Unpublished Report

Document ID:	SheepCRC_4_14
Title:	Can Altered Management or Animal Selection Yield Significant Reductions in Methane Emissions from Sheep Production Systems?
Author:	Alcock, D.
Key words:	sheep; methane; management; nutrition; grassgro

This report was prepared as part of the Sheep CRC Program 2007-2014. It is not a refereed publication. If the report is quoted it should be cited as:

Sheep CRC Report 4_14

Can Altered Management or Animal Selection Yield Significant Reductions in Methane Emissions from Sheep Production Systems?

Doug Alcock, LO (S&W), Cooma 2010

Summary

Inclusion of agriculture in a Carbon Pollution Reduction Scheme will increase the costs of running sheep grazing enterprises. It is therefore important for graziers to explore ways to reduce emissions and importantly also reduce emissions intensity (emissions per unit of output). This work has used the GrassGro simulation model to assess a range of breeding and management structures for their potential to alter methane emissions and intensity.

Management options considered include choice of lambing time, joining maidens as lambs and production feeding to finish lambs. The potential for using animal breeding was also tested and model parameters altered to represent improvement in traits such as fecundity, live weight gain, net feed intake and methane output directly.

All options except lamb joining were able to reduce emissions intensity. However since methane output relates directly to dry matter intake, at optimal stocking rates pasture utilisation is very similar and generates ostensibly the same level of emissions. The optimal stocking rate is largely unaffected by emissions permit price and if decisions are made solely on an economic basis the grazier is likely to continue with similar levels of production (and emissions) until the carbon price either makes the sheep enterprise unprofitable or an alternative enterprise relatively more profitable than sheep grazing.

Introduction

Climate change has become one of the most pressing issues of our generation. While the potential impact of human induced warming is arguably already being felt, the full impact will be on future generations. Global climate modelling suggests that no change to emissions may lead to temperature increases for NSW of 5+ºC by 2070 (Climate Change in Australia 2007).

After CO_2 one of the most significant global greenhouse gases is methane (CH_4). Methane emanates from many natural sources but significantly it is also a major by-product of ruminant fermentation with around 25g of methane produced per kg of dry matter intake depending on feed type and quality (Blaxter and Clapperton 1965). While anthropogenic CH_4 emissions are far lower than CO_2 the molecular structure of CH_4 makes it a far more potent greenhouse gas with a global warming potential (GWP) 23 times that of CO_2 (IPCC 2007).

The Australian national carbon accounts show that in 2007 agriculture was the second largest emitter (after stationary energy generation) at 16.3% of total net emissions (DCC 2009). Enteric methane is the single biggest contributor to Agricultural emissions contributing 10.8% of the national accounts in the year to December 2008 (DCC 2009).

Current accounting scheme calculates emissions from sheep by way of a simple linear relationship with intake. Based on one dry sheep equivalent requiring ~9 MJ of energy intake, and an average pasture digestibility of 64%, it would equate to ~1 kg DM/head/day and an annualised methane output of 6.86 kg/dse (Howden 1994) or 156 kg CO_2_eq kg at a GWP of 23 times CO_2. This agrees closely with the National Carbon Accounting System's implied emission factor for sheep of 6.8 kg methane/head (DCC 2009).

The significance of this number is clear in the context of some farm financial benchmark data. The top 20% of wool flocks in 2004/05 had a net profit of $9.97/dse (AgInsights 2005) but at an emissions permit cost of $25/tonne CO_2_eq this would fall to just $6.06/dse. Over the period

1998 – 2005 the average net profit of all farms was \$3.41/dse which converts to a net loss of \$0.50 per dse under emissions trading. The emissions reduction trajectory will see permit prices increase making many grazing enterprises unviable

In this context, management options to reduce methane, or at least the intensity of methane per unit of product, need to be assessed. Field measurement of whole farms methane production over long periods of time is not feasible, leaving computer modelling as the only viable way of estimating the impact of management changes on emissions. This work attempts to use a farm systems model to estimate the impact of management or genotype changes on the emissions profile and emissions intensity of sheep flocks.

Methods

Since methane production is largely a function of dry matter intake (DMI), enterprise methane production relates to the number of animals and pasture characteristics (eg herbage mass and digestibility) which control the daily intake. GrassGro uses simulation modelling to estimate the supply and quality of pasture on the basis of soil and pasture type with pasture growth driven by daily weather data (Moore *et al.* 1998). Herbage availability and the intake of pasture dry matter are simulated as described by Freer *et al.* (1998). Methane production is estimated using the equations of Blaxter and Clapperton (1965).

The pasture / soil system used in this work is the "Cowra" farm system used by Warne *et al.* (2006). Pastures are an annual grass and sub-clover mix grown on a red earth soil and simulation extended for the 37 years from 1965-2002 inclusive.

