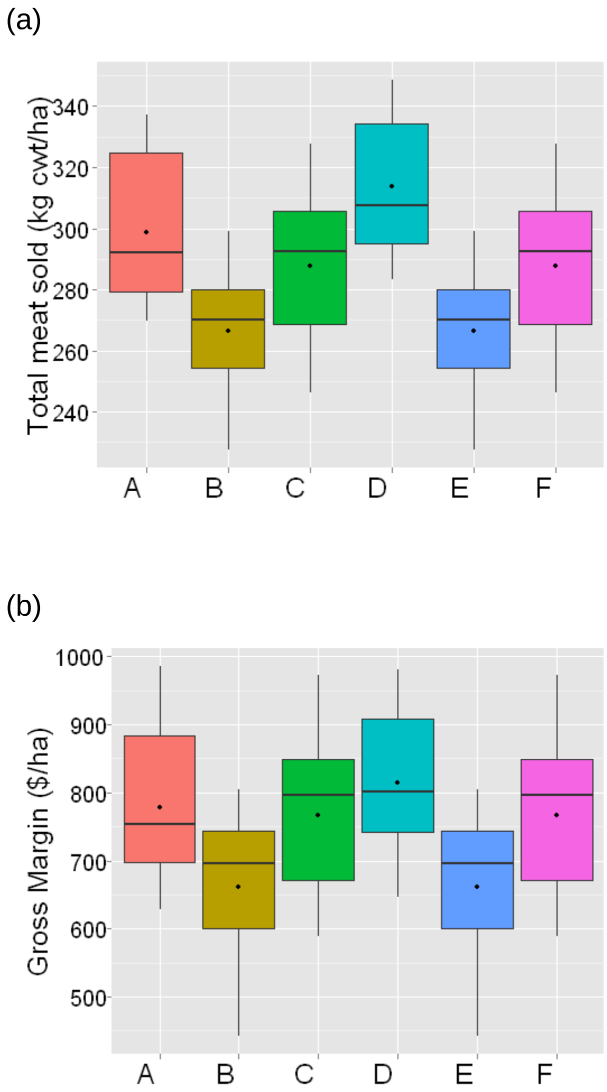
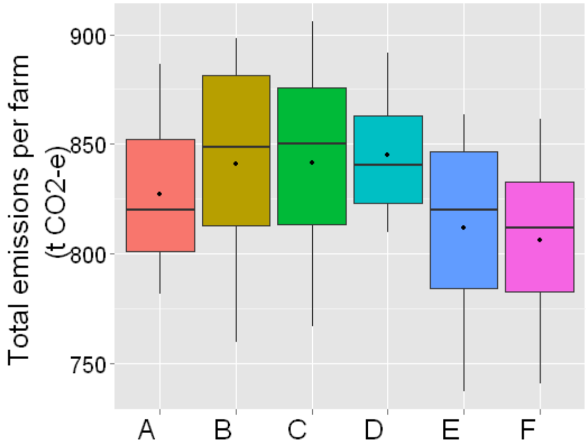


Figure 6. (a) Annual meat sold (kg carcass weight (cwt)/ha) and (b) gross margin ($/ha) for the pasture and feeding lambs finishing systems at Hamilton. Box-plots indicate variation over 40 years (1960-2009) showing minimum, 25, 50, 75th percentiles and the maximum, with the dot indicating the mean.

(a)



(b)

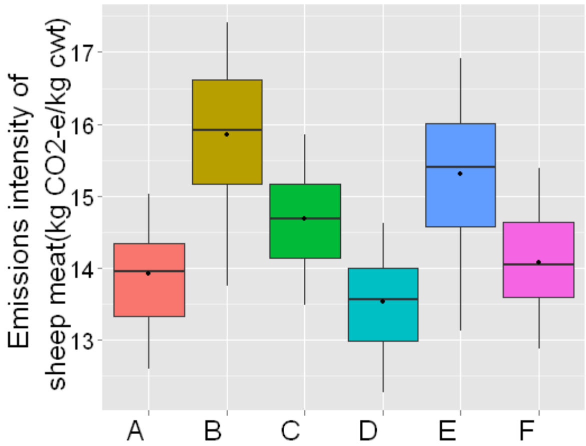


Figure 7. (a) Annual total emissions (t CO_2-e) per 200 ha farm and (b) emissions intensity of sheep meat production (kg CO2-e/kg carcass weight) for the pasture and feeding lambs finishing systems at Hamilton. Box-plots indicate variation over 40 years (1960-2009) showing minimum, 25, 50, 75th percentiles and the maximum, with the dot indicating the mean.

