Reducing Methane Emissions from Cattle Production in Central Queensland

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Abstract.

Beef cattle contribute about 7% of national greenhouse gas emissions through the release of methane into the atmosphere. Cattle in northern Australia produce more methane per unit of beef produced because of tropical (C4) grasses and slower average growth rates. In this paper the level of emissions from different herds and some strategies to reduce emissions are modelled. The results indicate that few options exist to reduce methane emissions without reducing beef production. The opportunity costs of reducing methane emissions by reducing stocking rates are estimated at one Central Queensland location at \$35 per ton of CO_2 equivalent. Opportunity costs of destocking in northern Australia are estimated to lie between \$50 and \$75 per ton of CO_2 equivalent.

Keywords: Greenhouse, abatement, livestock, valuation.

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1.0 Introduction

Atmospheric methane traps approximately 21 times more heat than the same amount of carbon dioxide. For this reason, the impact of methane and other greenhouse gases is normally reported in carbon dioxide (CO_2) equivalents. Part of the interest in reducing methane emissions stems from the fact that it breaks down much more quickly than carbon dioxide. While dioxide emissions remain in the atmosphere for about one hundred years (before being absorbed into ocean and terrestrial sinks), atmospheric methane breaks down within a decade. So, reducing methane emissions will have a more immediate impact on global warming.

The beef industry in Australia has a major interest in the debate about greenhouse policy because of the contribution of the sector to greenhouse gas emissions . Ruminant animals such as cattle and sheep release methane as a normal by-product of digesting grass. As well, methane is released from ponded manure systems in piggeries, dairies and feedlots. On average, dairy cows emit about 115 kilograms of methane per head per year in Australia, while beef cattle emit about 74 kilograms and sheep about 6.6 kilograms. The size of the beef cattle herd means that about half of all livestock emissions in Australia come from the beef sector (Zeil and Rolfe 2000).

The beef sector accounts for about 7% of Australia's greenhouse gas emissions through the release of methane. It is probably the nation's third highest contributor, after electricity generation (burning coal and gas) and transport (burning fuel and gas). Emissions from the industry are increasing as the cattle herd increases, although there are some offsetting decreases as the sheep flock decreases (Howeden and Reyenga 1998). Rossiter and Lambert (1998) argue that the size of the contribution from the beef industry means that this is the industry to concentrate on in terms of making significant reductions to overall emissions. This means that the involvement of Australia in emission reduction strategies will be of direct interest to members of the beef sector. There are three key reasons why the sector needs to become more aware of greenhouse issues.

The first is that if climate change does occur, pastoral industries will be among the key industries affected in Australia. The second reason is that if attempts are to be made to reduce emissions (or emissions growth), the beef industry may be called on to contribute. The third reason is that it may be cheaper to make reductions in sectors of agriculture than to make equivalent reductions in industry. In this case, the use of carbon offsets or other incentive mechanisms may help to provide financial incentives to pastoralists to make larger reductions[1] (Zeil and Rolfe 2000).

There has already been some attempt to identify reduction strategies for the beef industry (Zeil and Rolfe 2000). Many commentators (eg Hassall and Associates 1999) point out that reducing cattle numbers will help to reduce methane emissions. Hunter and McCrabb (1998) suggest that *substantial reductions in methane emissions would flow from improvements in production efficiency in northern Australia.(1998, page 96).* They indicate that finishing cattle on grain and improving breeding herd efficiencies may be ways of reducing methane emissions. Other strategies to reduce emissions focus on running younger cattle, and manipulating microbial activity in the rumen in some manner to reduce methane production.

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[1] McCarl and Schneider (2000) point out that agriculture may also be influenced if commodity and input prices are altered by greenhouse related policies, and that agriculture may provide products which substitute for greenhouse gas intensive products, thus displacing emissions.

Options that reduce methane emissions while increasing productivity are attractive because they provide win-win situations for producers and the environment. Other options have to be evaluated in term of their opportunity costs to determine whether they may be appropriate to use. As well as costs, other factors such as measurement and reliability relating to emission reduction strategies may be important in determining their appropriateness. Emissions from grazing herds are effectively a form of non-point pollution, and all the associated problems of tracking and verifying changes will apply. In contrast to many point source emissions in industry, methane emissions from beef cattle occur across most of our rangelands landscapes in Australia.

In this paper, issues surrounding the potential impact of greenhouse mitigation strategies on the beef industry are explored. Issues about the likelihood or severity of the greenhouse effect are not covered in the paper. There is also no discussion about the full range of activities, such as soil carbon increases and vegetation growth, that may be used at the property level to sequester carbon. Instead, the focus is on how the beef industry might be involved in reduction or offset strategies for methane emissions if Australia commits to reduced emissions growth in the future.

2. Methane emissions from livestock

Methane is produced in ruminant animals such as cattle and sheep as a waste product from the digestion processes in the rumen and the intestine, and from subsequent manure. Methane is also produced from the manure of non-ruminant animals such as pigs and poultry, especially when the waste is treated in ponded manure systems. Between 4 – 12% of the energy contained in the food of cattle is lost in the form of methane (Hegarty 1999). About 90% of the methane is burped out by the animal, while the other 10% is extruded with the manure.

Cattle that are able to process grasses and fodder more efficiently tend to have lower methane emissions. This means that faster growing cattle have higher feed efficiencies and lower methane emissions compared with slower growing cattle of the same weight. Larger cattle tend to eat more and have higher methane emissions than smaller cattle, simply because they have higher energy requirements to move themselves around.

The amount of methane that is produced is closely related to the digestibility of the diet of the animal. Tropical pastures, found across northern Australia, are typically less digestible (aproximately 13% less) than the temperate pastures in the southern half of Australia. Grains are higher in digestibility than either tropical or temperate grasses, which indicates that cattle in feedlots have lower methane emissions than similar cattle on grass.

The estimation of methane emissions from cattle is done on the basis of models that have been developed from respiration chamber data or field measurements. In the former method, cattle have been fed different diets in sealed chambers where the amount of gas that is emitted can be accurately measured. In this way, the amount of methane emitted can be related to factors such as the weight of the beast, the rate of liveweight gain, and the digestibility of the feed (eg Baxter and Clapperton 1965, McCrabb and Hunter 1999). Under the latter approach (eg Kaharabata et al 2000), field measurements of methane in the atmosphere are used to estimate emissions from different sources.