Enterprises used in the analysis (Table 1) are a subset of the enterprises analysed in Warne *et al.* (2006, as impact of management on methane production is unlikely to vary significantly between merino flocks of differing micron category. Stocking rates are optimised to meet ground cover targets and limit excessive supplementation. Profit is derived from Gross Margin by deducting \$100/ha for all enterprises. Refer to Warne *et al.* (2006) for greater detail on farm system, sheep flock and cost/price parameters.

Table 1. Subset of optimal enterprises taken from Warne *et al.* (2006)

Enterprise	Code	Progeny sale	Ewe Genotype	Lambing Time	Ewes/ha	Pasture Utilised %
Self replacing Merino	SRM (Weaners)	18 weeks	Fine M	July	10	42
Self replacing Merino	SRM (Hoggets)	12 months	Fine M	Sept	7	41
Dual purpose Merino	DP (Stores)	18 weeks	Fine M	July	8	43
Dual purpose Merino	DP (Trade)	44 kg	Fine M	July	7	41
Prime lambs	2nd X (Stores)	18 weeks	BLXM	July	6	41
Prime lambs	2nd X (Trade)	44 kg	BLXM	July	6	42
Prime lambs	2nd X (Heavy)	53 kg	BLXM	July	6	40

Management and selection strategies were tested for their impact on absolute emissions and emissions intensity where emissions intensity is defined as the kg of CO_2_eq per kg of live-weight sold. Gross margin per emissions unit was also calculated in order that the economic output could be considered in the context of any potential emissions permit cost.

Management strategies tested include*:*

a) Changing the time of lambing
b) Joining ewe lambs.
c) Strategic production supplements

Selection strategies tested include:

a) Increasing fecundity
b) Increased live-weight gain (LWG)
c) Reduced methane (Methane)
d) Lower net feed intake (NFI)

Changing the time of lambing

Lambing time was varied in monthly increments between April and September. Shearing, selling and replacement dates were altered in order that they occurred at the same time relative to the lambing date.

Joining ewe lambs

Base simulations were for enterprises in which maidens were joined as hoggets. These were compared with flocks joining maidens as lambs and reducing the age at disposal by 1 year in order to keep a similar flock structure.

Strategic production supplements.

Base simulations for finished lamb systems assumed sufficient production supplement would be supplied for young animals to be finished at the target weight by 5 months of age. By comparison a series of simulations were run with the target final sale date delayed in 2 month increments, with production feeding used only in the final 2 months. This simulated the scenario of retaining lambs longer to enable a greater opportunity of finishing animals at pasture. As a final comparison one simulation was done setting 12 months as the final sale date with no production feeding.

Increasing fecundity

Genotype parameters for the percentage of ewes conceiving singles and twins at average condition score were altered to generate weaning rates incrementally higher than the base simulations.

Growth, methane and feed efficiency

A 10% improvement in the relative genetic performance of the animals for these traits was simulated, by manipulating parameters not variable within GrassGro user interface. A parameter editor, provided by CSIRO Plant Industry, allowed parameter manipulations to simulate these changes to the animal genotype. These parameters are described in Sheep Explorer 2006 (www.pi.csiro.au/grazplan).

Results

Time of lambing

Time of lambing was altered at a constant stocking rate in order to compare the direct effect of choosing a different lambing time only. Figure 1 shows that even at a constant stocking rate the current optimal lambing time is also the point at which emissions intensity is lowest.

