Guidelines to accompany computerised inventory

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1. Introduction

This booklet is written as a companion to the computerised national enteric methane inventory. It provides a general overview of the methods used to estimate enteric methane emissions from New Zealand ruminants and provides full details of the algorithms used, along with the sources of all data used in the calculations. To illustrate the concepts a worked example is presented. This worked example is a fictitious example and although it is described in terms of an actual year (July 1990 – June 1991) the results do not correspond with the current national inventory values for that year since they are now reported on a calendar year which requires the amalgamation of segments of two separate July – June years.

A brief instruction manual on how to run the computerised inventory is presented in Appendix 3.

1.1 General methodology

The IPCC provides detailed advice and guidelines for the calculation and reporting of anthropogenic greenhouse gas emissions. These are set out in The Revised 1996 Guidelines for National Greenhouse Gas Inventories (IPCC 1996) and the Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC 2000). A key element of the recommended methodologies is the adherence to *good practice* guidelines which support the development of inventories that are 'transparent, documented, consistent over time, complete, comparable, assessed for uncertainties, subject to quality control and quality assurance, and efficient in the use of resources' (IPCC 2000). The New Zealand enteric methane inventory methodology has been developed specifically to conform to IPCC *good practice* guidelines.

Enteric methane emissions, arising mainly from ruminant livestock, are a major component of New Zealand's total greenhouse gas emissions. In IPCC terms they are a *key source category* and emissions should therefore be estimated using a *Tier 2* method.

The New Zealand *Tier 2* methodology for estimating enteric methane emissions comprises three basic steps. A flow diagram is presented in Figure 1 and each step is described in detail below

Step one involves gathering information on the total numbers for each **class** of livestock (dairy cattle, beef cattle, sheep and deer) from national sources and then developing a so called *enhanced* characterisation of population numbers within each livestock class. This *enhanced* characterisation involves the development of **sub-categories** of livestock (e.g. breeding stock, growing stock) and the adjustment of livestock numbers within a calendar year to reflect average seasonal birth, death and slaughter patterns. This means that all breeding animals calve/lamb on the same date each year and animals kept for meat are all killed on the same date. In reality births and deaths will occur over a range of dates but the complexities involved in attempting to model the diversity of farming systems found in practice means that a simplified approach is necessary. To fit in with New Zealand farming practice the population models commence July 1st of each year and the time series starts July 1st 1988.

Step two requires an estimate of the feed intake for the typical animal within each livestock sub-category. For all livestock sub-categories feed intake estimates are based on performance e.g. animal liveweight, liveweight change/milk production, calving/lambing percentage, wool production and feed characteristics. For the major livestock classes (dairy cattle, beef cattle, sheep and deer) intake is estimated using a monthly time step. For dairy cattle, beef cattle and sheep intake is estimated using Australian feeding standards (CSIRO 1991). The Australian feeding standards do not cover deer and information obtained from New Zealand and Australian experiments with grazing deer are used (Fennessy et al 1981; Suttie et al 1987; Mulley & Flesch 2001). .

Step three requires information on the quantity of methane emitted per unit of feed intake for each class of livestock. The information used in the New Zealand inventory to estimate methane emissions per unit of feed intake comes from experiments conducted in New Zealand under a range of farming conditions (For details see Clark et al 2003).

The computation of the methane emissions for each sub category of livestock for each month is as follows:

Population *Intake of each animal*methane emitted/kg intake

Annual methane emissions for each animal **sub-category** are the sum of monthly emissions.
Annual emissions for each **class** of livestock are the sum of the emissions for each sub-category.
Total emissions for New Zealand for a particular year are the sum of the emissions from each livestock class.

Full details of the three steps used to estimate methane emissions from each animal class, along with the principle data sources, and a worked example are presented separately for each livestock species (dairy cattle, beef cattle, sheep and deer) in this booklet.

1.2 Reporting Year

Until the 2005 reporting year New Zealand reported emissions from the livestock sector based upon a July 1 – June 30 reporting year using three year average values. In 2005 a decision was made to (a) change to a January to December reporting year and (b) use annual data rather than three year averages. To obtain a January – December report for each year a time series starting at July 1 1989 is constructed and then segmented to obtain January – December values. This step is not carried out by the inventory program but in a series of Excel spreadsheets that accompany the program.

1.3 Common Reporting Framework

All New Zealand inventory values are reported in a common framework (CRF) using a set of spreadsheets supplied by the UNFCCC. The national methane computer programme does not place its output into the CRF since it contains far more detail than is required. A separate computer programme has been written to abstract data from the national methane inventory programme into the CRF.

2. Dairy cattle

2.1 Population classification

2.1.1 Data Sources

The source of these data is Statistics New Zealand annual census/survey, supplemented by MAF estimates for those years when an annual census or survey was not undertaken. The data available from Statistics New Zealand has varied slightly over time but for every year data are available in the following four categories, which are used as input to the computerised inventory:

- Dairy Cows & Heifers (1 Year and Over) **NOT** in Milk or in Calf
- Dairy Cows & Heifers (1 Year and Over) in Milk or in Calf
- Dairy Breeding Bulls
- Dairy Cattle Total

2.1.2 Sub-category population models

The model developed for dairy cattle populations divides the population into four sub-categories:

- Milking cows & heifers
- Growing females <1 year old
- Growing females 1-2 years old
- Breeding bulls.

The modelled data for 1990 are presented in Table 1.

Table 1. Dairy cattle numbers on July 1 1990 and the month by month changes in population numbers to June 1991.

1990	Milking cows & heifers	Growing females 1-2 years old	Bulls	Growing females <1	Total
JULY	2709509	649221	32143	0	3,390,873
AUG	2662057	649221	32143	626771	3,970,192
SEPT	2662057	649221	32143	626771	3,970,192
OCT	2662057	649221	32143	626771	3,970,192
NOV	2662057	649221	32143	626771	3,970,192
DEC	2662057	649221	32143	626771	3,970,192
JAN	2662057	649221	32143	626771	3,970,192
FEB	2662057	649221	32143	626771	3,970,192
MAR	2662057	649221	32143	626771	3,970,192
APR	2662057	649221	32143	626771	3,970,192
MAY	2744663	42215	32373	626771	3,446,022
JUN	2744663	42215	32373	626771	3,446,022

The assumptions behind the development of the population sub-categories and the month by month changes are as follows.

(a) The total number of animals in July 1990 is equal to the total numbers in the 1990 June 30 census/survey.

(b) Milking cow numbers on July 1st 1990 includes dry cows which are assumed to be sold to slaughter during the July calving period. Between 1990 and 1996 data on the number of dry adult cows was collected by Statistics New Zealand. Since 1996 a combined figure for the number of dry cows and dry heifers is available. Based on the 1990 to 1996 data the number of dry cows is assumed to be 53% of the total of dry cows and heifers.

(c) Growing females 1-2 are assumed to be the previous years calves (minimum 11 months of age as at the 1st July of any year) plus dry heifers (47% of the total of dry cows and dry heifers). These dry heifers are assumed to be kept on farm for the whole year and not sold. The number of growing females 1-2 are not given as a separate category by Statistics New Zealand but are calculated by subtracting Dairy cows & heifers > 1 in milk + Dairy cows & heifers > 1 NOT in milk + dairy breeding bulls from the total number of dairy cattle.

(d) All calves are born on the 1st of August, which is taken to represent the average date of calving in New Zealand, and are classed as growing females <1 for the first 11 months. The number of calves reared is assumed to be equal to the number of growing females 1-2 present at the start of the next census.

(e) Growing females 1-2 are transferred to the milking cow category in May when aged 21 months. The number of animals in the milking cow category in May and June is then equal to the number of milking cows at the start of the next year + the number of dry adult cows at the start of the next year. The number of growing females 1-2 not transferred to the milking cow category equals the number of dry heifers > 1 present at the start of the next year.

(f) Bull numbers are kept constant between July and April but are increased in May so that their number equals the number present at the start of the next year.

