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Animal live weight calculations in the NZ Agricultural GHG Inventory Model

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Report for the Ministry for Primary Industries

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agresearch

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1. Executive Summary

New Zealand first used a Tier 2 methodology to report the inventory of agricultural greenhouse gas (GHG) emissions from the four major grazing species (beef and dairy cattle, deer and sheep) in 2003. The Tier 2 methodology means country specific methodologies and emission factors are used for emission estimate calculations.

New Zealand has sought to continually improve reporting of its agricultural GHG inventory, consistent with expectations in the IPCC Good Practice Guidelines. This includes improving the documentation of the models and assumptions behind them, and the use of country specific emission factors.

The existing documentation does not include the methodology and assumptions used to calculate the live weights of the four major grazing species. This report documents the methodology and assumptions currently used to estimate animal live weight (and live weight gain) for beef and dairy cattle, deer and sheep in the Agricultural Inventory Model (AIM), the model used to estimate New Zealand's agricultural GHG emissions.

2. Background

As part of continuing efforts to improve New Zealand's (NZ) annual reporting of greenhouse gas (GHG) emissions by the Ministry for the Environment (MfE), the Ministry for Primary Industries (MPI) has developed an Agricultural Inventory Model (AIM) to estimate agricultural GHG emissions, and supporting documentation.

NZ first submitted a Tier 2 National Inventory Report (NIR) in 2003 (MfE, 2003) based on work by Clark et al. (2003). A Tier 2 inventory methodology uses country specific methodologies and emission factors (EFs), is comprehensive, and designed specifically to capture unique national circumstances. AIM has been developed from this to be consistent with the IPCC guidelines and good practice guidance (IPCC, 2006). The methodology used by AIM includes "disaggregation" of livestock populations (see appendix 7.4) into growing and breeding animals. All calculations made are based on actual animal performance, and all relevant quantities (from live weight to actual emissions) are estimated monthly for the inventory reporting year (July to June).

Changes (e.g. in methodologies) have been described in the annual NIR (e.g. MfE, 2017), and by MPI in a document detailing the methodologies and assumptions used in AIM. The current version of this methodology document (MPI, 2016) reflects 2006 IPCC guideline changes (IPCC, 2006) and other changes in methodology and emission factor values. Notably it does not include a description of the methodology and assumptions used to calculate animal live weight (W) for the four major NZ grazing species (beef and dairy cattle, deer and sheep). Animal live weight and live weight gain (LWG) are both used in the calculations to estimate GHG emissions from these four species.

This report describes the methodology used to calculate animal live weight in the current version of AIM. Assumptions are detailed and parameters used are listed with references where these are known.

3. Tier 2 animal live weight calculation

3.1 General

3.1.1 Annual activity data

AIM's Tier 2 methodology uses activity data (AD) that is updated annually based on published information from industry and government (mostly MPI) sources. This activity data includes livestock performance characteristics that are used to calculate animal live weights (e.g. average carcass weight at slaughter, and the average live weights of mature breeding animals).

3.1.2 Other data required

Other information needed for animal live weight calculations includes birth and slaughter dates, the time required to reach maturity, and killing out (KO) percentages. KO is used to convert between slaughter carcass weights (CW) and animal live weights (see §3.5.1). One set of values are specified in AIM, and applied to all years i.e. it is not supplied as annual AD.

3.1.3 Mature and growing animals

Each species is split into several classes (MPI (2016) and Table A.7.4). Animals classed as mature are deemed to have reached their mature live weight and their live weight does not change. Animals in classes representing growing animals are grown over a specified time period either for slaughter, or as replacement breeding females. Each class of growing animals follow the same general pattern of growth i.e. from birth to an end live weight.