Brief description of lamb finishing systems at Hamilton:

A. Baseline system – grass and legume pasture only.
B. 20% farm area sown to lucerne.
C. 30% farm area sown to lucerne.
D. Pasture only but lambs production fed in paddock.
E. As for B, but with lower methane emissions from lucerne (Phillips 2011).
F. As for B, but with lower methane emissions from lucerne (Phillips 2011).

Increasing weaning rates in northern beef herds.

Herd size at the different weaning rates were determined to maintain the number of calves weaned at the same level as in the 50% weaning rate (Baseline) scenario (Table 3). It was not appropriate to simply maintain the number of weaners sold from the farm, as changes in the ratio of meat sold from cows (either cast of age or because they were not pregnant) occur as weaning rate increases. This is illustrated in Table 3. At lower weaning rates a larger number of cows were sold because they were not pregnant, all of the female weaners were retained on farm as replacements and additional heifers were purchased to maintain the breeding herd size, and male weaners were sold. By contrast at higher weaning rates less of the breeding herd was sold because fewer cows were not pregnant, and not all of the female weaners were required as replacements in the breeding herd resulting in a higher number of weaners being sold. Total cow and weaner meat sold per year is shown in Figure 8.

Adopting the approach of maintaining the number of calves weaned resulted in similar gross margins from the livestock enterprises at the four different weaning rates (≈$200,000 per farm).

Table 3. Annual summary of the breeding herd size, number of cows sold as cast of age or non-pregnant, number of calves weaned, the number of replacement heifers purchased to maintain the breeding herd and number of weaners sold at the four weaning rates modelled.

Livestock category	50% weaning	60% weaning	70% weaning	80% weaning
Breeding herd size	995	822	699	617
Cows sold – CFA	7	16	29	47
Cows sold – non-pregnant	434	267	149	66
Calves weaned	488	484	480	484
Replacement heifers purchased	197	41	0	0
Weaners sold	244	242	301	371

Total farm emissions declined at higher weaning rates in line with reduction in breeding herd size, by over 40% at the highest weaning rate compared to the baseline (3432 and 2006 t CO_2-e/farm for the baseline and 80% weaning rates respectively, Figure 9). There was relatively little difference in emissions intensity of total meat turn-off (Figure 10) because of the reduction in mature cows sold. There was however a substantial reduction in emissions intensity of weaner meat production from 100 to 35 kg CO_2-e/kg CWT for the 50 and 80% weaning rates respectively (Figure 11).

Additional farm income from a CFI project at a price of $20/t CO_2-e is shown in Figure 12. The CFI income in moving from 50 to 60, 70 or 80% weaning rates was estimated at $13,320, $22,260 and $28,520 per farm (4.2, 7.9 and 10.3% of gross farm income respectively).

At higher weaning rates there is an opportunity for a proportion of the farm to the locked up for conservation or tree production. The additional income associated with has not been calculated in this analysis.

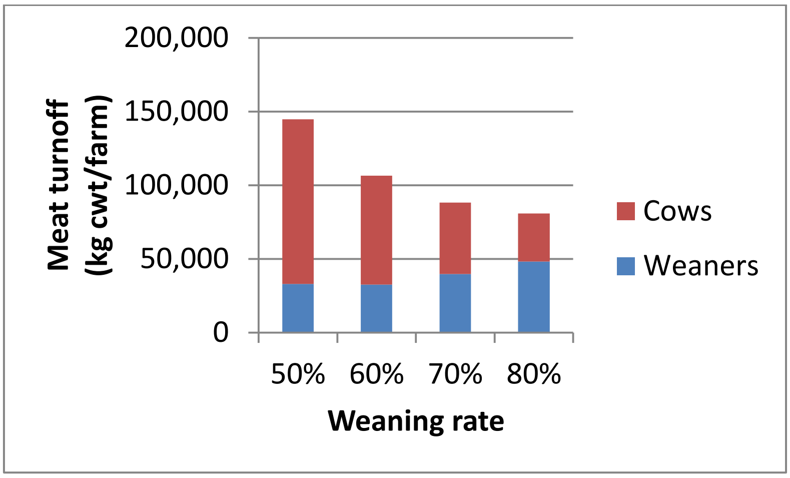


Figure 8. Meat turn-off (kg carcass weight per farm) from cast-for-age and non-pregnant cows and weaners at 50, 60, 70 and 80% weaning rates for a self-replacing breeding herd in south-west Queensland.

