OVERSEER® Technical Manual

Technical Manual for the description of the OVERSEER® Nutrient Budgets engine

ISSN: 2253-461X

Animal model

June 2018

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Published by:

OVERSEER Limited

http://www.overseer.org.nz

The OVERSEER owners are:

Ministry for Primary Industries (MPI), Fertiliser Association of New Zealand Inc. (FANZ) and AgResearch Ltd (AgResearch).

Preface

OVERSEER® Nutrient Budgets

OVERSEER® Nutrient Budgets (OVERSEER) is a strategic management tool that supports optimal nutrient use on farm for increased profitability and managing within environmental limits.

OVERSEER provides users with information to examine the impact of nutrient use and flows within a farm and off-farm losses of nutrients and greenhouse gases. An OVERSEER nutrient budget takes into account inputs and outputs and the key internal recycling of nutrients around the farm.

See the OVERSEER website for more detailed information: http://www.overseer.org.nz

This technical manual

OVERSEER is made up of a user interface and an engine. These two components work together to enable users to generate nutrient budget reports. The Technical Manual provides details of the calculation methods used in the OVERSEER engine.

The OVERSEER engine is based on extensive published scientific research. Technical information about the model's development and use can be found in a growing number of conference proceedings and peer-reviewed papers. Given the ongoing upgrades many of the earlier papers no longer reflect the current version.

The Technical Manual chapters provide detailed descriptions of the methods used in the OVERSEER engine's main sub-models. The Technical Manual sets out the underlying principles and sources of data used to build the model engine. It is a description of the model as implemented, and hence references may not now be the most appropriate or cover the range of data of information currently available, or may not necessarily be the most up to date. If the source of some information and/or assumptions is not known or could not be found, this is acknowledged.

The chapters will continually be updated to reflect the current version.

If readers have feedback or further technical information that they consider could contribute to the future development of the model, please provide feedback via the website http://www.overseer.org.nz.

Scientific contribution to model development:

OVERSEER is a farm systems model covering a wide range of science disciplines. Since the model's inception, a large number of researchers from many disciplines and organisations have contributed to its development.

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Animal model

1. Introduction

1.1. Background

A key requirement of OVERSEER® Nutrient Budgets (OVERSEER) is the estimation of both animal dry matter (DM) and nutrient intake. The initial model was based on stock units (SU), which is a measure of annual pasture DM intake. Early surveys indicated that SU's were not always calculated properly to take into account differences in animal productivity, duration animals were on the property, or the effect of imported supplements. Thus, total SU's were not always estimated reliably, particularly under high production systems or trading systems. A method was added to calculate revised stock units (RSU, Woodford and Nicol, 2004) based on a metabolic energy sub-model. This was fortuitous because it allowed OVERSEER to expand easily to a monthly model and incorporate greenhouse gas emissions using methods similar to those used in the New Zealand greenhouse gas inventory.

Animal data can be entered using two methods: entering stock numbers on a monthly basis for dairy, sheep, beef, deer and dairy goat enterprises (monthly stock numbers option); or entering peak cow numbers for dairy, and revised stock units (RSU, Woodford and Nicol, 2004) for sheep beef and deer. For both options, information on animal production can also be entered. Other animal types (non-dairy goats, pigs, camelids, and horses) can be entered on an annual basis using RSU's.

This chapter focuses on how the data used to describe animals present on the farm is linked with animal characteristics so that animal metabolic energy (ME) requirements can be estimated. The relationship between chapters of the technical manual and animal ME requirements is shown schematically in Figure 1. Thus, this document should be read in conjunction with other chapters. In particular, calculation of animal ME requirements are dependent on estimation of animal properties (Characteristics of Animals chapter), and the animal model which sets up parameters for use in the animal metabolic energy requirements sub-model (Animal Metabolic Energy Requirements chapter).

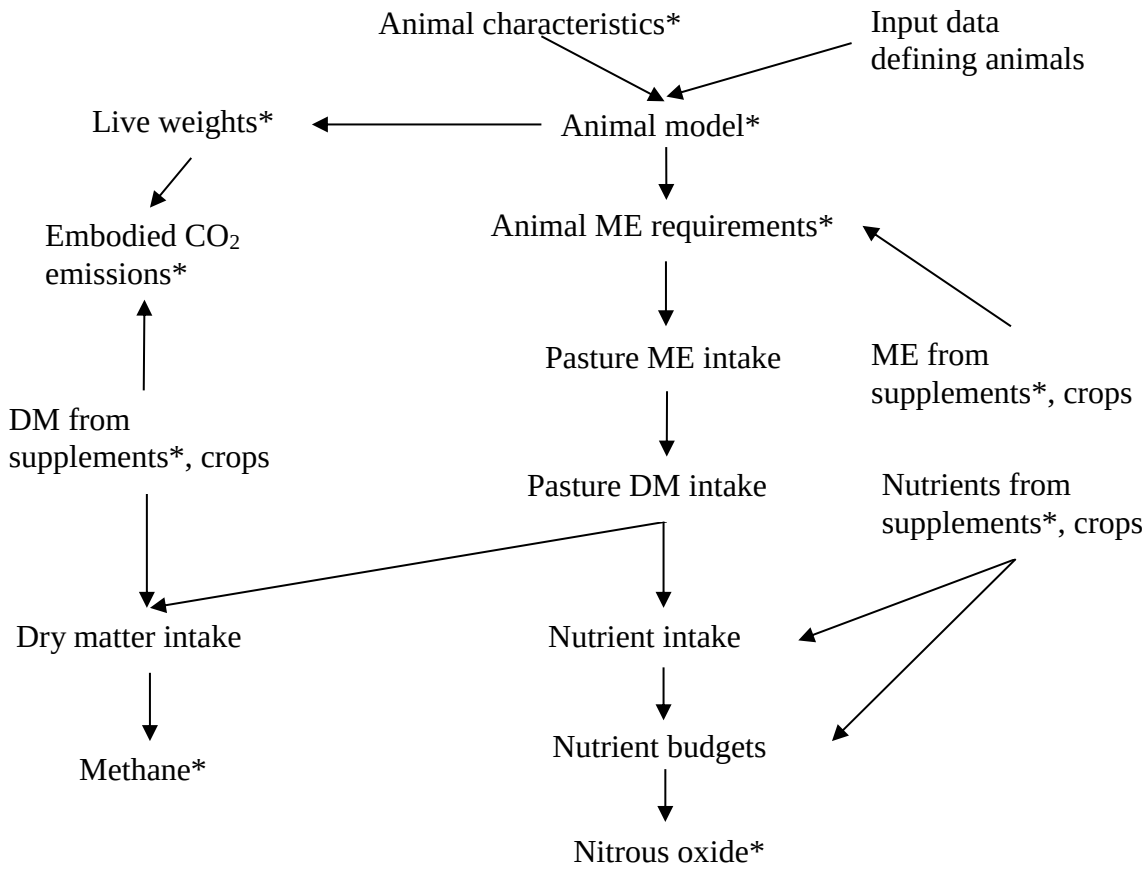

Figure 1. Schematic diagram of the relationships between some OVERSEER sub-models. * Sub-models that have been described in this or other chapters of the Technical Manual.

1.2. Workings of the Technical Manual

The aim of the Technical Manual is to provide a level of detail so that users of OVERSEER can clearly see the underlying principles and sources of data used to build the components of the model. This chapter is part of a series of chapters that make up the technical manuals currently under development to explain the inner working of the OVERSEER engine.

In the equations in this manual, units are shown using standard parentheses ( ). Cross-references to other equations and sections within this manual or to other chapters of the technical manual are shown using 'square parentheses' [ ]. Equations with multiple '=' options are cascading alternatives in the order they are considered. The condition is shown on the right hand side. The variable names used are generally shortened names of the property, and this naming convention is similar to the convention used in the OVERSEER engine model.

1.3. Abbreviations and subscripts

Abbreviations

DM dry matter

CO_2 carbon dioxide

ME metabolic energy (MJ)

RSU Revised Stock Units (6000 MJ ME intake per year) (Woodford and Nicol, 2004).

Subscripts

antype animal enterprises dairy, dairy replacement, sheep, beef, deer, dairy goats, or other.

nut the nutrients nitrogen (N), phosphorus (P), potassium (K), sulphur (S), calcium (Ca), magnesium (Mg) and sodium (Na), and either chloride (Cl) or the calculated value for the change in acidity.

2. Entering stock data

Animal data can be entered using two methods: entering stock numbers on a monthly basis for dairy, sheep, beef, deer and dairy goats (section 2.1); or entering peak cow numbers for dairy (section 2.2), and revised stock units for sheep beef and deer (section 2.3.1). In addition, other animal types (non-dairy goats, pigs, camelids, horses) can be entered using RSU's (section 2.3.2).

2.1. Monthly stock numbers

Animal numbers can be entered on a monthly basis using the specific stock numbers option. For each enterprise, mobs of animals are entered by selecting the breed and class, and entering the number of animal present on the farm each month. For dairy cows, the first three classes are for three milking mobs that can have different calving dates and drying off dates.

If stock numbers are entered monthly, when estimating the portion of animals on farm structures (section 2.4.4), the proportion each month is based on the number of animals that are present on farm that month.

2.1.1. Definition of a mob

For the purpose of OVERSEER, a herd is defined as a group of animals that live together or are kept together. A mob is defined as a group of animals with the same characteristics (sex, breed, age, weight range, breeding status). In many cases, a mob and a herd may be the same (for example many dairy herds).

The animal numbers are entered as mobs in a 12 month cycle starting in July and ending in June. The numbers entered are the number on the farm – the animals may be on blocks, or on wintering pads/animal shelters.

For breeding mixed aged animals (breeding females and males), the mob is generally present all year, but numbers each month may change as culls are sold, replacements brought in, or they are grazed off. A mob starts from the 1st July and ends 30th June.

Trading mobs, and mobs of replacement animals may only be on the farm for a portion of the year. A mob starts from July or when the animals are brought onto the farm, and ends when the animals are removed from, or remain on, the farm or June of the following year. Thus a 'farm' with a mob of 5-month-old animals brought in December and fattened, and sold in September of

the next year is entered as two OVERSEER mobs: the first from December to June, start age of 5 months with a source of 'Brought' and a fate of 'On farm', and the second from July to September, with a stating age of 12 months and a source of 'On farm' and a fate of 'Sold'. Source and Fate are defined in the next section.

2.1.2. Data inputs

Each animal class can have inputs of breed, weight and the source and fate of animals, or inputs are assumed (default) based on the class selected. Weights are used to determine base animal weights and growth rates that are used as inputs into the animal metabolic requirement sub-model (Animal Metabolic Energy Requirements chapter), and to estimate embodied CO_2 associated with transport of animals (Carbon Dioxide, Embodied and Other Gaseous Emissions chapter). Each animal class has an entered or default source and fate associated with them. The source and fate information is used to estimate live weight is brought in or sold from the farm, and the net nutrients that leave the farm as product. It is also used in the greenhouse gas sub-model to estimate embodied CO_2 emissions associated with transport. For sheep and beef enterprises, the option for selecting whether hoggets or heifers are mating is also available.

The additional inputs when using the monthly stock number option for adding stock numbers are defined as:

- Mature weight — weight (kg) can be entered or is assumed to be the standard reference weight. Mature weight (kg) for growing animals is defined as the maximum weight the average animal in the mob will attain if fully grown (animals > 5 years old). Optional input.
- Herd weight — for breeding females, mature weight is replaced by herd weight. Herd weight is the maximum herd weight (kg) excluding the conceptus. This is typically the weight immediately post calving for dairy animals, or in autumn for other animal enterprises. Optional input.
- Start live weight — weight (kg) at the start of the year can be entered by the user, or is estimated from the start age, mature weight and a typical age live weight distribution. Either start live weight or start age must be entered for growing (non-breeding mob) animals.
- End live weight — weight (kg) at the end of the year can be entered, If absent it is estimated: by dividing carcass weight by a typical dressing-out percentage; or using age at the end of the year, mature weight and a typical age live weight distribution. Optional input.
- Carcass weight — if fate is sold to works, then average carcass weight (kg) can be entered. Optional if live weight at end is not entered.
- Start age — age of the first entry of animal numbers in the row. Either start live weight or start age must be entered for growing (non-breeding mob) animals.
- Source — options are 'Brought', 'On-farm' or 'Weaned'. On-farm animals should also be reflected at the end of another row of younger age animals that remain on farm. Must be entered for growing (non-breeding mob) animals.