Different models have been developed to calculate the emissions of cattle in northern Australia (tropical grasses), southern Australia (temperate grasses) and feedlots (see http://www.greenhouse.gov.au/inventory/methodology/agriculture.html). These models are used to calculate the annual contribution of methane from livestock in Australia, which are included in the National Greenhouse Gas Inventory (NGGI) (see http://www.greenhouse.gov.au/inventory/inventory/inv_content.html).

The models for estimating methane emissions from pasture firstly calculate the feed intake for each animal per day (Rolfe and Zeil (2000). Feed intake per day (**I** kg dry matter/head/day) is estimated from liveweight and liveweight gain of the beast as follows:

$$I = (1.185 + 0.00454W - 0.0000026W^2 + 0.315LWG)^2 \qquad \text{.... (1)}$$

Where:

W = liveweight in kg
LWG = liveweight gain in kg/head/day

For animals on tropical pastures (assumed to be northern Australia), the total daily production of methane (**M** kg CH_4/head/day) is given by Kurihara et al. (1999) as:

$$M = (41.5 \times I - 36.2) / 1000 \qquad \text{...(2)}$$

This means that for northern Australia, methane emissions are calculated simply on the basis of the liveweight and liveweight gain of the animal. For southern Australia, the liveweight and liveweight gain information is combined with estimates of the digestibility and gross energy content of temperate grasses to produce estimates of methane emissions. For cattle in feedlots, dry matter intake is calculated as a percentage of mean liveweight, and emissions are calculated from the estimated intake of soluble residue, hemicellulose, and cellulose from the ration.

To calculate methane emissions for a state, cattle numbers are estimated for various classes of cattle, and default values for average weights and liveweight gains are given for each quarter. Methane emissions per class of cattle are estimated for each quarter and then summed (NGGIC 1996). There is little difference between this approach and calculating methane emissions for annual average weights and liveweight gains (Rolfe 2001). Because the annual approach is easy to use it is adopted here for the calculations reported below[2].

3. Emissions at the property scale.

The models used in the national inventory can be applied to calculate emissions at a property level. The scale of methane emissions from the average beef property in Queensland can be estimated using some assumptions about cattle weights and weight gains. In ABARE (2000) specialist beef producers in Queensland were estimated to have 1,157 head (average from 1993/94 to 1997/98), as shown below in Table 3. Assumptions have been made about animal weights, and an average weight gain of 0.35 kgs/day has been used for liveweight gain, apart from cows where a default of 0.15 kgs/day has been chosen.

[2] The emissions methodology is based on calculating feed intake on a daily basis, while the NGGI approach is to estimate emissions per beast per quarter. Simulation exercises reveal that the NGGI approach will underestimate emissions for cattle with liveweight gains > 0.6 kgs/day, and overestimate emissions for cattle with liveweight gains <0.4 kgs/day (Rolfe 2001).

Table 1. Methane emissions from the average Qld beef specialist property

	Number	Average weight	LWG	Annual methane emitted (kg/head)	Total annual methane (kg)
Bulls	27	600	0.35	130.79	3 531.21
Cows	470	500	0.15	110.02	51 707.95
Heifers	119	350	0.35	86.50	10 293.99
Calves	269	250	0.35	64.69	17 400.51
Other cattle (steers)	273	450	0.35	106.54	29 086.02
Total					112 019.70

This example shows that the average beef specialist property in the state is emitting 112 tons of methane per year. This amount can be converted into carbon dioxide equivalents by multiplying the amount of methane by 21. This means that the average beef specialist property is emitting 2,352 tonnes of carbon dioxide equivalents each year from beef cattle.

In comparison, the emissions from fuel use on beef properties is very small. The average specialist beef property spent an average of $10,294 on fuel, oil and grease between 1993/94 and 1997/98 (ABARE 2000). If fuel prices are assumed at $0.70 per litre, total fuel use is approximately 14,700 litres. At a conversion rate of 2.69 for diesel, this would generate approximately 39,543 kgs of carbon dioxide equivalents. This means that the average beef specialist property in Queensland produces 2,352 tons of carbon dioxide equivalents from methane and 39.5 tons of carbon dioxide equivalents from fuel use. Methane emissions count for 98.3% of the property emissions (excluding any for vegetation clearing and land use change).

3.1 How much do emissions vary between cattle?

There are three key ways that emissions can vary between cattle. The first relates to the type of feed eaten, where the inventory distinguishes between tropical grasses, temperate grasses, and feedlot rations. The second relates to the weight of the beast, where heavier cattle tend to produce more methane than lighter cattle. The third relates to growth rates, where higher liveweight gains mean better feed utilisation and lower methane emissions.

Some examples can be drawn up to demonstrate the scale of methane emissions from different beef cattle operations in northern Australia. These are compiled by identifying the average weight and liveweight gain of cattle in a herd over a year, and using this information to estimate methane emissions. Only simple examples have been used below, and other herd dynamics such as deaths and herd replacements have not been considered at this stage.

Case studies have been presented below to represent comparisons between breeding herds on native and improved pasture, and fattening operations on native and improved pasture. The rates of liveweight gain used are 0.4 and 0.6 kgs/day for native and improved pasture respectively. While these rates are at the higher end of the scale for both pasture types, they provide some indication of the differences that do exist. To account for additional feed needs of lactating cows, a weighting for breeders raising a calf has been set at being equivalent to 0.15 kgs/day over a one year period.

Case Study A - a breeding operation on native pasture in northern Australia with 1,000 breeders.

Cows are assumed to average 500 kilograms in weight. It is assumed that there is a calving rate of 75%, and that cows have a calf maintenance requirement that is equivalent to a liveweight gain of 0.15 kgs/day. Calves are assumed to gain 127 kgs in the year following birth (0.35 kgs/day), and have an average weight of 104 kgs. Average annual methane emissions are 110 kilograms for the cows and 32.6 kilograms for the calves. Total emissions for the herd are 134.5 tons per year.