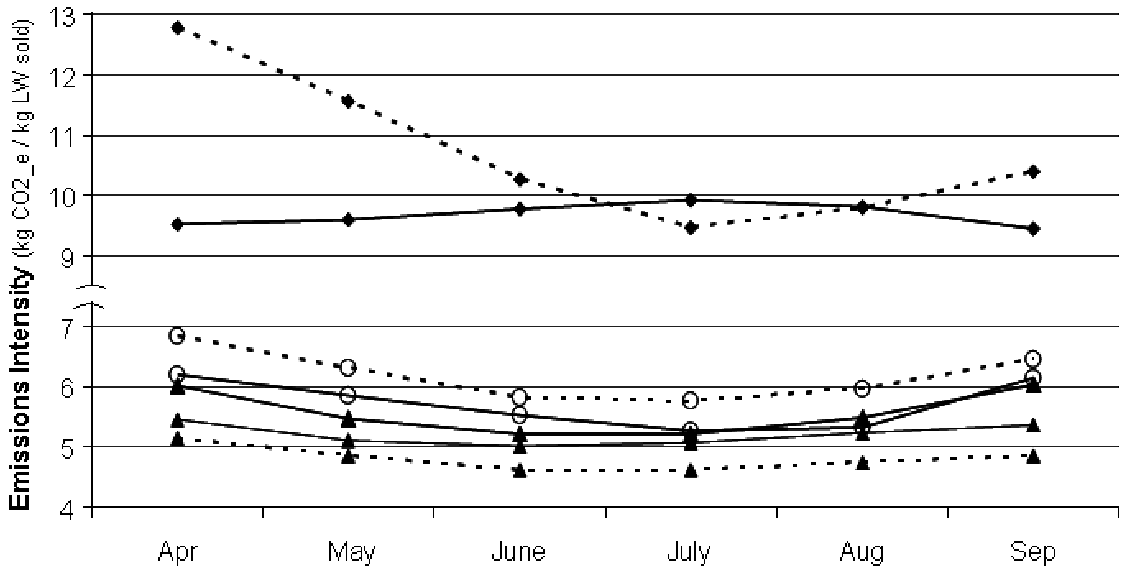

Figure 1. Impact of lambing time on enterprise emissions intensity (annual pasture at Cowra)

The alignment of lowest emissions intensity with the optimum lambing time previously determined by Warne *et al.* (2006) also flows on to the maximising of profit per emissions unit as shown in Figure 2.

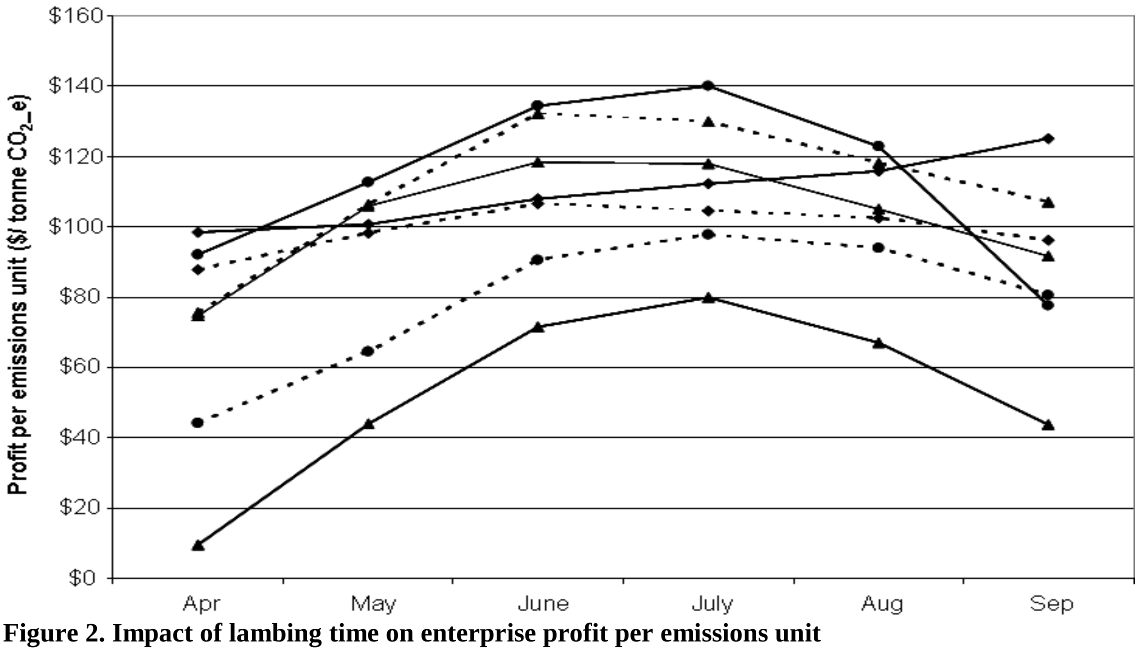

Figure 2. Impact of lambing time on enterprise profit per emissions unit

When the feeding and ground cover rules are considered, the actual sustainable stocking rate declines progressively as the lambing time shifts away from the optimum. The current optimal lambing time will not change under an emissions trading scheme though autumn lambing at the sustainable stocking rate will lower absolute emissions simply because the number of stock is lower.

Joining ewe lambs

Joining maiden ewes as lambs has been suggested to reduce methane emissions, by removing an age group of female animals from the farm system while joining the number of ewes but not substantially reducing the number of lambs weaned. This proved to be the case for self replacing flocks that dispose of surplus young stock as weaners. However, if all young stock are retained for sale as hoggets or replacements ewes are bought, no emissions savings accrue. Figure 3 illustrates that the self replacing merino flock can reduce emissions intensity by about 12%. All other production systems saw either little reduction or a slight increase in emissions intensity by joining ewe lambs. Stocking rates were re-optimised for the lamb joining systems to achieve the best economic output while meeting the constraints of the ground cover and feeding rules specified.

Industry structures where a self replacing merino flock joins maidens as lambs and sells surplus ewes weaners to dual purpose flocks to be joined as lambs may yield a small net reduction in emissions intensity. However if stocking rates are optimised absolute emissions will actually rise due to the better match between feed demand and pasture supply.

