A comparison of greenhouse gas emissions from the New Zealand dairy sector calculated using either a national or a regional approach

MAF Technical Paper No: 2011/34

Prepared for Ministry of Agriculture and Forestry
By AgResearch December 2008

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ISSN 2230-2794 (online)
ISBN 978-0-478-37596-1 (online)

April 2011

Ministry of Agriculture and Forestry
Te Manatū Ahuwhenua, Ngāherehere

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NEW ZEALAND

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Publisher

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Te Ahuwhenua, Te Kai me te Whai Ora. Tuatahi

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December 2008

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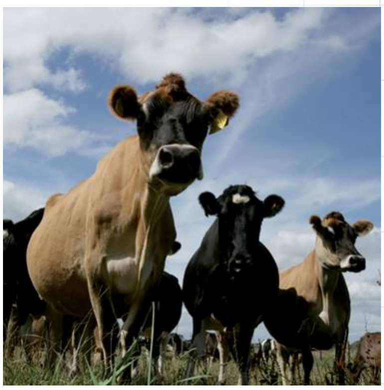

A comparison of greenhouse gas emissions from the New Zealand dairy sector calculated using either a national or a regional approach

Report for MAF

August 2008

Harry Clark

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1. Executive summary & recommendations

Estimating national CH_4 and N_2O emissions using a regional rather than a national approach results has little impact on 1990 emission estimates but reduces estimates for 2006 by 2.3%. Overall this results in a reduction in the estimated increase in CO_2e emissions between 1990 and 2006 of 257.66Gg.

Estimating N2O emissions for each region based on drainage classes (poor, imperfect, and well-drained) does not change emission estimates. However, this may simply be a result of the inability to ascribe differential stocking rates to each drainage class because of a lack of data.

Utilising newly available data on diet quality in the South Island further reduces the increase in emissions between 1990 and 2006. Adopting a regional approach and these new pasture quality data results in a reduction of 383.82Gg CO_2e .

Recommendations

MAF should consider moving immediately to estimating dairy cattle emissions on a regional basis.

MAF should consider incorporating the updated Gibbs (2008) pasture quality data into a regional based dairy cattle inventory.

There appears to be no benefit to using regional soil drainage categories at present. Any changes in this direction need to be delayed until regional data are available on stocking rate by drainage class.

2. Introduction

Enteric methane (CH_4) and nitrous oxide (N_2O) arising from New Zealand ruminants are currently estimated using methodologies that follows the guidelines published by the IPCC (IPCC 1996, 2000, Clark et al 2003, De Klein et al ????). When estimating CH_4 and N20 emissions from agriculture the ruminant population is disaggregated by species (sheep, beef cattle, dairy cattle and deer) and class (age, breeding status) but not region. This is because (a) a previous attempt to estimate emissions using a regional breakdown based on climatic regions gave identical answers to a far simpler national model (Ulyatt et al 1991; Clark 2001) and (b) obtaining regional data for some of the main drivers of agricultural greenhouse gas emissions (GHG) (eg animal weight and animal performance) is not possible for all animal species.

Adopting a regional approach for the estimation of all of New Zealand's ruminant animal GHG emissions may not be feasible for all livestock species it may be feasible for the dairy sector, which is now the largest source of agricultural GHG emissions; total CO_2 equivalent emissions arising from the dairy sector have risen from 25% of total agricultural emissions in 1990 to almost 40% of agricultural emissions in 2006 (MfE 2008). It is also a sector that has undergone rapid changes in structure in recent years; cow numbers have risen by close to two million and there has been a shift in the regional distribution of dairy herds due to the rapid expansion into new areas, particularly the South Island. This structural change has resulted in large differences in the performance of dairy animals between regions, meaning that a single national model may no longer be the most accurate way of estimating GHG emissions from the dairy sector. In addition the data currently used to estimate emissions from the dairy sector for dairy cattle performance (Livestock Improvement Corporation, Dairy Statistics) and animal population (MAF Livestock Statistics) are available on a regional basis. These data are comprehensive enough to allow the construction of a time series of emissions from 1990 to present for the dairy sector.