3.1.4 Growth in 12 month periods from birth

Growth is calculated in monthly steps from the animal's birth month until it is slaughtered or reaches maturity. Animal live weights are calculated for each month in a given year of the animal's life. These weights are then mapped to the inventory reporting year (July to June) using an offset based on the birth month. For example, an animal born in August has its calculated birth weight assigned to August, then 11 subsequent (monthly) live weights are calculated, with the last (the animal is now 12 months old) assigned to July. Animals will change age class (in the population models) after each 12 month period of growth. For example, the above animal (born in August), becomes a rising two year old (e.g. R2) in the August 12 months after its birth.

3.1.5 Final live weight

The final live weight is either the average live weight at slaughter (if grown for slaughter) or, for animals grown as breeding replacements, usually, the average live weight of a mature breeding female (see §3.5).

3.1.6 Live weight gain

Live weight gain is calculated as the average change in live weight over a specified period, e.g. the lifetime of the animal.

3.1.6.1 Animals grown as breeding replacement stock

Average live weight gain for animals grown as breeding replacements is calculated from the difference between the estimated live weight at birth and at maturity (calculated from carcass weight and KO). The difference in live weight is divided by the duration of growth (i.e. number of days growth) based on birth date and date of slaughter to give average LWG. Refer footnote 3 of table 4.

3.1.6.2 Animals grown for slaughter

Average live weight gain for animals grown for slaughter is calculated from the difference between the estimated live weight at birth to the average live weight at slaughter. If necessary, live weight at slaughter is calculated using carcass weight (supplied as activity data) and an appropriate KO. This difference in live weight is divided by the duration of growth (i.e. number of days growth from birth to slaughter) to give average LWG. See A.7.3.2 for detailed weight calculations of lambs being grown for slaughter, which includes two slaughter dates.

3.2 Birth dates and birth live weight

Live weight at birth for all species is estimated as a percentage of the live weight of the average breeding female; 9% for females, and 10% for males (Table 1). These values were approximated from AFRC (1993) as reported in Clark et al. (2003). Current birth dates for the four species (Table 2) follow changes in the 2011 and 2012 MPI Agricultural Inventory Advisory Panel. The birth weight calculated is assigned to the birth month of the animal, in the youngest age class for the species.

Table 1. Birth live weight as percentage of mature breeding female live weight.

Gender	Birth live weight[1] (%)
Female[2]	9%
Male	10%

[1] As percentage of mature breeding female live weight.

[2] Applied to all lambs.

Table 2. Birth dates by species.

Species	Birth date
Beef	20 September
Dairy	1 August
Deer	19 November
Sheep	11 September[1]

[1] Thomson et al, 2010.

3.3 Linear growth for growing animals

Growth rates of all growing animals are linear for any growth period e.g. birth to slaughter, or birth to the end live weights for replacement breeding animals (Table 3).

This assumption is unchanged from that described by Clark et al. (2003) who stated that "it was considered that not enough data were available to attempt to develop a more complex model" that took into account differences in birth dates, rates of growth and times to slaughter or maturity. Clark et al. (2003) acknowledged that in reality there would be periods of non-linear growth.

Table 3. Distinct linear growth periods by species and class.

Species	Class(es)	Period of linear growth
Beef	All slaughter classes	Birth to slaughter
	Breeding replacements	Birth until reach mature breeding cow live weight
Dairy	Breeding replacements	Birth to 1st calving[1]
Sheep	Lambs	Birth to 1st slaughter
	Lambs for 2nd slaughter[2]	1st slaughter to 2nd slaughter[3]
	Lambs to maturity	1st slaughter to cull ewe slaughter
Deer	Slaughter hinds (R1[4])	Birth to 1st slaughter (15 months)
	Slaughter hinds (R2)	1st slaughter to maturity (2 years old)
	Slaughter stags (R1)	Birth to 1st slaughter (15 months)
	Slaughter stags (R2, R3)	1st slaughter to maturity (3 years old)

[1] 90% of the breeding female W when nearly 2 years old. The 90% value is based on Clark et al. (2003) and recommended target calving live weights available from Dairy NZ (2018). They then join the class of mature milking cows and are assigned their W, making an instantaneous jump in live weight.