- Fate — options are ‘Sold store/removed’, ‘Sold works’ or ‘Remain on-farm’. Sold store is all other animals not sold to the works, including those for breeding or fattening on another farm. Animals that remain on farm at the end of the year (July) should also be reflected in the beginning (June) of another row of older age animals. Must be entered for growing (non-breeding mob) animals.

The animal class selected also determines the input data options that are shown. For the different categories of animal classes, the following inputs are shown.

- Mixed age breeding — maximum weight during the year. Used for mixed aged breeding females and males.
- Breeding females — used when a specific age and/or weight is known, hence live weight at the start and end of enters for a mob, and start age is shown.
- Breeding replacements — all options except carcass weight and fate are shown. These animals are assumed to enter the breeding mob. If source is ‘Weaned’ then only mature weight and end live weight are shown. The mating of hoggets and heifers can also be specified for sheep and beef respectively.
- Non-breeding — all options are shown except when source is ‘Weaned’, in which case, start live weight and start age are not shown, and the sex (female, male, mixed) of the juvenile mob (lambs, calves, fawns) is shown.

Additional inputs are shown in Table 1.

Table 1. Additional inputs and units for monthly stock number input options.

Enterprise	Data	Units	Comment
Dairy	Replacement rate	%	Default
	Calving data	date [1]	Default
	Milk solids yield [2] (protein + fat)	kg/year	Compulsory
	Lactation length	Days	Default
	Milk volume [2]	litres/year	Default
	Fat	kg/year	Default
	Calves fed milk powder	T/F [3]	False by default
Sheep	Lambing percentage	%	Compulsory
	Replacement rate	%/year	Default
	Mean lambing date	date [1]	Default
	Mean weaning date	date [1]	Default
	Weaning weight	kg	Default
	Greasy wool production	kg	Default
Beef	Calving percentage	%	Default
	Replacement rate	%/year	Default
	Mean calving date	date [1]	Default
	Mean weaning date	date [1]	Default
	Weaning weight	kg	Default
Deer	Fawning percentage	%	Default
	Replacement rate	%/year	Default
	Mean fawning date	date [1]	Default
	Mean weaning date	date [1]	Default
	Weaning weight	kg	Default
Dairy goats	Replacement rate	%/year	Default
	Mean kidding date	date [1]	Default
	Total Milk solids yield [2] (protein + fat + lactose)	kg/year	Default Default
	Weaning weight	kg	Default

[1] date is entered as day and month.
[2] milk in the vat.
[3] T/F is a True/False check box selection

2.1.3. Generate tool

There is an option to generate numbers for a breeding animals (multiple mobs) based on a simplified range of inputs.

2.1.3.1. *Data inputs*

The inputs for dairy cows are:

- Dominant breed. Options are listed in the Characteristics of Animals chapter.
- Peak number of cows milked.
- Whether or not peak numbers are constant over time or decrease due to a default culling regime.

- Number of breeding males
- How replacements are managed, with options of ‘Calves reared on farm’, ‘Off farm from 9 months’, and ‘On farm permanently’.
- Grazing off – monthly percentage of animals grazed off. See section 2.4.4.

The generate option also uses inputs from outside the generate option which are displayed as default values to be updated if required. These are:

- Replacement rate.
- Date for median calving.

For sheep, beef and deer animals the data inputs are:

- Dominant breed, with options listed in the Characteristics of Animals chapter.
- Number of breeding females (mid-winter numbers)
- Number of breeding males
- For deer, the number of velveting stags
- For sheep, whether hoggets are lambed
- For Beef, whether R2 heifers are calved
- Average maximum weight of breeding cows (default based on breed)
- Live-weight of non-replacement female animals sold
- Winter grazing off – monthly percentage of animals grazed off from April to September

The generate option also uses inputs from outside the generate option which are displayed as default values to be updated if required. These are:

- Replacement rate
- Date for median lambing, calving or fawning
- Weaning rate
- Weaning date
- Weaning weight

For dairy goats, the options are:

- Dominant breed, with options listed in the Characteristics of Animals chapter.
- Number of breeding females (mid-winter numbers)
- Number of breeding males
- Average maximum weight of breeding goats (default based on breed)
- Winter grazing off – monthly percentage of animals grazed off from April to September

The generate option also uses inputs from outside the generate option which are displayed as default values to be updated if required. These are:

- Replacement rate
- Date for median kidding

The procedure used to generate numbers for a breeding mob is described in section 2.1.3.2.

2.1.3.2. *Generate procedures*

The number of breeding female animals is estimated as described in section 5.2.4, and then reduced if grazing off occurs. Average herd weight is estimated as described in the Characteristics of Animals chapter.

If the number of male animals (rams, bulls or stags or velvet stags) is entered, then that number is allocated to each month, and no grazing off occurs. Weight for male animals is estimated from the female mature weight as described in the Characteristics of Animals chapter.

The number of replacements is estimated as the number of breeding females times the replacement rate. For dairy, replacements are grazed off from birth if the dairy replacement enterprise is not declared, otherwise the estimated number of dairy replacements remain on farm until weaning, up to 9 months or permanently depending on the user-selected replacements management option.

The number of replacements assigned to the beginning and end months of the period they are on farm is proportional to the number of days in the month the animals are estimated to be on the farm. Hence, if the birth date is mid-July, and the replacements are on for 3 months, then the number of replacements is halved for July and October.

Beef and deer replacements leave at age 24 months, sheep at age 12 months. The estimated number of replacements are then allocated to mobs, starting at the month weaning occurred. For each mob:

- Mature weight is set to the mature weight for female animals as described in the Characteristics of Animals chapter.
- The start weight is the weaning weight for the first mob of replacement animals, and is estimated for other mobs as shown in Equation 1 where the given age used is the age of those animals in the mob on farm in the earliest month.
- The end weight is estimated as shown in Equation 1 where given age used is the age of those animals in the mob on farm in the last month.

Weight at a given age is estimated as:

Equation 1: $\text{weight} = \text{weanweight} + (\text{matureweight} - \text{weanweight}) * (\text{femalelwt}_{\text{Age}} - \text{femalelwt}_{\text{weanAge}}) / (1 - \text{femalelwt}_{\text{weanAge}})$

weanweight is the weaning weight (kg) [Characteristics of Animals chapter].

matureweight is the entered or default mature weight (kg) [Characteristics of Animals chapter].

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

Age is the age (months) that the weight is required.

weanAge is the age at weaning (months) [Characteristics of Animals chapter].

The number of non-replacement animals (the difference between the number of animals weaned and the number required for replacements) is added as trading stock from the month of weaning until 12 months of age, or from weaning until the age where the entered estimated live weight of the non-replacement females is reached. The number of animals weaned also includes those from hoggets (sheep) or R2 heifers (beef) if the relevant options are selected.

2.2. Using peak cow numbers

The peak cow sub-model allows the following inputs:

- Breed, with options listed in the Characteristics of Animals chapter.
- Peak number of cows milked.
- Whether the peak number of cows is constant over time or decreases due to a default culling regime. The culling regime is estimated as described in section 5.2.4.
- If replacements are declared as being on the farm, then an option describing how replacements are managed is provided. Options are
    - 'Calves reared on farm' – calves are on farm until weaning at 3 months from mid calving date.
    - 'Off farm at 9 months' – calves are on farm for 9 months from the mid calving date.
    - 'On farm permanently'.
    - When replacements are not declared, calves are assumed to be removed at birth.
- Replacement rate.
- Average mob weight.
- Proportion of animals grazed off each month.

The peak cow sub-model allows three calving mobs by specifying median (mid) calving date, drying off date and the proportion of milking animals in that mob.

When using the peak cow numbers data entry option, the number of animals over the year is either constant or varies with a default culling practice (section 6.2). When estimating the portion of animals grazed off or on farm structures (section 2.4.4), the proportion each month is based on the number of animals that are present on farm, that is, peak cow number less culls, if numbers are not constant.

2.3. RSU based systems

Revised stock units (RSU) by definition are a measure of animal ME requirements; 1 RSU is defined as being equivalent to 6000 MJ ME intake per year (Woodford and Nicol, 2004).

2.3.1. Sheep, beef and deer

The total number of RSUs is entered. OVERSEER assumes that stock management is similar to that of a breeding farm, that the total RSU reflects all animals (breeding and trading) on the farm, and that the method used to estimate RSU's is similar to the one used in the metabolic sub-model

(Animal Metabolic Energy Requirements chapter). For beef animals, the proportion of RSU's that are male animals is also entered.

The proportion of animals grazed off each month (section 2.4.4) can also be entered for each animal enterprise.

On each block, there are options for 'Finishing' for beef and deer, and 'Merino' for sheep. Finishing assumes that the block is mainly used for trading animals where product removal as live weight is higher than a 'breeding' operation. A 'Merino' block is a dryland sheep production system.

2.3.2. 'Other' enterprise

RSUs for 'Other' enterprises are calculated using entered animal numbers and pre-defined animal classes and associated RSUs per animal (Table 2), or user defined classes.

Table 2. RSU per animal for pre-defined animal classes in the 'Other' enterprise.

Animal type and class	RSU/animal
Goats [1]	
Bucks and does to 1 year	0.5
Angora does	1.1
Feral does	0.9
Feral wethers and bucks	0.5
Horses [2]	
Pony in 'light work' or 'turned out'	6
Pony broodmare and foal	8
Small hack (up to 15.2 hands) in light work	8
Small hack broodmare and foal	10
Large (500-600 kg) hack in light work'	12
Yearling thoroughbred	12
Large hack broodmare and foal	14
Camelids	
Alpacas [3]	0.8
Llamas [4]	1.6

[1] Source: Woodford and Nicol (2004).
[2] Source: Animal Welfare Advisory Committee (1993).
[3] Source: Southern Alpaca Stud (2007).
[4] Source: Source unknown.

For horses, the above RSU's per animal are based on an estimated 50% utilisation of the available pasture (Animal Welfare Advisory Committee, 1993).

2.4. Animal distribution

Pastoral blocks must have animals on them consuming pasture. Animals can be on fruit crop blocks consuming pasture, and on fodder crop or cropping blocks consuming either pasture or the crop.

2.4.1. Pastoral blocks

On pastoral blocks, the animals present and the percentage of pasture production on that block that is consumed by each animal enterprise on that block can be entered, or a default distribution is assumed. The default distribution is based on the ME intake of each animal enterprise at the farm level. The user can select which animal enterprises are present on a block, and the ratio of intake between each animal enterprise on a given block.

In addition, the months animals are grazing a particular block can also be set. By default, animals are assumed to graze blocks all months for pastoral blocks, in months where canopy closure is less than full for fruit crops.

In addition, if sheep are present, then whether the block is grazed predominately by merino animals can be selected. For beef and deer, if the blocks are finishing blocks, defined as blocks where above average product removal is expected, can be selected.

2.4.2. Cropping and fruit crop blocks

On cropping and fodder crop blocks, the proportion of the crop fed to each animal enterprise is specified.

On cropping and fodder crop blocks, animals start grazing sown permanent pasture starting on the third month after sown to allow for establishment.

2.4.3. Non-farm animals

On fruit and cropping blocks, the animals need not be a farm based animal. These are termed 'Non-farm animals'. Non-farm animals allow grazing of cropping or fruit crop blocks without having to enter specific information about the animal. An example of its use would be an orchard that allows neighbours sheep to graze the inter-row area or cropping contractors where the crop rotation is known but not necessarily the animals that may be grazing the crop.

2.4.4. Percentage of animals on farm structures

Percentage of animals is the percent of animal days each month animals are on pads or are feeding in the milking shed, or are grazed off). So 50% could mean all cows in the herd are on for half the month, half the herd are on throughout the month, or some combination, such as 70% of the herd is on the pad for about 3 weeks.

2.4.5. On farm structures

Animals can also be placed on farm structures, that is, feed pad, wintering pad/animal shelter or a winter pad/loafing pad. These are defined in the Introduction chapter. The proportion of animals each month is defined in section 2.4.4.

3. Enterprise outputs

Apart from animal inputs, the OVERSEER model is an enterprise based model. Thus the allocation of supplements, crops, animals to a block, and embodied greenhouse gas emissions are at an enterprise level.