This report presents the results obtained by estimating total dairy sector GHG emissions from the sum of emissions in 17 different regions for the years 1990 and 2006 and compares them with the current estimates of dairy sector emissions which are based a national aggregated model.

3. Methods

3.1 Primary Data Sources

Data on the number of animals present on New Zealand farms are collected each year by MAF. These data are collected on an annual basis and come from either a full census or a comprehensive survey conducted in July/August of the relevant year. The published numbers refer to the animal population on farms as at June 30th (http://www.maf.govt.nz/statistics/pastoral/livestock-numbers/). Data are available for each of 73 Local Territory Authorities (LTA) and these data are broken into different classes of stock eg milking cows and heifers, non-milking cows and heifers, yearlings and bulls. The only exception to this is where populations in a given LTA are very small and the data are suppressed for privacy reasons. Data which are suppressed at the LTA level are however included in the national and North/South Island population summaries.

The LIC publishes comprehensive data annually on the performance of the dairy sector in New Zealand for each milking season in the publication 'Dairy Statistics' – available from http://www.lic.co.nz/lic_Publications.cfm?. These data are the primary source of the animal performance data used in the current national inventory of CH_4 and N_20 emissions. Data obtained from this source includes total milk produced, milk composition (% fat, % protein), weight of dairy cows by breed and proportion of each breed in the national herd. Currently these data are only used at an aggregated national scale but in fact they are broken down by region. The LIC regions comprise 17 regions, 11 in the North Island and 6 in the South Island. In addition to publishing data on animal performance the LIC also publishes data on dairy cow populations. However, these data are only for the milking cow population and refer to the peak number of cows in milk during the milking season. They are therefore not entirely analogous with the MAF population data.

3.2 Methods used to obtain regional data

3.2.1 Regions

The need to have a readily verifiable and credible source for animal performance data it was decided to base a regional analysis of dairy sector emissions on the 17 LIC regions (Table 1). A further advantage of using these regions is that the data go back to 1990 therefore making it feasible to construct a time series of animal performance that dates back to the base year currently used in the national inventory calculations. A very important point regarding the regional performance data is that aggregated regional data are the national data currently used in the national inventory procedure. This means, for example, that milk yield per cow nationally is the weighted average of the milk yield per cow in each region. The crucial point about this is that the only difference between the regional and national methods used in this report to provide two different emission estimates is that the regional method involves 17 separate calculations and the national method a single calculation. In essence the regional vs national estimates are a test of how linear the national inventory model is; if it was a linear model the regional and national approaches would yield exactly the same answers.

3.2.2 Calculation years

Currently the national inventory data for agricultural emissions are compiled on a calendar year basis. However, to coincide with livestock production cycles the data are actually calculated on a July – June year. To obtain the figures for any particular calendar year (eg 1990) involves calculating two years data on a monthly basis (July 1989 – June 1990 and July 1990 – June 1991) and combining the last six months of the first year with the first six months of the second year. For simplicity this report will only present data on the production year rather than attempt to estimate emissions for a calendar year. This will apply for both the regional and national approach. The years chosen are July 1989 – June 1990 and July 2005 – June 2006. The national data for these two periods are those currently used to obtain the calendar year time series. For simplicity the years will be referred to as 1990 and 2006.

