A Review of New Zealand's National Methane Inventory Model

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Final Report

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1.0. Introduction

As a signatory to the Kyoto Protocol, New Zealand has undertaken to take responsibility for greenhouse gases in excess of 1990's levels. In order to meet these commitments a methane inventory model for ruminant animals has been developed to calculate annual methane production from the main ruminant animal species in New Zealand. This IPCC Tier 2 national inventory model uses a breakdown of growing and breeding animals, the calculation of herbage intakes based on performance data for each animal sub category on an annual or seasonal timescale, and the utilisation of New Zealand derived information to calculate the extent to which feed energy is converted to methane (Clark et al., 2003). This report set out to review the national methane inventory model as follows:

- Review the accuracy and validity of data used in the national inventory model
- Identify limitations and consequences
- Identify what further research and development work is needed.

The review and the comments contained in it have been based on the paper by Clark et al. (2003) entitled *Enteric methane emissions from New Zealand ruminants 1990-2001 calculated using an IPCC Tier 2 approach.* No other information was available to the authors, nor was it possible to undertake any scenario testing using the actual model. The approach used was to have the reviewers independently comment on the model documentation. These comments were then drawn together under the following sections.

- Livestock populations
- Animal production assumptions used
- Estimating feed intake from energy requirements and energy in pasture
- Conversion of feed intake consumed to methane

2.0. Livestock populations

The documentation provided (Clark et al., 2003) indicates that the model follows IPCC (2000) guidelines. The farmed ruminant population has been divided into principal livestock categories and subcategories based on 1990 animal numbers. This review only addresses ruminant emissions: dairy cattle, beef cattle, sheep, deer and goats (included due to numbers present in 1990). Horse and swine enteric methane emissions are also reported to UNFCCC but are less than 0.2% of enteric emissions. Animal numbers have been obtained from census and survey data obtained by MAF through the annual agricultural production survey carried out by Statistics New Zealand, and the subcategories used reflect New Zealand farming systems. The census data appears to be the best data available. Replacement rate, deaths and slaughter policies have been standardized to "average" New Zealand circumstances but are not reflected in the model documentation. A detailed check of the data used in the model would be a significant task and is beyond the scope of this review.

2.1. Dairy cattle

The documentation around the livestock population assumptions could be improved by being clearer and more detailed. Clark et al. (2003 – page 44) indicate that no allowance has been made for deaths of animals throughout the year because of the difficulties of reconciling monthly milk yields with cow deaths. However, this argument does not apply to heifers and breeding bulls. Normally, heifers would be culled and slaughtered/sold after pregnancy testing rather than carried on-farm as surplus dry two year old heifers. Similarly, there are no monthly deaths within breeding bulls and the level of culling/turnover is not specified. In breeding bulls, there would normally be a significant level of turnover. In recent decades, there has also been a trend to lease bulls so that they are only on the milking platform for the mating season. Because these animals are effectively owned by beef finishers, these animals might appear in the beef cattle numbers as 1-2 year bulls. However, moving to this level of detail in the inventory would not greatly impact on methane emissions because of the relatively small numbers involved and the difficulty in obtaining the data.