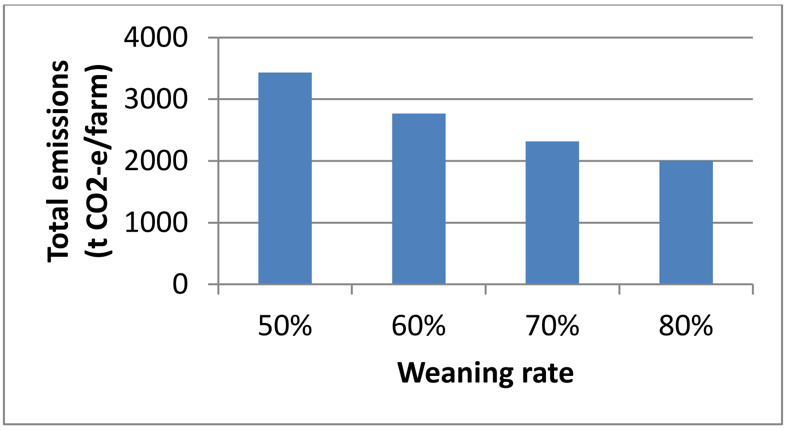


Figure 9. Total GHG emissions (t CO_2-e per farm) at 50, 60, 70 and 80% weaning rates for a self-replacing breeding herd in south-west Queensland.

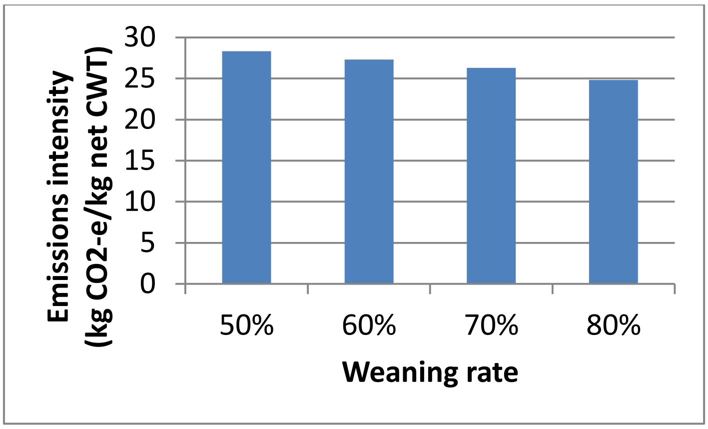


Figure 10. Emissions intensity (kg CO_2-e/kg carcass weight) of net (total meat sold minus replacement heifers purchased) meat turn-off at 50, 60, 70 and 80% weaning rates for a self-replacing breeding herd in south-west Queensland.

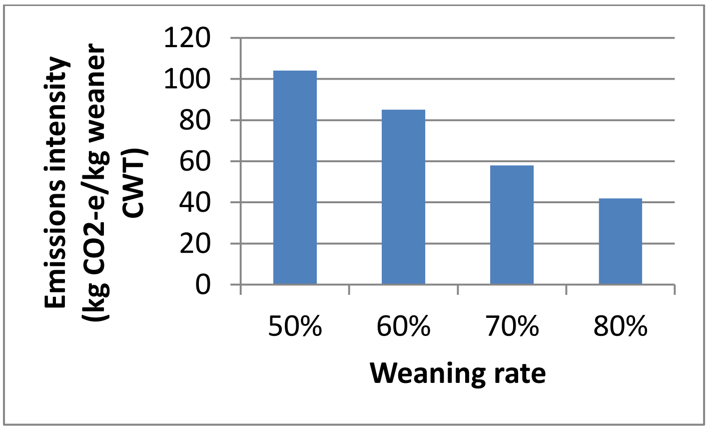


Figure 11. Emissions intensity (kg CO_2-e/kg carcass weight) of weaner meat turn-off at 50, 60, 70 and 80% weaning rates for a self-replacing breeding herd in south-west Queensland.