In this case, a total of 750 calves weighing approximately 170 kgs each have been turned over after one year for a methane yeild of 134,475 kgs. This equates to 1.055 kgs of methane produced for every kilogram of liveweight beef produced.

Case Study B - a breeding operation on improved pasture in northern Australia with 1,000 breeders.

Cows are assumed to average 550 kilograms in weight. It is assumed that there is a calving rate of 85%, and that cows have a calf maintenance requirement that is equivalent to a liveweight gain of 0.15 kgs/day. Calves are assumed to gain 220 kgs in the year following birth (0.6 kgs/day), and have an average weight of 150 kg. Average annual methane emissions are 118 kilograms for the cows and 47 kilograms for the calves. Total emissions for the herd are 157.1 tons per year.

In this case, a total of 850 calves weighing approximately 260 kgs each have been turned over after one year for a methane yeild of 157,108 kgs. This equates to 0.711 kgs of methane produced for every kilogram of liveweight beef produced. Even though much more methane has been produced by the herd in Case Study B than Case Study A, this has been more than offset by increased beef production, so that methane emissions per kilogram of beef produced are much lower.

In comparison to Case Study B, a similar herd of breeding cows in southern Australia will produce a smaller output of methane. 1000 cows and calves on improved pasture in southern Australia with an average cow liveweight of 550 kilogram, a calving rate of 85%, and average calf weight of 150 kilograms will produce 118 tons of methane (assuming grass digestibility is 73%). This is 75% of the methane emitted by a similar herd in northern Australia.

Case Study C - a steer fatting operation on native pasture in northern Australia with 1,000 steers.

It is assumed that 500 steers are purchased in each year as weaners at 230 kilograms. Average weight gain is 0.4 kgs per day, which means that steers gain 150 kgs per annum. Steers are sold out after two years at 530 kilograms. Average weights are 305 kgs in the first year and 455 kgs in the second. Average methane emissions for the steers are 78 kilograms in the first year, and 109 kilograms in the second year. Total emissions for the herd are 93.4 tons per year.

Over one year, the 1,000 steers could be expected to gain a total of 150,000 kilograms liveweight. This means that the beef is grown on the native pasture for approximately 0.623 kgs of methane output for every kilogram of beef (liveweight) that is produced. It is notable that if this situation is compared to Case Study A, methane emissions per kilogram of beef produced are higher for breeders than for fattening cattle.

Case Study D - a steer fatting operation on improved pasture with 1,000 steers.

It is assumed that 500 steers are purchased in each year as weaners at 230 kilograms. Average weight gain is 0.6 kgs per day, which means that steers gain 220 kgs per annum. Steers are sold out after two years at 670 kilograms. Average weights are 340 kgs in the first year and 460 kgs in the second. Average methane emissions for the steers are 90.53 kilograms in the first year, and 132.45 kilograms in the second year. Total emissions for the herd are 111.5 tons per year.

Over one year, the 1,000 steers could be expected to gain a total of 220,000 kilograms liveweight. This means that the beef is grown on the improved pasture (eg high quality buffel country) for approximately 0.5067 kgs of methane output for every kilogram of beef (liveweight) that is produced. Again, it is notable that if this situation is compared to Case Study B, methane emissions per kilogram of beef produced on improved pasture are higher for breeders than for fattening cattle.

When this case study is compared to steers on native grass pasture in Case Study C, it is notable that total methane emissions is higher for steers on improved pasture (because the average weight of the cattle is higher). However, the methane emissions per unit of beef produced is much lower. In comparison, 1,000 steers on improved pasture in southern Australia with the same average liveweights and animal performance as in Case Study D will produce approximately 80 tons of methane (assuming grass digestibility is 73%).

3.2 Methane emissions per kilogram of beef produced.

Differences between production systems become clearer when the outputs are expressed as the amount of methane emitted per kilogram of beef produced. Using the examples above, steers on native pasture in northern Australia would produce 0.623 kilograms of methane for every kilogram of beef (liveweight) that is produced. Steers on improved pasture in northern Australia would produce 0.507 kilograms of methane for every kilogram of beef (liveweight), and steers on improved pasture in southern Australia would produce 0.364 kilograms of methane for every kilogram of beef (liveweight).

Because the breeding herd in northern Australia tends to be less efficient (eg lower branding rates, higher cow mortality) than the herd in southern Australia, the amount of methane produced per unit of beef in northern Australia is likely to be more than double the rate in southern Australia.

Feedlots have lower emissions of methane per unit of beef produced. For example, a steer on a high quality feedlot ration that gains 220 kilograms of beef over 100 days from a 400 kilogram starting weight would only emit 22.3 kilograms of methane over that time. Only 0.1 of a kilogram of methane is emitted for each kilogram of beef produced, less than one-sixth of the rate for steers on native pasture in northern Australia. However, there are a number of indirect emissions that should also be taken into account when considering the feedlot option. These include carbon used in fossil fuels to grow and transport the grain, transport the cattle, operate the feedlot, and so on (Howden and Reyenga 1998). There may be emissions of 0.5 to 2.0 kilograms of CO_2 equivalents associated with grain production to the point of harvest (Howden and O'Leary

1997). When these additional factors are considered, there may not be major advantages in terms of emissions for the feedlot option.

4. Searching for options to reduce methane emissions.

A number of options to reduce methane emissions have been outlined (Rossiter and Lambert 1998, Hassall and Associates 1999, Rolfe and Zeil 2001). Some modelling of emissions from beef properties in Queensland are used to explore the effects of these different options.

4.1 Improving feed utilisation

One of the main options is to improve the utilisation of feed in the rumen in some manner so that less dry matter is converted into methane and more is utilised by the animal. The key argument is summarised by Hunter and McCrabb (1998), who note that the difference in methane emissions is most noticeable over the lifetime of an animal.

A steer in southern Australia that fattens on grass to 300 kilograms and then grain to 550 kilograms by 18 months of age will only produce 74 kilograms of methane in its lifetime. By contrast a steer in northern Australia that fattens slowly on grass and reaches 550kg at 5 years of age will produce 360 kg of methane over its lifetime. A steer in northern Australia that fattens more quickly and reaches the same weight at 2.5 years will produce 196 kilograms of methane[3]. These estimates are summarised in Figure 1.