[2] 2nd lamb slaughter was introduced through MPI Agricultural Inventory Advisory Panel in 2011 to reflect some lambs (currently 16%) being held back to get winter premium. See Appendix 7.3.2.

[3] LWG in this period is 50% of LWG in period from birth to 1st slaughter.

[4] R1 means an animal growing from 0 (birth) to 1 year old i.e. a "rising" 1 year old, etc.

3.4 Live weights of mature animals

The live weight of mature, mainly breeding, animal classes is assumed to have no within year pattern of live weight change, i.e. live weights are assumed constant over a given year. The average live weight for breeding females is supplied as activity data, while assumptions for the live weight of breeding males (Clark et al. 2003) were necessary due to lack of data (see footnotes in Table 4). These classes all specify a non-zero LWG for breeding males (Table 4) as part of the activity data set for their species, as LWG is required for nitrous oxide (N_2O) calculations.

Other classes of animal are also assumed to have constant live weights, e.g. wethers (Table 4). The methodology for estimating deer live weights now follows Suttie (2012); see Appendix 7.2 for details.

Table 4. Classes of animal with no within year pattern of live weight change.

Species	Class	Live weight (kg)	LWG[1] (kg/day)
Beef	Breeding bulls	600[2]	0.5[2]
	Breeding cows[3]	Annual AD	
Dairy	Breeding mature bull	500[4]	0.5[4]
	Breeding cows[5]	Annual AD	
Deer[6]	Breeding hinds		0
	Breeding stags		0
Sheep	Rams	n/a[7]	0.05
	Wethers	Adult breeding ewe	0

[1] Required for use in N_2O calculations. Also see 2 and 4.

[2] Specified as constant in activity data. Data were not available on the weights and performance of breeding bulls and an assumption was made that their average weight was 600 kg and that they were growing at 0.5 kg per day on average (Clark et al. 2003). Also see 4.

[3]Calculations made by MPI external to AIM. Clark et al. (2003) noted that "This "average" live weight of an adult breeding beef cow was assumed to apply for the whole of the year and no within year pattern of live weight change was 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 live weights. However, no data sources could be identified that allowed a direct estimation of beef breeding cow weights to be made".

[4] As for beef bulls, except live weight assumed 500kg. These assumptions described as a "conservative estimate as the breeding bull population will comprise animals of different breeds, whose mature weights will vary between 560-770kg (SCA, 1990), and ages." (Clark et al. 2003). [5]Assumed to be the 'average' conceptus-free weight over the whole year and no assumptions were made as to any within year pattern of live weight change (Clark et al. 2003).

[6] Suttie (2012) revised deer, including a pattern of live weights to use. See Appendix 7.2.

[7] Assumed to be 40% greater than adult ewes (Clark et al. (2003) referencing SCA (1990)).

3.5 End live weights

3.5.1 Slaughter animals

Animal classes from each species are grown for slaughter over a specified period for each species. Live weight at slaughter is estimated using a specified killing out percentage and slaughter (carcass) weight, i.e.

$$W = CW/(KO/100)$$

Activity data for slaughter (carcass) weight for beef and sheep are sourced from livestock slaughter statistics available from the Ministry for Primary Industries (http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/agriculture/). These are used to estimate the live weights of adult sheep and lambs at slaughter, assuming killing-out percentages of 40 percent for ewes and 45 percent for lambs (Thomson et al., 2010), and 50% for beef cattle (Muir and Thomson, 2008).

Live weights of growing hinds and stags at slaughter are estimated from Deer Industry New Zealand statistics, assuming a killing-out percentage of 55%. Live weights of breeding stags and hinds are based on a report by Suttie (2012).

3.5.2 Breeding replacement animals

Breeding replacement animal classes from each species are grown over a period specified for each species. This is typically longer than slaughter animals, resulting in a slower growth rate. These animals eventually enter the mature female breeding herd appropriate to the species, e.g. as mature breeding ewes for sheep.