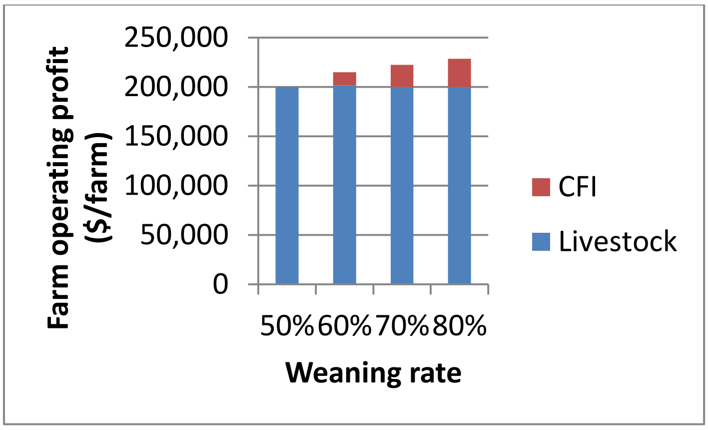
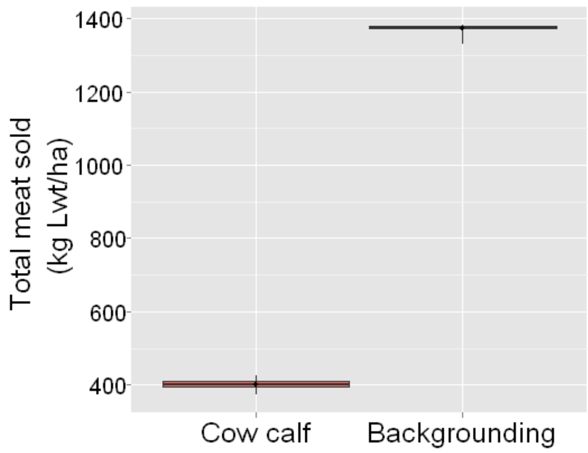


Figure 12. Farm operating profit ($/farm) showing profit from livestock and income generated from a CFI project (each relative to the 50% weaning 'baseline' scenario) at 50, 60, 70 and 80% weaning rates for a self-replacing breeding herd in south-west Queensland.

Emissions from a beef supply chain – cow-calf, backgrounding and feedlot

Total meat sold from the cow-calf self replacing beef systems at Hamilton was approximately 400 kg livewight per ha (Figure 13a), and 1400 kg liveweight per ha from the backgrounding system. Based on the assumptions in Appendix 3, the backgrounding system was more profitable (Figure 13b).

(a)



(b)

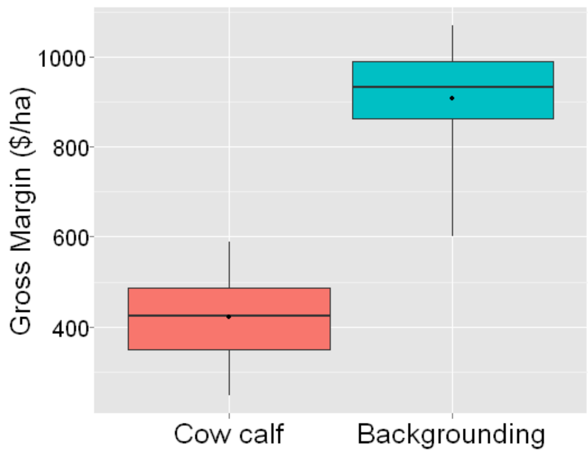


Figure 13. (a) Annual meat sold (kg liveweight (lwt)/ha) and (b) gross margin ($/ha) for the cow-calf and backgrounding beef systems at Hamilton. Box-plots indicate variation over 40 years (1960-2009) showing minimum, 25, 50, 75th percentiles and the maximum, with the dot indicating the mean.

Over the lifetime of the steers total emissions averaged 4.76 t CO_2-e/head and 9.5 kg CO_2-e/kg liveweight gain, with 61, 24 and 15% of total emissions for cow-calf breeding, backgrounding and feedlot systems respectively. GHG emissions per head (Figure 14) and per kg liveweight gain (Figure 15) were highest in the cow-calf system and lowest in the feedlot. In the cow calf system the emissions from the breeding herd were attributed to the steers and surplus heifers sold resulting in higher emissions. Higher emissions from the backgrounding system compared to the feedlot reflect the longer time and lower growth rates on pasture (average of 300 days and 0.6 kg/day liveweight gain) compared to on the feedlot ration (average of 100 days and 1.5 kg/day liveweight gain).