(g) No allowance has been made for deaths of animals throughout the year. This is because of the difficulties of having to revise milk yields upwards each month as cows die so that milk yields reconcile with the national totals obtained from official statistics. Data are not readily available on the number of adult dairy cows dying between calving and the end of lactation but the methodology adopted here means that the number of dairy cows on farms in each month may be overestimated slightly. To balance this the annual milk yield of each dairy cow is likely to be slightly underestimated since it is calculated using data on the number of cows present on July 1st and the milk yield for the season starting on July 1st. The net impacts of this will be negligible.

2.2 Feed Intake Estimates

2.2.1 Performance data

Data on milk yield and composition are taken from Dairy Statistics which is published annually by the Livestock Improvement Corporation (LIC). The inputs needed by the inventory programme are:

Total milk processed (millions litres), including town and factory supply

Milkfat %

Protein %

Total milk processed can be taken directly from the Dairy Statistics publication but the % Milkfat and % Protein have to be calculated from data on total milk processed, total milkfat processed and the total protein processed. Prior to 1998 MAF data on total milk processed is used because the LIC data does not include an allowance for town milk supply. Any data presented as litres are converted into kg using a factor of 1.03 (www.mleczarstwo.com)

Annual milk yield per cow is calculated by the inventory programme from data on the total amount of milk processed and the number of milking dairy animals and is not explicitly used as an input. Annual milk yield data is converted automatically by the programme into a monthly milk yield based on a lactation pattern typical of those of a New Zealand dairy cow (Ian Brookes, Massey University, personal communication).

The average weight of a dairy cow has to be entered directly. This is obtained from the LIC publication Dairy Statistics. This publication provides survey data on the weights of dairy cows by age and breed. The weight of an "average" dairy cow is calculated taking into account the proportion of each breed in the national herd and the age structure of the national herd. Data on the breed and age structure are also obtained from LIC Dairy Statistics. A separate Excel spreadsheet is provided to complete the calculations of dairy cow liveweight. This requires the user to input the number and weights of each age class of animal for the required year plus the proportion of each breed in the national herd. Data on dairy cow weights are only available from 1996 onwards. The weights for years prior to this are estimated using the trend in breed weights 1996 – 2001 and data on the breed composition of the national herd in the years 1989 -1995. The adult dairy cow weight is assumed to be the 'average' conceptus-free weight over the whole year and no assumptions as to any within year pattern of liveweight change are made. In reality lactating animals will lose weight over the early part of lactation and gain weight in later lactation but computer simulations show that the impacts of this on estimated annual dry matter intake are negligible...

Growing dairy replacements are assumed to be 9% of the weight of the average cow at birth (approximated from AFRC 1993) and reach 90% of the weight of the average adult cow weight at calving. Growth between birth and calving at two years of age is assumed to be linear. For all years the birth date of all calves is assumed to be August 1.

Data are not available on the weights and performance of breeding bulls and an average weight of 500 kg and a growth rate of 0.5 kg per day has been assumed in all calculations. These data are entered into the programme each year and can be changed if desired. No data are available to substantiate these assumptions but they seem reasonable as the breeding bull population will comprise animals of different breeds, whose mature weights will vary between 560-770kg (CSIRO 1990)), and ages.

Estimating the energy concentration (MJ ME/kg dry matter) of the diet ingested by the "average" grazing ruminant is difficult because of variations due to season, location, climate, species composition and management system. No comprehensive published data are available that allow the estimation of a time series dating back to 1990. Several laboratories routinely analyse pasture samples but they do not have data that allow a time series of pasture energy concentrations dating back to 1990 to be constructed. A single set of monthly ME and digestibility values for all years is therefore used for all years and no input is needed, although there is the option to changes values if required. The values used are presented in Table 2. These data were collected from a 12 month study in 2001-2 of 10 dairy farms as part of a Massey University postgraduate study programme (Ian Brookes, personal communication).

Table 2. Assumed monthly energy concentrations of the diets consumed by dairy cattle. These monthly values apply for all years from July 1988.

Month	MJ ME/kg dry matter	Digestibility (%)
July	12.6	84
August	11.5	79
September	11.7	79
October	12.0	80
November	11.6	79
December	10.8	74
January	11.1	76
February	10.6	74
March	10.7	74
April	11.3	79
May	12.0	81
June	11.7	80

2.2.2 Estimation of energy requirements and feed intake

Energy requirements are calculated automatically by the computer programme using the algorithms presented in the publication "Feeding standards for Australian livestock: Ruminants (CSIRO 1990). These are chosen in preference to other published algorithms (e.g. IPCC 2000, AFRC 1993) because they specifically include methods to estimate the energy requirements of grazing animals. Full details of the algorithms used are presented in Appendix 1. Briefly, the method separates energy requirements into maintenance and production requirements. The maintenance requirement is a function of animal liveweight, the level of productivity and the amount of energy expended in the grazing process. The energy needed for production is influenced by the level of productivity (e.g. milk yield and liveweight gain), physiological state (e.g. pregnant or lactating) and the stage of maturity of the animal. All calculations are carried out at monthly time step by assuming that the same level of performance, liveweight etc applied to every day of the month. An option exists in the programme to change the algorithms if required. Calculated energy requirements are converted to dry matter intakes by dividing by the energy concentration of the diet (Table 2). Estimated monthly feed intakes (kg/month) for each sub-category of animals in 1990 are presented in Table 3.

Table 3. Monthly dry matter intakes per animal (kg) for the four sub-categories of dairy cattle for the period July 1 1990 – June 30 1991.

Month	Milking cows & heifers	Growing females 1-2 years old	Bulls	Growing females <1
JULY	380	129	210	0
AUG	357	158	243	9
SEPT	336	157	231	17
OCT	320	163	228	71
NOV	309	174	233	80
DEC	337	213	275	103
JAN	305	211	262	108
FEB	281	213	256	114
MAR	289	240	280	134
APR	180	216	243	126
MAY	161	161	229	127
JUN	181	181	231	136

2.2.3 Methane emission per unit of intake and total methane emissions

Data on the amount of methane emitted per unit of intake obtained from experiments on New Zealand dairy cows has been summarised in a previous report (Clark et al 2003). The value adopted for the current national inventory calculations is 21.6 g CH_4/kg intake, which equates to a loss of 6.5% of gross energy, assuming that feed has an energy concentration of 18.45MJ/kg. The value of 21.6g/CH_4/kg DMI is used as a default setting in the computer programme and no input is required by the user, although the default value can be changed if required. The default value applies to all categories of dairy cattle except young calves that are on a milk diet for the first two months of their lives and emit no methane.

Table 4 presents estimated methane emissions for each sub category and the total estimated emissions from the dairy sector for the 1990 year. These data are calculated on a monthly basis using the population data of Table 1, the intake data of Table 3 and the figure of 21.6g CH_4/kg dry matter intake.

Table 4. Estimated monthly and total methane emissions for each sub-category of dairy cattle from July 1 1990 –June 30 1991. All units are Gg methane.

Month	Milking cows & heifers	Growing females 1-2 years old	Bulls	Growing females <1
JULY	22.24	1.81	0.15	0.00
AUG	20.50	2.22	0.17	0.00
SEPT	19.32	2.21	0.16	0.00
OCT	18.38	2.28	0.16	0.96
NOV	17.75	2.43	0.16	1.08
DEC	19.38	2.98	0.19	1.39
JAN	17.57	2.96	0.18	1.46
FEB	16.17	2.99	0.18	1.54
MAR	16.61	3.37	0.19	1.81
APR	10.37	3.02	0.17	1.70
MAY	9.36	0.00	0.16	1.73
JUN	10.53	0.00	0.16	1.85
Total	**198.17**	**26.28**	**2.03**	**13.52**

The total estimated methane emissions for the dairy sector in the year July 1 1990 – June 30 1991 are the sum of these four sub-categories (240Gg). For international comparisons an annual methane per head figure is required and this is calculated by the computer programme as the total emission (1990 = 240Gg) divided by the total number of dairy animals present at the start of the year (1990 = 3390873). In the above example (Table 4) for 1990 the figure is 70.78 g CH_4 per year. In addition to estimating an implied emission factor for all dairy animals, the data presented in Table 1 and Table 4 also allow estimates to be obtained of emissions factors for each sub-category of dairy cattle. These are automatically generated by the computer programme. The computer programme also outputs monthly energy requirements, monthly dry matter intake, monthly methane emissions and annual methane emissions for each sub-category for each year along with monthly population data. Since the change to a January –December reporting year the emissions for any single year comprise the January to June values obtained from one July to June dataset (e.g. July 1989 – June 1990) and the July – December values from the following years July-June dataset (e.g. July 1990 – June 1991). These calculations are carried out automatically by a series of spreadsheets which link to the main inventory computer programme.