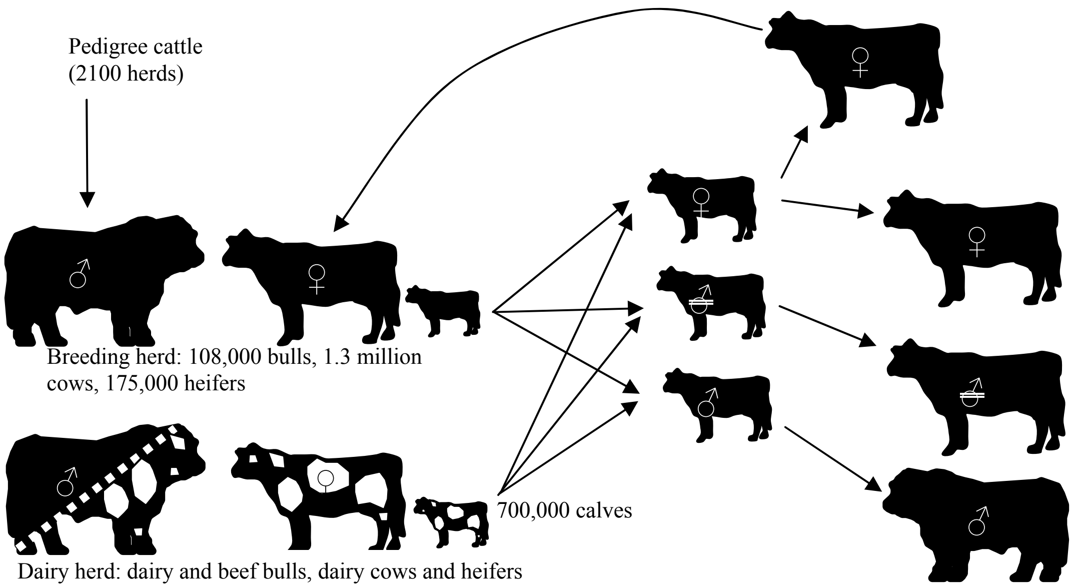
2.2. Beef cattle

Beef cattle statistics provide the greatest challenge because of the lack of national quality data and the difficulty posed by integrating the beef of dairy origin – particularly Friesian bulls, beef x bulls and beef x heifers (Figure 1*).* It is not clear what might be happening to the beef x steers and heifers (typically Hereford x Friesian) which might be reared from the dairy industry.

In Table A2 (Clark e al., 2003) the opening cattle numbers in June are the same for all 3 categories of replacement heifers (< 1, 1-2 and 2-3 year olds). On a commercial farm, there would always be fewer numbers in the older age categories as deaths and culling occurred. The same trend should, therefore, occur nationally. The same problem occurs in the two age groups of slaughter heifers, steers and bulls. These numbers have probably resulted from dividing the total animals slaughtered by the number of age categories. There may be merit in revisiting the beef cattle statistics in the future in an attempt to better represent what is happening nationally

Nationally, there are a wide range of beef farming systems- from extensive beef cows to intensive bulls in high producing cell grazing systems. While it may be difficult in splitting out all the different beef systems, there may be merit in obtaining differential pasture quality data on beef cows and finishing cattle (particularly bulls) as finishing cattle may well be grazing pastures with ME levels more akin to dairy pastures.

Figure 1. A summary of the animals contributing to the New Zealand beef farming industry. Animal numbers are approximate being collated from a variety of sources and in different years. ♂̶ = steer. (From Fisher and Stafford, 2007).



2.3. Sheep.
Table A3 (Clark et al., 2003 – page 48) suggests that transfers in and out of the breeding flock occur at the end of March yet page 49 indicates that transfers in and out of the breeding ewe flock occurs at the end of February. This may be a typo. Unless being retained solely for wool production, it is hard to see why almost 1.5 million dry ewes would be retained through the year. Normally these would be sold as they appeared – pre lambing and at weaning. Ewe numbers are confusing and could benefit from more documentation/explanation to clarify how numbers are reconciled.

2.4. Deer
The inventory model has all young deer slaughtered in March but, as with lambs, many are slaughtered earlier. There may also have been a change in slaughter times between 1990 and 2001, given the increasing premiums for pre-Christmas slaughter and the use of Wapiti genetics to get faster growth rates.

3.0. Livestock Production Assumptions.

Productivity data is difficult to collect because of the lack of consistent and detailed recording on-farm. Nevertheless, the assumptions made are likely to have a large impact on the estimate of the methane produced per animal.

3.1. Dairy cows

3.1.1. Dairy cow liveweight. LIC statistics report dairy cow liveweights measured on herd test cows during lactation. A dairy cow may have markedly different weights during the year depending on pregnancy status and stage of lactation so it is not clear whether these liveweights represent a typical "average" dairy cow liveweight over the year. As a comment, the LIC Dairy Statistics show a surprising increase in cow liveweights between 2000/01 and 2003/04. Average Friesian cow weights increased from 446 kg to 490 kg and Jersey cow weights from 348 kg to 378 kg. Given the importance of dairy cow liveweight to the model, more detailed examination of such rapid changes is warranted.

3.1.2. Growing dairy replacements. Using a figure of 9% of cow bodyweight may over-estimate dairy heifer birthweights (Clark et al., 2003 – page 15). There is virtually no data on calf birthweights, but Muir et al. (2004) reported a liveweight of 38.7 kg for 65 Friesian bull calves weighed within 24 hours of birth on 4 Waikato farms in August 2000. Whilst the Friesian dams were not weighed, LIC Dairy Statistics give an average weight of 446 kg for Holstein-Friesian cows in 2000/2001. These bull calves would have weighed around 8.7% of their cow bodyweight. Since heifer calves are likely to be 2 kg lighter than bull calves, heifer calf birthweight is likely to be around 8.2% of cow bodyweight. However, it is unlikely that such discrepancies will have an impact on national methane output.

There is no indication of the milk that is being fed to dairy heifer replacements but data from Thomson and Muir (2004) indicates that it is around 316 litres per calf and this will affect the overall calculation of milk production.