3.5.2.1 Dairy and beef breeding cows

Estimation of the live weights of mature breeding beef cattle is problematic due to lack of reliable data. For dairy cattle a special calculation method is used by MPI that organises data from industry organisations (e.g. the Livestock Improvement Corporation (LIC)). The derived average live weights for mature breeding dairy cows are then used to derive an estimate of the average live weight for mature breeding beef cows. These calculations and their associated activity data are outside the scope of this report, and are carried out by MPI as part of the preparation of activity data for the annual inventory submission. These mature breeding cow live weights are used to estimate cattle birth weights, and thus the live weight growth curve (albeit linear) and live weight gains.

3.6 Assignment of monthly live weights

Live weights for growing animals are calculated by simple linear interpolation using the average LWG applicable for an animal class in a given month, and the days elapsed since the mid-point of the birth month. The actual calculations are done in a step-wise manner moving from one month to the next. The live weights are assigned to the mid-point of each month starting with the birth weight assigned to the animal's birth month.

For mature and non-growing animals, the constant live weight values specified for the class are assigned to each month, and there is a non-zero LWG value read (as activity data) as this (non-zero LWG) is required for N_2O calculations.

4. Recommendations

The methodology document produced by MPI is updated to incorporate a description of the calculation of animal live weights and live weight gains. The live weight calculations

used are mostly based on Clark et al. (2003) which cited a lack of data as the reason for using a linear growth model. These assumptions (e.g. linearity of growth) and availability of suitable data sources could be revisited.

5. Acknowledgements

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7. Appendix

7.1 Glossary of common terms and abbreviations

Table A7.1. Glossary of common terms and abbreviations.

Term	Description
AD	Activity data
AIM	NZ Agricultural GHG Inventory Model (MPI)
CW	Carcass weight. Weight of animal carcass after the slaughter process.
ME	Metabolisable energy
MfE	Ministry for the Environment
EF	Emission factor
GHG	Greenhouse gas
KO	Killing out percentage (%), converts animal live weight to its weight after slaughter i.e. CW = W x (KO/100) e.g. typically ~40% for sheep.
LWG	Live weight gain
W	Animal live weight. W (and not lwt) used for consistency with SCA (1990).
MPI	Ministry for Primary Industries
NIR	National Inventory Report, published by MfE
Tier 2	More detailed methodology to estimate GHG emissions, can use country specific methodologies and/or emission factors

7.2 Deer live weights

Suttie (2012) updated many aspects of the methodologies for deer, including a tabulation of live weights for red deer stags and hinds. This pattern of live weight change (Table A7.2) is now used to calculate revised estimates of stag and hind live weights. The existing AD in AIM for mature breeding stags and hinds live weights (relative to the 1989 values) is scaled by the live weights in Table A.7.2 to yield stag and hind live weights.

Table A.7.2. Red deer live weights in June (Suttie (2012), Table 12).

Year[1]	Hind live weight (kg)	Stag live weight (kg)
1990	100	133
1992	104	138
1998	109	145
1999	104	139
2000	110	147
2002	111	148
2003	109	145
2004	109	145
2005	113	150
2011[2]	113	150

[1] Intermediate years estimated by linear interpolation.

[2] Values after 2011 assumed the same as 2011.

7.3 Example calculations of animal weight

7.3.1 Physiological animal growth mapped to inventory reporting years

All animals are grown in 12 monthly (i.e. yearly) steps from birth until maturity or slaughter. Animal weights are calculated monthly, and mapped to the inventory reporting year (July to June). When the birth month is July, this is trivial, in other cases the weights are mapped to July to June. For an animal born in August, its weight when 12 months old will be mapped to July, while its birth weight will be recorded for the month of August. See the example for lambs in section 7.3.2 to see this mapping.

7.3.2 Lambs

The growth of lambs proceeds from birth to slaughter, and is characterised by two slaughter dates. The second slaughter date for lambs was introduced to reflect the practice of carrying over some lambs to obtain a winter premium.

A specified fraction of lambs (84%) are slaughtered at the first slaughter date. The growth rate to the first slaughter date is reduced (by 50%) as the remaining animals are grown to the second slaughter date.