3.2.3 Performance data by region

3.2.3.1 Milk production and composition

Milk production data used in the national inventory calculations comes from two sources, MAF and LIC. Up until 2002 LIC did not include ‘town’ milk supply in their milk production estimates and prior to this date national milk supply totals, which included an estimate of the ‘town’ milk supply, were supplied by MAF (Rod Forbes, personal communication). Since 2002 LIC supply a figure for total milk supply and these data are now used annually. This means that a method had to be developed to estimate the milk supply in each region in 1990 that included the town milk supply. Given that town milk supply is a small proportion of total milk supply (<5%) a simple linear method was used; milk production data for 1990 was obtained for each region from the LIC used to calculate the proportion of milk produced in each region. These proportions were then multiplied by the national milk production reported by MAF to give an estimate of the actual milk produced in each region. This regional milk production total was then divided by the number of milking cows in each region to give per cow production. The milk fat and milk protein percentages for 1990 are not available for each of the 17 LIC regions but for six larger regions, for example the South Island is aggregated into a single region. In the absence of data on each region the relevant data from the six 'mega' regions was assigned to the appropriate sub-region. For the 2006 year data for each of the 17 chosen regions was taken directly from the 2005-6 LIC statistics.

Data on milk production and composition for 1990 and 2006 are presented in Table 2.

3.2.3.2 Cattle weight

The weight of milking cows is important since it is one of the variables that influences dry matter intake and hence CH_4 emissions and nitrogen (N) excretion.

The average live weight of milking cows of the two main breeds (Friesian and Jersey) and crossbreed cows (Friesian x Jersey) are reported by the LIC. These data are reported by age of cow as well as breed. In addition the LIC publish the proportion of each breed in each region and the proportion of each breed nationally. Currently these data are used to produce a weight for the 'average' New Zealand cow; this 'average' is weighted for breed type and age. To produce a value for the weight of the 'average' cow in each region the data on cow weight by breed and age was combined with data on the proportion of each breed in each region (Table 2). For 1990 data on the proportion of each breed are only available for the six 'mega' LIC regions and these data are assigned to the relevant sub-region. For 2006 data are available for all 17 regions. As with milk production a crucial point is that the national data is simply the sum of the regional data so that the primary data source is the same. 2.

3.2.3.3 Dairy cattle populations

Although MAF publish data on an LTA basis the LTA's do not align with the LIC regions. This means that it is not possible from currently published sources to directly map the MAF data onto the LIC regions. It may be possible to re-aggregate the MAF data on a different regional basis but this exercise is far beyond the scope of this project and a simple procedure was therefore adopted. The LIC publish the number of milking cows in each region and this was used to estimate the proportion of the national herd of milking cows in each region. These proportions were then applied to the MAF data on the total number of dairy animals in each class of animal (milkin, non-milking etc) on farm as at June 30th to obtain an estimate of the number of animals in each class in each region (Table 3).

3.2.3.4 Diet quality

The quality parameters used currently in the national inventory are digestibility (D), metabolisable energy (ME) and nitrogen content (N). These data are taken from farm surveys (Clark et al 2003) and are only available on a national basis. These national figures were simply applied to each region.

3.2.4 Calculations

Emission estimates for each region were obtained by running the current national inventory model (Clark 2008) with the appropriate regional data. In essence the model was run 17 times for each calculation year. The emissions for each region were then summed to obtain a national total for 1990 and 2006. These regionally derived national emissions totals could then be compared with the current nationally derived total.

Table 2: Breakdown of live weight and milk production data from dairy cows in New Zealand on a regional basis								
Region	Live weight		Milk (L/cow)		Milkfat (%)		Milk protein (%)	
	1990	2006	1990	2006	1990	2006	1990	2006
Northland	448.93	454.90	2448	3226	4.60	4.89	3.59	3.65
Central Auckland	451.22	452.69	2719	3342	4.65	4.80	3.61	3.66
South Auckland	451.22	452.69	2719	3631	4.65	4.98	3.61	3.72
Bay of Plenty	457.68	460.04	2731	3593	4.66	4.82	3.53	3.64
Central Plateau	451.22	452.69	2719	3681	4.65	4.86	3.61	3.66
Western Uplands	451.22	452.69	2719	3194	4.65	4.94	3.61	3.71
East Coast[1]		460.04		3114		4.20		3.48
Hawkes Bay	454.59	459.54	2839	3538	4.66	4.82	3.61	3.66
Taranaki	435.35	440.62	2789	3371	5.11	5.27	3.89	3.87
Wellington	454.59	459.54	2839	3654	4.66	4.85	3.61	3.68
Wairarapa	454.59	459.54	2839	3412	4.66	5.05	3.61	3.75
Nelson/Marlborough	457.51	458.13	3126	3513	4.45	5.07	3.52	3.75
West Coast	457.51	458.13	3126	3383	4.45	5.20	3.52	3.83
North Canterbury	457.51	458.13	3126	4081	4.45	4.84	3.52	3.77
South Canterbury	457.51	458.13	3126	3995	4.45	4.84	3.52	3.77
Otago	457.51	458.13	3126	4121	4.45	4.79	3.52	3.73
Southland	457.51	458.13	3126	4191	4.45	4.89	3.52	3.80
Current Inventory	446.18	454.50	2746	3568	4.80	4.92	3.52	3.69