The model assumes that heifers reach 90% of the average cow weight at first calving (i.e. at 2 years of age). LIC data (Table 1) suggests that as two year olds, heifers are between 80 and 85% of the average weight of the other cows in the herd (i.e. those three years and older). Moreover, Table 1 using LIC data suggests that cows continue to increase in weight until 5 or 6 years of age this will affect the energy requirements for maintenance and growth if the liveweights are lower in younger cows.

Table 1. Effect of age on cow liveweight for the 2006/07 season

	Friesian		Crossbred		Jersey	
Age	%	Weight	%	Weight	%	Weight
2	18.7	409	20.4	369	17.8	320
3	15.1	443	17.5	423	16.3	367
4	14.4	468	15.9	451	15.3	384
5	13.9	489	13.7	471	13.8	398
6	11.1	505	10.6	485	11.4	404
7	8.2	488	7.6	476	8.6	413
8	6.3	496	5.5	477	6.4	419
Overall		468		442		381
2yr weight as a % of older herd mates		84.9		80.1		81.2

LIC 2006/07.

3.1.3. Dairy cow milk production. The methane inventory model uses total milk data from data supplied by MAF policy (Tony Wharton, personal communication). This includes the amount processed through NZ dairy factories plus an allowance for town milk supply. However, this does not appear to include colostrums/penicillin milk or milk fed to calves. The model indicates that milk production per cow increased from 2800 litres in 1990 to 3594 litres in 2001 – an increase of 794 litres (Clark et al., 2003 - page 16). Yet the LIC figures (Table 2) indicate that milk yields went from 3221 litres in 1990 to 3706 litres in 2001 – an increase of only 485 litres.

A further calculation from the data in the model shows that milk fat yield increased from 134 kg in 1990 to 168 kg in 2001 – an increase of 34 kg. Yet the LIC figures (Table 2) indicate that milk fat production went from 144 kg in 1990 to 177 in 2001 – an increase of 30 kg. Further consideration is required as to the most appropriate source of data for milkfat used in the model.

A further complication is if we re-calculate the milk fat production from the LIC data given (figures in red below) the respective figures go from 152 in 1990 to 173 kg in 2001 – an increase of only 21 kg. It is hard to see how these differences could be simply rounding errors. Given the importance of increasing per cow milk production, this area needs further re-examination.

Table 2. Per cow and per hectare changes since 1990

		Herd Test Results		
Year	Litres/cow	MF%	MF/cow	MF/ha
90	3221	4.72	147 (152)	352
91	3190	4.81	148	351
92	3361	4.83	157	
93	3298	4.77	148	374
94	3560	4.84	160	407
95	3253	4.77	156	386
96	3501	4.72	163	405
97	3641	4.78	173	425
98	3373	4.67	168	430
99	3189	4.51	147	392
00	3601	4.69	165	439
01	3706	4.68	177 (173)	472
02	3791	4.64	175	471
03	3736	4.68	179	471
04	3871	4.75	184	509
05	3812	4.75	176	494
06	3951	4.72	186	520
07	4014	4.85	189	534

LIC Stats 2006-2007

3.2. Beef cattle.

3.2.1. Beef cow liveweight. Beef and dairy cows are not separated in the slaughter statistics so to obtain an estimate of the weights of beef breeding cows the following procedure was adopted in the model. "The number of beef cows slaughtered was assumed to be 25% of the total beef breeding herd. Other cows slaughtered were assumed to be dairy cows. The carcass weight of slaughtered dairy cows was estimated using the adult cow liveweights and an estimated DO% of 40%. The total weight of dairy cattle slaughtered (number x carcass weight) was then deducted from the national total carcass weight of slaughtered adult cows. This figure was then divided by the number of beef cows slaughtered to obtain an estimate of the carcass weight of adult beef cows. Liveweights were then estimated using an assumed DO% of 45%". There are too many assumptions involved in the calculation of beef cow liveweight. Given that emissions from beef cattle are still approximately 25% of NZ livestock emissions, more accurate data is needed. A survey of beef cow liveweights is necessary to obtain better data.

Better data on cow replacement rates might be available from industry – for example Landcorp's beef cow replacement rate is 23% (Nicoll, personal communication) and could be used as a proxy for the national cow replacement rate.

Beef cows are generally used as clean up animals and get offered poorer quality feed. Their role as pasture quality regulators means that they gain lose and gain substantial amounts of weight (Anon, 2005), yet the model assumes liveweight stays constant and they are grazing same feed quality as sheep.

3.2.2. Milk production. National beef cow milk yields are based on an Angus cow milk yield of 800 litres. There is little data available on beef cow milk production and this may be an underestimate since at least part of the national herd is made up of Hereford x Friesian cows with reputedly higher productivity in terms of calf weaned/kg intake.