3. Beef cattle

3.1 Population classification

3.1.1 Data Sources

The source of these data is Statistics New Zealand annual census/survey, supplemented by MAF estimates for those years when an annual census or survey was not undertaken. The data available from Statistics New Zealand has varied slightly over time but for every year data are available in the following three categories, which are used as inputs to the computerised inventory programme:

- Breeding beef cows
- Breeding bulls
- Total beef cattle

The other data needed as input to complete the population characterisation are the number of steers, heifers and bulls slaughtered each year in New Zealand. These data are supplied by MAF Policy.

3.1.2 Sub-category population models

These six data inputs generate 11 sub-categories.

- Breeding beef cows
- Breeding cow replacements (age <1, 1-2, 2-3)
- Breeding bulls
- Growing heifers destined for slaughter (age <1, 1-2)
- Growing steers destined for slaughter (age <1, 1-2)
- Growing bulls destined for slaughter (age <1, 1-2).

The modelled data for July 1st 1990- June 30th 1991 are presented in Table 5. As with dairy cattle the beef sub-category model tries to represent the 'average' situation and does not represent a particular farming system.

3.1.3 Assumptions

(a) The total population in July is equal to the total number in the June 30th census/survey.

(b) The breeding cow population is assumed to be 75% adult cows and 25% heifers. No detailed surveys are conducted to verify these assumptions but they are consistent with data obtained from the Meat & Wool Economic service monitor farms. All breeding cows and replacement breeding females are assumed to calve in September. All calves are assumed to be fully weaned by the end of February. Transfers of replacement females into the breeding cow herd takes place in September and the transfer of older breeding females to slaughter out of the beef herd take place at the end of February.

(c) Replacement breeding females are assumed to calve at three years old and the number of replacement females in the younger age categories (<1 and 1-2 years of age) is the same as the number of animals in the 2-3 year old category.

(d) The number of breeding animals retained is such that, after allowing for a 2% per annum death rate, the number in June is equal to the numbers at the start of the next year.

(e) The total number of animals destined for slaughter is calculated by deducting number of animals in the breeding population from the total number of beef cattle. All animals destined for slaughter are assumed to be killed at two years old. The relative proportion of heifers, steers and bulls in the non-breeding categories is obtained using Statistics New Zealand data and/or MAF Policy slaughter statistics.

(f) The number of non-breeding animals is such that, after allowing for a 2% per annum death rate, the number in June is equal to the numbers at the start of the next year.

Table 5. Beef cattle numbers on July 1 1990 and the month by month changes in population numbers to June 1991.

	Breeding					**Slaughter animals**					
	Breeding cows	Females	Females	Females	Breeding Bulls	Heifers	Heifers	Steers	Steers	Bulls	Bulls
		0 - 1	1 - 2	2 - 3		0 - 1	1 – 2	0 - 1	1 - 2	0 - 1	1 - 2
JULY	1032355	344118	344118	344118	74860	345969	345969	530330	530330	352214	352214
AUG	1030634	343545	343545	343545	75087	345393	345393	529446	529446	351627	351627
SEPT	1373606	343401	342972	342972	75314	344817	344817	528564	528564	351041	351041
OCT	1371317	342829	342400	342400	75540	347360	347360	524107	524107	383439	383439
NOV	1369031	342258	341830	341830	75767	346782	346782	523235	523235	382801	382801
DEC	1366749	341687	341260	341260	75993	346205	346205	522365	522365	382164	382164
JAN	1364471	341118	340691	340691	76220	345629	345629	521495	521495	381528	381528
FEB	1362197	340549	340123	340123	76446	345054	345054	520628	520628	380893	380893
MAR	1055350	351783	351783	351783	76673	344480	344480	519761	519761	380259	380259
APR	1053594	351198	351198	351198	76899	343907	343907	518897	518897	379626	379626
MAY	1051841	350614	350614	350614	77126	343334	343334	518033	518033	378995	378995
JUN	1050090	350030	350030	350030	77353	342763	342763	517171	517171	378364	378364

3.2 Feed Intake Estimates

3.2.1 Performance data

The principle sources of information used when estimating the feed intake of beef cattle are MAF Policy livestock slaughter statistics. The inputs needed by the programme are weight at slaughter of steers, heifers and bulls, the liveweight of breeding bulls, the growth rate of breeding bulls and the liveweight of breeding cows.

The average weight at slaughter of the three sub-categories of growing animals (heifers, steers and bulls) is estimated from the carcase weight at slaughter, assuming that the carcase weight is 50% (the killing out percentage) of the liveweight at slaughter (Barton et al 1994; Khadem et al 1994a; Khadem et al 1994b; Purchas & Grant 1995; Barton & Pleasants 1997; Muir et al 2000)). These slaughter data are taken directly from MAF slaughter statistics for the June year and used as input values and the liveweight is calculated internally. Weights at birth are assumed to be 9% of an adult cow weight for heifers and 10% of the adult cow weight for males Growth between weight at birth and slaughter weight at two years of age is assumed to be linear; growth rates are calculated internally and do not need to be entered. In reality age at slaughter will vary and growth rates will not be linear. However, it was considered that not enough data are available to attempt to develop a more complex model that takes into account differences in birth dates, rates of growth and times of slaughter.

There are no published data on the weights of beef breeding cows analogous to those published for adult milking dairy cows. Data on the carcase weight of adult cows and the number slaughtered are available from the MAF slaughter statistics but these data include both adult dairy cows and adult beef cows. To obtain an estimate of the weights of beef breeding cows a separate calculation tool written in Excel is provided. The data inputs into the Excel spreadsheet are (a) total number of adult female cattle slaughtered, (b) total carcase weight of adult female cattle slaughtered, (c) estimated weight of a dairy cow (see Dairy Section) and (d) total number of beef breeding cows. The calculation tool uses the following procedure. The number of beef cows slaughtered is assumed to be 25% of the total beef breeding cow herd. This is the average replacement rate of beef breeding cows. Other adult cows slaughtered are assumed to be dairy cows. The carcase weight of dairy cattle slaughtered is estimated using the adult dairy cow weights (See Dairy Section) and a killing out percentage of 40% (Rob Davison, Meat and Wool Economic Service of New Zealand, personal communication). The total weight of dairy cattle slaughtered (number × carcase weight) is then deducted from the national total carcase weight of slaughtered adult cows. This figure is then divided by the number of beef cows slaughtered to obtain an estimate of the carcase weight of adult beef cows. Liveweights are then obtained assuming a killing out percentage of 45% (Rob Davison, Meat and Wool Economic Service of New Zealand, personal communication). This "average" liveweight of an adult breeding beef cow applies for the whole of the year and no within year pattern of liveweight change is assumed. This method of estimating the weights of beef breeding is potentially subject to large errors due to errors in estimating killing out percentage, breeding cow replacement rates and in the estimation of dairy cow liveweights. However, no data sources can be identified that allow a direct estimation of beef breeding cow weights.

The milk yield and milk composition of breeding cows is seldom measured. In the inventory method the milk composition is assumed to be the same as that for dairy cows and a total lactation yield of 800 litres per breeding beef cow and heifer has been adopted. This is based on the estimated milk yield of an Angus cow (MAF 1980). These data are entered directly into the computer programme. Approximately 40% of beef calves are not reared by beef cows but supplied by the dairy industry. These calves are assumed to receive the equivalent of 200 litres milk in the form of milk powder (Financial Budget Manual 2002) and no inputs are required. Replacement breeding beef females calve at three years of age, by which time they have reached the same weight as breeding beef cows. Growth between birth and slaughter is linear and is calculated automatically.