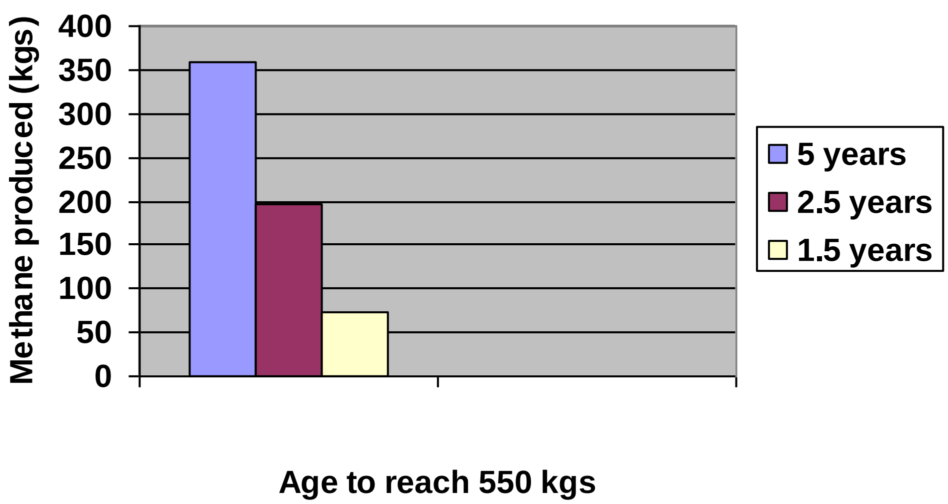


Figure 1. Estimated CH_4 emissions by steers reaching 550kg weight at different ages.

Hunter and McCrabb (1998) argue that finishing cattle on grain for 2-5 months can reduce methane emissions by 34-54%, although there will be off-setting carbon losses involved in growing and transporting grain. However, simply improving the available feedstocks for cattle is unlikely to reduce overall emissions. Instead, it will increase the amount of beef produced per

[3] McCrabb and Hunter (1999) give slightly lower estimates. The estimates reported here follow the NGGI methodology.

unit of methane emitted. If pasture utilisation is improved in Queensland, the overall impact is likely to be that both methane emissions and beef production will increase (Howden and Reyenga 1998).

If beef producers can improve the feed utilisation of cattle, they will reduce the amount of methane emitted at each particular liveweight. But improved feed utilisation means that cattle will grow faster and heavier. Beef producers are likely to have heavier stock and to turn off more beef, or to run more stock on the same feed with the same end result. The outcome of better feed utilisation is that more beef will be produced, methane emissions per kg of beef produced will fall, and overall methane emissions may or may not rise. If feed is added, as in supplementary or grain feeding, then overall emissions will rise.

3.2 Reducing turnoff weight

Improving feed utilisation only contributes to overall methane reductions when it is coupled with reduced animal weights; i.e. by running younger, lighter cattle. For example, if the amount of total feed utilised in Case Study C is held constant, liveweight gains are increased to 0.44 kgs/day, and only younger steers (1-2 years) are run, an additional 143 steers can be run on the same amount of feed. This represents an increase in beef production of 25.7%, while methane output actually falls by 2%. This scenario is listed below as Case Study E.

Case Study E - a steer fatting operation on native pasture with 1,143 steers.

It is assumed that 1,143 steers are purchased in each year as weaners at 230 kilograms. Average weight gain is 0.44 kgs per day, which means that steers gain 160 kgs per annum. Steers are sold out after each year at 390 kilograms. Average weight over the year is 310 kg. Total feed intake for the year is equivalent to 1,000 steers in Case Study C. Average methane emissions for the steers are 80 kilograms per year. Total emissions for the herd are 93.4 tons per year.

In this case, fattening animals up to two years instead of three years allowed a 2% reduction in methane output for the same amount of feed intake. However, when the contribution of the breeding herd is factored in, there is no net reduction. This is because there should be an increase in the breeding herd to supply more fattening cattle. For example, in Case Study C, 500 steers were introduced per year, and held for two years. At an 85% calving rate, this would have involved 588 cows to produce those steers. In case study E, 1,143 steers are introduced per year and held for only one year. At an 85% calving rate, this would have involved 1,344 cows. On native pasture (i.e. Case Study A), the additional 756 cows needed would produce 83,160 kgs of methane per year, far in excess of the 2% saving outlined in Case Study E.

When the contributions of the breeding herd are considered alongside the fattening animals, it is clear that total emissions are lowest when a smaller number of breeding cows are needed to produce the fattening herd. There is no advantage in reducing the average age of turnoff if an increase in the breeding herd is necessary to provide throughput numbers.

3.4 Improving breeding herd management

One of the important ways in which beef producers can improve the amount of beef produced for every unit of methane emitted is to improve the performance of breeding herds. Each breeding cow emits a lot of methane in comparison to younger animals because of its large size and transportation and lactation requirements. Potential improvements in reproduction rates, turnoff rates, and reductions in mortality all contribute to improvements in the amount of beef produced for a certain level of methane emissions.

Rolfe (2001) demonstrates the gains from improving breeding herd and fattening herd management. In each case, improvements lead to both increased production and increased methane yeilds. However, efficiency gains mean that production increases faster than methane outputs, so that methane output per unit of beef falls. A 10% increase in the output of a breeding herd (Case studies A and B) through higher calving rates generate reductions in methane per kilogram of beef of 10% and 7.3% respectively. In contrast, a 10% improvement in the fattening herd (Case studies C and D) through higher weight gains generate reductions in methane per unit of beef produced of 3.2% and 4.2% respectively. These outcomes are demonstrated in Figure 2.

Similar results would be achieved by other measures which reduced herd mortality and improved turnoff rates. Beef producers already face large incentives to achieve these improvements because of the potential gains in production. This means that these types of improvements are already occurring over time due to market forces. However, there may be opportunities for further gains to be made with appropriate research, development and extension inputs.

Figure 2. Effects of a 10% improvement in production on methane emissions per kilogram of beef produced.