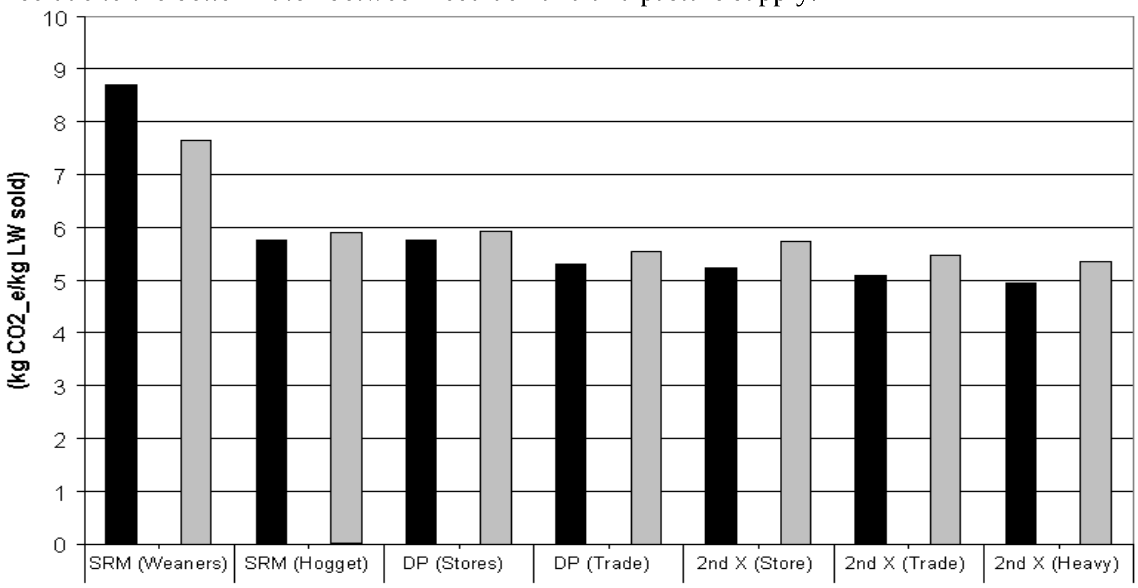

Figure 3. Changes in emissions intensity accruing from accelerated joining.

Strategic Finishing Systems

The total methane output per lamb from a grazing system depends on the daily methane output of those lambs and the time spent in the grazing system (Alcock *etal* 2008). If a lamb can be finished at a younger age there are less days spent grazing and emitting methane but at a higher daily rate of emissions due to the increase in daily dry matter intake. In general by shortening the interval to slaughter, less feed will be consumed because the maintenance component of the intake is reduced.

Production feeding was modelled to explore the impact of feeding to reduce the average slaughter interval for the three finished lamb production systems described. A range of finishing strategies was optimised to the most profitable stocking rate that still met the ground cover and maintenance feeding constraints.

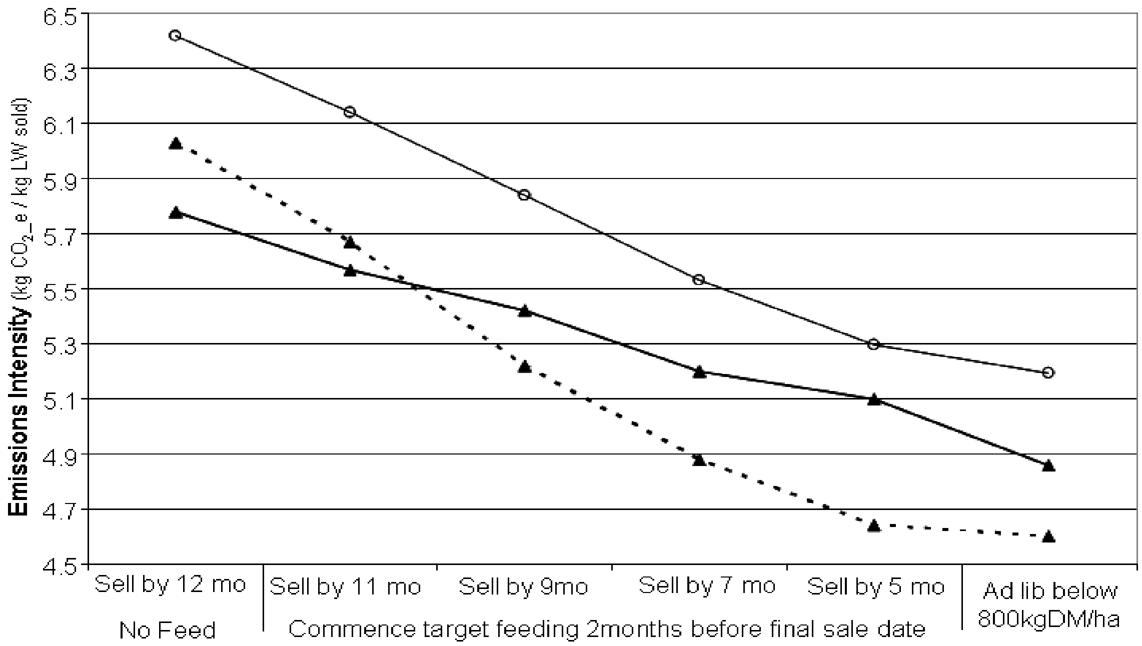

Figure 4. Reduction in emissions intensity from production feeding to alter the slaughter interval for three lamb production enterprises at Cowra