3.1. Model structure

The OVESEER engine requires an estimate of the ME requirements from each animal enterprise for each month. For each mob entered into the monthly stock numbers input page, or for dairy enterprise entered using the peak cow number option, default values for a typical animal in that mob is defined and ME requirements for the typical animal are estimated using the metabolic energy requirements sub-model. The inputs and outputs from the metabolic energy requirement sub-model are described in section 3.10. The estimated animal ME requirements are then accumulated up to a mob basis, and all the mobs added together to give ME requirements for an animal enterprise (sections 5 and 6). ME requirements for an animal enterprise can also be estimated based on entered RSU's (section 7). The relationship between animal input data structures and ME requirements is shown in Figure 2.

Enterprise monthly ME requirements are then provided to the pasture requirement sub-model, which estimates enterprise based animal pasture intake and nutrient intake.

This section describes other enterprise based outputs that are used by other sub-models within OVERSEER.

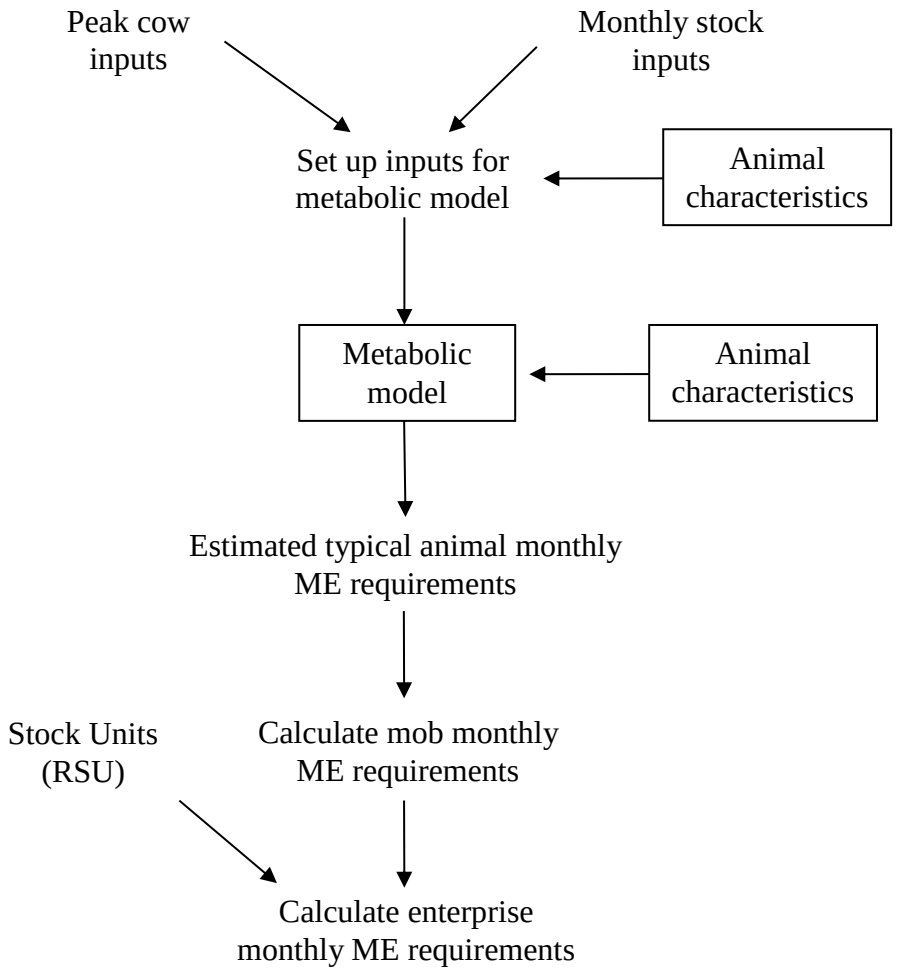

Figure 2. Relationship of animal input structures and estimation of a ME requirements. The stages in boxes use procedures outlined in the Characteristics of Animals and Metabolic Energy Requirements of Animals chapters.

3.2. Enterprise based ME requirements

The following list is the estimated enterprise based ME requirements that are used within OVERSEER. For animals prior to weaning from the mother, ME requirements is the requirements excluding requirements that are supplied by milk, that is, it is the ME requirements that are meant by pasture, supplements and crops. All except MEintake are used in the estimation of embodied greenhouse gas emissions (Carbon Dioxide, Embodied and Other Gaseous Emissions chapter). MEintake is used to estimate ME intake of pasture, and in the distribution routines for supplements, crops and pasture. MEyoung is also used to apply different enteric methane emissions to young and old sheep (Methane chapter).

- MEintake — ME requirements of the animal enterprise per month (MJ ME/month).
- MEintakeBreeding — ME requirements of the animal enterprise's breeding mob(s) (MJ ME/year). This includes ME associated with raising young up to weaning. Dairy and dairy replacement enterprises are combined.

- MEWinterOff — ME requirements of the animal enterprise per month that would be consumed while the animals are wintered off (MJ ME/month).
- MEyoung — total ME requirements of sheep less than 1 year of age (MJ ME/year).
- MEyoungtrade — total ME requirements of sheep less than 1 year of age from trading mobs (MJ ME/year).
- MEmaleDeeer — ME requirements of male deer (MJ ME/year).
- MEintakeDairyRep — ME requirements of the dairy replacement enterprise per month that would be consumed when dairy replacements are grazed off (MJ ME/month).

3.3. Sheep breed proportion

For sheep, the proportion of total ME requirements of the sheep enterprise that are attributed to the Merino, and Corriedale breeds, and to Crossbreds (all other sheep breeds) is used in the estimation of wool production. The proportions are estimated as:

Equation 2: pMerino = totMerino / totME

Equation 3: pCorriedale = totCorriedale / totME

Equation 4: pCrossbred = totCrossbred / totME

totMerino and totCorriedale is the total animal ME requirements for sheep with the Merino and Corriedale breeds, and totCrossbred is for other breeds (MJ ME/year).

totME is the total ME requirements for sheep (MJ ME/year).

3.4. Proportion of ME requirements while lactating

The proportion of ME requirements while lactating for breeding females and milking mobs for a given month is used to determine whether animals are lactating in that month, and to proportion estimated values between lactating and non-lactating phase in a given month. For lactating female dairy cows and dairy goats, the proportion of intake while lactating each month is estimated as:

Equation 5: $RatioLactation_{mon} = SumRatio_{mon} / MEintake_{antype, mon}$

MEintake is the ME requirements for animal enterprise per month (MJ ME/month).

where the proportion of intake while lactating for each mob is aggregated as:

Equation 6: $SumRatio_{mon} = \sum(MEmonth_{mon} * PropIntakeWhileLactating_{mon} * Nanimals_{mon})$

MEmonth is the monthly ME requirements for a mob (MJ ME/month).

PropIntakeWhileLactating is the the proportion of intake while lactating each month for a mob [Animal metabolic energy requirements chapter].

Nanimals is the number of animals in a mob each month.

3.5. Live weight

Live weight is used in the estimation of product removal [section 8.2.2], and embodied greenhouse gas emissions (Carbon Dioxide, Embodied and Other Gaseous Emissions chapter). The category of enterprise-based live weights and corresponding variable name calculated is shown in Table 3. Throughout the manual, the mob based variable name for live weight replaces 'liveweight' with lwt, for example, liveweightonfarm is the enterprise variable name, and lwtonfarm is the mob-based variable name.

Table 3. Category of live weight changes estimated and associated variable.

Category	Live weight (kg/year)
Reared on farm	liveweightonfarm
Breeding mob reared on farm	liveweightonfarmBreeding
Brought[1]	liveweightbrought
Sold to store[2]	liveweightsoldstore
Sold to works	liveweightsoldwork
Wintered (grazed) off	liveweightWinterOff
Male deer sold	liveweightsoldMaleDeer

[1] animals brought on to the farm, either as purchases or transferred on.
[2] includes animals transferred from the farm.

The estimation of embodied greenhouse gas emissions (Carbon Dioxide, Embodied and Other Gaseous Emissions chapter) also requires estimation of the live weight distance travelled (kg.km) for several categories shown in Table 5. For each category, the weight distance travelled (kg.km) is estimated as:

Equation 7: $\text{liveweightxxxDist} = \sum(\text{lwtxxx}) * \text{xxxDist}$

xxx represents one of the code categories in Table 4.
liveweightxxxDist is the weight distance travelled (kg.km/year).
lwtxxx is the live weight (kg/year) for each mob for the given category.
xxxDist is the entered of default distance travelled (km) [Carbon Dioxide, Embodied and Other Gaseous Emissions chapter].

Table 4. Category of live weight distance changes estimated and associated variables for live weight distance and for distance travelled.

Category	Code	Live weight distance (kg.km)	Distance (km)
Brought	Brought	liveweightBroughtDist	BroughtDist[1]
Wintered (grazed) off	WinterOff	liveweightWinterOffDist	WinterOffDist[1]
Replacements off	RepOff	liveweightRepOffDist	ReplaceDist[1]
Replacements returned	RepReturn	liveweightRepReturnDist	ReplaceDist[1]

[1] defined in the Carbon Dioxide, Embodied and Other Gaseous Emissions chapter.

3.6. Live weight changes for sheep

For the greenhouse gas allocation, live weight is split between lambs and other mobs for both trading and breeding mob types. Animals with a start age less than nine months are assumed to

be lambs. The actual age at sale may be greater than nine months, with a maximum possible age of 21 months. Thus, live weight sold (kg/year) either to store or to the works is added to the variables shown in Table 5 when the mob type and age conditions are met.

Table 5. Allocation of sold live weight to variables.

Variable	Mob type	Age condition
lwtsoldlamb	Breeding	Start age < 9 months
lwtsoldmutton	Breeding	Otherwise
lwtsoldlambtrade	Trading	Start age < 9 months
lwtsoldmuttontrade	Trading	Otherwise

3.7. Enterprise area

When distributing or allocating block based inputs or calculated values to farm based entities such as animal enterprises, an enterprise based area is used. This is estimated for each block as:

Equation 8: $EntAreaBl_{antype} = area_{block} * blockSU_{block,\ antype} /100$

$area_{block}$ is the block area (ha).

$blockSU_{block,\ antype}$ is the percentage of the total block intake eaten by a given animal enterprise from a given block (section 3.10.2).

and for the enterprise as a whole as:

Equation 9: $EntArea_{antype} = \sum_{block} EntAreaBl_{antyp}$

3.8. RSU per animal

The number of RSU per animal is used to: initialise sub-models when an estimate of animal energy requirements is required to begin calculations, or provide estimates of animal numbers when RSU systems are used. RSU per animal are shown in Table 6.

Table 6. RSU per animal for each enterprise.

Enterprise (Source)	RSU per animal
Dairy	7.0
Dairy replacements	4.0
Sheep	1.2
Beef / dairy grazing	5.0
Deer	2.0
Dairy goat	1.2
Others	1.4

3.9. Number of RSU

If the monthly stock number option is used:

- aside from the ‘Other’ enterprise, the number of RSU for each enterprise is estimated as total animal ME requirements (MJ ME/year) divided by 6000 MJ ME/year.
- the number of RSU for the ’Other’ enterprise is estimated as described in section 7.6.

Otherwise:

- if the peak cow option is used, the number of RSU for dairy and dairy replacement enterprises is estimated as animal ME requirements (MJ ME/year) divided by 6000 MJ ME/year.
- the number of RSU for sheep, beef and deer enterprises is the entered number of RSU.
- the number of RSU for the ‘Other’ enterprise is estimated as described in section 7.6.

The number of RSU is used before animal energy requirements are calculated. An initial value is required, but the actual value is not that important. If peak cow numbers are entered, an initial value is estimated as

Equation 10: RSU_{dairy} = MilkSolids * 14.3 * 10.5 / 6000

Milksolids is the entered milk solids production (kg milksolids).
14.3 is an estimated amount of DM intale required to produce 1 kg milk solids (kg DM/kg milksolids).
10.5 is a typical pasture ME content (MJ ME/kg DM).
6000 is by definition of a RSU (MJ ME/year)

For dairy replacements, it is estimated as:

Equation 11: $RSUd_{airyreplacements} = RSU_{dairy}$ * RepRSU

RepRSU is 0.01, 0.04 and 0.17 for dairy replacements removed from the farm at weaning, at 9 months, or permanently on the farm.