The model assumes that approximately 40% of beef calves are supplied by the dairy industry. This is likely to change over time and could be back-estimated from the change in bull kill. These calves are presumed to be reared on 200 litres of milk in the form of milk powder. This is likely to be an underestimate as whilst 50% of these bull calves are reared on around 155 1itres of reconstituted milk powder by calf rearers (Thomson et al., 2005), the other 50% are reared by dairy farmers using 316 litres of colostrum and vat milk (Thomson and Muir, 2004). We would recommend increasing the milk used for rearing calves to 235 litres.

3.2.3. Young growing stock*:* The DO% of 50% used in young growing stock is too low and a figure of 54% more appropriately reflects the relationship between hot carcass weight:liveweight off pasture for heifers, steers and bulls (Muir et al., 2008). This will have the effect of reducing the liveweight and methane output of these animals.

3.3. Sheep.

The model documentation has limited information on details such as the change in lambing percentage between 1990 and 2001. Although the actual lambing percentage does not affect the operation of the model it would be useful when assessing the validity of the model and the changes since 1990. The predicted 19.1% increase per ewe methane production between 1990 and 2001 presumably results from a combination of increasing lambing percentage, an increase in lamb liveweights and a lift in ewe liveweights from 47 kg in 1990 to 55 kg in 2001. This is more than counteracted by the significant drop in ewe numbers over the same period.

3.3.1. Ewe liveweight. The DO of 43% for adult ewes seems high. Muir et al. (2008) suggests that a figure of 39% is more appropriate, but they concluded that more data is required. This discrepancy in DO% would help explain the relatively low ewe liveweights used in the model (Clark et al; 2003 - Table 7). For example, the model indicates that the average ewe liveweight in 2001 was 55.1 kg. Yet mixed age ewe liveweights collected from 60 farms (132,000 ewes) in South Canterbury in 2001 were 63.4 kg (Tom Fraser, unpublished data from FB 2000). If the DO figure in the model is changed to 39%, the liveweights in 2001 would increase from 55.1 kg to approximately 60.7 kg. It is also possible that the average ewe carcass weight under-estimate ewe liveweights simply because many of the ewes being culled are done so on the basis of weight and constitution. Many ewes may also be losing weight prior to slaughter simply because they are held on short feed awaiting “booking space”. Identification of cull ewe weights versus flock ewe weights will require on-farm surveys. Whilst there is good data on ewe carcass weights, lack of quality data on DO% provides limitations to the calculation of ewe liveweight. A liveweight survey of breeding ewes, cull ewes together with better data on DO% would be beneficial.

3.3.2. Ram liveweight. Breeding rams were assumed to weight 40% more than adult ewes. This suggests that if the average ewe liveweight is 63.4 kg (e.g. Tom Fraser, unpublished data) then the average ram liveweight is 88.8 kg, which seems appropriate both for rams being purchased as two-tooths and for flock rams, since rams are typically maintained at or around their purchase weight so they do not become too heavy for mating (George Cruickshank, pers comm). However, the sheep input sheets suggest that rams are growing at 50 g/d, meaning a ram would increase in weight by 18.25 kg per year. Cruickshank (2005) surveyed the Wairarapa Romney Improvement Group (4% of the NZ sheep flock) and found that rams lasted an average of 3.9 years. So an individual two tooth ram purchased at 88 kg growing at 50 g/day would be an unlikely 161 kg when it was culled four years later. It would be more accurate for rams to be purchased at 88 kg and to maintaining their weight thereafter. Whilst rams are likely to change in weight over the year reflecting feed supply and the priority assigned them on the farm, this data is not available.

3.3.3. Lamb liveweight. The DO of 45% used to calculate the liveweight of lambs from carcass weight appears to be slightly high, with Muir et al. (2008) suggesting this figure should be nearer 44%. Lamb birth weight has been assumed to be 9% of adult ewe birthweight (Clark et al., 2003 – page 18). Poukawa data indicates that single lambs averaged 8.8% of ewe bodyweight. Twin and triplet lambs collectively averaged 14.7% (7.4% per lamb) and 17.9% (6% per lamb) of ewe mating bodyweight, respectively (Table 3). Since more lambs will have been born as twins in 2001, more accurate data could be included in the model. This means that in 1990 the total lamb weight per Romney ewe would have been 9.1% at a lambing percentage of 97%, increasing in 2001 to 10.7% at a lambing percentage of 125%. This will affect energy requirements during gestation and energy requirements for lactation and lamb growth.