A single set of monthly ME and digestibility values for all years is used for all years and no input is needed, although there is the option to changes values if required. The values used are presented in Table 6. These data are obtained from a national survey of 19 beef and sheep farms conducted between March 2001and February 2002. (Litherland et al, 2002).

Table 6. Assumed monthly energy concentrations (MJ ME/kg dry matter) of the diets consumed beef cattle. These monthly values apply for all years from July 1 1988.

Month	MJ ME/kg dry matter	Digestibility (%)
July	10.8	74
August	10.8	74
September	11.4	78
October	11.4	78
November	11.4	78
December	9.9	68
January	9.9	68
February	9.9	68
March	9.6	66
April	9.6	66
May	9.6	66
June	10.8	74

3.2.2 Estimation of energy requirements and feed intake

Energy requirements are calculated automatically by the computer programme using the algorithms presented in the publication "Feeding standards for Australian livestock: Ruminants (CSIRO 1990). Full details of the algorithms used are presented in Appendix 2. All calculations are carried out at monthly time steps by assuming that the same level of performance, liveweight etc applies to every day of the month. An option exists in the programme to change the algorithms if required. Calculated energy requirements are converted to dry matter intakes by dividing by the energy concentration of the diet (Table 6).

The estimated monthly feed intake requirements (kg/month) for each sub-category of animals in 1990 are presented in Table 7.

3.2.3 Methane emission per unit of intake and total methane emissions

Data on the quantity of methane emitted per unit of intake from experiments on New Zealand beef cattle are limited (12 cattle measured 5 times under extensive grazing conditions) and in the absence of a robust data set the value of 21.6 g CH_4/kg intake obtained from dairy cow experiments is used. The value of 21.6g/CH_4/kg DMI is used as a default setting in the computer programme and no input is required by the user, although the default value can be changed if required. The default value applies to all categories of beef cattle except young calves that are on a milk diet for the first two months of their lives and emit no methane.

Table 8 presents estimated methane emissions for each sub category and the total estimated emissions from the beef sector for the 1990 year. These data are calculated on a monthly basis using the population data of Table 5, the intake data of Table 7 and the figure of 21.6g CH_4/kg dry matter intake.

The total estimated methane emission for the beef sector in 1990 is the sum of these 11 sub-categories, 234.62 Gg. For international comparisons an annual methane per head figure is required and this is calculated by the computer programme as the total emission (1990 = 234.62Gg) divided by the total number of beef animals present at June 30 (1990 = 4596594). In 1990 the figure is 51.04 kg CH_4 per year.

The computer programme outputs monthly energy requirements, monthly dry matter intake, monthly methane emissions and annual methane emissions for each sub-category for each year along with monthly population data. A summary page lists the time series of total methane emissions from the beef sector starting at 1990 and the annual beef sector population totals. Since the change to a January –December reporting year the emissions for any single year comprise the January to June values obtained from one July to June dataset (e.g. July 1989 – June 1990) and the July – December values from the following years July-June dataset (e.g. July 1990 – June 1991). These calculations are carried out automatically by a series of spreadsheets which link to the main inventory computer programme.

Table 7 Monthly dry matter intakes per animal (kg) for all categories of beef cattle for the period July 1 1990 – June 30 1991.

	Breeding					Slaughter animals					
	Breeding cows	Females	Females	Females	Bulls	Heifers	Heifers	Steers	Steers	Bulls	Bulls
		0 – 1	1 - 2	2 - 3		0 – 1	1 – 2	0 - 1	1 - 2	0 - 1	1 – 2
JULY	196	93	147	240	326	147	241	201	331	206	337
AUG	238	98	151	286	326	156	248	214	340	218	347
SEPT	193	0	89	141	284	10	143	24	196	34	199
OCT	197	2	97	149	294	19	155	37	214	46	217
NOV	193	7	98	147	284	26	158	47	217	56	220
DEC	247	16	132	192	387	46	219	78	306	89	307
JAN	247	22	138	197	387	57	229	93	320	103	321
FEB	232	25	129	182	349	60	215	97	300	105	302
MAR	181	89	156	218	412	135	262	183	367	192	369
APR	179	92	156	219	399	141	263	193	368	200	371
MAY	193	101	167	238	412	157	281	216	394	222	397
JUN	168	85	138	208	315	133	226	182	311	187	317
Total	**2464**	**628**	**1597**	**2417**	**4176**	**1086**	**2639**	**1565**	**3663**	**1660**	**3704**

Table 8. Estimated monthly and total methane emissions for each sub-category of beef cattle from July 1 1990 –June 30 1991. All units are Gg methane.

	Breeding					**Slaughter animals**					
	Breeding cows	Females	Females	Females	Bulls	Heifers	Heifers	Steers	Steers	Bulls	Bulls
		0 – 1	1 - 2	2 - 3		0 - 1	1 – 2	0 - 1	1 - 2	0 - 1	1 – 2
JULY	4.37	0.69	1.09	1.79	0.53	1.11	1.83	2.35	3.86	1.50	2.46
AUG	5.30	0.73	1.12	2.12	0.53	1.18	1.87	2.50	3.96	1.59	2.53
SEPT	5.71	0.00	0.66	1.04	0.46	0.00	1.08	0.00	2.28	0.00	1.45
OCT	5.83	0.00	0.71	1.10	0.48	0.00	1.17	0.00	2.46	0.00	1.75
NOV	5.69	0.05	0.72	1.08	0.47	0.19	1.19	0.53	2.49	0.45	1.77
DEC	7.28	0.12	0.97	1.42	0.64	0.35	1.64	0.90	3.50	0.72	2.47
JAN	7.29	0.16	1.01	1.45	0.64	0.42	1.71	1.06	3.66	0.83	2.58
FEB	6.84	0.18	0.95	1.34	0.58	0.45	1.61	1.11	3.43	0.85	2.43
MAR	4.13	0.68	1.18	1.66	0.68	1.01	1.95	2.09	4.18	1.54	2.96
APR	4.08	0.70	1.19	1.66	0.66	1.05	1.96	2.19	4.19	1.60	2.97
MAY	4.39	0.76	1.27	1.81	0.69	1.17	2.09	2.45	4.47	1.78	3.17
JUN	3.80	0.65	1.04	1.57	0.53	0.99	1.68	2.07	3.53	1.49	2.52
Total	**64.72**	**4.70**	**11.92**	**18.03**	**6.87**	**7.92**	**19.78**	**17.25**	**42.01**	**12.34**	**29.06**

4. Sheep

4.1 Population classification

4.1.1 Data Sources

The source of these data is Statistics New Zealand annual census/survey, supplemented by MAF estimates for those years when an annual census or survey was not undertaken. The data available from Statistics New Zealand has varied slightly over time and some manipulations of these data are required to obtain the input values required by the computer programme. The data required by the computer programme has 9 sub-categories:

Breeding rams
Breeding ewes
Dry ewes
Ewe hoggets breeding in first year of life
Ewe hoggets dry -not breeding in first year of life)
Ram hoggets
Wether hoggets
Wethers
Lambs
The total number of sheep is also required.

In the current data set collected by Statistics New Zealand data are available in all of the categories except Ram hoggets and Wether hoggets and these are estimated using the proportions derived from those years when data have been collected. In some years an “other” category has been used explicitly by Statistics New Zealand and in others the total number of sheep is slightly more than the sum of the individual categories. In these cases these unclassified animals are assumed to be early born lambs and they are added to the lamb category.

4.2 Sub-category population models

These nine data inputs generate 11 internal sub-categories. These sub-categories are used because there are internal transfers between categories within a year (e.g. lambs become hogget at six months of age) and a larger number of categories are needed to keep track of these within year transfers. However, it is possible to collapse the output down to seven sub-categories for reporting purposes since some of the categories have no entries at certain times of the year (Table 9).

The assumptions behind the population categorisation are as follows;

(a) The total population in July is equal to the total number in the June 30th census/survey

(b) All lambs are born on the 1st September and become hoggets at the beginning of March. All lambs are assumed to be sold by the end of February or transferred into the hogget categories in March. A 2% per annum death rate is assumed for lambs and hoggets in all months.