[1]data not available for 1990

Table 3: Breakdown of dairy livestock proportions and animal numbers on a regional basis

Region	Proportion (%)		Milking cows and heifers		Non-milking cows and heifers		Calves and rising 1-year olds		Breeding bulls	
	1990	2006	1990	2006	1990	2006	1990	2006	1990	2006
Northland	11.20	6.79	293706	280764	9319	15938	61964	51013	3355	3066
Central Auckland	4.21	2.97	110311	122942	3500	6979	23273	22338	1260	1343
South Auckland	39.73	27.63	1041391	1143276	33044	64899	219704	207725	11895	12486
Bay of Plenty	6.94	4.86	181931	201267	5773	11425	38382	36569	2078	2198
Central Plateau	3.49	5.29	91582	218839	2906	12423	19321	39762	1046	2390
Western Uplands	0.29	0.78	7673	32151	243	1825	1619	5842	88	351
East Coast[1]		0.11		4459		253		810		49
Hawkes Bay	0.13	0.95	3417	39401	108	2237	721	7159	39	430
Taranaki	17.56	12.24	460255	506264	14604	28739	97101	91985	5257	5529
Wellington	3.90	4.84	102141	200073	3241	11357	21549	36352	1167	2185
Wairarapa	3.96	4.06	103830	167789	3295	9525	21905	30486	1186	1833
Nelson/Marlborough	2.03	2.08	53118	85894	1685	4876	11206	15606	607	938
West Coast	2.15	3.26	56422	134776	1790	7651	11903	24488	644	1472
North Canterbury	1.67	8.90	43664	368321	1385	20908	9212	66921	499	4023
South Canterbury	0.61	3.02	15927	125079	505	7100	3360	22726	182	1366
Otago	1.06	4.11	27877	169957	885	9648	5881	30880	318	1856
Southland	1.07	8.13	28134	336442	893	19098	5935	61129	321	3674
Total	100.00	100.00	2621378	4137697	83177	234880	553037	751790	29941	45190

[1]data not available for 1990

4. Results

4.1 Structural changes in the dairy sector since 1990

Table 3 demonstrates clearly that the dairy industry now is structured very differently from the dairy industry in 1990. Milking dairy cow numbers have increased by over 50% and there has been a big increase in the number and proportion of animals located in the South Island; in 1990 approximately 9% of cows were located in the South Island but by 2006 this had risen to approximately 30%. These population increases have not been at the expense of production per cow since not only do these regions have large cow populations but each cow is more productive than their North island counterparts.

4.2 CH_4 and N_2O emissions

Table 4 presents total emissions for 1990 and 2006 calculated using either a regional approach or a national approach. These data show clearly for the three categories of emissions (enteric CH4, CH4 from waste and N2O from pastoral soils) that for 1990 estimating emissions using a national or a regional approach yields very similar results; total CO_2e emissions for 1990 using the regional approach = 7366.86Gg, total CO_2e emissions for 1990 using the national approach = 7413.4Gg, a difference of 46.54Gg CO_2e (0.6% lower from regional approach), However, Table 4 shows that the differences in the two approaches are much larger in 2006 and emissions estimated using the regional approach are lower for all three categories. By 2006 the difference between the two different approaches had grown to 304,7Gg CO2e (regional 12782.29Gg; national 13086.99Gg) meaning that the estimated emissions from the regional approach were now 2.3% lower than those estimated using the national approach. Putting the results in the context of changes from the 1990 baseline the increase in emissions from the dairy sector by 2006 is reduced from 5673.59Gg to 5415.93Gg by calculating emissions on a regional basis (257.66Gg). At $25/tonne this is a potential ‘saving’ of $6.4m/year.