If stock number data is entered using the stock reconciliation option,

Equation 12: $RSU_{antype} = count_{antype}$ * $RSUanimal_{antype}$

count is the sum of maximum number of animals in each column.
RSUanimal is the number of RSU per animal [section 3.8].

3.10. Animal distribution

The distribution of animals is used when allocating feed or the transfer of nutrients. A series of Boolean (true/false) variables are used to identify where animals are, and hence in some cases the types of feed they are consuming (section 3.10.1). The proportion of pasture eaten by an animal enterprise in a block is used to allocate block-based values to different animal enterprises.

3.10.1. Animal locations

Throughout the model, the placement of animals are used when allocating feed or the transfer of nutrients, or when checking for consistency in input data. The frequently used locations variables are:

- For a given enterprise

    - Whether that enterprise is on the farm.
- For a given block
    - Whether any animal enterprise is consuming pasture on that block.
- For a given animal enterprise and month
    - Whether an animal enterprise is on any block in a given month
    - Whether an animal enterprise is consuming pasture on any block in a given month.
- For a given animal enterprise, block and month
    - Whether animal enterprises are on a given fodder or cropping block in a given month defoliating a crop.
    - Whether animal enterprise on a given block in a given month is fed farm-grown supplements.
    - Whether an animal enterprises is consuming pasture on a given block in a given month (section 3.10.3).

3.10.2. Proportion of pasture intake on a block

The proportion of pasture eaten by an animal enterprise in a block is used to allocate block-based values to different animal enterprises (BlockSU), and can be entered by the user, or a default distribution is assumed. If there is only one block, one animal class, or the option to assume animals on blocks eat pasture at the same ratio as farm intake is selected, then on blocks where pasture is consumed excluding cropping or fodder crop blocks, the proportion of pasture intake on a block is calculated as:

Equation 13: $BlockSU_{block,\ antype} = RSU_{antype} / \sum_{antype} RSU_{antype} * 100$

The proportion of pasture intake on a block is calculated initially before the metabolic energy requirements, and hence RSU are estimated (section 3.9). For the initial calculation, a default RSU, based on the number of animals, is used.

For fodder crops, proportion of pasture intake on a block is the area-weighted average of the BlockSU of the pastoral blocks the fodder crop rotates around.

For cropping blocks, the proportion of pasture intake on a block is the average of the proportion of stock eating pasture as entered by the user for the grazed pasture pre-crop that extends into the reporting year, or for grazed pasture sown during the reporting year allowing for 2 months for establishment.

3.10.3. Months animals graze pasture on a block

The months animals graze pasture can be selected by the user, or a default is used. The initial default value is set based on the following rules:

- On pastoral blocks, if stock reconciliation input is used, the months animals can graze pasture are the months animals are present on the farm. Dairy and dairy replacements are estimated from the class of animals.

- On pastoral blocks, if stock data is entered using RSU or peak cow numbers, animals are assumed to graze pasture in all months. The exception is dairy replacements, which graze pasture in the months they are on the month, which is dependent on how replacements are managed, and the calving dates.
- On fruit crop blocks, the same rules apply as for pastoral blocks if farm animals are used for grazing.
- For fodder crops, animals that are on pastoral blocks the fodder crop rotates around can graze the pasture phase.
- For cropping blocks, animals graze pasture if proportion of stock eating pasture as entered by the user for the grazed pasture pre-crop that extends into the reporting year, or are selected to graze pasture for 2 months after establishment and farm animals are used for grazing.
- For a given animal enterprise and given month, then if animals are on wintering pads or grazed off for 100% of the time, then animals cannot be grazing a block.

It is based on whether animal ME requirements are greater than zero for a given month once these are calculated.

4. Animal metabolic energy requirements

4.1. Metabolic energy requirements sub-model inputs

The required inputs for the metabolic energy requirements sub-model are listed in Table 7. Some inputs are described in more detail in the Animal Metabolic Energy Requirements chapter.

Table 7. Input data for calculating metabolic requirements.

Variable	Description
Animal enterprise	Dairy cows, dairy replacements, sheep, beef, deer, dairy goats.[#]
Breed	Animal breed.[*]
Mean birth day	Day of year for mean birthing.[#]
Mean weaning day	Day of year for mean weaning.[#]
Lactlen	Lactation length (days).[*]
StartAgeMonth	Age (months) of mob at the start of the year.[#]
LactatingFemale	Whether lactation occurs in 12 month period (T/F).[**]
GestatingFemale	Whether gestation occurs in 12 month period (T/F).[**]
Male	Mob is male e.g. bulls (T/F).[**]
Mixedsex	Mob is mixed sex e.g. lambs, calves or fawns (T/F).[**]
WeaningRate	Weaning rate (%).[#]
SRW	Standard reference weight (kg).[*]
Currentweight	Average current weight of the animals at the start of the year (kg).[*]
Weaningweight	Weaning weight (kg).[*]
Hkm	Distance walked horizontally in a day (km).[*]
Vkm	Distance walked vertically in a day (km).[*]
WoolGrowth	Yearly wool growth (kg wool/animal/year).[#]
Cmilkfat	Fat content of milk (%).[*]
Cmilkprotein	Protein content of milk (%).[*]
AnnualMilkYield	Annual milk volume for dairy cows and dairy goats (litres/animal/year).[#]
MonLwtChange	Monthly live weight changes (kg/month/year).[#]
PropOnPads	Proportion of time animals are on pads or under restricted movement.[#]
DietME	Monthly average diet ME content (MJ ME/kg DM).[#]

* described in more detail in Characteristics of Animals chapter.
** defined by the mob class as defined in the Characteristics of Animals chapter.
[#] described in more detail in this chapter.

4.2. Outputs: typical animal ME requirements

The metabolic requirements sub-model provides the following outputs describing the requirements of typical animal in the mob (MJ ME/month):

- MEmonth — Animal ME requirements for a typical animal.
- MEprewean — Animal ME requirements for young 'on the mother' up to weaning.
- MEmilk — Animal ME requirements for young 'on the mother' up to weaning that came from the milk portion of the diet for each female breeding animal per month.

The energy requirement for the milk portion of pre-weaned animals is accounted for in the lactation component of the mother.

The metabolic model also provides the proportion of monthly intake of a breeding or milking female animals' intake that occurred while lactating.

5. Calculations based on monthly stock numbers

The monthly stock numbers option allows stock and key information such as class, breed, source and weights to be entered. This information is used to estimate inputs for a typical animal, and these are used as inputs for the animal ME requirements sub-model (sections 5.2 and 5.3). Outputs from the animal ME requirements sub-model (section 5.4) are then used to derive the enterprise-based outputs as defined in sections 3.2 to 3.4. At the same time, mob enterprise based live weight outputs (section 5.4.4) are estimated to derive the enterprise-based outputs as defined in sections 3.5 and 3.6, and the inputs and product allocation ratio used in the Carbon Dioxide, Embodied and Other Gaseous Emissions chapter are determined. Error checks that are made during the calculation phase are described in section 5.7.

5.1. Standard procedure

The input data listed in Table 7 is used to populate the metabolic sub-model for each mob.

- Animal enterprise — The enterprise the mob belongs to as determined by the data entry.
- Breed — Based on the user-selected breed, with the options described in the Characteristics of Animals chapter.

For each enterprise, the following are set or estimated:

- Has Breeding males — If any breeding class is male.
- Mean birth day — Characteristics of Animals chapter.
- Mean weaning day — Characteristics of Animals chapter.
- Lactation length — For dairy cow and dairy goat enterprises only.
- Weaning age month — Weaning age in months (section 5.2.9).
- Replacement rate — Characteristics of Animals chapter.
- Fat content of milk — For animals other than dairy cows or goats. Characteristics of Animals chapter.
- Protein content of milk — For animals other than dairy cows or goats. Characteristics of Animals chapter.
- Prop on pads — The proportion of time animals are on wintering pads/animal shelters in a given month.
- Diet ME — Section 5.3.5.1.
- Milk production per animal — For dairy cow and dairy goat enterprises only, section 5.3.4.

Then, for each mob the following are identified based on the user-selected class of animals as described in the Characteristics of Animals chapter.

- Lactating female — Based on the user-selected class
- Gestating female — Based on the user-selected class
- Mixed age — Based on the user-selected class

- Male — Based on the user-selected class
- Breeding mob — Based on the user-selected class

Then, for each mob, the following are estimated using the methods described in the Characteristics of Animals chapter.

- Standard reference weight (kg/animal) — Standard reference weight (SRW) for females is estimated from the breed, and adjusted for male and mixed sex mobs [Characteristics of Animals chapter].
- Mature weight (kg/animal) — Characteristics of Animals chapter.
- Weaning weight (kg/animal) — Characteristics of Animals chapter.
- Herd weight (kg/animal) — Characteristics of Animals chapter,
- Distances walked (km) — Characteristics of Animals chapter - based on the average slope for the animal enterprise
- Fat content of milk (%) — For dairy cows based on breed Characteristics of Animals chapter
- Protein content of milk (%) — For dairy cows based on breed Characteristics of Animals chapter
- Weaning rate (%) — Section 5.3.3
- Wool growth (sheep) (kg/year) — Section 5.3

Then for each mob, the following are estimated using the methods described in the sections indicated:

- Expected number of breeding animals — Section 5.2.4
- Expected number of replacements — Section 5.2.7
- Number of animals grazed off — Section 5.2.6
- Number of breeding animals — Section 5.2.3
- Number weaned on farm — Section 5.2.5
- Start age — Section 5.3.1
- Start month — Section 5.2.9
- End age — Section 5.3.2.1
- Start weight — Section 5.3.2.2
- End weight — Section 5.3.2.4
- Monthly live weight change — Section 5.3.2.1

The metabolic energy requirements for a typical animal in a mob are then estimated using the entered and estimated data as specified above using the animal ME requirements sub-model (section 4.1). Following this:

- The calculated ME outputs from the metabolic requirement sub-model (section 4.2) are distributed to mob and enterprise based outputs (section 5.4).
- Live weight changes for breeding or trading mobs are estimated (section 5.4.4).
- The number of animals reared and live weight change of replacements (used in the greenhouse gas product emission allocation sub-model) are estimated.
- Product allocations that are used in the greenhouse gas product emission allocation sub-model are estimated (section 5.6).
- Error checks are undertaken (section 5.7).

5.2. Enterprise based inputs

5.2.1. Number of milking cows

The number of milking cows, referred to as NumberMilkers in equations, is taken as the sum of the maximum monthly number of cows entered for each milking herd (mob). No more than three dairy milking herds are allowed. The month in which the maximum number of cows occurs may differ depending on the herd.

5.2.2. Number of milking goats

The number of milking goats, referred to as NumberMilkersGoats in equations, is taken as the sum of the maximum monthly number of does entered for those mobs classified as 'Does milking' or 'Does milking all year'. The month in which the maximum number of does occurs may differ depending on the mob.

5.2.3. Number of breeding females

The number of breeding animals on the farm is taken as the sum of the maximum number entered for those mobs with classes of breeding female stock. For dairy cows and dairy goats, this is taken as the number of milking cows or milking goats respectively (section 5.2.1 and 5.2.2).

5.2.4. Expected number of breeding animals

The expected number of breeding animals each month is used when creating mobs for the generate mobs tool (section 2.1.3), and used in the greenhouse gas sub-model. These are used to define default numbers – actual numbers and distributions can be entered using the monthly stock numbers option. This is done by assuming that at birth, the number of animals is the maximum number of animals that are present for the breeding mob. Thus:

Equation 14: $\text{NumberAnimals}_{mon} = \text{MaxNumber}$

mon is calendar month determined from the birth month, and number of months since birth.

MaxNumber is the maximum number of stock

Each month, from birth to 12 months after birth, the next month's numbers are the same as the previous month's:

Equation 15. $\text{NumberAnimals}_{mon-1} = \text{NumberAnimals}_{mon}$

However, in certain months, the number of animals is changed as replacements are added or culls removed, as outlined below.