This characterisation of emissions from the cow-calf, backgrounding and feedlot allows definition of where CFI projects may be targeted. The largest emissions are from the cow calf system. Improving reproductive performance will assist in reducing emissions in this system as demonstrated for the beef herd in south west Queensland in this report, however there may be less capacity to increase weaning rates in southern Australia. Options for backgrounding include use of higher quality forages to reduce the time spent on pasture before entering the feedlot. In the feedlot options such as lower protein rations are currently under investigation.

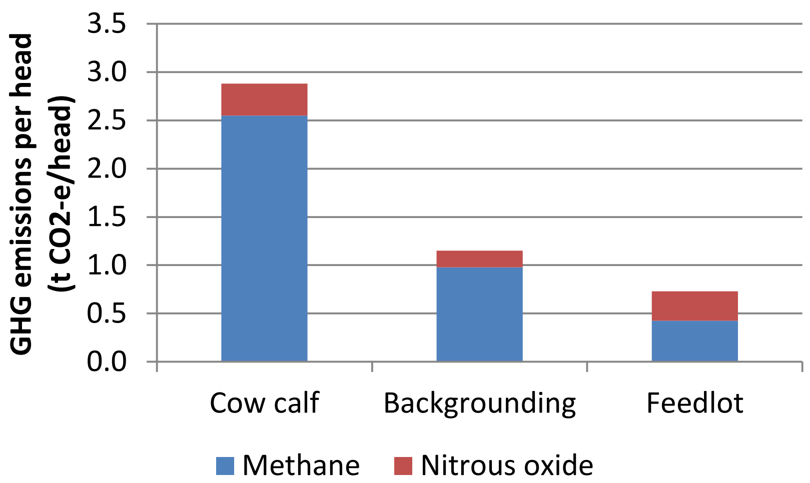


Figure 14. GHG emissions per steer (t CO_2-e/head) of methane and nitrous oxide in the cow-calf, backgrounding and feedlot parts of the supply chain. The time spent and liveweight gain of steers in each part of the supply chain is shown in Figure 2.

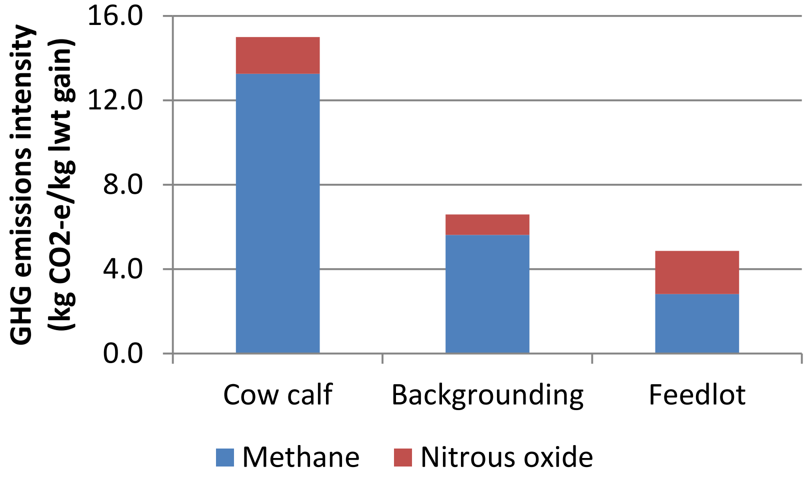


Figure 15. GHG emissions intensity of liveweight gain (kg CO_2-e/kg lwt gain) of methane and nitrous oxide in the cow-calf, backgrounding and feedlot parts of the supply chain. The time spent and liveweight gain of steers in each part of the supply chain is shown in Figure 2.

5 Conclusions

The potential CFI methodologies investigated in this project focussed on improving farm management to reduce total emissions and/or emissions intensity from livestock production systems. The options included improving diet quality for earlier finishing of stock and increasing reproductive rates. In general where larger changes to the production system were made more substantial reductions in emissions were observed. For example, changing from a pasture to feedlot lamb finishing system at Birchip imposed a larger change in diet quality compared to replacing perennial ryegrass based pasture with lucerne at Hamilton. As a result the modelled changes in emissions and emission intensity were larger at Birchip than at Hamilton.