Table 3. Total lamb birthweight as a percentage of ewe liveweight at mating. Data from the Elite ewe flock at Poukawa (Muir pers com)

Birth rank	Ewe Genotype EFxR	FxR	PDxR	R
1	8.52	8.34	9.16	9.12
2	13.96	13.42	15.14	14.36
3	18.09	16.56	20.06	16.95

East Friesian x Romney (EFxR), Finn x Romney (FxR)
Poll Dorset x Romney (PDxR), Romney (R)

3.3.2. Ewe milk yield. Ewes were assumed to have a milk yield of 100 litres, based on UK data with hill sheep rearing a single lamb. Over a 98 day lactation (assuming weaning at 14 weeks) this means a milk production of around 1 litre/day. Yet Poukawa data (Muir et al., 2000) shows well fed Romney ewes produced an average of 1.5 litres/day (singles) and 1.66 litres/day (twins). Peterson et al. (2006 a & b) found similar milk yields (1.4 - 1.6 litres/day) and that milk volume increased slightly when birth rank increased. It is unlikely that many commercial ewes in NZ would be as well fed during lactation as ewes at Poukawa and Massey so the actual answer probably lies somewhere between the UK and the NZ trial data. It is likely that changes of this magnitude will have little impact on overall methane output but may need to be adjusted in the future as performance continues to improve.

3.3.3. Lamb slaughter. The model assumes all lambs are born on the 1st September and slaughtered at 6 months unless retained as replacements. If this assumption is incorrect and lambs are killed earlier, then methane output will be reduced. An abattoir/farm survey in the mid 1990's by MIRINZ (for Meat & Wools NZ) suggested the average age to slaughter was around 5.5 months. Whilst the lamb slaughter data is unequivocal, collection of more accurate data on current lambing date would assist clarifying lamb age at slaughter.

3.4 Deer

The model makes assumptions about dressing out percentages, birthweights, liveweight changes over the years and within year. This data is very limited and further data needs to be collected. However, in terms of contribution to methane output it is less critical than for dairy, sheep and beef.

The use of Wapiti genetics, particularly as a terminal sire to get better growth rates and early slaughter has undoubtedly had an effect on carcass weights. However, what is not clear is whether it has affected timing of slaughter between 1990 and 2001.

The milk production of lactating hinds is reported as 240 litres in the documentation and 242 litres in the input sheets. This may be an over-estimate since Arman et al (1974) reported milk production of 140 to 180 kg in red deer for the first 150 days of lactation (i.e. most of the lactation period for a NZ red hind). Red deer hinds at Lincoln University (Barrell, unpublished data) gave daily outputs of 1000 to 1300 ml over 24 hours at 60 to 80 days of lactation which was similar to the data of Arman et al (1974).

4.0. Animal energy requirements

The methane inventory model calculates dry matter intake based on assumed energy requirements divided by the energy content of the diet. The use of energy equations derived by CSIRO (1990) seem to be the most appropriate available and in the absence of any hard scientific data on improved efficiency, assumes that any increase in production must be met by a linear increase in energy intake. The following energy equations in Clark et al. (2003) need to be checked.

Page 51	No value M for milk fed lambs
Page 52	DMD should be 'D' from EGRAZE equation base of P51.
Page 52	The E_g predictions are taken directly from AFRC 1993, not SCA 1990 and are based on a lamb birth weight of 4 kg.
Page 52	With the cattle prediction there is a clear typographical error in the central coefficient (0.00.0201 should be 0.0201) but this may not have carried to the inventory. As for sheep, there is a need to convert the E_g value calculated to an ME value

There seems to be quite a large difference in the figures used for % N in body tissue (see input sheets). A figure of 3.71% is used for deer, 3.26% for dairy and beef and 2.6% for sheep. These differences seem particularly high for dairy and beef animals and perhaps these figures need to be revisited.

New Zealand's livestock industries have undoubtedly become more efficient since 1990. In the case of dairy cows, Clark et al. (2003 – page 27) indicate that the increase in methane emissions per cow increased by approximately 7% (from 70.2 kg/cow in 1990 to 74.7 kg in 2001) because of a higher DMI resulting from a 2% increase in cow size and a 28% higher milk yield per milking cow and heifer (Clark et al., 2003 – page 27). Improvements in efficiency will have come about from a combination of better feeding levels reducing the contribution of energy to maintenance, an 8-10% improvement in efficiency through crossbreeding Friesian and Jersey genetics (Lopez-Villalobos, 1989). These improvements in efficiency are currently captured by the model because it is based on animal liveweight and production level. There is also a 9.3% increase in efficiency from the same amount of dry matter through genetic selection (Montgomerie, 2007, cited Kolver, 2007) which may or may not be captured.