For dairy, numbers can be held constant over the whole milking season (i.e. culls are sold at the same time replacements are brought into the herd). Alternatively, it is assumed that 6 months after calving, some non-performing milkers are removed from the herd. This is assumed to be no more than 6%. Thus:

Equation 16: NumberAnimals = MaxNumber * cullrate

Cullrate is 0.06 or the replacement rate (as a proportion), whichever is smaller.
Replacerate in the replacement rate (%) of the breeding females

If the replacement rate is greater than 6%, the rest of the culls are removed at the end of milking season. Thus:

Equation 17: NumberAnimals = MaxNumber * (1 - Replacerate/100)

Replacerate in the replacement rate (%) of the breeding females

For sheep, assumed that 75% of the culls are removed at weaning, and 25% are removed two months before lambing once non-pregnant ewes have been identified by scanning. Replacements are added to the breeding mob at weaning. Thus in the month after weaning:

Equation 18: NumberAnimals = MaxNumber – CullsOut + ReplacementIn

where

Equation 19: CullsOut = MaxNumber * Replacerate/100 * 0.75

Equation 20: ReplacementIn = MaxNumber * Replacerate/100

and 10 months after the mean birth month, a further reduction occurs using the method in Equation 18, except the number of replacements added is zero and the number of culls removed is

Equation 21: CullsOut = MaxNumber * Replacerate/100 * 0.25

For beef, deer, and dairy goats, breeding animals are culled in the month after weaning but replacements are added in the same month. Thus, the method in Equation 18 is used except that the number of replacements and culls is estimated as:

Equation 22: CullsOut = MaxNumber * Replacerate/100

Equation 23: ReplacementIn = MaxNumber * Replacerate/100

5.2.5. Number weaned on farm

The number of weaned animals on farm is taken as the sum of the maximum number entered for a mob with classes of weaned breeding stock. These are replacements plus juvenile trading stock.

5.2.6. Numbers grazing off

When using the monthly stock numbers input, the number of animals grazed off is not entered directly; however, grazing off is indicated by lower stock numbers in those months animals are grazed off. An estimate is required for the embodied greenhouse gas emissions sub-model. This is done by estimating the number of expected breeding females each month based on the maximum number of animals in that mob (section 5.2.4). Then if the number of animals is less than the expected number of animals, it is assumed they are grazed off, that is, the number grazed off is:

Equation 24: $Ngrazeoff_{mon} = ExpectedNumber_{mon} - Nanimals_{mon}$

ExpectedNumber is the expected number of breeding females [section 5.2.4].

Nanimals is the entered number of breeding females.

5.2.7. Expected number of replacements

For dairy cows, the expected number of replacements is estimated as:

Equation 25: ExpectedNumberReplacements = BreedingNumber * dairyreplacement/100

Breedingnumber is the number of breeding animals [section 5.2.3].

dairyreplacement is the number of replacements (%) [Characteristics of Animals chapter].

5.2.8. Number of replacements on farm at each age

The number of replacement animals on the farm at each age (1-24 months) is taken as the sum of number entered for a mob with class of breeding replacements or replacement calves of a given age. The age is estimated from the start age [section 5.3.1] of the mob. This is used to estimate transport and embodied CO_2 costs of grazing off animals in the greenhouse gas emissions sub-model.

5.2.9. Start month

The start month is used to align months animal data is entered (July to June) with the cycle used in the rest of the model (January to December).

For mixed age animals, the start month is the month when data entry starts, that is, July.

For mobs that the source is weaned animals, it is the month that weaning occurs.

Otherwise, the start month is the calendar month that corresponds to the month for the first entry of numbers describing a mob.

5.2.10. Weaning age month

For non-dairy animals the age (in months) is estimated as:

Equation 26: WeanAgeMonth = INTEGER(Lactlength/30)

LactLength is the lactation length [Characteristics of Animals chapter].

30 is the average number of days in a month.

INTEGER rounds the number to the nearest integer.

5.2.11. Distributing milk production to herds

If the monthly stock numbers option is used, three milking herds can be entered, and thus can have different breeds. The following procedure distributes farm milk product inputs (milk solids, milk fat, and milk volume) and estimates default values based on herd breed.

Equation 27: $propMilkSolids_i = pMilkSolids_i / \sum(pMilkSolids_i)$
Equation 28: $propMilkFat_i = pMilkFat_i / \sum(pMilkFat_i)$
Equation 29: $propMilkVol_i = pMilkVol_i / \sum(pMilkVol_i)$

where

Equation 30: $pMilkSolids_i = \sum(Number_{mon} * SolidsCow_i)$
Equation 31: $pMilkVol_i = \sum(Number_{mon} * VolCow_i)$
Equation 32: $pMilkFat_i = \sum(Number_{mon} * FatCow_i)$

i is the herdnumber (1-3).
SolidsCow, VolCow and FatCow are breed average production for the i^{th} herd [Characteristics of Animals chapter].
$breed_i$ is the user selected breed of the i^{th} herd.

5.3. Estimating metabolic energy requirements sub-model inputs

The inputs for the metabolic energy requirements sub-model are described in section 4.1. This section describes the mob based inputs.

The mean birth day and the mean weaning day are estimated as outlined in the Characteristics of Animals chapter. For dairy cows, each milking herd may have a different mean birth day. As weaning day depends on birth day, then each milking herd may have a different mean weaning day.

For the metabolic energy requirement sub-model input, wool production (annual greasy wool shorn) is estimated as being 2.0 kg and 4.5 kg wool per animal per year for lambs (less than 1 year old) and other sheep respectively. This would result in a small over-estimation of ME requirements for sheep with lower wool growth rates such as lambs or some meat breeds.

The proportion of animals on pads is estimated from inputs describing the use of wintering pad/animal shelters.

The other mob based inputs (start age, monthly live weight changes, weaning rate, milk volume per animal, milk fat and protein content, and diet ME content) are described in the following sections.

5.3.1. Start age

Live weight start age (age in months) is used to determine the position on the growth curves (Characteristics of Animals chapter). For mobs that are not mixed age, if start age is not entered but start weight is, then the start age is estimated from entered start weights because the

relationships between weight and age have been established (Characteristics of Animals chapter). Thus start age is estimated as:

- If source is 'Calves reared on-farm', it is the age (months) at weaning (section 5.2.9) plus 1.
- Otherwise, it is the entered start age.
- Otherwise, if the entered live weight is greater than the mature weight then start age is 42, 30, 42, 42 and 60 months for dairy, sheep, beef, deer and dairy goats enterprises respectively.
- Otherwise, start age is the minimum age in months for which the entered start weight is greater than the mature weight times the proportion of mature live weight at a given age ($femalewt_i$ Characteristics of Animals chapter).

5.3.2. Monthly live weight change

Increase in live weight due to growth is estimated each month. For trading animals the end age and end live weight are required for Equation 36.

5.3.2.1. *Monthly live weight change*

Replacement animals that enter a mixed age breeding female mob at age 24 months are below mature live weight, and hence on a mob basis, there is live weight gain. Thus, the typical animal in a breeding mobs is assumed to gain live weight to cover this, which is estimated as:

Equation 33: $LwtChange_{mon} = (1 - femalewt_{24}) / 12 * matureweight * replacement/100$

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

matureweight is the mature weight (kg/animal) [Characteristics of Animals chapter].

replacement is the percentage of breeding animals replaced each year (%).

Sheep are assumed to be at their mature weight at 24 months, that is, $femalewt_{24}$ is 1 (Characteristics of Animals chapter). Hence there is no live weight gain.

For all enterprises, the variation in weight during the year in breeding female mobs and deer breeding stag mobs is integrated into the metabolic energy sub-model (Animal Metabolic Energy Requirements chapter).

For mixed age non-breeding animals, live weight change is assumed to be zero.

Otherwise, the live weight change (kg/month) each month for a typical animal in the mob between start age and end age is estimated as:

Equation 34: $LwtGrowth_{mon} = diffwt * pweight$

diffwt is the difference between start and end weights [Equation 35].

pweight is the proportion of weight change that occurs in a given month [Equation 36].

where the difference in weight is estimated as:

Equation 35: diffwt = lwtendweight – lwtstartweight

lwtendweight is the end live weight (kg) [section 5.3.2.4].

lwtstartweight is the start live weight (kg) [section 5.3.2.2].

If the animals are entered for only one month, the proportion of the total weight is 1, otherwise it is estimated as:

Equation 36: $pweight = (femalelwt_{age+1} - femalelwt_{age}) / (femalelwt_{endage} - femalelwt_{startage})$

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

age is the age of the animal (months).

endage is the end age (months) [section 5.3.2.1].

startage is the start age (months) [section 5.3.1].

5.3.2.2. *Start live weight*

For mixed age animals, the start live weight (kg/animal) is the mature weight (Characteristics of Animals chapter).

For mobs that are weaned breeding animals, start live weight is the entered weaning weight unless that is not entered, in that case it is estimated as described in the Characteristics of Animals chapter.

For other mobs, start live weight is:

- the entered start live weight; or
- if start live weight is not entered but live weight start age can be estimated, it estimated as shown in Equation 37; otherwise
- it is the mature weight.

Age related start live weight (kg/animal) is estimated as:

Equation 37: $lwtstartweight = matureweight * femalewt_{startage}$

matureweight is the mature weight (kg/animal).

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

startage is the start age (months) [section 5.3.1].

5.3.2.3. *End age*

End age is the age of animals in the mob for the last month for which an entered number of animals exist.

5.3.2.4. *End live weight*

The end live weight (kg/animal) is either the entered end live weight; or if this is absent but carcass weight has been entered, then it is based on the entered carcass weight:

Equation 38: lwtendweight = carcassWeight / dressingout

carcassWeight is the entered carcass weight (kg).

dressingout is the dressing out rate [Characteristics of Animals chapter].

otherwise, end live weight is the age related end weight:

Equation 39: $lwtendweight = matureweight * femalewt_{endage}$

matureweight is the mature weight (kg/animal).

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

endage is the end age (months) [section 5.3.2.1].

or if start age equals end age:

Equation 40: $lwtendweight = matureweight * (femalewt_{endage} - femalewt_{endage + 1}) * 0.5$

matureweight is the mature weight (kg/animal).

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

To avoid modeling problems, end weight must be greater than or equal to the start weight.

5.3.3. Weaning rate

The entered weaning rate is used when supplied. If absent, a default weaning rate (Characteristics of Animals chapter) is used. If hoggets are lambed or heifers calve, default weaning rates of hoggets or heifers are used (Characteristics of Animals chapter).

5.3.4. Milk volumes per animal

Although the metabolic energy requirements sub-model is mob based, it is based on a single typical animal. The sub-model requires input of milk volume per animal.

5.3.4.1. *Dairy cows*

For dairy cows, annual milk volume per cow (litres/cow/year) is an input into the metabolic sub-model, and for a given milking mobs is estimated as:

Equation 41: $MilkVolumeCow_i = Herdmilkvolume_i / HerdNumMilkers_i * 1.02 * fnumber$

Herdmilkvolume is the annual milk volume (litres/year) for the i^{th} herd.

HerdNumMilkers is the maximum number of milkers in the i^{th} herd.

1.02 is a constant to adjust for the shape of lactation curve.

fnumber is a adjustment factor to account for varying numbers in the herd over time.

To account for varying numbers in the herd over time, the adjusted factor is estimated as:

Equation 42: $fnumber = milksolids * propMilkSolids_i / calcMS$

milksolids is entered annual milk solids production (kg MS/year).

$propMilkSolids_i$ is the proportion of milk solids produced by the i^{th} herd [section 5.2.11].

and where:

Equation 43: $calcMS = milksolids * propMilkSolids_i / HerdNumMilkers_i * Nanimals_{i,\ mon} * propLactation_{mon}$

milksolids is entered annual milk solids production (kg MS/year).

$propMilkSolids_i$ is the proportion of milk solids produced by the i^{th} herd [section 5.2.11].

HerdNumMilkers is the maximum number of milkers in the i^{th} herd.

Nanimals is the number of animals in the i^{th} herd in a given month.

Proplactation is the proportion of annual lactation that occurs in a given month [Characteristics of animals chapter].

If the annual milk volume is entered, herd milk volume is estimated as:

Equation 44: $Herdmilkvolume_i = MilkVolume * propMilkSolids_i$

MilkVolume is the entered milk volume (litres per year).

$propMilkSolids_i$ is the proportion of milk solids produced by the i^{th} herd [section 5.2.11].

i is the herd number.

Otherwise, a default is estimated using the procedure in the Characteristics of Animals chapter, which requires the herd's annual milk solids and breed. Each herd's annual milk solids production is estimated as:

Equation 45: $HerdMilksolids_i = FarmMilksolids * propMilkSolids_i$

FarmMilksolids is the entered milk solids (kg/year).

$propMilkSolids_i$ is the proportion of milk solids produced by the i^{th} herd [section 5.2.11]

i is the herd number.