Table A.7.3.2 tabulates the calculation of lamb live weights from birth to the end of its first year of life using AD for 2015. Note slaughter dates are at the end of the month, and the live weight calculated needs to be adjusted to allow extra days growth. In all AIM calculations for metabolisable energy (ME), DMI etc., the W value for the mid-point of the month is used.

Adult breeding ewe CW = 25.097kg (AD)
KO% = 40%
Adult breeding ewe W = 25.097/(40/100) = 62.742kg
Lamb birth weight = 62.742 * 0.09 = 5.647kg
Lamb CW = 18.117kg (AD)
Lamb slaughter live weight = 18.117/(45/100) = 40.259kg

Birth date = 11Sep
1st slaughter date = 28Feb (171 days growth) LWG = (40.259-5.647)/171 = 0.202
2nd slaughter date = 31Aug (184 days growth) LWG = 0.5 * 0.202 = 0.101

Table A.7.3.2. Lamb live weights, growing for 12 months.

Month	W (mid-month) (kg)	W (end-month) (kg)
Jul	54.175	
Aug[1]	57.313	59.033
Sep[2]	6.456	
Oct	12.630	
Nov	18.804	
Dec	24.977	
Jan	31.252	
Feb	37.223	40.057[3]
Mar[4]	41.828	
Apr	44.915	
May	48.002	
Jun	51.089	

[1] Adjusted W (end-month) to 31Aug to match 2nd slaughter date. These lambs are ~12 months old.

[2] Birth month. Adjusted W to 15Sep (4 days growth at 0.202kg/day from birth, 11Sep).

[3] Adjusted W to 28Feb, to match the first slaughter date.

[4] Animals from mid-Feb to Aug are assumed to grow at a reduced LWG, 50% of initial LWG value.

7.4 Animal details by species and class

Key parameters used in calculation of animal live weights in AIM Table A.7.4 (MPI, 2016).

Table A.7.4. Listing of all animal classes by species with details used by AIM for live weight calculations.

Species	Class category	Class	Birth Date	Days growth to slaughter, cull or maturity	Killing out percentage (%)
Dairy	Breeding	Milking cows mature		639 (cull or maturity)	50 (all cattle)
	Breeding replacements	Growing heifers 0-1	1Aug		
	Breeding replacements	Growing heifers 1-2			
	Male	Breeding Bulls			
Beef	Breeding replacements	Breeding growing cows 0-1	20Sep		
	Breeding replacements	Breeding growing cows 1-2			
	Breeding replacements	Breeding growing cows 2-3			
	Breeding	Breeding mature cows		1095 (maturity)	50 (all cattle)
	Male	Breeding Bulls – mixed age			
	Slaughter	Slaughter heifers 0-1			
	Slaughter	Slaughter heifers 1-2		730 (slaughter)	
	Slaughter	Slaughter steers 0-1			
	Slaughter	Slaughter steers 1-2		730 (slaughter)	
	Slaughter	Slaughter Bulls 0-1			
	Slaughter	Slaughter Bulls 1-2		730 (slaughter)	
Sheep	Breeding	Breeding ewes		396 (1st lamb slaughter to cull ewe slaughter)	40% (sheep)
		Dry ewes			
	Breeding replacements	Growing breeding sheep			
	Slaughter	Growing non breeding sheep			
		Wethers			
	Slaughter	Lambs	11Sep	171 (1st slaughter), 184 (2nd slaughter)	45% (lambs)
	Male	Rams			
Deer	Slaughter	Hinds 0-1	19Nov		55% (all deer)
	Slaughter	Hinds 1-2		466 (slaughter 28Feb)	
	Breeding	Mix age breeding hinds			
	Slaughter	Stags 0-1			
	Slaughter	Stags 1-2		466 (1st slaughter 28Feb)	
	Slaughter	Stags 2-3		629 (from live weight at 1st slaughter to full grown, 3 years total)	
	Male	Mix age breeding stags			