CFI projects must also be targeted to where the emissions occur in the production system. In the lamb finishing system case study at Birchip emissions from the lambs only were targeted which accounted for 35% of the total emissions per hectare. To further reduce emissions the breeding stock must also be targeted. The analysis of the beef supply chain in south west Victoria also highlighted that the breeding systems provided a large proportion of the emissions and helped to identify where projects to reduce emissions could be targeted.

The methodology developed in this project integrated biophysical modelling with inventory calculators to predict emissions of methane and nitrous oxide from the systems. One recommendation from this project is that there is a need for biophysical model development so that all greenhouse gas emissions can be modelled with realistic farm management in a single modelling framework.

As noted by Cottle *et al.* (2011) reductions in methane production will require an integrated suite of options including faster turnoff of livestock for slaughter, increasing reproductive efficiency, and selection of more efficient animals. The modelling presented in this report confirms that grain finishing lambs in the 'wheat-sheep' zone and increasing weaning rates in the northern beef industry can reduce emissions while maintaining or increasing production. In the grain finishing example, reductions in GHG emissions were small and potential CFI income low. Substantial emissions reductions were simulated by increasing weaning rates in south-west Queensland, but this represented a change in reproductive performance equivalent of moving from the industries 25^{th} to 70^{th} percentile. The question of what the appropriate 'baseline' is in this example needs further definition.

In many cases individual technologies or management options will not be capable of achieving large emissions reductions per farm, so the potential for CFI projects to generate much income for farmers is low. However there is still a benefit to the industry of improving the efficiency of production. Emissions intensity is an important metric in this respect.

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Appendix 1: Economic assumptions for lamb enterprises

Table 1.1. Cost and prices used for the economic analysis of lamb enterprises at Birchip and Hamilton.

Costs	
Replacement ewes	$100 per head (+$2 per head cartage)
Replacement rams	$500 per head
Pasture maintenance	$41 per hectare
Labour cost	$3 per lamb
Casual labour	$0.17 per DSE
Supplementary feed price	$178.8 per tonne
Shearing	$5.89 ewes, $8.5 rams
Crutching	$1.04 ewes and lambs, $1.95 rams
Ewe scanning	$0.8 per head
Animal health- ewes	$3.18 per had
Animal health- lambs	$3.05 per head
Additional production feeding labour cost (feedlot and paddock)	$0.04 per lamb per day
Wool tax	2%
Wool commission, warehousing and testing	$39 per bale
Wool cartage	$18 per bale
Livestock selling costs	5%
Livestock sales- cartage	$2 per head
Prices	
Lamb price	$4.11 per kg carcass weight
Ewe price	$2.87 per kg carcass weight
Skin price	$10 per head
Ram price	$60 per head

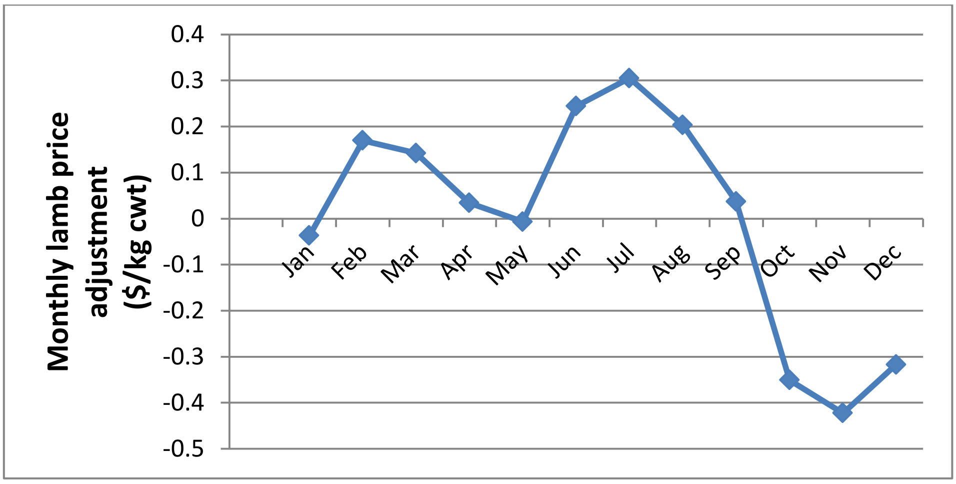

Figure 1.1 Monthly lamb meat price adjustment used to reflect seasonal prices.