5.3.4.2. *Dairy goats*

For dairy goats, milking mobs can be milked all year or as part of an annual lactation cycle. To estimate the milk production for each mob, an estimate is made of the milk production per month for those months when lactation occurs. Thus:

Equation 46: $GoatMilkVolumeMonth = GoatMilkVolume / MilkMonths$

where MilkMonths is the total number of the months when lactation occurs across all milking mobs. Annual volume of milk production per goat (litres/goat/year) is then estimated:

Equation 47: $MilkVolumeGoat = GoatMilkVolumeMonth * lactlength/30$

Lactlength is the lactation length (days) of the milking mob.

30 is the average number of days per month.

For dairy cow enterprise, farm milk fat production (kg/year) can be entered. This input, along with milk solids, can be used to estimate the fat and protein content (%) of milk (Characteristics of Animals chapter). Fat production (kg fat/year) for each milking mob can be estimated from herd fat and protein production, where herd fat production (kg milk fat/year) is estimated as:

Equation 48: $HerdFat_i = FarmFat * propFat_i$

FarmFat is the entered fat production (kg milk fat/year).

propFat is the proportion of fat produced by the i^{th} herd [section 5.2.11].

i is the herd number.

5.3.5. Diet ME contents

5.3.5.1. *Diet ME*

The ME content of the diet is used in the metabolic energy requirement sub-model and is the average ME of the diet, weighted for the amounts of different foods eaten.

To be able to estimate the ME content of the diet, a description of supplements and the timing of their feeding out is required. However, supplement and crop allocations can be influenced by animal ME requirements. Hence, an iterative process is used whereby diet ME is estimated so that animal ME requirements can be estimated, supplement and crop allocations calculated and diet ME re-estimated before animal ME requirements are obtained. To begin the iterative process, diet ME content (MJ ME/kg DM) is first initialised to be the same as animal pasture based ME content, that is:

Equation 49: $DietME_{mon} = antype\_ME_{antype, mon}$

antype_ME is the ME content pasture (MJ ME/kg DM) [section 5.3.5.2].

On the second call, animal requirements have been estimated using the first estimate of diet ME, and the amount of supplements fed to each animal enterprise. Hence diet ME can then be estimated as:

Equation 50: $DietME_{mon} = MEintake_{antype, mon} / DMintake$

MEintake is animal ME requirements (MJ ME/month).

DMintake is DM intake (kg DM) [Equation 51].

DM intake is the amount of DM eaten as either pasture, or as supplements of crops fed to the animals. Thus:

Equation 51: $DMintake = DMpasture + supplementDMeaten_{antype, mon}$

DMpasture is animal pasture DM intake (kg DM/month) [Equation 52].

supplementDMeaten is the amount of supplement and crop ME fed to an animal enterprise (kg DM/month).

As pasture DM intake is not calculated until ME requirements are calculated, and diet ME is an input into ME requirements, then DM pasture is estimated as:

Equation 52: $DMpasture = MEeaten / antype\_ME_{antype, mon}$

MEeaten is the amount of pasture ME consumed (MJ ME/month) [Equation 53].

antype_ME is the ME content of pasture consumed (MJ ME/kg DM) [section 5.3.5.1].

The amount of pasture ME consumed is estimated as the difference between animal ME requirements and ME fed to animals as supplements and crops. Thus:

Equation 53: $MEeaten = (MEintake_{antype, mon} - supplementMEeaten_{antype, mon})$

MEintake is the calculated animal ME intake (MJ ME/month).

supplementMEeaten is the amount of supplement ME fed to an animal enterprise (MJ ME/month).

5.3.5.2. *ME content of pasture consumed*

The pasture consumed by an animal enterprise can come from multiple blocks. The ME content of the consumed pasture for a given animal enterprise (antype_ME, MJ ME/kg DM) is thus estimated as a weighted (to take account of different block sizes) average of the block pasture ME contents.

Equation 54: $antype\_ME_{antype, mon} = \sum_{block}(MEcontent_{mon} * EntAreaBl_{block}) / \sum_{block}EntAreaBl$

$MEcontent_{mon}$ is the ME content (MJ ME/kg DM) of the pasture for a given block [Characteristics of Pasture chapter].

EntAreaBl is the enterprise area (ha) [section 3.7].

A similar approach is applied for digestibility (%), to give

Equation 55: $antype\_Digest_{antype, mon} = \sum(Digestibility_{mon} * EntAreaBl_{block}) / \sum EntAreaBl_{block}$

Digestibility is the digestbility (%) of the pasture for a given block [Characteristics of Pasture chapter].

EntAreaBl is the enterprise area (ha) [section 3.7].

On the first use of antype_ME, the percentage of available block intake eaten by each animal enterprise on a given block has not been calculated. Hence, a default value is estimated based on the regional value for pasture.

Equation 56: $antype\_ME_{antype, mon} = defaultME_{region, mon}$

$defaultME_{region, mon}$ (MJ ME/kg DM) is the regionally based pasture ME content [Characteristics of pasture chapter].

5.4. ME outputs

5.4.1. ME distribution

The metabolic energy requirements sub-model returns ME requirements for a typical animal in a mob, including requirements for non-weaned young, irrespective of whether the animal is present on the farm or not. The ME requirements for the mob each month (AddME, MJ ME/month) is estimated as:

Equation 57: $AddME_{mob, mon} = MEmonth_{mon} * Nanimals_{mon} + (MEprewean_{mon} - MEmilk_{mon}) * Nanimals_{mon} * weanrate/100$

Nanimals is the entered number of animals.

MEmonth, MEprewean and MEmilk are ME requirements for a typical animal (MJ ME/month) [section 4.2].

Weanrate is the weaning rate [section 5.3.3].

The second component of Equation 57 describes non-milk intake from young animals still with the mothers prior to weaning. For dairy cows, it is assumed that young are weaned from the mother within days when the diet is all milk, and hence the second component of Equation 57 is ignored.

Monthly ME requirements for a given enterprise is thus:

Equation 58: $MEintake_{antype,\ mon} = \sum_{mob} AddME_{mob,\ mon}$

If the mob is a breeding mob (Characteristics of Animals chapter) then:

Equation 59: $MEintakeBreeding_{antype} = \sum_{mob} AddME_{mob,\ mon}$

mob is a breeding mob for a given animal enterprise.

AddME is the monthly ME requirements (MJ ME/month) [Equation 57].

The ME requirements (MJ ME/month) used to estimate embodied CO_2 emissions associated with wintering off is estimated as:

Equation 60: $MEWinterOff_{antype,\ mon} = \sum_{mob}(MEmonth_{mon} * Ngrazeoff_{mon})$

MEmonth is ME requirements for a typical animal (MJ ME/month) [section 4.2].

Ngrazeoff is the estimated number of animals grazed off [section 5.2.6].

For sheep, sheep breed based ME requirements associated with young animals (less than 1 year) (section 3.3) is estimated as:

Equation 61: $MEyoung = \sum(MEyoungAnimal * Nanimals_{mon})$

MEyoungAnimal are ME requirements for young animals (MJ ME/month) [section 4.2].

Nanimals is the entered number of animals.

and if young animals are being traded, then:

Equation 62: $MEyoungtrade = \sum(MEyoungAnimal * Nanimals)$

In addition, AddME is also added to the sheep breed based enterprise ME requirements (section 3.3).

For deer:

Equation 63: $MEdeerMale = AddME * sexratio$

sexratio is 1 for a male mob, and 0.5 for a mixed sex mob.

and this is added to enterprise based MEmaleDeer (section 3.2).

5.4.2. Dairy adjustment for calves feed milk powder

If calves are not fed milk powder (i.e., they are fed milk from the vat prior to selling) then milk production is higher than that recorded in the vat, and hence ME requirements are higher. The ME provided by milk is estimated but not included in ME requirements for the replacements. Hence ME provided by milk is added to the dairy cow ME requirements as:

Equation 64: $MEintake_{dairy,\ mon} = MEintake_{dairy,\ mon} + MEmilk_{mon} * Nanimals_{mon} * dairyreplacement / 100$

MEintake is the monthly ME intake for dairy enterprise (MJ ME/month).

MEmilk are ME requirements (MJ ME/month) [section 4.2].

Nanimals is the entered number of animals.

dairyreplacement is the replacement rate (%) [Characteristics of Animals chapter].

5.4.3. Grazed off dairy replacements

If the total number of replacements is less than the expected number of replacements, then these animals are assumed to be grazed off. The ME requirements for grazed off replacements are estimated as:

Equation 65: $MEintakeDairyrep_{mon} = \sum(MEmonth_{mon} * (Expected - numberReplacements_{mon}))$

Expected is the expected number of replacements [section 5.2.7].

numberReplacements is the number of replacements on farm [section 5.2.8].

MEmonth is ME requirements of a typical animal (MJ ME/month) [section 4.2].

5.4.4. Percentage intake by male beef animals

The pc intake by male animals is estimated as:

Equation 66: $pcmale = \sum(pccalves_{mon} + pcmob_{mon}) / \sum MEintake_{beef,\ mon}$

pccalves is the intake from male calves before weaning (MJ ME/month) [Equation 67].

pcmob from mobs of male animals (MJ ME/month) [Equation 68].

MEintake is the monthly ME requirements for a given enterprise (MJ ME/month) [section 5.4.1].

where the intake, excluding milk, from male calves is estimated as:

Equation 67: $pccalves = (MEprewean_{mon} - MEmilk_{mon}) * Nanimals_{mon} * Weanrate /100 / 2$

MEprewean and MEmilk are ME requirements for a typical animal (MJ ME/month) [section 4.2].

Nanimals is the entered number of animals.

Weanrate is the weaning rate [section 5.3.3].

and the intake from mobs of male animals in is estimated as:

Equation 68: $Pcmob = MEmonth_{mon} * Nanimals_{mon} * fsex$

MEmonth is ME requirements for a typical animal (MJ ME/month) [section 4.2].

where fsex is 0.5 for mixed sex mobs, and 1 for males or steers.

5.5. Live weight changes

This section describes the mob based changes in live weight, which are then added to the enterprise based changes (section 3.5).

5.5.1. Monthly animal weight

The monthly animal weight is estimated as:

Equation 69: $AnWeight_{mon} = AnWeight_{mon-1} + LwtChange_{mon}$

$AnWeight_{mon-1}$ is the weight in the preceeding month (kg).

$LwtChange_{mon}$ is the current month's weight change (kg/momnth) [section 5.3.2.1].

5.5.2. Breeding female mob

For a typical breeding female animal, the sources of weight changes as it ages are shown schematic in Figure 3. The mob based live weight changes for each stage are described in sections 5.5.2.1 to 5.5.2.5. Note that the mob-based live weight changes described in sections 5.5.2.1 to 5.5.2.5 are added to the enterprise live weight changes described in section 3.5.

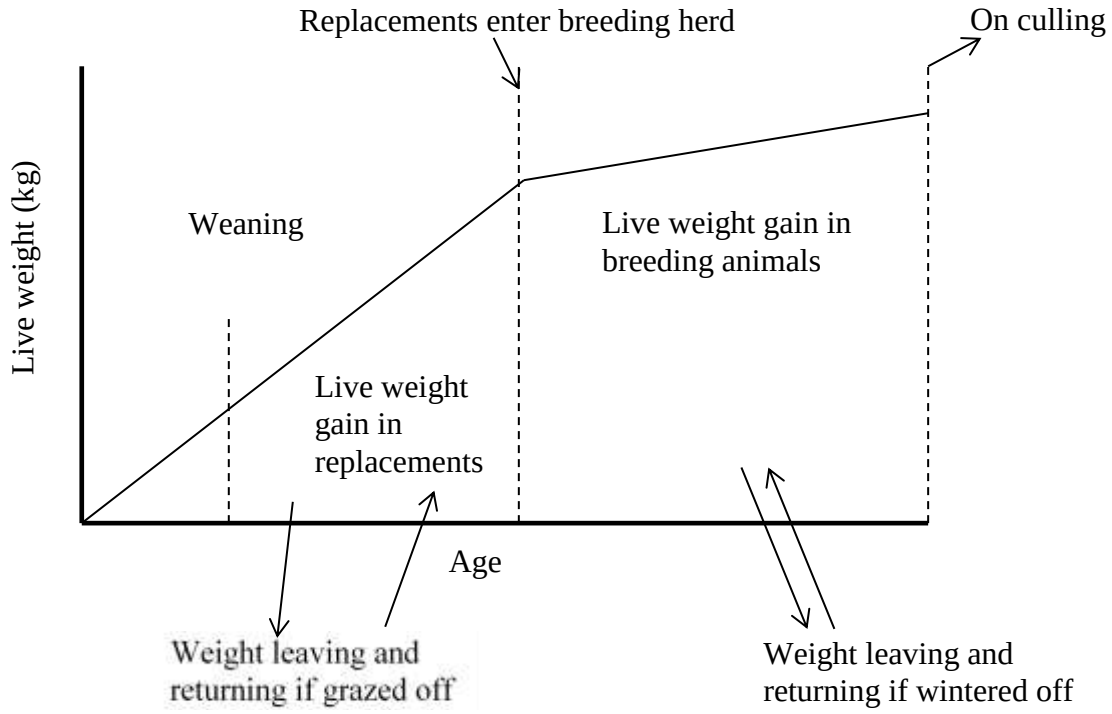

Figure 3. Schematic representation of live weight changes for a typical breeding female as it ages.