There have also been improvements in efficiency within the sheep industry. Higher reproductive rates and mating hoggets will reduce the maintenance energy component of the flock. Lamb carcass composition undoubtedly changed between 1990 to 2001 due to an emphasis on leaner carcasses. Since the production of fat tissue requires significantly more energy than lean tissue it is possible that the energy required to produce a kg of lamb may have declined between 1990 and 2001 in tandem with the reduced fatness of the lambs being produced. There may be data available on the change in lamb fatness, or it may be possible to undertake the necessary research to obtain this data and enable improved figures for NE gain to be used.

The model assumes that increased production equals increased intake because there is no clear evidence of an improvement in efficiency at the cellular level. Yet there is evidence from other industries that the efficiency of energy utilization per unit of feed intake has been changed by genetic selection. Selection for feed conversion efficiency per kg of DMI has been highly effective in the pig and poultry industries (Bordas and Minvielle, 1999, Van der Steen, 2005). Within the sheep industry, there has been no selection for feed conversion efficiency *per se*. Yet selection is occurring for weaning weight, with average increases of 2.8 kg for weaning weight BV in rams on Sheep Improvement Ltd between 1992 and 2007. Selection for weaning weight in lambs (high and low weaning weight lines) resulted in increased feed intake but there was also an associated effect on feed conversion efficiency. For example, when lambs were fed the same level of milk, the high weaning weight lambs grew faster than the low weaning weight selection lines (Oddy et al. 1995). Any change in feed conversion efficiency (FCE) since 1990 will have an impact on our methane output. Future selection directly for FCE is likely to have an even bigger impact.

5.0. Energy in pasture

Intake calculations are highly sensitive to the energy estimation of diet. The ME of pasture available to grazing animals varies with season, location, climate, species of plant and animal, composition, animal selection, amount on offer and management systems. For example, breeding ewes are farmed in locations ranging from unimproved tussock through to sheep farms in Canterbury and Southland adjacent to dairy farms. In beef production systems, there is likely to be a similar range from breeding cows controlling weeds in hill country through to the intensive cell systems used by some bull beef finishers.

Because of a lack of available data, the model uses the same pasture ME dataset for deer and dairy and similarly combines sheep and beef animals together. However, it could be argued that because of the low grazing residuals used that deer are more analogous to sheep than dairy cattle. A survey of pasture quality on deer farms would no doubt provide useful data.

The model uses data from Litherland et al (2002) for beef and sheep (19 farms sampled) and data from Massey University postgraduate study programme (10 farms sampled) for deer and dairy. There is little description of types of pasture or climate for the farms sampled to see how representative they are of New Zealand or how these values might have changed over time along with changes in pasture cultivars/ species or management. Clark et al. (2003) makes the point that it is not possible to look at differences over time as there was a change in methods from wet chemistry to NIR. However, there may be some merit in undertaking some wet chemistry on current pastures and comparing with old data.

The ME data provided by Litherland et al (2002) indicates that pasture ME is lower in autumn than in summer. This data is surprising and may reflect a seasonal or sampling effect and may reflect the limitations of using a single years data.

Litherland et al. (2002) also showed significant variation between areas and seasons suggesting that using a national figure will mask differences. For example, autumn pasture in Southland had a ME of 11 MJME whereas Canterbury autumn pastures had a mean ME of 8.1 MJME (Table 4). In a recent study, Gibbs (2008) also found considerable regional variation in a study of South Island dairy farms (Table 5). The figures reported were also higher than those used in the inventory model. It would seem sensible to use higher ME figures where they are available (e.g. SI dairy) and use the other data as default where better data are not available. Between 1990 and 2007, there was a change in dairy cow distribution, with 6.65% of cows located in the South Island in 1990, 25.8% in 2002 and 31.3% in 2007 (www.maf.govt.nz/statistics). Given the likely difference in feeding levels and types of feed being offered, there may well be regional differences in methane production which need to be considered
It should be possible using regional livestock numbers and pasture quality data to calculate the change in emissions which would result from moving to a spatially explicit inventory.

Table 4. Regional and seasonal variation in ME of plucked pasture samples (Litherland et al. 2002).