Figure 4 shows a potential reduction in emissions intensity between 16% and 24% from feeding lambs *ad libitum* once green herbage mass falls below 800 kg DM/ha going into summer when compared to holding the animals at pasture for up to 12 months of age or until the animals reach target weights. This represents a significant saving in emissions intensity but, when stocking rates are optimised, earlier finishing allows for higher ewe numbers, similar overall pasture utilisation and slightly higher absolute emission levels due to the additional intake of feed supplements.

Feeding to keep the slaughter interval of young animals as short as possible enables the enterprise to maintain a higher gross margin inclusive of emissions permits compared with finishing at pasture alone with no emissions cost (permit cost of $25/tonne CO_2_e and grain at $150/tonne). The margin is largest for a heavy 2nd cross lamb enterprise and reducing the slaughter interval to 5 months could off-set a permit price of $50/tonne CO_2_e (Table 2).

Table 2. Sensitivity of 2nd cross heavy lamb (53kg LWt) enterprise gross margin to grain price with and without emissions trading.

	Sell by 12 mo	Sell by 11 mo	Sell by 9 mo	Sell by 7 mo	Sell by 5 mo	Sell by 12mo
* *ad libitum feeding once green herbage falls below 800 kgDM/ha*	None	Feed from 2months before final sale date				ad lib feed *
$GM with wheat at $150/t no Carbon price	$275	$295	$329	$358	$382	$401
$GM with wheat at $300/t no carbon price	$275	$251	$282	$298	$308	$310
$GM with wheat at $150/t emissions permit cost $25	$225	$243	$276	$305	$327	$343
$GM with wheat at $300/t emissions permit cost $25	$225	$199	$229	$245	$253	$252

Return on investment in production feeding will be sensitive to the price of supplements. An increase in grain price from $150 to $300 would reduce the gross margin by as much as $90/ha and with little gain from shortening the slaughter interval beyond 7 months of age for the heavy 2nd Cross lamb enterprise (Table 2).

Increasing fecundity

Genotypes with inherently higher fecundity were modelled by altering the proportion of ewes conceiving twin lambs in average body condition. Results cannot be extrapolated to management which alters reproduction through nutrition and ewe fat score. Comparisons for all enterprises were made at the optimal stocking rate for each level of fecundity and only at the previously determined optimal lambing time.

At optimal stocking rates, increasing fecundity makes little difference to absolute emissions since over the long term total intake of pasture remains similar. There is however a re-allocation of the feed resource away from breeding ewes toward lambs since the sustainable stocking rate (ewes joined / hectare) declines as the number of lambs per ewe increases.

Figure 5 shows that this reallocation of feed improves the emissions intensity of all of the enterprises tested. Over all a reduction in emissions intensity of between 3% and 4% can be expected for each 10 % increment in weaning rate