5.5.2.1. *Cull females*

The live weight of cull female animals (kg/year) is estimated as:

Equation 70: lwtsoldworks = Matureweight * NumBreedingFemale * Replacementrate / 100

Matureweight is the entered or default mature weight (kg).

NumBreedingFemale is the number of breeding or milking females [section 5.2.1

Replacementrate is the entered or default replacement rate (%) [Characteristics of Animals chapter].

The live weight that is sold is assumed to be sold to the works. For sheep, lwtsold is included as mutton (section 3.3).

5.5.2.2. *Growth of breeding females*

Live weight gain of the breeding female mob due to animals growing (kg/year) from the entered weight to mature weight is estimated as:

Equation 71: $lwtonfarm = Nanimals_{mon} * changelwt_{mon}$

Nanimals is the entered number of animals.

lwtchange is the monthly live weight change (kg) [section 5.3.2.1].

5.5.2.3. *Grazed-off live weight of breeding females*

Live weight of breeding females that is grazed off each month is estimated as:

Equation 72: $lwtWinterOff = AnWeight_{mon} * grazeoffNumber_{mon}$

AnWeight is the monthly animal weight (kg) [section 5.5.1].

grazeoffNumber is the number of animals grazed off each month [section 5.2.6].

5.5.2.4. *Replacements entering the breeding herd*

If replacements are grazed off, then replacements added to the breeding mob are considered to be animals brought onto the farm, hence are included in replacement live weight returning. Thus live weight brought (kg) is estimated as:

Equation 73: $lwtbrought = (ExpectedNumberReplacements - ReplacementsOnFarm) * AnWeight_{mon}$

ExpectedNumberReplacements is the expected number of replacements based on breeding numbers and replacement rates [section 5.2.7].

ReplacementsOnFarm is the actual number of replacements on the farm at 24 months (dairy, beef, deer) or 12 months (sheep, dairy goats) [section 5.2.8].

AnWeight is the monthly animal weight (kg) when the replacements return [section 5.5.1].

5.5.2.5. *Growth to weaning*

Growth up to weaning is live weight reared on the farm

Equation 74: $lwtonfarm = WeanWeight * ExpectedWeaned$

WeanWeight is the weaning weight (kg) [Characteristics of Animals chapter].

ExpectedWeaned is the expected number of weaned animals [section 5.2.5].

5.5.2.6. *Live weight gain of replacements*

For each month of age, the live weight gain while replacements are on the farm is estimated as:

Equation 75: $lwtonfarm = \sum(NumberReplacements_{age} * lwtchange_{age})$

NumberReplacements is the number of replacements on the farm each month [section 5.2.8].

lwtchange is the monthly live weight change (kg) [section 5.3.2.1].

Each month, if the number of replacements decreases between months then:

Equation 76: $lwtsoldstore = replacementweight_{age - 1} * (replacementnumber_{age - 1} - replacementnumber_{age})$

replacementweight is the weight of replacements at a given age (kg).

replacementnumber is the number of replacements at a given age [section 5.2.8].

In contrast, if the number of replacements increases between months then:

Equation 77: $lwtbrought = replacementweight_{age - 1} * (replacementnumber_{age} - replacementnumber_{age-1})$

For dairy systems, if the number of replacements decreases between months and the number of replacements on farm is less than the expected number, it is assumed that replacements have been grazed off. Thus:

Equation 78: $lwtrepout = replacementweight_{age-1} * (ExpectedNumberReplacements - replacementnumber_{age})$

replacementweight is the weight of replacements at a given age (kg).

replacementnumber is the number of replacements at a given age [section 5.2.8].

ExpectedNumberReplacements is the expected number of replacements [section 5.2.7].

In contrast, if the number of replacements increases between months, it is assumed that replacements up to the expected number of replacements have returned from grazing off. Thus, if the number of replacements on farm is greater than the expected number, the live weight returning is estimated as:

Equation 79: $lwtrepReturn = replacementweight_{age-1} * (ExpectedNumberReplacements - replacementnumber_{age-1})$

replacementweight is the weight of replacements at a given age (kg).

replacementnumber is the number of replacements at a given age [section 5.2.8].

ExpectedNumberReplacements is the expected number of replacements [section 5.2.7].

5.5.3. Trading and other breeding mob classes

The live weight gain of animals raised on farm is estimated as:

Equation 80: $lwtonfarm = lwtchange_{mon} * Nanimals_{mon}$

lwtchange is the monthly live weight change (kg) [section 5.3.2.1].

Nanimals is the entered number of animals.

This is also added to the breeding live weight gain on farm if the mob is a breeding mob not covered in the previous sections.

If number of animals in a current month is less than the number of animals in the previous month then and the selected source is ‘Sold’ then:

Equation 81: $lwtsold = AnWeight_{mon} * (Nanimals_{mon-1} - Nanimals_{mon})$

AnWeight is the monthly animal weight (kg) when the replacements return [section 5.5.1].

Nanimals is the entered number of animals.

If number of animals in a current month is less than the number of animals in the previous month then and the selected source is ‘Brought’ then:

Equation 82: $lwtbrought = AnWeight_{mon} * (Nanimals_{mon} - Nanimals_{mon-1})$

AnWeight is the monthly animal weight (kg) when the replacements return [section 5.5.1].

Nanimals is the entered number of animals.

In the last month of the grid, the live weight sold if fate is ‘Store’ or ‘Works’ (kg/year) is estimated as:

Equation 83: $lwtsold = AnWeight_{mon} * Nanimals_{mon}$

AnWeight is the monthly animal weight (kg) when the replacements return [section 5.5.1].

Nanimals is the entered number of animals.

lwtsold is added to the to store or works live weight changes depending on the selected fate, and added to male deer and included in sheep specific estimates (section 3.6) as appropriate,

5.6. Product allocations

The allocation of greenhouse gas emissions allocated to product (milk, wool, velvet) or live weight gain (panimal) is used in greenhouse gas reporting. Estimation of panimal requires estimates of the number of breeding animals, the replacements rate, mature weight and weaning weight.

For dairy cows and dairy goats, the inputs required to estimate panimal are:

- Entered allocation
- Live weight sold from milking animals
- Live weight sold from replacements
- Weight of milk per cow
- Fat content of milk
- Protein content of milk

where the weight of milk is the volume of milk multiplied by the density of milk (Characteristics of Animals chapter).

The panimal for sheep, beef and deer requires estimates of the number of breeding animals, the replacements rate, mature weight and weaning weight. Product allocation is not considered for the ‘Other’ animal enterprise.

5.7. Error checks

The monthly stock numbers sub-model undertakes two checks:

- If the number of weaned animals on farm is greater than zero when there are no breeding animals, then the following message is shown:

  There are weaned animals but no breeding female animals for <animal enterprise>

- If there are breeding males but there are no breeding females animals, then the following message is shown:

There are breeding <breeding male name> but no breeding female animals for <animal enterprise>

6. Calculations for dairy peak cow numbers

The peak cow number sub-model uses a similar procedure as the monthly stock numbers sub-model. The entered information is used to estimate inputs for a typical animal, and these are used as inputs for the animal ME requirements sub-model (sections 5.2, 5.3, 6.2 and 6.3). Outputs from the animal ME requirements sub-model (section 5.4) are then used to derive the enterprise based outputs as defined in sections 6.4. At the same time, mob enterprise based live weight outputs (section 6.5) are estimated to derive the enterprise based outputs as defined in sections 3.5 and 3.6, and the inputs and product allocation ratio used in the Carbon Dioxide, Embodied and Other Gaseous Emissions chapter are determined (section 6.6).

6.1. Milking mobs

The peak cow number allows for three calving dates to be entered. These are treated the same as the three milking mobs allowed under the monthly stock numbers sub-model, except that class and breed are the same.

Peak cow numbers are distributed to milking mobs based on the entered proportion in each milking mob. The method to determine monthly numbers for a milking mob is based on the expected number of breeding animals (section 5.2.4), but the birth date is set as the entered mid calving date, and maximum number is the number of peak cows in each mob.

6.2. Number of milking cows

The number of milking cows, referred to as NumberMilkers in equations, is the entered peak cow number.

6.3. Number of replacements on farm

The number of replacements on farm is taken as the number on farm, i.e. assumed constant, until they are grazed off farm (weaning, 9 months, or 24 months). The number of replacements for each calving mobs is estimated as:

Equation 84: $\text{NumberReplacements} = \text{NumberMilkers} * \text{replacementrate}/100 * \text{propherd}_i$

NumberMilkers is the entered peak cow number.

replacementrate is the replacement rate (%) [Characteristics of Animals chapter].

propherd is the entered proportion of animals distributed between up to three milking mobs.

6.4. ME requirements

6.4.1. Milking mob ME

The ME requirements for each milking mob each month are estimated as:

Equation 85: $\text{AddME}_{\text{mob, mon}} = \text{MEmonth}_{\text{mon}} * \text{Nanimals}_{\text{mon}} *$

$(1 - GrazeoffProp_{antype, mon})/ 100$

Nanimals is the number of milkers [section 6.2].

MEmonth is the ME requirements of a typical animal (MJ ME/month) [section 4.2].

GrazeoffProp is the entered proportion of animals (%) that are grazed off.

Monthly ME requirements of a given enterprise are thus:

Equation 86: $MEintake_{antype, mon} = \sum AddME_{mob, mon}$

By definition, dairy animals are a breeding mob (Characteristics of Animals chapter) hence:

Equation 87: $MEintakeBreeding_{antype} = \sum AddME_{mob, mon}$

AddME is the monthly ME requirements (MJ ME/month) [Equation 57].

The ME requirements (MJ ME/month) used to estimate embodied CO_2 emissions associated with wintering off are estimated as:

Equation 88: $MEWinterOff_{antype, mon} = MEmonth_{mon} * Nanimals_{mon} * GrazeoffProp_{antype, mon} / 100$

Nanimals is the entered number of animals.

MEmonth is the ME requirements for a typical animal (MJ ME/month) [section 4.2].

GrazeoffProp is the entered proportion of animals (%) that are grazed off.

6.4.2. Replacements

ME requirements for replacement animals is estimated using the same methodology as above, except that input values are used to describe two mobs of dairy replacements, one 12 months older than the other. Replacements in the older of the two mobs are assumed to be pregnant in the later part of the year. The ME requirements for each mob each month is estimated as:

Equation 89: $AddME_{mob, mon} = MEmonth_{mon} * NDairyReplacements_{mon}$

NDairyReplacements is the number of replacement animals

MEmonth is the ME requirements for a typical animal (MJ ME/month) [section 4.2].

NDairyReplacements is the number of replacement animals [section 6.3].

AddME is added to MEintake of the dairy replacement enterprise and MEintakeBreeding for dairy if the number of replacements on farm is greater than zero, or to MEintakeDairyRep when replacements are grazed off.

6.5. Live weight changes

Live weight changes between dairy and dairy replacements are easier to define that the stock monthly input option as the change in animal numbers is known. This section describes mob based live weight changes, which are then added to the enterprise based changes (section 3.5).

Cows culled from the milking mob are assumed to be sold to the works, with the weight sold (kg/year) estimated as:

Equation 90: lwtsoldworks = matureweight * replacementrate/100 * numbermilkers

matureweight is the mature weight of dairy cow (kg) [Charactersitics of Animals chapter].

replacementrate is the replacement rate (%) [Charactersitics of Animals chapter].

numbermilkers is the number of milkers [section 6.2].