(c) Ram and wether hoggets present on the 1st July are removed from the population on the 1st September since they became replacement rams/wethers or are sold to slaughter.

(d) Breeding and non-breeding hoggets present on the 1st July are transferred into the two tooth categories on September 1st.

(e) Transfers in and out of the adult breeding ewe population takes place at the end of March. The number in the breeding ewe category is adjusted such that, after allowing for an annual death rate (assumed to be 5% for breeding ewes), the number in June is equal to the number at the start of the next year.

(f) The breeding ram and adult wether populations are assumed to change in a linear manner between the population at the start of the 1990 year and the start of the 1991 year.

Table 9. The sheep population in July 1990 and the month by month changes in numbers in each sub-category to June 1991.

	Rams	Mature breeding ewes	Dry ewes	Growing breeding sheep	Growing non-breeding sheep	Wethers	Lambs
JUL	695105	39499535	1520574	1975656	12400468	1769491	0
AUG	692495	39341537	1484252	1974668	12338465	1765425	0
SEP	689885	39184171	1478315	1974668	9220818	1761360	39776680
OCT	687276	39027434	1472402	1966769	9183935	1757294	39697127
NOV	684666	38871325	1466512	1958902	9147199	1753228	39617733
DEC	682056	38715839	1460646	1951067	9110611	1749162	39538497
JAN	679446	38560976	1454803	1943263	9074168	1745097	39459420
FEB	676836	38406732	1448984	1935489	9037872	1741031	39380501
MA	674227	38253105	1443188	1927748	9001720	1736965	13996087
APR	671617	38379914	1097776	2212834	11755317	1732899	0
MAY	669007	38227006	1093402	2204018	11708483	1728834	0
JUN	666397	38074707	1089046	2195237	11661836	1724768	0

4.3 Feed Intake Estimates

4.3.1 Performance data

MAF livestock slaughter statistics (average carcase weight for the year ending 30th June each year) are used to estimate the liveweight of adult sheep and growing lambs. The only inputs needed each year are the slaughter weight of adult ewes and the slaughter weight of adult lambs. These are converted to liveweights automatically using a killing out percentage of 45% for lambs (Lord et al 1988; Fennessy et al 1990; Scales 1993; Kirton et al 1995a, b; Scales et al 2000) and 43% for ewes (Kirton et al 1985; McCutcheon et al 1993). Lamb birthweight is calculated internally as 9% of the adult ewe weight and all lambs are assumed to be born on the 1st September. All lambs destined for slaughter are killed at 6 months of age. Growth rates are linear between birth and slaughter. In reality lamb age at slaughter will be from 3 months onwards and lamb growth rates will not be linear. However, not enough data are available to develop a more complex model. Breeding and non-breeding replacement ewe hoggets are assumed to grow at the same rate as slaughter lambs until March 1st and then grow at a rate that allows them to reach full adult size at the time of mating aged 20 months (second mating in the case of breeding ewe hoggets) by which time they are categorised as two tooth's. Adult wethers are assumed to be the same weight as adult breeding females.

In common with adult beef and dairy cattle no within year pattern of liveweight change is assumed for either adult wethers or adult ewes. Ewes are assumed to have a total milk yield of 100 litres per lamb and the fat % of the milk is set at 8%. This is the estimated milk yield of a small-medium sized ewe (a UK hill breed) rearing a single lamb producing milk of an average composition (AFRC 1993, CSIRO 1990). Both of these values can be changed by the user. The milk yield is scaled linearly as lambing % increases above 100%. Ewes are assumed to lactate for 3 months and the distribution of milk yield follows the algorithms of MAFF 1984. Based on CSIRO standard reference weights for mature animals (CSIRO 1990), breeding rams are assumed to weigh 40% more than adult ewes and grow at 50g/day. Wool growth (greasy fleece growth) is set at 5kg/annum in mature sheep (ewes, rams and wethers) and 2.5kg/annum in growing sheep and lambs but can be changed by the user. These values are consistent with the total New Zealand wool crop.

A single set of monthly ME and digestibility values is used for all years and no input is needed, although there is the option to changes values if required. The values used are those already presented for beef cattle in Table 6.

4.3.2 Estimation of energy requirements and feed intake

Energy requirements are calculated automatically by the computer programme using the algorithms presented in the publication "Feeding standards for Australian livestock: Ruminants (CSIRO 1990). Full details of the algorithms used for sheep are presented in Appendix 3. All calculations are carried out at a monthly time step by assuming that the same level of performance, liveweight etc applies to every day of the month. An option exists in the programme to change the algorithms if required. Calculated energy requirements are converted to dry matter intakes by dividing by the energy concentration of the diet (Table 6).

The estimated monthly feed intake requirements (kg/month) for each sub-category of animals in 1990 are presented in Table 10.

4.3.3 Methane emission per unit of intake and total methane emissions

New Zealand data on methane emissions from sheep have been summarised by Clark et al (2003). The values adopted for the national inventory are 20.9 g CH4/kg dry matter for adult sheep and 16.8 g CH4/kg intake for sheep under one year old. A change in methane yield as sheep approach or attain maturity is neither fully expected nor fully explained. Nevertheless field experiments consistently point to significantly lower methane yields for immature sheep. These values are set by default in the computer programme but can be changed by the user. Lambs do not emit methane for the first 8 weeks and after that only emit methane from the grass portion of the diet.

Table 11 presents estimated monthly and total methane emissions for each sub category for the 1990 year. These data are calculated using the population data of Table 9, the intake data of Table 10 and the figures of 20.9.6g CH_4/kg dry matter intake for adult sheep and 16.8 g CH_4/kg intake for sheep under one year old.

The total estimated methane emission for the sheep sector in 1990 (July 1990 – June 1991) is the sum of these 7 sub-categories, 517.41 Gg. For international comparisons an annual methane per head figure is required and this is calculated by the computer programme as the total emission (1990 = 517.41Gg) divided by the total number of sheep present at the start of the year (1990 = 57860829). In 1990 the figure is 8.94 kg CH_4 per year.

The computer programme outputs monthly energy requirements, monthly dry matter intake, monthly methane emissions and annual methane emissions for each sub-category for each year along with monthly population data. A summary page lists the time series of total methane emissions from the sheep sector starting at 1990 and the annual sheep population totals.

Since the change to a January –December reporting year the emissions for any single year comprise the January to June values obtained from one July to June dataset (e.g. July 1989 – June 1990) and the July – December values from the following years July-June dataset (e.g. July 1990 – June 1991). These calculations are carried out automatically by a series of spreadsheets which link to the main inventory computer programme.

Table 10. Monthly dry matter intakes per animal (kg) for all categories of sheep for the period July 1 1990 – June 30 1991.

	Rams	Mature breeding ewes	Dry ewes	Growing breeding sheep	Growing non-breeding sheep	Wethers	Lambs
JULY	46	32	25	33	29	25	0
AUG	46	40	25	43	29	25	0
SEPT	40	41	23	44	27	23	0
OCT	41	42	23	45	28	23	0
NOV	40	41	23	45	28	23	2
DEC	54	52	29	58	38	29	9
JAN	54	29	29	36	38	29	33
FEB	49	26	26	33	35	26	34
MAR	57	31	31	40	42	31	27
APR	55	30	30	29	31	30	0
MAY	57	31	31	31	33	31	0
JUN	44	27	25	28	27	25	0
Total	**583**	**421**	**319**	**430**	**385**	**319**	**104**

Table 11. Estimated monthly and total methane emissions for each sub-category of sheep from July 1 1990 –June 30 1991. All units are Gg methane.