Appendix 2: Economic assumptions for the beef breeding enterprise in south-west Queensland

Table 2.1 Cost and prices used for the economic analysis of beef enterprise in south-west Queensland.

Costs	
Replacement heifers	$251 per head
Replacement bulls	$4500 per head
Animal health – bulls	$85.73 per head
Animal health – cows	$8.83 per head
Animal health – calves	$0.69 per head
Animal health – replacement heifers	$2.98 per head
Ear tags	$2.00 per head
Selling costs - Yard dues	$3.00 per head
Selling costs - MLA levy	$5.00 per head
Selling costs - Freight	$5.50 per head
Prices	
Steers price	$2.20 per kg carcass weight
Heifers price	$2.10 per kg carcass weight
Cull cows price	$2.60 per kg carcass weight
Bull price	$2.90 per kg carcass weight

Appendix 3: Economic assumptions for the cow-calf and backgrounding beef production systems at Hamilton

Table 3.1 Cost and prices used for the economic analysis of beef cow-calf system at Hamilton.

Costs	
Replacement bulls	$4500 per head
Animal health – bulls	$85.73 per head
Animal health – cows	$8.83 per head
Animal health – calves	$0.69 per head
Casual labour cost	$0.30 per DSE
Ear tags	$2.00 per head
Selling costs - Yard dues	$3.00 per head
Selling costs - MLA levy	$5.00 per head
Selling costs - Freight	$5.50 per head
Pasture maintenance	$41 per hectare
Supplementary feed	$159 per tonne
Prices	
Steers and surplus heifer price average	$3.78 per kg carcass weight
Cow price average	$3.05 per kg carcass weight

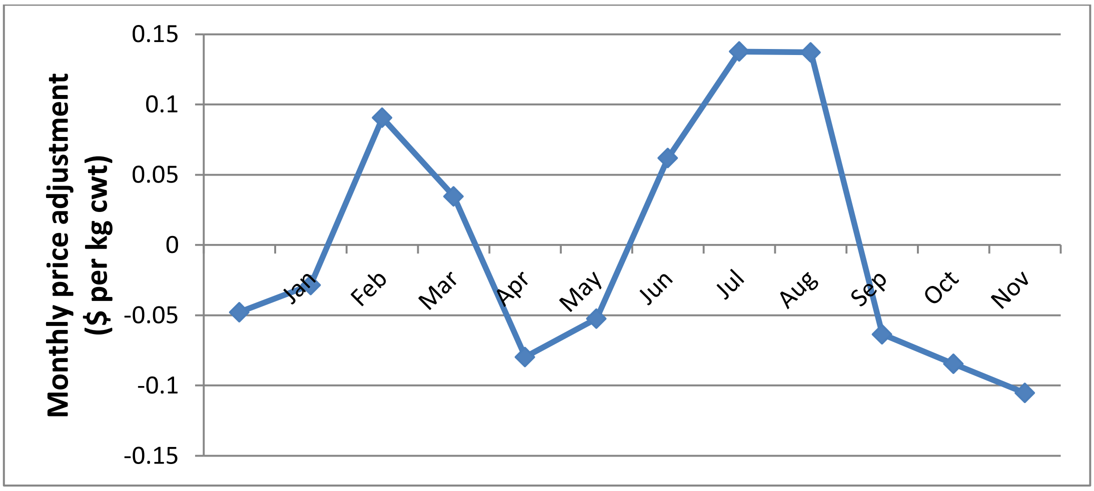

Figure 3.1 Monthly meat price adjustment used to reflect seasonal prices.

Table 3.2 Cost and prices used for the economic analysis of beef backgrounding enterprise at Hamilton.

Costs	
Steer purchase price	$230 per head plus $10 cartage
Animal health	$9.5 per head
Casual labour cost	$0.30 per DSE
Selling costs - MLA levy	$5.00 per head
Selling costs - Freight	$12.00 per head
Pasture maintenance	$42 per hectare
Supplementary feed	$159 per tonne
Prices	
Steers and surplus heifer price average	$3.78 per kg carcass weight
Cow price average	$3.05 per kg carcass weight