Table 4: Methane (CH_4) and nitrous oxide emissions from the dairy sector in New Zealand calculated using either a regional breakdown or current national average

	Enteric CH_4 (Gg)		CH_4 from waste (Gg)		Nitrous Oxide (Gg)	
	1990	2006	1990	2006	1990	2006
Northland	24.83	26.01	1.03	1.11	0.75	0.78
Central Auckland	9.73	11.56	0.40	0.49	0.57	0.64
South Auckland	91.82	111.39	3.82	4.78	2.72	3.24
BOP	16.17	19.64	0.67	0.84	0.50	0.62
Central Plateau	8.07	21.45	0.34	0.92	0.24	0.62
Western Uplands	0.68	2.97	0.03	0.13	0.02	0.10
EC/HB[1]	0.31	4.24	0.01	0.18	0.13	0.26
Taranaki	41.19	48.49	1.73	2.08	1.23	1.45
Wellington	9.19	19.70	0.38	0.85	0.30	0.61
Wairarapa	9.34	16.04	0.39	0.69	0.29	0.48
Nelson/Marlb[2]	4.92	8.20	0.21	0.35	0.16	0.27
West Coast	5.23	12.67	0.22	0.54	0.16	0.46
North Canterbury	4.04	37.57	0.17	1.62	0.12	1.10
South Canterbury	1.48	12.63	0.06	0.54	0.05	0.41
Otago	2.58	17.41	0.11	0.75	0.08	0.59
Southland	2.61	34.74	0.11	1.50	0.08	0.99
Regional Inventory	**232.18**	**404.71**	**9.68**	**17.38**	**7.38**	**12.64**
Current Inventory	**232.90**	**413.30**	**9.70**	**17.69**	**7.48**	**13.02**
Difference	-0.72	-8.59	-0.02	-0.32	-0.10	-0.38

[1]East Coast/Hawkes Bay [2]Nelson/Marlborough

5. Discussion

5.1 General

The results obtained from the two different approaches described in this report clearly show that it is possible to obtain different estimates for national emissions of agricultural GHG emissions using essentially the same data. The difference between the two approaches is simply that the data are disaggregated into smaller sub-units (regions) which allow non-linearity's in the models used to estimate emissions to be expressed. It is not surprising that the models used in the national inventory estimates are non-linear. The main driver of emissions of both CH_4 and N_2O emissions is the quantity of feed eaten since this affects both CH_4 directly (enteric emissions) and indirectly through emissions from voided faecal and urinary material (CH4 from waste, N_2O from soils). The feed consumption model estimates intake based on achieved performance (milk yield and composition) and liveweight and this estimate of intake is not linearly related to increased performance/weight since each additional unit of milk produced requires a smaller % increase in total feed consumed than the previous unit of milk. This is simply because the proportion of the feed required for maintaining the animal becomes smaller as the quantity of milk produced increases. Therefore the trend to greater regional differentiation in milk yield per cow combined with changes in the distribution of cows between regions means that the non-linear properties of the feed intake model are now more strongly expressed.

This study only looked at using a regional approach to estimate national emissions utilising the same primary data. It is however possible to extend the regional approach by utilising data for each region that are best suited to that region. This adds a further dimension to the region vs national comparison since both the data sources and the calculation unit are different. Two different approaches were used to explore how this would affect the national emission estimates.