	Rams	Mature breeding ewes	Dry ewes	Growing breeding sheep	Growing non-breeding sheep	Wethers	Lambs
JULY	0.66	26.21	0.81	1.10	5.95	0.94	0.00
AUG	0.66	33.19	0.79	1.42	6.08	0.94	0.00
SEPT	0.58	33.40	0.70	1.80	5.13	0.83	0.00
OCT	0.60	33.88	0.72	1.85	5.41	0.86	0.00
NOV	0.57	33.14	0.69	1.84	5.34	0.83	1.42
DEC	0.77	42.09	0.89	2.36	7.15	1.06	6.02
JAN	0.76	23.44	0.88	1.46	7.28	1.06	21.79
FEB	0.69	21.09	0.80	1.34	6.70	0.96	22.17
MAR	0.80	24.44	0.92	1.28	6.41	1.11	6.23
APR	0.78	23.83	0.68	1.06	6.04	1.07	0.00
MAY	0.80	24.97	0.70	1.15	6.43	1.10	0.00
JUN	0.62	21.25	0.56	1.02	5.26	0.88	0.00
Total	**8.29**	**340.94**	**9.12**	**16.59**	**73.20**	**11.64**	**57.64**

5. Deer

5.1 Population classification

5.1.1 Data Sources

Data for total farmed deer are collected by Statistics New Zealand and MAF. There is some discrepancy between these sets of data although the reasons for this are unknown. For consistency the inventory uses Statistics New Zealand data for all years. These data generally comprise total numbers only with no breakdown by breed, age or sex. The input needed by the computer program is therefore a figure for the total number of deer present at June 1^{st} of the relevant year.

5.1.2 Sub-category population models

To obtain a breakdown into sub-categories a model was developed based upon that presented in the MAF Deer Monitor Farm publications (Deer Monitoring Report 2000, 2001, 2002). This divides the population into seven sub -categories:

Breeding hinds
Hinds < 1 year old
Hinds 1-2 years old
Stags <1 year old
Stags 1-2 year old
Stags 2-3 year old
Mixed age and breeding stags

The proportion of animals allocated to each sub-category is based upon data presented in the MAF Deer Farm Monitoring Reports of 2000, 2001 and 2002 and population numbers are adjusted on a monthly basis to take account of births, deaths, transfers between age categories and the time of slaughter. The monthly population numbers in each sub-category for 1990 are shown in Table 12.

Table 12. The total deer population in July 1990 and the month by month changes in numbers in each sub-category to July 1991.

	HINDS			STAGS			
	breeding	<1yr	1-2yr	<1yr	1-2yr	2-3yr	Mixed age breeding
JULY	414012	200807	101842	200807	34316	23911	60220
AUG	413322	200472	101673	200472	34259	23871	60120
SEPT	412632	200137	101503	200137	34202	23831	60019
OCT	411942	199803	101333	199803	34145	23791	59919
NOV	411252	199468	101164	199468	34088	23751	59818
DEC	511725	236150	199298	236150	199411	34048	59718
JAN	511035	235761	199129	235761	199354	34008	59618
FEB	510345	235372	198959	235372	199297	33968	59517
MAR	484474	234983	119175	234983	40157	27980	70469
APR	483672	234594	118978	234594	40090	27934	70352
MAY	482870	234205	118781	234205	40024	27888	70236
JUN	482067	233816	118583	233816	39957	27841	70119

The model makes the following assumptions**.**

(a) The total population in July is equal to the total number in the June 30th census/survey.

(b) The proportions in each category at the start of the year are as follows breeding hinds (0.4), hinds >1 (0.19), hinds 1-2 (0.10), stags <1 (0.19), stags 1-2 (0.03), stags 2-3 (0.02), mixed age breeding stags (0.06).

(c) All deer calves are born in December and young breeding hinds calve at two years of age.

(d) Transfers of breeding animals between age class takes place in December and surplus hinds are sold in March.

(e) The number of breeding hinds is adjusted such that, after allowing for a death rate (assumed to be 2% per annum for all breeding animals), the number in June is equal to the number at the start of the next year.

(f) Growing stags destined for slaughter leave the population in March. The number remaining are such that, after allowing for a death rate of 2% per annum, the number in June is equal to the number at the start of the next year.

5.2 Feed Intake Estimates

5.2.1 Performance data

The weights of growing hinds and stags are estimated from MAF slaughter statistics and the inputs required by the model are June 30th slaughter data for stags and hinds. Liveweight is calculated using a killing out percentage of 55% (Simone Hoskin, personal communication). This is a default value although it can be changed if desired.

No separate data are available to allow calculation of the weights of adult breeding hinds and stags. Fennessy et al (1981) published the liveweights of adult red deer breeding stags and hinds. Based on these data, baseline figures (1989) of 110 kg for hinds and 150 kg for stags are assumed. These weights are automatically updated each year by the same percentage change as that recorded in the slaughter statistics for growing stags/hinds. No within year pattern of liveweight change is assumed. The total milk yield of lactating hinds was assumed to be 240 litres and this is distributed evenly over the first four months of lactation. For calves a common birth date of mid-December is assumed and calf weight at birth is 9% of the adult female weight.

Estimating the energy concentration (MJ ME/kg dry matter) of the diet ingested by the "average" grazing deer is not possible because of a lack of data. . Dairy cattle values are assumed (Table 2) principally because pasture quality has to be high on many deer to farms to allow young breeding animals to reach target weights at the time of mating and for growing animals to reach target slaughter weights in time for the high-priced chilled venison markets.

5.2.2 Estimation of energy requirements and feed intake

Energy requirements are calculated automatically by the computer program. There is no system for estimating the energy requirements of deer analogous to those published for cattle and sheep. An approach similar to that used for cattle and sheep was adopted using algorithms derived from Australian and New Zealand studies on red deer (Fennessy et al 1981; Suttie et al 1987; Mulley & Flesch 2001). This comprises algorithms that estimate the maintenance energy requirements (based upon animal liveweight) and production requirements (based upon rate of liveweight gain, sex, milk yield and physiological state). These algorithms are also presented in Appendix 4. All calculations are carried out at a monthly time step by assuming that the same level of performance, liveweight etc applies to every day of the month. An option exists in the program to change the algorithms if required. Calculated energy requirements are converted to dry matter intakes by dividing by the energy concentration of the diet (Table 2).

The estimated monthly feed intake requirements (kg/month) for each sub-category of deer in 1990 are presented in Table 13.

5.2.3 Methane emission per unit of intake and total methane emissions

When the New Zealand methane inventory methodology was developed no data were available on methane emissions by deer. The value adopted for all sub-categories of deer is 21.25g CH_4/kg dry matter which is the mean of adult cattle and adult sheep. Some data on deer are now available but the data set is too small to obtain a robust deer estimate of the quantity of CH_4/kg dry matter. These values are set by default in the computer program but can be changed by the user. Calves do not emit methane from the milk portion of the diet.

Table 14 presents estimated monthly and total methane emissions for each sub category of deer for the 1990 year. These data are calculated using the population data of Table 12, the intake data of Table 13 and the figure of 21.25 g CH_4/kg dry matter intake.

The total estimated methane emission for the deer sector in 1990 is the sum of these 7 sub-categories, 21.72 Gg. For international comparisons, an annual methane per head figure is required and this is calculated by the computer program as the total emission (1990 = 21.72 Gg) divided by the total number of deer present at the start of the year (1990 = 1035915). In 1990 the figure is 20.96kg CH_4 per year.

The computer program outputs monthly energy requirements, monthly dry matter intake, monthly methane emissions and annual methane emissions for each sub-category for each year along with monthly population data. A summary page lists the time series of total methane emissions from the deer sector starting at 1990 and the annual population totals.

Since the change to a January –December reporting year the emissions for any single year comprise the January to June values obtained from one July to June dataset (e.g. July 1989 – June 1990) and the July – December values from the following years July-June dataset (e.g. July 1990 – June 1991). These calculations are carried out automatically by a series of spreadsheets which link to the main inventory computer programme.

Table 12. Monthly dry matter intakes per animal (kg) for all categories of deer for the period July 1 1990 – June 30 1991.

	HINDS			**STAGS**			
	breeding	<1yr	1-2yr	<1yr	1-2yr	2-3yr	Mixed age breeding
JULY	72	51	80	51	65	78	78
AUG	85	58	95	59	73	87	87
SEPT	81	57	93	59	72	86	86
OCT	100	60	114	61	74	87	87
NOV	100	62	120	64	83	88	88
DEC	115	19	72	17	74	83	83
JAN	112	12	72	11	74	82	82
FEB	111	11	70	10	73	78	78
MAR	117	18	74	18	72	87	87
APR	64	47	70	46	67	81	81
MAY	69	48	75	48	67	80	80
JUN	68	50	76	51	67	81	81
Total	**1093**	**493**	**1011**	**495**	**861**	**997**	**997**

Table 12. Estimated monthly and total methane emissions for each sub-category of deer from July 1 1990 –June 30 1991. All units are Gg methane.