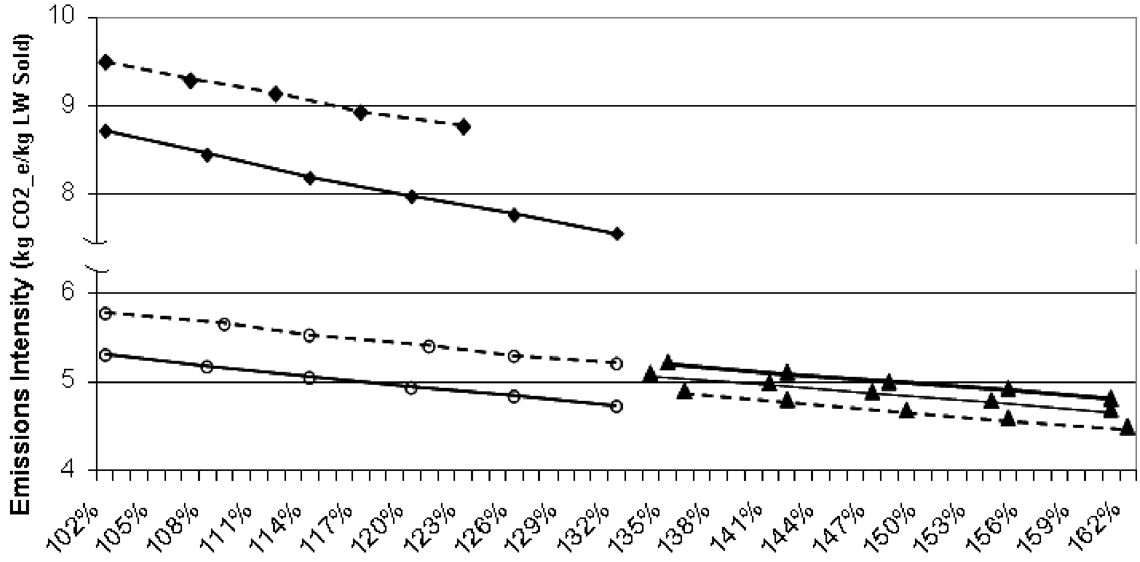

Figure 5. Impact of fecundity on emissions intensity for a range of enterprises on annual pasture at Cowra.

SRM (Weaners) SRM (Hoggets) DP (Stores) DP (Trade)

2nd X (Store) 2nd X (Trade) 2nd X (Heavy)

The economics response to increased fecundity varies widely across enterprises. Enterprises finishing prime lambs net greater returns from increase weaning rate than do merino or store lamb enterprises. Figure 6 shows relative difference in profit per hectare at each weaning rate inclusive of emissions permit costs ($25/tonne CO_2_e) compared to the base level profit (prior to changing fecundity or emissions trading).

The merino weaner enterprise is not very responsive to fecundity in terms of economic output largely because surplus weaners are a relatively low value commodity and contribute a relatively small proportion of total income compared to other enterprises. For enterprises producing finished lambs, if selection could be used to increase the weaning rate by thirty percentage points this would offset the full cost of emissions. In this case systems have been compared in steady state assuming no difference in the value of stock on the basis of their inherent fecundity.

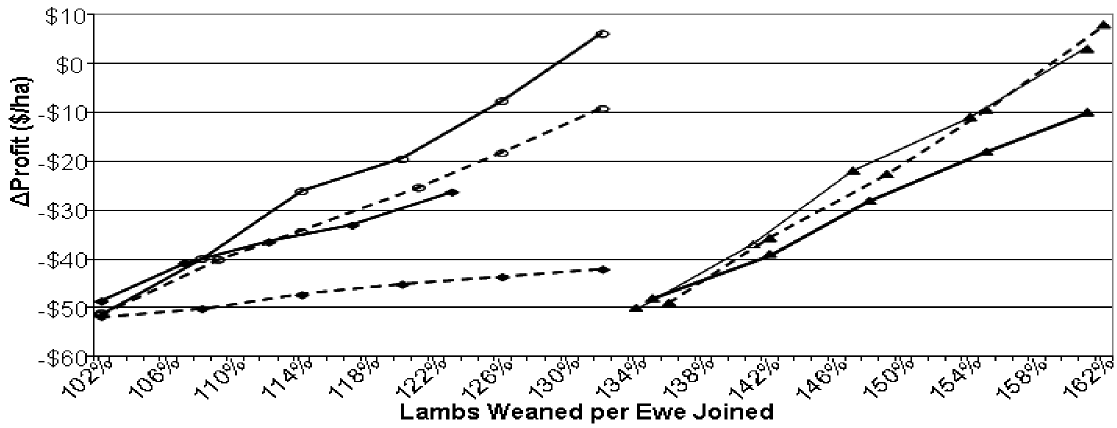

Figure 6. Change in profit with increased fecundity and implementation of a carbon price relative to the base scenario (emissions permit cost @$25/tonne CO_2_e)

Growth, methane and feed efficiency

Genetic traits related to the efficiency of feed use are often considered an attractive option for reducing methane emissions and especially for reducing emissions intensity. Animal model parameters were changed in order to represent altered genotypes with a 10% improvement in the traits of live weight gain (LWG), direct methane output (Methane), net feed intake (NFI) or a combination of all three modifications (All). Figure 7 shows the emissions intensity of these new genotypes compared to the standard after enterprise stocking rates have been re-optimised for the new genotypes