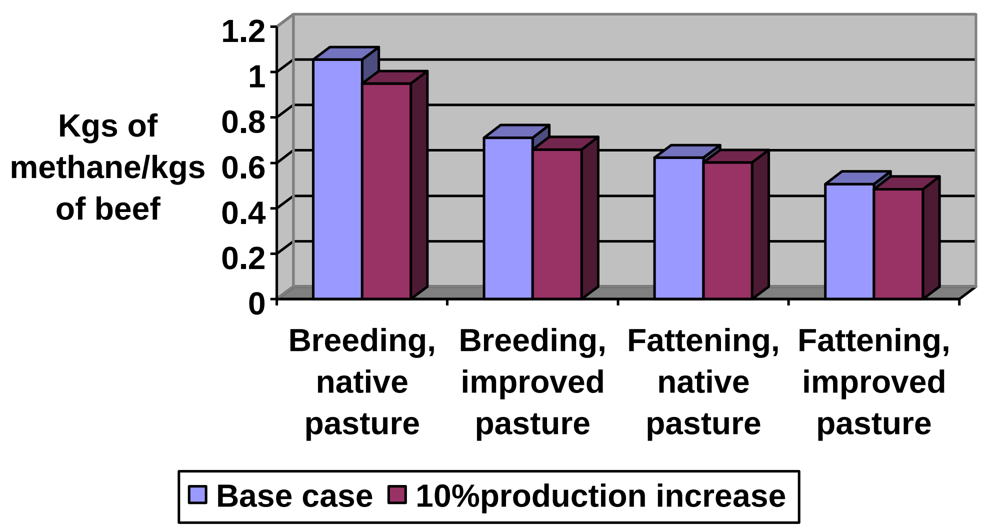


Figure 2 demonstrates that breeding operations on native pasture have the higher level of methane emissions per kilogram of beef produced, and also the highest potential to reduce methane emissions per unit of beef produced. In contrast, fattening operations on improved pasture have lower methane emissions per unit of beef produced, and lower reductions in this rate if production is improved.

3.5 Reducing stocking rates.

The case studies that have been examined above have explored options for altering management or feeding strategies that have maintained the overall grazing pressure. Another option to consider is to reduce grazing pressure in some regions. Reductions in grazing pressure are likely to have beneficial impacts on carbon stocks in many areas because of likely increases in stocks of pasture and scrubs, and potential increases in soil carbon stocks. However, the impacts on total methane emissions should also be included.

Case study results are available from a Meat and Livestock Australia funded grazing trial site in Central Queensland[4]. The trials have been run by the Department of Primary Industries and Tropical Beef Centre at "Keilambete", which is near Rubyvale, west of Emerald. The trials have run since 1994, and involve comparisons between paddocks grazed at low, medium and high grazing pressures[5]. The trials are also replicated across sites that have been cleared of the timber (broadleaf ironbark forest on granite country). Each year steers have been run in the trial paddocks and liveweight gains recorded.

The information from the trial data can also be utilised to predict methane emissions, using the same NGGI (1997) approach. The average liveweight and liveweight gain of the steers in the trial can be used to predict dry matter intake and methane emissions. The results are summarised in Table 2.

The trials took place in the 1990s when there were substantial climatic variations, with subsequent impacts on animal performance. There are large variations in the amount of beef produced in the different trials. The data shows that methane emissions per hectare were lowest under low grazing pressures (in both cleared and timber sites). Production of beef was higher at the high and medium grazing pressures than at the low grazing pressures, indicating that these strategies might be preferred by landholders[6].

Table 2. Production of beef (kgs) and methane (kgs) from grazing trials

	Treatment	Cleared – Low grazing pressure	Cleared - Medium Grazing Pressure	Cleared - High Grazing Pressure	Timber - Low Grazing Pressure	Timber - Medium Grazing Pressure	Timber - High Grazing Pressure
Average	Beef produced per beast	147.83	119.33	118.17	146.50	131.00	114.83
	Total methane/beast	81.68	72.24	73.96	78.87	77.53	73.83
	Beef produced per hectare	48.36	57.66	70.42	34.00	44.68	35.98
	Methane emissions/hectare	28.48	38.34	54.17	21.23	32.11	32.79
	Methane per kg of beef	0.59	0.66	0.77	0.62	0.72	0.91
	Stocking rate ha/beast	3	1.9	1.8	4.1	2.8	3

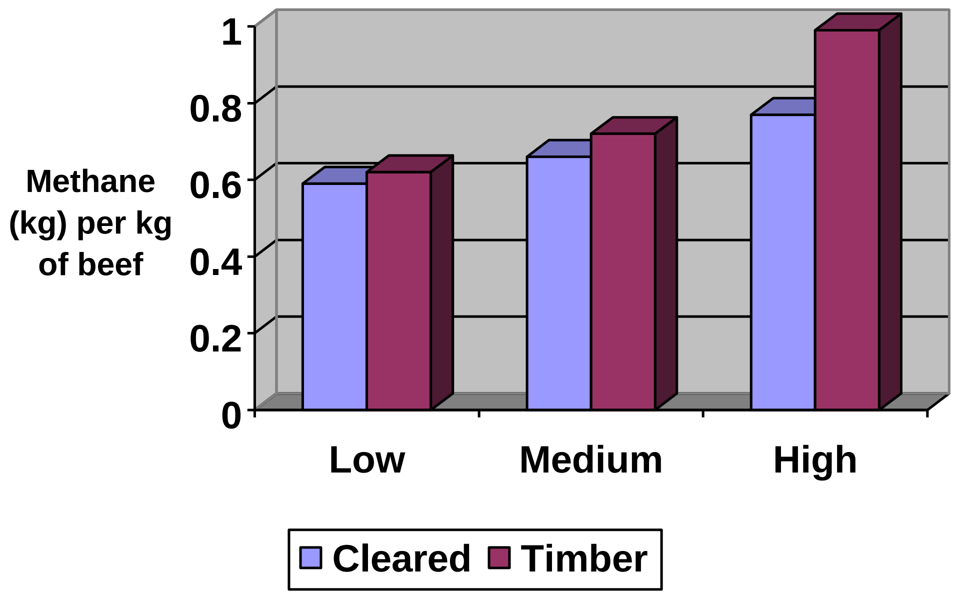
[4] The provision of data from the MLA project (NAP3.208) by Mr Paul Jones (DPI) is gratefully acknowledged. Data summaries and estimation of methane yields are the responsibility of the author.