	HINDS			STAGS			
	breeding	<1yr	1-2yr	<1yr	1-2yr	2-3yr	Mixed age breeding
JULY	0.64	0.22	0.18	0.22	0.05	0.04	0.10
AUG	0.75	0.25	0.21	0.25	0.05	0.04	0.11
SEPT	0.72	0.25	0.20	0.25	0.05	0.04	0.11
OCT	0.89	0.26	0.25	0.26	0.05	0.04	0.11
NOV	0.89	0.27	0.26	0.27	0.06	0.05	0.11
DEC	1.27	0.10	0.31	0.09	0.32	0.06	0.11
JAN	1.24	0.06	0.31	0.05	0.32	0.06	0.11
FEB	1.22	0.06	0.30	0.05	0.31	0.06	0.10
MAR	1.22	0.09	0.19	0.09	0.06	0.05	0.13
APR	0.67	0.24	0.18	0.24	0.06	0.05	0.12
MAY	0.72	0.24	0.19	0.24	0.06	0.05	0.12
JUN	0.71	0.25	0.20	0.26	0.06	0.05	0.12
Total	**10.94**	**2.28**	**2.78**	**2.29**	**1.46**	**0.60**	**1.36**

6. References

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7. Appendices

Appendix 1: Algorithms used to estimate the energy requirements of New Zealand cattle and sheep.

Cattle and sheep

The Australian Feeding Standards equations were used in the estimation of energy requirements for cattle and sheep. These estimate the net energy requirements needed for maintenance and production and convert these net energy values to metabolisable energy requirements using an efficiency factors appropriate to the process (e.g. maintenance, milk production, liveweight gain etc).

Maintenance energy requirements (ME_m):

Cattle and sheep

$$ME_m \text{ (MJ/d)} = \frac{K.S.M.(0.28W\hat{}0.75\exp(-0.03A))}{km} + 0.1MEp + \frac{EGRAZE}{km} + ECOLD$$

where:

K	= 1.0 for sheep and 1.4 for cattle.
S	= 1.0 for females and castrates or, 1.15 for entire males.
M	= 1 for animals except milk fed animals.
W	= liveweight (kg).
A	= age in years, with a maximum value of 6 years.
k_m	= net efficiency of use of ME for maintenance.
MEp	= the amount of dietary ME being used directly for production.
EGRAZE	= additional energy expenditure of a grazing compared with a similar housed animal.
ECOLD	= additional energy expenditure in cold stress by animals in below lower critical temperature environments.

ECOLD was not used in the calculation of maintenance requirements as it was found to be unimportant in New Zealand conditions.

km = 0.02 M/D + 0.5

where M/D is the metabolisable energy (MJ ME per kg dry matter) of feeds with a gross energy content of 18.4 MJ per kg dry matter.

EGRAZE (MJ net energy/d) = $((C.DMI(0.9-D))+(0.05T/GF+3)))W$

where:

C	= 0.05 (sheep, goats) or 0.006 cattle.

DMI	= dry matter intake from pasture, kg/d.
DMD	= dry matter digestibility (decimal).
T	= 1.0 or 1.5 or 2.0 for respectively level, undulating or hilly terrain. Assumed to be 1 for dairy cows and 1.5 for sheep and beef cattle.
GF	= availability of green forage (tonnes DM/ ha). Assumed to be 2.5 tonnes.

** *EGRAZE requires DMI to be known but in this report the equations are being used specifically to estimate energy needs and hence intake. To get around this an iterative routine was developed (Ken Louie, personal communication) which "guessed" an initial DMI for use in EGRAZE and then repeated the calculation with an updated DMI obtained from the calculated total energy requirements divided by the energy concentration of the diet. This iterative process was repeated until the DMI was stable: this usually took four to six iterations.*

Energy requirements for gestation ($E_{.g.}$)

Sheep

$E_{.g.}$(MJ/day)= 0.25*Wl.*(Et*0.07372.*exp(-0.00643*t))

Where:

Wl is the lamb birthweight.

Et=10^(3.322-4.979*exp(-0.00643*t))

t= number of days pregnant.

When the average lambing percentage is above 100%, the lamb birthweight is increased by the same percentage.

Cattle

$E_{.g.}$(MJ/day) = 0.025*Wc.*(Et*0.00.0201*exp(-0.0000576*t))

Where:

Wc is the calf birthweight.

Et=10^(151.665-151.64*exp(-0.0000576*t))

t= number of days pregnant.

Cattle and sheep

k_c = 0.13

where k_c is the efficiency of conversion of dietary energy to the energy needed for gestation.

Energy requirements for liveweight gain in non-lactating animals (EBG)

Cattle and sheep

EBG (MJ/kg) = (6.7 + R) + (20.3 – R) / [1 + exp(-6(P-0.4))]

where:

R = [(EBCg/d) / (4SRW $kg^{0.75}$)]-1

EBC = 0.92*LWG

SRW is the Standard Reference Weight (i.e. the mature weight of an adult of that breed).

P = current liveweight/SRW.

k_g = 0.042 M/D + 0.006

where:

k_g is the efficiency of use of dietary energy for liveweight gain.

M/D is the metabolisable energy (MJ ME per kg dry matter) of feeds with a gross energy content of 18.4 MJ per kg dry matter.

Energy requirements for milk production (E_l)

Cattle

E_l = 0.0376*F + 0.0209*P + 0.948

where F is fat and P is protein (g/kg).

Sheep

E_l = 0.0328 F + 0.0025 D + 2.203

where F is fat % and D is the day of lactation.

Cattle and sheep

k_1 = 0.02 M/D + 0.4

where k_1 is the efficiency of use of ME for milk production.

M/D is the metabolisable energy (MJ ME per kg dry matter) of feeds with a gross energy content of 18.4 MJ per kg dry matter.

Metabolisable energy requirements for wool growth (E_w)

E_w (MJ/d) = 0.13 (Fl – 6)

where Fl is the greasy fleece growth. Only growth in excess of 6g/d) contributes to E_w.

Appendix 2: Algorithms used to estimate the energy requirements of New Zealand deer

Deer

The Australian Feeding Standards do not cover deer and values for deer were obtained from several sources. The maintenance energy requirements and the energy requirements for liveweight gain were taken from Fennessey et al (1981) and Suttie et al (1987). The adjustments for pregnancy are adapted from the recommendations of Mulley nd Flesch (2001). Milk yield is that reported by Mulley and Flesch (2001) and the energy value of milk that reported by Kay (1985).

Maintenance energy requirement (ME_m)

ME_m = 0.7 MJ ME/kg LW ^0.75

For pregnant hinds the constant was increased by 10, 30 and 60% respectively in the first, second and third trimesters respectively.

Energy requirements for liveweight gain ($E_{.g.}$)

Hinds $E_{.g.}$ = 56 MJ ME/kg liveweight gain.

Stags $E_{.g.}$ = 37 MJ ME/kg liveweight gain.

Energy requirements for lactation (E_l)

E_l = 8.2 MJ ME litre milk.

Appendix 3: Brief instruction manual on how to run the computerised inventory

Introduction

The agricultural greenhouse gas inventory calculation program (INVENTORY) is purpose written software coded in DELPHI that has its input and output generated using a series of Excel workbooks. INVENTORY comprises four modules (dairy cattle, beef cattle, sheep and deer) that can be run individually or collectively through the same user interface. It can calculate enteric methane (CH_4), direct and indirect nitrous oxide emissions from pasture deposited and stored animal wastes (N_2O) and CH_4 from stored animal wastes. Methane emissions can be calculated without calculating N_2O emissions but N_2O emissions cannot be calculated independently because they rely on data calculated in the CH_4 routines. INVENTORY is also accompanied by a series of linked Excel spreadsheets that (a) convert a continuous time series of monthly values starting in July 1988 into a time series based on calendar years and (b) place the output into the format required for UNFCCC reporting purposes.