5.2 Dairy sector nitrous oxide emissions using drainage classes on a regional basis

A further simulation was carried out on a regional basis, by dividing land drainage classes in each region into three categories (poor, imperfect, and well-drained) based on data from the New Zealand Land Resource Inventory. Different leaching fractions were used for the three different land drainage categories, based on results from NzOnet studies. The total amount of faecal and urinary N excreted by dairy cattle in each region was allocated to these three drainage classes in proportion to the % land area in each drainage class. This has the disadvantage that in practice it would be expected for stocking rates, and hence returns of faecal and urinary N, to be higher on the better drained areas and lower on the poorer drained areas. However, data are not currently available to allocate differential stocking rates to each drainage class. In essence adopting this approach meant that N2O emissions for each region were the sum of emissions from three difference land classes. The results are shown in Table 5. Interestingly emissions for 1990 using the regional method with drainage classes gives a higher estimate of emissions in 1990 but the lowest change in emissions between 1990 and 2006 for any of the three methods used. Going to this extra level of detail would appear to be unwarranted based on the results presented her but their is a strong caveat in that a full assessment requires the availability of stocking rate data on a drainage class basis.

Table 5: Nitrous oxide emissions 1990 and 2006 calculated on (a) a national basis, (b) a regional basis with a national average leaching factor and (c) a regional basis with da separate leaching factor for poor, imperfect, and well-drained soils. All data are Gg N_2O

	National	Regional	Regional with drainage class	
1990	**7.48**	**7.38**	**7.55**	
2006	**13.02**	**12.64**	**12.76**	
Difference	**5.54**	**5.26**	**5.21**	

5.3 Dairy sector emissions using South Island pasture quality data

A parallel MAF funded project to the one reported here (Gibbs 2008) was obtaining data on pasture quality on South Island dairy farms in order to improve the national estimates of pasture quality. This project collected pasture quality data from 70 farms in different parts of the South Island over a period of 2 years. These data consisted of estimates of metabolisable energy content, dry matter digestibility and N content of the diet consumed by grazing dairy cows. A simulation of national emissions farms for 1990 and 2008 was then conducted using either the current national pasture quality values for all regions or the updated values obtained from the Gibbs (2008) study for the South Island and the current national values for all other regions..

Results from this simulation showed that using the updated Gibbs (2008) values for pasture quality reduces the national greenhouse gas emissions (Table 6) particularly for 2006. This is not surprising since they only apply to 8.5% of dairy livestock in 1990 but 29.5% of dairy livestock in 2006. Using the new pasture quality data results in a further reduction of 152.8Gg CO_2 in the 2006 emission estimates; the difference between 1990 and 2006 estimates using a national approach = 5673.59 and the regional approach incorporating the new pasture quality values = 5289.77). This results in a potential saving of 383.82Gg CO_2e - $9.9m/annum at $25/tonne.

Table 6: Methane and nitrous oxide emissions from the dairy sector when calculated on a regional basis using actual pasture quality data for the South Island, accounting for increased supplementary feeding (extra feed), and the current national inventory values

	Enteric methane (Gg)			Waste methane (Gg)			Nitrous oxide (Gg)		
	Regional (new pasture data)	Regional (national pasture data)	National	Regional (new pasture data)	Regional (national pasture data)	National	Regional (new pasture data)	Regional (national pasture data)	National
1990	231.37	232.18	232.90	9.64	9.68	9.70	7.35	7.38	7.48
2006	399.76	404.71	413.30	17.12	17.38	17.69	12.50	12.64	13.02

5.4 Recommendations

MAF should consider moving immediately to estimating dairy cattle emissions on a regional basis. This should be non-contentious since the regional approach uses the same primary data.

MAF should consider incorporating the updated Gibbs (2008) pasture quality data into a regional based dairy cattle inventory. This may be contentious since these data refer to the years 2004-2006 and the question arises as to whether pasture quality changes over time. Do these values over=estimate pasture quality in 1990.

There appears to be no benefit to using regional soil drainage categories at present. Any changes in this direction need to be delayed until regional data are available on stocking rate by drainage class.

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