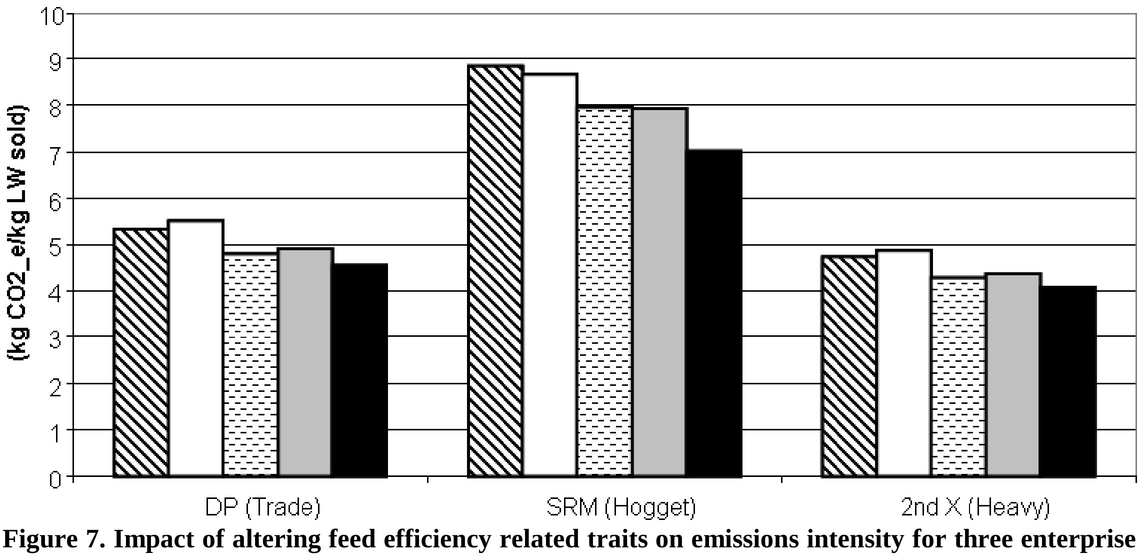

Figure 7. Impact of altering feed efficiency related traits on emissions intensity for three enterprise types at Cowra.

Improving live weight gain did not serve to reduce emissions intensity because of attendant effects on mature size and maintenance requirements for breeding ewes. Both the Methane and NFI selections provide a similar reduction in emissions intensity. Combining all traits only leads to a further significant increment of gain in the self replacing merino enterprise.

Selecting more efficient animals show greater promise for off-setting emissions costs while at the same time reducing absolute emissions. Figure 8 shows that all traits considered would lead to an overall reduction in emissions and not surprisingly this reduction was greatest when animals where directly selected for reduce methane production. Combining a 10% improvement in all traits yields up to an 18% reduction in total emissions. The practicality of achieving a 10% improvement in any or all of the traits analysed depends on heritability and the genetic correlation of these traits with each other and with other traits of commercial importance.

Selection for a 10% improvement in NFI, while giving a relatively small reduction in total emissions, consistently gave the best improvement in profit when emissions permit costs were included. LWG selection gave useful improvements in profit for enterprises delivering finished lambs but lead to an 8% reduction in profit in the self replacing merino enterprise. This is largely due to the increase in mature size, dry matter intake and subsequent methane production of breeding ewes out weighing any benefit in lamb growth.

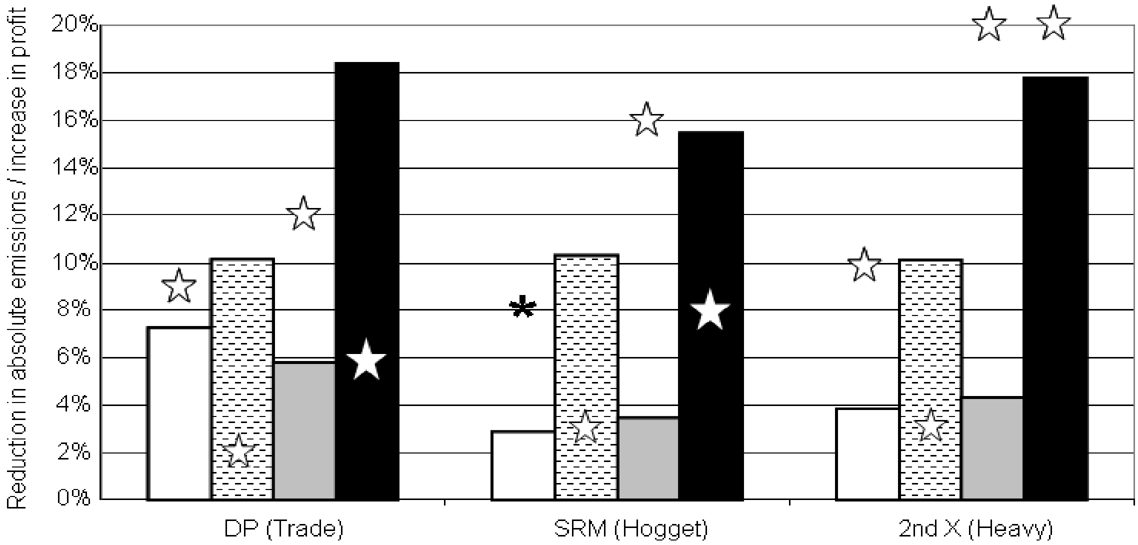

Figure 8. Impact on absolute emissions and profit of selecting for 10% improvement in growth and efficiency traits

Discussion

While methane emissions contribute significantly to the Australian carbon accounts, this modelling suggests that adoption of the most profitable enterprise management structures would lower emissions intensity while having little effect on absolute emissions.