Hardware requirements

INVENTORY has been written to run under a Microsoft Windows environment and has successfully been tested under Windows 95 and Windows XP. To avoid issues of installation it is designed to run from an external source (eg pen drive) as well as an internal hard drive. It has no specific memory or storage requirements and should run on any modern PC - until a recent PC upgrade it was running on a 6 year old laptop.

Installation

An installation program is available but because of an over zealous firewall it cannot be sent through via AgResearch email. A CD copy of an installed INVENTORY can be obtained from Darran Austin (MAF) or Harry Clark (AgResearch). The installation program will automatically install a version in a folder named ‘Inventory’, while the CD version is already installed in a under a folder named ‘Inventory’. It is advisable to create a working directory in which to store input and output data.

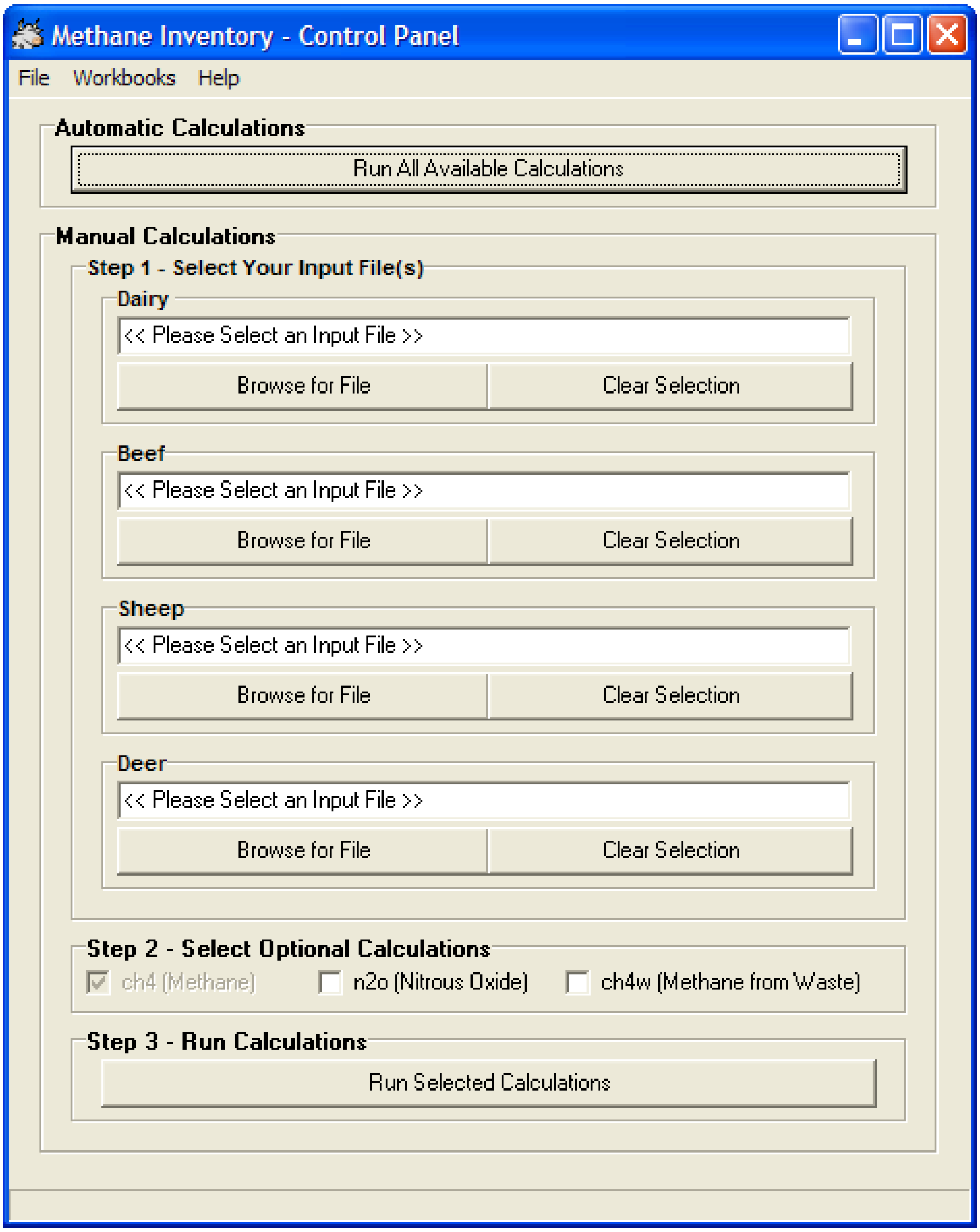
Running Inventory

INVENTORY is started from a file ‘Inventory.exe’ which can be found under the root directory. Right click on this file to create a shortcut and send this to the Desktop. Use this file to start INVENTORY.

Once started, a screen called ‘Methane Inventory – Control Panel’ appears (See diagram) and this is used to select which routines to run. If ‘Browse for file’ is selected in either dairy, beef, sheep or deer a list of input files stored in the INVENTORY ‘Input’ folders appear. If input files are stored in other directories they are accessed from the file dialogue box. Clicking on an appropriate input file will automatically load the input file into the relevant animal type input box. This can be repeated for other animal types if required.

Once the input files are loaded the user needs to select which calculations to perform. Enteric CH4 will automatically be calculated but N2O and waste CH4 need to be selected if required. Finally, the program can be started by clicking on ‘Run Selected Calculations’.

TIP: If all input files are in the ‘Input’ folder contained under the root directory (Methane) of the installed program clicking on ‘Run all available calculations’ will load all input files and run the program.



Once the programme is finished it will ask the user if it is OK to overwrite existing output files. Click Yes. It will then ask if you want to view the file. Click No.

Entering data into the Input Sheets

All input sheets are named as '*species* input' where '*species*' is dairy, beef, sheep or **deer. The installed version of INVENTORY automatically installs an input sheet for each species in a folder 'Input Sheets' which is a sub-directory of Methane, the root** directory. In the version provided the installed input sheets are those used to calculate the latest New Zealand agricultural greenhouse gas inventory (2006 calendar year).

Each input sheet is in a similar format – an Excel workbook with multiple worksheets. The only sheet that needs to be altered annually for the current national inventory is the worksheet '*species* input' where '*species*' is dairy, beef, sheep or deer. Data are arranged in column format and for each New Year data are simply appended to each column. Comments in a cell in each column indicate the source of the columns data. Because of a switch from 3 year averaging to single years currently the dates on the input rows are incorrect and are in fact 1 year behind i.e. row 1989 refers to data for the July 1 – June 30 year commencing 1988. This problem has been solved in a new version which is currently being tested.

INVENTORY takes output from a predetermined directory and filename any existing input files that need to be kept must be moved to a different directory.

Most of the input data needed can simply be taken from published sources without any manipulation but in some cases some manipulation is required. A number of Excel spreadsheet routines have been written to make these calculations easier and these are available upon request from Harry Clark of AgResearch.

Output sheets

All output sheets are written to a folder 'Output sheets' which is a sub-directory of Methane, the root directory. INVENTORY automatically writes the latest calculations to this directory with filenames '*Species* results' where '*Species*' is dairy, beef, sheep or deer.

INVENTORY automatically sends output to a predetermined directory and filename it will overwrite any existing files with the same name. Therefore to save any previous results sheets they must be moved to a different directory.

Manipulation of Output sheets

January – December Years

Two Excel files have been written to convert the current results from INVENTORY, which are in July – June years into the required January – December years. These two files (*Species* results single years July – June from 1988 and *Species* results single years Jan – Dec from 1989 where '*Species*' is dairy, beef, sheep or deer need to be placed in the same directory as the results sheets. They need to be run in turn – select 'Enable Macro's' and 'Update'.

Common Reporting Framework

A separate Excel routine has been written to facilitate rapid transfer of data into the CRF. This was completed in July 2008 and used for 2007 inventory calculations. MAF Policy hold copies of this routine.