[5] The grazing pressures were calculated using feed budgets at the end of the summer growing season (about March/April). High grazing pressures were aimed at using 75% of available feed, while medium and low grazing pressures were aimed at using 50% and 25% respectively.

[6] High grazing pressures had other less desirable consequences on resource management such as higher rates of soil loss.

The amount of methane that is emitted per kilogram of beef that is produced trends upwards as stocking rates move from low to high (Table 2). The relationship is mirrored across both timber and cleared sites, as shown in Figure 3. This indicates that reductions in grazing pressure will tend to reduce total beef production, but increase the amount of beef that is produced per unit of methane emitted.

Figure 3. Methane emissions per kilogram of beef produced at different stocking rates



The explanation for such a result is that under low grazing pressures, cattle have more choice about available feed, and tend to have higher weight gains. Production is more efficient, and methane emissions per unit of beef produced are relatively low. As stocking rate increases, overall production increases because of the higher cattle numbers, but weight gains per beast tend to fall. Methane emissions per beast tend to rise, because of the lower feed conversion efficiency, and methane emissions per kilogram of beef produced trends upwards. In this case study, weight gains on cleared sites were higher than on timber sites, meaning that more beef was produced per unit of methane in cleared areas.

3.7 Using a vaccine.

Over the past ten years, researchers from CSIRO have been developing vaccines for sheep and cattle against methanogenic organisms. Field trials of vaccines on cattle are continuing, and early indications are that a vaccine will increase animal performance by approximately 3%, and reduce methane emissions by approximately 20% (Baker, pers comm). It is unclear how much variation there might be in these results in the field.

There are two main advantages of a vaccine. The first is that the application is verifiable, which will give rise to a greater degree of confidence about outcomes than is the case with many other strategies. The second advantage is that there are offsetting production gains, giving a potenial win-win situation. For example, if a steer gaining 0.5 kgs/day is vaccinated and production increases by 3%, the steer should put on an additional 5.5 kilograms over a 12 month period.

3.8 Feed supplements

McCrabb and Hunter (1999) note that finishing cattle on grain in northern Australia has the potential to significantly reduce the amount of methane that a beast would emit over its lifetime. This is because the beast would reach slaughter weight much more quickly. Similar advantages may be achieved by supplementary feeding where grain, cottonseed or other feed additives are offered to cattle in a grazing situation. Part of the advantages of such supplements (apart from increased protein levels) are that they give animals a more constant feed intake at times when protein levels in grasses may vary.

However, there has been little work done to identify the impact of supplements on methane emissions and whether some supplements enable feed conversion rates to increase. There has also been little work done on estimating methane emissions from supplementary feeding programs. It is likely that this will involve the combination of estimation procedures from grazing and feedlot situations.

5. The opportunity costs of reducing methane emissions in northern Australia

There has been little work done in Australia to estimate the opportunity costs of reducing methane emissions from beef cattle. Adams et al (1992)[7] estimated that it would cost $730 US per ton of carbon to reduce emissions through a tax forcing herd reduction, but only $204 US per ton of carbon to reduce emissions through altered rations (changing feed mixes). These amounts equate to approximately $200US and $56US respectively for carbon dioxide equivalents.

Lenzen (1998)[8] identified primary industries in Australia such as meat and dairy production as having some of the highest level of greenhouse gas emissions per $ of GDP production. Howden and Reyenga (1998) report that optimal stocking rates generate about 2 kilograms of liveweight gain in animals per kilogram of methane emitted. This translated to about 7 kilograms of carbon dioxide equivalents per dollar sale price at 1994 levels. This suggests that the opportunity cost of red meat production was approximately $142A per ton of carbon dioxide equivalent.

Opportunity costs can derived for two broad categories. The first is the opportunity cost of destocking grazing areas, while the second relates to the costs involved in reducing grazing pressure. Both of these opportunity costs are estimated here, utilising the data presented earlier in the paper.

Opportunity costs of destocking.

The opportunity cost of destocking beef producing areas varies according to the region. The case studies provided above indicate that for northern Australia, the production of methane per kilogram of liveweight beef production ranges from approximately 1:1 in the breeding operation down to 0.5:1 in the fattening operation. The most accurate way of estimating emissions is to combine a contribution of the breeding herd with the lifetime emissions of a fattening beast.

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[7] Cited in McCarl and Schneider (2000).
[8] Cited in Howden and Reyenga (1998).

A steer reaching 550 kilograms at 2.5 years has emitted 196 kilograms of methane. To this should be added one year of emissions from the cow (approximately 118 kilograms), 2.5% of one year of emissions from the bull (approximately 4 kilograms), and a further 24 kilograms to account for herd inefficiencies (cows failing to breed). Total emissions to produce the steer can thus be calculated at 342 kilograms, or 0.62 kilograms of methane per kilogram of liveweight. For a steer taking 5 years to maturity in northern Australia, the corresponding total emissions is 506 kilograms, or 0.92 kilograms of methane per kilogram liveweight.

It would not be accurate to equate the market price of beef cattle with the potential opportunity costs of reducing stocking rates. First, the variable costs associated with operating a beef herd should be counted out of the net return. Second, some allowance should be made for the capital costs involved in owning additional stock, and the potential savings from reducing cattle numbers.

Liveweight prices for store cattle for fattening purposes have often been above $1.50/kg in Queensland in 2001. From this total sale price needs to be deducted the various allowances to gain some idea of the opportunity costs involved in reducing stocking numbers. QBII (2000) estimates that variable costs on beef properties are about 15% of revenue on Central Queensland brigalow blocks, and about 28% of revenue on northern speargrass country. ABARE (2000) indicate that on medium size beef properties (1000 – 2800 cattle) in Queensland, variable costs are approximately 24.4% of cattle sale income.