	Summer	Autumn	Winter	Spring	Mean
Waikato	9.0	9.1	10.9	11.1	10.1
Tararua	10.7	10.1	10.9	11.5	10.9
Canterbury	9.4	8.1	10.3	11.3	9.8
Southland	10.6	11.0	11.2	11.5	11.1

Table 5. Comparison of model dairy ME data with recent South Island dairy data

	Model Dairy/deer	Gibbs (2008) SI Dairy farm survey
July	12.6	No data
Aug	11.5	12.2 (11.4-13.3)
Sep	11.7	12.2 (11.2-13.1)
Oct	12.0	12.2 (10.6-13.0)
Nov	11.6	11.9 (10.1-13.5)
Dec	10.8	11.6 (9.7-13.5)
Jan	11.1	11.6 (10.3-13)
Feb	10.6	11.8 (10.4-13.1)
Mar	10.7	11.9 (10.5-13.2)
Apr	11.3	11.9 (10.6-13.1)
May	12.0	12 (10.6-13.1)
Jun	11.7	12.1 (10.9-13.3)
Average	**11.5**	**12.0**

The data used may also not entirely represent what animals are eating. The survey data used in the model (Litherland et al., 2002) was obtained by farmers taking pluck samples (as opposed to ground level cuts) to simulate what the animals were eating. It is very difficult and time consuming to harvest pluck samples from low pasture covers and such samples will still not be of what the animals have grazed – rather what is left is what the animal’s haven’t grazed. Whilst the sheep and beef data used by the model is the best available, more comprehensive and detailed survey information is likely to provide more accurate sheep and beef pasture data.

6.0 Methane Emissions

There seem to be differences between the methane production in the model's output sheets (those dated 25/9/06) and that described in the documentation (Clark et al., 2003 – page 4). The discrepancies are only presented for sheep (Table 6) but there are similar discrepancies for beef, dairy and sheep. Collectively the methane emissions for dairy cattle, beef cattle, sheep and deer increased by 97.6 gG/annum between 1990 and 2001. Yet the figures from the output sheets for the same period suggest an increase of only 52.5 gG/annum. Output sheets for goats were not available.

Table 6. Methane emissions (gG/annum) as presented for sheep by Clark et al. (2003) compared with the model output sheets.

	Model documentation	Output sheets
1990	514.7	567.0
2001	438.7	465.5
Difference	-76	-101

The CH_4 figures being used for sheep of 12 kg/year in 2010 and 10.6 kg/year in 2001 (Clark et al., 2003 – page 5) are well above the IPCC default value in their 2000 Good Practice Guidelines (8 kg CH_4/hd/year; source below), used in other inventories (e.g. Canada, www.ec.gc.ca/pdb/ghg/inventory_report/2004_report/ann13_e.cfm). In their review of sheep emission data, Pelchen & Peters (1998) found the highest emission group (growing sheep) produced 23.16 g CH_4/d or only 8.4 kg CH_4/year; well below the 10.6 kg/year figure used in 2001. We assume that these differences are due to the method of calculation, with the NZ inventory calculating total methane produced by "sheep" and dividing the annual methane output by the sheep present at balance date (30^{th} June). This means that lamb data is included with ewes so the implied emissions are higher.

The claim (though supported by measurements in Appendix D – p 57) that younger sheep produce less methane than older sheep is in contrast to the reviewed literature. Pelchen and Peters (1998) reviewed CH_4 emissions in a large number (1137) of animals and found emissions were 23.2 in growing sheep v 20.5 g CH_4/d for adult sheep, which is in a contrary direction to that found in NZ. We are not in a position to review the unpublished NZ data on methane emissions but recent published work (Knight et al. 2008) found that there were significant differences between ewes and lambs on a daily basis but the data was less convincing when corrected for DMI as the differences were only significant at 35 weeks and not at 13, 17 and 25 weeks of age. Further work to define this age differential should be conducted. Since there is no similar data in cattle suggesting an age effect it would be worth undertaking similar research in cattle.

The 8.3% increase in total methane emissions (1015 to 1099 gG/annum) between 1990 and 2001 seem high given the other changes in landuse that have occurred. For example, the methane inventory model indicates that total herbage intake increased from 48.9 million tonnes in 1990 to 53.1 million tonnes in 2001 (Table 7). Yet over same period, grazing land actually declined by 13%, from 14,032015 ha to 12,207,853 between 1990 and 2002 (www.mfe.govt.nz/publications, www.stats.govt.nz, www.maf.govt.nz/mafnet/rural-nz, www.stats.govt.nz/analytical-reports/agriculture-in-nz/forestry.htm, www.maf.govt.nz/statistics). This suggests that 3.48 tonnes/ha was being consumed in 1990, increasing to 4.35 tonnes/ha in 2002. This is a 25% increase in feed consumed. Allowing for utilization of 75%, this suggests that 33% more feed is being grown in 2002. Some less fertile land will have been removed for forestry and vineyards along with increases in N fertilizer use and areas of maize silage on better land. Land use intensification due to increased dairying as well as increased irrigation usage on dairy farms will have increased the amount of feed grown nationally. Nevertheless, the absolute increase does seem high and other factors such as improvements in feed quality or in feed conversion efficiency may well be implicated. Both will have the effect of altering the amount of feed required.