Most of the management technologies considered can improve emissions intensity by 10% - 20% comparing the worst with the best practises. The exception to this is the joining of maidens as lambs rather than hoggets which showed little difference in emissions intensity except for the SRM (weaners) enterprise. It will depend on the individual farm enterprise as to whether current management leaves useful room for efficiency gains.

Generally the most efficient system with regard to emissions intensity is also the most profitable within the sustainability constraints considered. For this reason enterprises which operate furthest from their technical optimum still have room to alter management in order to offset some or all of the potential costs associated with carbon emissions. The extent to which an enterprise may off-set emission costs will depend on the gap between current and optimal management and on the price on an emissions permit.

The practicality of the options modelled is not equal. Some options such as optimal lambing time and feeding to reduce the slaughter interval of prime lambs can be taken up by producers immediately; however the breeding/selection options are not immediately available with the exception of breeding for LWG. Animals with higher inherent fecundity can certainly be obtained. For instance the trait leaders for the Border Leicester breed have Australian Sheep Breeding Values of around +20% for number of lambs weaned (NLW) (Sheep Genetics 2009). The top thirty sires for NLW also have Border$ index values that rank them in the top 10% of animals born in 2008 so there seems little antagonism between selection for fecundity and breeding a more profitable animal.

Breeding directly for reduced methane output is in its infancy and currently in the realms of scientific investigation with several ongoing projects looking at designing a rapid and reliable test for methane output. Early work suggests heritability in the order of 0.3 for one particular measure of methane output but nothing yet is known about the genetic correlation of this new trait with other production traits (Roger Hegarty *pers comm*). While more is known about NFI, methods for its direct measurement are expensive and unless a suitable genetic marker can be found enabling rapid screening of large numbers of animals, returns for progress would need to be large to encourage rapid uptake of NFI in the breeding objective.

Economic benefit from the traits considered in this work does not include any costs of transition to an improved genotype. The inevitable lag in the transition to more efficient genotypes will be determined by the heritability and measurement cost of the trait and economic value relative to other production traits.

This work confirms that the most profitable enterprise management structures are unlikely to change with emissions trading so enterprises which currently operate well short of the economic optimum can alter management with confidence that benefits will accrue both in the presence and the absence of a carbon price. Importantly the response curves have very broad plateaux of near optimal management typical of agricultural management decisions (Pannell 2006). This means "near enough will be good enough" since there is little penalty for selecting slightly sub optimal management. Unfortunately it is also likely that many farms already operate at near optimal management leaving little room for useful improvement.

Acknowledements

The author would like to acknowledge the assistance of Roger Hegarty in modifying the animal model parameters to represent altered genotypes with higher feed use efficiency. This work was funded by the Department of Climate Change and conducted as a contribution to the Sheep CRC sub programme 1.4.

References

Alcock DJ, Hegarty RS, Bird S. 2008. Feed management to lower greenhouse gas emissions from grazing systems. E H Graham Centre Riverina Outlook Conference 2008 "The Climate for Fodder"

Australian Government, Department of Climate Change. 2009. Australia's National Greenhouse Accounts. National Greenhouse Gas Inventory accounting for the Kyoto target May 2009.

Australian Government, Department of Climate Change. 2009. National Inventory Report 2007 The Australian Government submissions to the UNFCC May 2009.

Blaxter KL, Clapperton JL. 1965. Prediction of the amount of methane produced by ruminants. *British Journal of Nutrition* **19**, 511-522.

Climate Change 2007. IPCC Fourth Assessment Report. IPCC Geneva Switzerland

CSIRO and BoM (2007) Climate change in Australia – technical report, CSIRO. Downloaded 02/05/08.

Freer M, Moore AD, Donnelly JR. 1997. GRAZPLAN: Decision support systems for Australian grazing enterprises. II. The animal biology model for feed intake, production and reproduction and the GrazFeed DSS. *Agric. Syst.* **55**, 77-129.

Howden SM, White DH, McKeon GM, Scanlan JC, Carter JO. 1994. Methods for exploring management options to reduce greenhouse gas emissions from tropical pastures. *Climatic Change*. **30**: 49-70.

Moore AD, Donnelly JR, Freer M. 1997. GRAZPLAN - decision support systems for Australian grazing enterprises .3. Pasture growth and soil moisture sub-models, and the GrassGro DSS. *Agric. Syst*. **55**, 535-582.

Pannell DJ. 2006. Flat Earth Economics: The Far-reaching Consequences of Flat Payoff Functions in Economic Decision Making. Review of Agricultural Economics **28**, 553-556.

Sheep Genetics 2009. LAMBPLAN ASBV Percentile Report Analysis BORDER 15/10/2009 http://www.sheepgenetics.org.au/ViewImage.aspx?ITEM=98&NAME=percentile_02.pdf