For this exercise, 25% of sale price is adopted to represent potential variable costs and 10% selected to represent interest on capital. This means the available sale price can be reduced by 35% to gain some indication of the opportunity costs involved with reducing stock numbers in order to reduce methane emissions. On the basis of cattle prices in 2001, sale prices of $1.50/kg can be discounted to $0.98/kg. This represents the potential loss per kilogram of beef that beef producers might suffer if they destocked to reduce methane outputs.

Methane has 21 times the impact of carbon dioxide, and 47.6 kilograms of methane have the same impact as one ton of carbon dioxide. To reduce methane emissions by 47.6 kilograms involves giving up between 52 kilograms (5 year old steers) and 77 kilograms (2.5 year steers) of beef production. At $0.98/kilogram, this opportunity cost ranges between $50 and $75 for every ton of carbon dioxide equivalent. For southern Australia, where growth rates are higher and grasses are more digestible, the opportunity costs will be higher.

Opportunity costs of reducing stocking rates

The data from the Keilambete trials reported in Table 2 can be used to estimate the opportunity costs of reducing methane emissions by reducing grazing pressure. Because the data is from open woodland grazing country, it is representative of extensive areas of northern Australia. First, an analysis of the most profitable grazing pressure is warranted.

The data from the Keilambete trials indicates that medium grazing rates are likely to be preferred over high stocking rates. Under high grazing pressure, there appeared to be more soil movement and annual reductions in the amount of pasture produced. In the timber sites, more beef was produced per hectare under medium grazing pressure than under high grazing pressure, while in the cleared sites, negative weight gains were recorded under high grazing pressure in two out of six seasons. When risk factors are taken into account, medium stocking pressures are likely to be more profitable that high stocking rates in that country type. More beef may be produced at medium grazing pressure compared to high grazing pressures. However, producers that accept higher risks and focus on maximising production may logically choose high grazing pressures.

There are three broad outcomes that may be possible from reducing grazing pressure (or stocking rates). The first is that reducing stocking pressure may allow beef production to increase, because the remaining animals have more feed available, and thus higher weight gains. In this case, lower cattle numbers are offset by increased financial returns from the amount of beef sold.

The second possible outcome is that reduced grazing pressure leads to a small fall in total beef production, but this is compensated for by the reductions in risks to the producer and the reduced variation in animal condition. In this case, lower cattle numbers may be offset by increased financial benefits over time, particularly when risk factors are taken into account.

The third possible outcome is that reduced stocking pressure may lead to lower beef production and reduced financial outcomes to the producer. In this case, the lower cattle numbers and lower beef production would mean that methane outputs are lower, but this would occur at a cost to producers.

Under the two scenarios where there may be financial incentives for producers to reduce stocking pressure, different implications exist for methane emissions. If reduced stocking numbers actually increase the amount of beef production, then overall methane production may rise (even though the amount of beef produced per unit of methane may fall). In the other case where reduced stocking numbers is attractive financially because of reduced risk, even though beef production will probably fall, then methane production is also likely to fall.

This means that reductions in stocking rates will only sometimes provide win-win situations. In some cases reducing stock numbers may be attractive financially but may not generate reductions in methane emissions. The identification of win-win situations from reductions in stock numbers will have to be assessed on a case by case basis.

Reductions in stocking pressure that reduce methane emissions at a cost to producers are of particular interest in terms of the opportunity cost involved. In the Keilambete example, reductions from medium to low stocking rates would mean a drop in 10.68 kgs/hectare of beef production in the timbered country, and 9.3 kgs/hectare in the cleared country. These reductions would allow methane emissions to fall by 10.88 kgs and 9.86 kgs per hectare in the timbered and cleared country respectively. If beef producers were to reduce stocking rates in order to reduce methane emissions, approximately 1 kilogram of beef production would have to be lost to reduce every kilogram of methane emissions. The next question to consider is the costs that producers might incur to potentially meet emission reduction targets through lower stocking numbers.

The market price of beef cattle has to be discounted to take account of the variable costs and capital costs associated with operating a beef herd. As well, some allowance should be made for the additional flexibility that low stocking rates afford producers, both in terms of the improved weight gains and marketability of the remaining cattle, and the lower risks that producers run in the event of dry years.

From the $1.50/kg market price used in the example above, 25% of sale price is adopted to represent potential variable costs, 10% selected to represent interest on capital, and 15% selected to represent an allowance for reduced risk and increased per head returns associated with running reduced numbers. This means the available sale price can be reduced by 50% to gain some indication of the opportunity costs involved with reducing stock numbers in order to reduce methane emissions. On the basis of cattle prices in 2001, sale prices of $1.50/kg can be discounted to $0.75/kg. This represents the potential loss per kilogram of beef that beef producers who are already stocking at conservative rates might suffer if they reduced stocking rates to reduce methane outputs.

Methane has 21 times the impact of carbon dioxide, and 47.6 kilograms of methane have the same impact as one ton of carbon dioxide. To estimate the cost of preserving one ton of carbon dioxide equivalents in methane, the opportunity cost of $0.75 should be multiplied by 47.6. In this way, the opportunity cost of reducing cattle numbers to reduce greenhouse gas emissions can be estimated to be $35 per tonne of carbon dioxide equivalent. Clearly, the option of reducing cattle numbers below efficient operating levels is an expensive way of meeting greenhouse gas reduction targets, but is much lower than the estimates provided by Adams et al (1992) or Howden and Reyenga (1998). It is also lower than the costs of destocking estimated above.

6.0 Evaluating strategies to meet emission reduction targets.

Beef cattle in Australia contribute about 7% of national greenhouse gas emissions as itemised in the national inventory (Zeil and Rolfe 1990). The size of the contribution means there will continue to be interest in determining where there might be cost effective ways of reducing methane emissions from livestock. In order to consider which options might be successful in reducing emissions from livestock, it is important to judge them against a number of criteria.

These might include:

- Clear targets and sufficient information so that beef producers know how they might be expected to modify their behaviour,
- Adequate technology and options for change, so that beef producers have options to reduce greenhouse gas emissions,
- An adequate degree of certainty, so that beef producers know the outcomes of different management strategies, which measures have priority and the timing and extent of emission reduction targets.