Table 7. Herbage intake (million tonnes/annum) by farmed ruminants 1990 - 2001 (Clark et al. 2003)

Year	Dairy	Beef	Sheep	Total
1990	11.0	10.8	25.7	48.9
1991	11.3	11.0	24.9	48.6
1992	11.7	11.4	24.1	48.6
1993	12.2	12.0	23.8	49.4
1994	12.9	12.3	23.5	50.0
1995	13.6	12.4	23.5	50.8
1996	14.2	12.0	23.4	50.9
1997	14.4	11.8	23.6	51.2
1998	14.7	11.6	23.7	51.3
1999	15.4	11.6	23.1	51.7
2000	16.6	11.7	23.2	53.1
2001	17.2	11.8	22.4	53.1
% increase 1990-2001	56.4	9.3	-12.8	8.6

7.0. Conclusions and recommendations

This model has calculated New Zealand's methane inventory from animal numbers based on population and slaughter statistics and intake from liveweights and production functions. It has clearly been a major undertaking and the best data available at the time has been used. This review has indicated some of the limitations to the model output – in most cases these are problems with the available data. Where possible, we have indicated how the model might be improved to make future forecasting of methane emissions more accurate. As it was not possible to run the model, this review is based on the model documentation reported by Clark et al. (2003) and input and output sheets supplied for the model. The review has been unable to determine the significance and sensitivity of any input adjustments to emission levels.

- Figures used by the inventory model suggest an increase in feed consumed of 8.6% between 1990 and 2001. Yet over the same period grazing land declined by 13% because of alternative land uses. This suggests that the remaining grazing land had to grow 33% more feed to meet the production requirements of New Zealand's farmed ruminants. In spite of increases in N fertiliser use and areas of maize silage, producing this much extra DM seems unrealistic. It is also reasonable to assume that feed quality has increased since 1990 thereby affecting animal intake.

- It is possible that selection for production increases in dairy cattle and sheep have resulted in improvements in feed conversion efficiency. If this has occurred it will reduce the amount of total feed required nationally and help explain the above anomaly. Demonstrated improvements in FCE between 1990 and 2001 would reduce New Zealand's CH_4 liability.

- There are discrepancies in milk yield between the figures used in the model and LIC figures. This is because the model uses estimated total milk production divided by the number of animal on hand at balance date whereas LIOC figures are actually yields recorded for in-milk cows. The milk yields should be revisited to incorporate the more accurate LIC reported values.

- The pasture ME data used in the model appears to be low. A national survey undertaken by experienced technical staff would provide much needed data on pasture quality across farm types and across regions. Whilst establishing a time series is likely to be difficult, some assessment of modern pastures using old technology (e.g. in vitro analysis) may enable comparison with historical data.

- Checking the population characteristics and statistics used in the methane inventory model is a large undertaking and beyond the scope of this review. Whilst there is no reason to suggest that errors have been made, it would be prudent to check the data used and perhaps collect some additional data (e.g. lambing date).

- There appears to be a discrepancy between the methane production in the output sheets and that used by Clark et al (2003). This discrepancy is in the order of 40-50 Gg of methane. It may be that the output sheets made available were not the final version used for the model.

- There are a number of the production assumptions used in the inventory model which could be improved. In particular, the liveweights used for ewes seem light and better data is needed. Figures used for DO% in beef cows, ewes, lambs, deer and finishing cattle need to be re-evaluated (Muir et al, 2008).

- The impact of moving to a regional (Tier 3) emissions model for enteric methane in a manner compatible with possible regionalization for N_2O emission should be considered as a way of making the inventory more sensitive to changes in the location and intensity of each livestock sector.

- The methane output of 10.6 kg/sheep in 2001 is 32% above the 8 kg/sheep used as the IPCC default value. This may reflect differences in the method of calculation, with lamb emissions being included in with the emissions from ewes. The claim that younger sheep produce less methane than older sheep is in contrast with the literature and needs further investigation as to the correctness or reason/mechanisms.

- Population models need to be re-examined since they make a number of assumptions about changes in populations between census counts and these models seem to lack realism in some circumstances. More detail needs to be included in the model documentation. The appendices are hard to follow particularly with unexplained increases and decreases between months. In some cases (e.g. beef cattle) there are identical numbers of animals in 2-3 different age categories. This is unlikely to occur in a commercial situation.

- The methane inventory should look at operating at a more detailed level so that the model can be "future-proofed" and to take into account the changing nature of New Zealand farming. For example, this would enable differentiation of more productive farm types as better pasture data becomes available (e.g. South Island dairy). Removing less productive land (into forestry) and changing to different farm types and regions would improve the sensitivity and accuracy of the model.

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