Most of the options that have been canvassed earlier in the paper do not meet these criteria very well. The principal problem is variability across seasons, locations and animals. The data in Table 1 reflects the variability across seasons and management options for one property in Central Queensland. There is also major variation in animal performance between individual animals and in different circumstances. This level of variation means that it would be very difficult to set clear targets for most management options of interest, and that there would continue to be a great deal of uncertainty about levels of emissions and potential reductions in any one year.

The second major problem is that there are few strategies that effectively reduce overall methane emissions from beef cattle. The only two clear alternatives that appear to achieve this are a reduction in cattle numbers and the vaccination option. It is unfortunate that methane emissions per unit of beef are highest in northern Australia, where there are virtually no alternatives to pastoral activities, rather than in southern Australia, where alternatives are more feasible.

Most of the management options that increase the efficiency of beef production are important ways of achieving increased beef production for only limited increases in methane output. However, these options (improved feed efficiency, improved feed quality, improved herd management) all tend to increase both overall beef production and methane output.

There appears to be potential for reduced stocking rates to contribute to methane reduction strategies. However, there are a number of difficulties with this strategy in relation to prediction of the net outcomes and the certainty of those outcomes. The main difficulty is that reductions in stocking rates have a wide range of possible production and emission outcomes, and the actual impact in terms of production, financial and emission outcomes will probably have to be evaluated on a case by case basis.

6.1 Using Taxes to Reduce Emissions

The issue of using a tax-based instrument on livestock to reduce methane emissions can also be addressed here[9]. It would be difficult to apply such a tax in practice to achieve the desired results. First, the variation in methane emissions between cattle would make it difficult to apply the tax effectively.

There is little benefit in applying a tax on a per head basis because there is so much variation in emissions between cattle. This variation occurs between cattle, between regions, and across changed seasonal conditions. In some cases, where stocking rates are high, a reduction in cattle numbers in response to a tax may not change overall methane outputs very much.

There is little rationale in applying a tax on a weight or output basis, because the rate of methane emissions per kilogram of meat produced varies so widely (see Figure 4). The additional problem with applying a tax on the amount of meat production is that it would provide no incentives to find more efficient ways of producing meat per unit of methane emission.

It would be very difficult to apply a tax on the basis of management options because of the uncertainties associated with impacts on emission levels. Most management options would have to be assessed on a case by case basis to determine their effectiveness. It is only with an option such as the vaccine, where there may be some certainty about the impacts on emission levels, where it may be possible to use some incentive/penalty mechanism to encourage compliance.

The second main problem with a tax instrument is that it may have to be imposed at very high levels to generate large reductions in stock numbers. Because variable costs are a low proportion of the cost structure in many grazing enterprises, any form of a tax on livestock is unlikely to influence many cattle operations. This is particularly the case in northern Australia, where there is little or no alternative to grazing.

In the case study example reported above, a reduction in stocking rate to reduce methane emissions by one kilogram would mean a sacrifice of one kilogram of beef production. At the 2001 market levels, after allowing for variable costs and other factors, the opportunity cost of breducing methane emissions by one kilogram is approximate $0.75. This potential reduction equates to $35/tonne of carbon dioxide equivalents. If tax rates had to be applied at this level, it is unlikely to be an economic way to search for emission reductions.

7.0 Conclusions.

The evidence presented in this paper demonstrate many of the difficulties that the beef industry faces in grappling with the issue of methane emissions. The difficulties stem from the fact that

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[9] While the Australian Government has not seriously flagged the use of taxes to reduce methane (or carbon) emissions, tax instruments have been considered more seriously in other countries such as New Zealand.

these emissions are the dominant contribution to greenhouse gases from most grazing properties. If the industry has to contribute to reduced emissions growth, then methane emissions will be a key issue.

There are two ways of examining the issue of reducing methane emissions. The first approach is to focus on the efficiency of production, and to maximise the output of beef for every unit of methane that is emitted. Under this approach, many improvements in productivity will automatically reduce the amount of methane emitted per unit of beef that is produced. Improvements in feed quality and herd management are the key areas to pursue. It appears likely that the biggest per head gains in efficiency are to be made by improving herd management in northern Australia, and to improve the liveweight gains of fattening cattle that currently achieve less than 0.5 kgs/day over their lifetime.

However, all these increases in production will probably lead to increased total outputs of methane. Depending on the improvement, more and/or heavier cattle will be run, making more efficient use of the available feed stocks. Improved productivity is an important avenue for the industry to pursue in grappling with issues of methane production, but it will not lead to a reduction in overall emissions. However, it may allow increases in beef production to occur for only slight increases in methane output.

To reduce methane emissions, the two areas to pursue are direct manipulation of the rumen (eg with a vaccine) or reduced cattle numbers. The vaccine being developed by CSIRO looks promising, and if successful, would be the most cost effective way of reducing methane emissions. Reducing livestock numbers is a much more expensive option.

It is possible that in some situations, reduction in grazing numbers and grazing pressure will contribute to both a reduction in methane emissions and improvement in financial outcomes. These are the situations where the reduction in beef output (and methane output) are compensated by the reduced risk of herd management in dry seasons. When a reduction in cattle numbers does not change overall productivity much (because the remaining cattle have higher weight gains), methane emissions remain fairly stable. When cattle numbers are reduced from low or moderate rates, the resulting fall in methane emissions has to be weighed up against the lost income that beef producers will face.

For one case study in Central Queensland, the opportunity cost of reducing methane emissions by one kilogram through lower stocking pressure was one kilogram of beef produced. After accounting for a number of operating, capital and management costs, this opportunity cost was valued at $35 for a ton of CO_2 equivalents. When the destocking option was considered for northern Australia, estimated costs per ton of CO_2 equivalent ranged between $50 and $75.

While these types of examples demonstrate that while there may be some opportunities for improved management to ameliorate methane emissions, the option of reducing cattle numbers to make major reductions in emissions will be an expensive one. The diversity of the industry means that blunt instruments such as taxes on outputs are impractical. However, the limited knowledge about predicting emissions at a property level and the restricted number of reduction options available also make it hard for any voluntary reduction mechanisms to be feasible either.

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