The average growth of breeding females (kg/year) between joining the herd as replacements at age 24 months and exiting as culls is estimated as:

Equation 91: lwtonfarm = matureweight * (1 – $femalewt_{dairy, 24}$) * replacementrate/100 * numbermilkers

matureweight is the mature weight of dairy cow (kg) [Charactersitics of Animals chapter].

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

replacementrate is the replacement rate (%) [Characteristics of Animals chapter].

numbermilkers is the number of milkers [section 6.2].

The weight of animals grazed off (kg/year) is used in embodied CO_2 calculations and is estimated as:

Equation 92: lwtWinterOff = herdweight * numberMilkers * Ngrazeoff

herdweight is the average weight of dairy cows in a herd (kg) [Characteristics of Animals chapter].

numbermilkers is the number of milkers [section 6.2].

Ngrazeoff if the maximum proportion of animals grazed off, entered by the user.

The weight of dairy replacements reared on farm (kg/year) is their weight gain up to weaning, and is estimated as:

Equation 93: lwtonfarm = matureweight * $femalewt_{dairy,weanage}$ * NumberMilkers * dairyreplacement / 100

matureweight is the mature weight of dairy cow (kg) [Charactersitics of Animals chapter].

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

numbermilkers is the number of milkers [section 6.2].

dairyreplacement is the replacement rate for dairy cows (%).

For dairy replacements the weight reared on farm (kg/year) is the weight gain up to weaning, and is estimated as:

If dairy replacements are grazed off, that is not on the farm permanently, then the weight leaving the farm (kg/year) is estimated as:

Equation 94: lwtsoldstore = matureweight * femalewt$_{dairy,age}$ * NumberMilkers * dairyreplacement / 100

matureweight is the mature weight of dairy cow (kg) [Charactersitics of Animals chapter].

femalewt is the proportion of mature live weight at a given age [Characteristics of Animals chapter].

age is the age (months) that replacements are on the farm to.

NumberMilkers is the number of milkers [section 6.2].

dairyreplacement is the replacement rate for dairy cows (%).

and the weight returning to the farm (kg/year) is estimated as:

Equation 95: lwtbrought = matureweight * femalewt$_{dairy,24}$ * NumberMilkers * dairyreplacement / 100

Terms are defined in Equation 94.

These are also used to estimate the live weight of replacements leaving or returning to the farm.

Weaning rate is assumed to be 100%, and non-replacement calves are assumed to be sold to store (kg/year) as:

Equation 96: lwtsoldstore = birthweight * (1 - dairyreplacement / 100) * NumberMilkers

Birthweight is the birth weight (kg) [Charactersitics of Animals chapter].

dairyreplacement is the replacement rate for dairy cows (%).

NumberMilkers is the number of milkers [section 6.2].

All live weight gains on farm are included in breeding live weight gains.

6.6. Product allocations

The same procedure as described in section 5.6 is used.

7. Calculations for RSU based systems

A RSU is defined as 6000 MJ ME requirement per year (Woodford and Nicol, 2004). Annual ME requirements of RSU based systems assume this definition (section 7.1.2). Monthly ME requirements are estimated by distributing this across the year using a distribution defined in sections 7.1.1 to 7.1.3. The intake of animals grazed off the farm should be excluded because RSU is a measure of intake that occurs on the farm. The resultant monthly ME requirements is then distributed to enterprise based outputs (section 7.1.4) that align with the same variables used for monthly stock numbers sub-model. RSU input data is at the enterprise level, not at a typical animal or mob based as for the other input systems. RSU's can be entered for deer, sheep and beef, or for other enterprise (goats, horses, camelids, and user defined).

7.1. RSU based ME requirements

The RSU entered should take account of whether animals are on the farm or whether they are grazed off farm over winter. However, the distribution of RSU assumes that animals are present all year. If grazing off farm occurs, the distribution across the year and the estimated monthly

ME requirement are adjusted. However, the total of all monthly ME requirements remain equal to the annual ME requirement based on the number of RSU entered.

7.1.1. Standard distributions

The typical monthly ME requirements distribution for each animal type (Table 8, Figure 4) was estimated from monthly animal ME requirements data, determined as part of methane calculations for the New Zealand greenhouse gas inventory (Clark *et al*., 2001).

Table 8. Distribution of total ME requirements between months

Month	Sheep	Beef	Deer
Jan	0.082543869	0.098678666	0.109682967
Feb	0.091709693	0.097303304	0.103030523
Mar	0.092105515	0.087617663	0.083390515
Apr	0.086270707	0.07981017	0.079288587
May	0.074617302	0.074020299	0.075757661
Jun	0.083115836	0.073672426	0.070765134
Jul	0.062899683	0.04598804	0.069705819
Aug	0.090541699	0.044432888	0.067866098
Sep	0.097717512	0.094480725	0.075973905
Oct	0.085458972	0.100495464	0.081100985
Nov	0.075690136	0.100050225	0.075370641
Dec	0.077329075	0.10345013	0.108067167

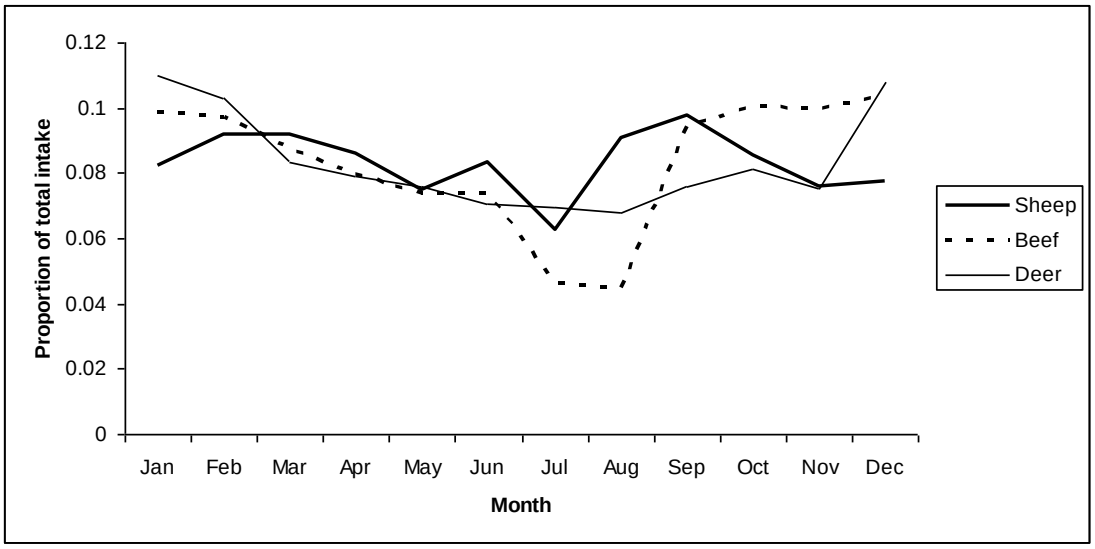

Figure 4. Distribution of total requirements between months

There is some evidence that distribution varies between regions. In addition, the distribution for steers differs from cows, indicating that beef herds with a high male percentage, and farms with finishing blocks may have a different requirement distributions. In both cases, there was insufficient data available to adjust for this and therefore no regional adjustments were incorporated.

7.1.2. Annual ME requirements

By default, RSU is distributed on a monthly basis as indicated in the previous section. If grazing off occurs, then the same number of RSU are on the farm, but the monthly distribution is different. An example based on 1 RSU (6000 MJ ME/year) is shown in Figure 5 assuming a standard distribution for sheep (section 7.1.1). The second scenario illustrates the distribution when sheep are grazed off in May and June, but the same amount of annual ME intake, as defined by the entered number of RSU's, occurs in both scenarios.

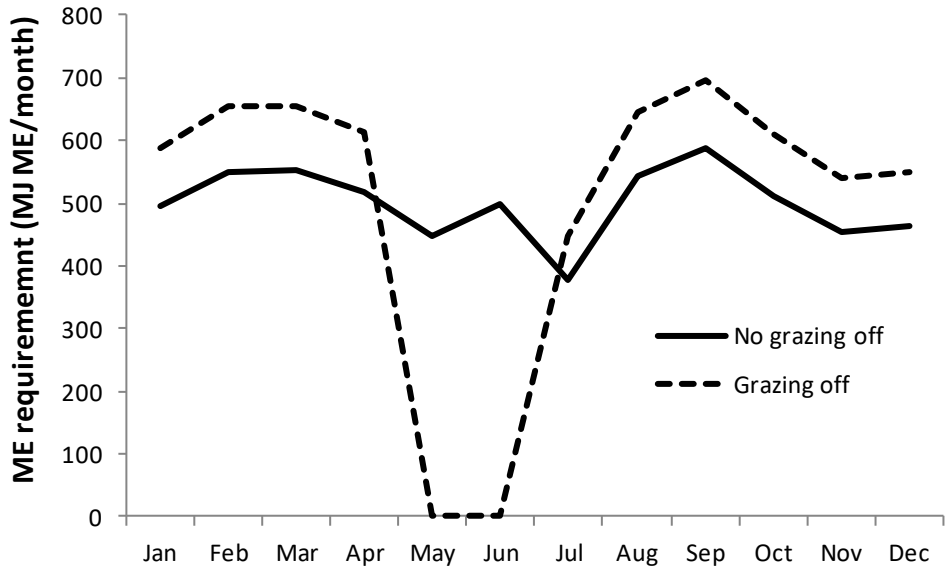

Figure 5. Monthly ME requirements of a one RSU sheep enterprise in which animals are either grazed off in May and June or remain on farm all year.

To take account of grazing-off, the entered RSU is adjusted for grazing off, and then distributed monthly (7.1.3). This adjustment in effect increases the number of RSU so that when grazing off is included in the monthly distribution, the total annual ME is the same as the entered annual ME. The adjusted annual metabolic energy requirements (RSUME, MJ ME/year) is estimated as:

Equation 97: $RSUME_{antype} = RSU_{antype} * 6000 * \sum stddist_{mon} / \sum distgraze_{mon}$

RSU is the entered RSU for sheep, beef or deer enterprises, or calculated RSU for 'Other' enterprise [section 7.6].

6000 is MJ ME/RSU, by definition.

stddist is the standard proportion of requirement each month [section 7.1.1].

distgraze is the standard proportion of requirement each month, adjusted for grazing off [Equation 98].

where

Equation 98: $distgraze_{mon} = stddist_{mon} * (1 - GrazeoffProp_{antype,\ mon} / 100)$

GrazeoffProp is the user entered monthly proportion (%) of animals are grazed off.

7.1.3. Monthly ME requirements

Monthly ME requirements are distributed using the distribution pattern defined in section 7.1.1. As RSU is a measure of requirements that occurs on the farm, it should exclude requirements from animals grazed off the farm. Thus, each month, the monthly ME requirement is estimated as:

Equation 99: $MEmonth_{mon} = RSUME_{antype} * dist_{mon}$

RSUME is annual animal energy requirements (MJ ME/year) based on the number of RSU [Equation 97].

dist is the proportion of requirement for each month [Equation 100].

Animals can be identified as being absent from blocks for a selected set of months. The standard monthly distribution (section 7.1.1) is adjusted (set to zero) for any month if animals are not on the farm as they are not on blocks, or on wintering pads/animal shelters. Grazing off is not included as this is accounted for in the previous sections. The distribution is then standardised as:

Equation 100: $dist = adjstdist / \Sigma(adjstdist)$

adjstdist is the standard proportion of requirement each month [section 7.1.1], with monthly values set to zero if animals are not on the farm.

7.1.4. ME outputs

The monthly ME requirements of animals on farm (MJ ME/month) is estimated as:

Equation 101: $AddME = MEmonth_{mon} * (1 - GrazeoffProp_{antype, mon} / 100)$

MEmonth (MJ ME/month) is as in Equation 99.

GrazeoffProp is the user entered proportion (%) of animals that are grazed off.

The enterprise ME outputs (section 3.2) are then estimated as:

Equation 102: $MEintake_{antype, mon} = AddME$

AddME is as in Equation 101.

It is assumed that breeding stock require 80% of the total ME requirement. Thus, ME requirements for breeding stock (MJ ME/month) is estimated as:

Equation 103: $MEintakeBreeding_{antype} = \sum(AddME * 0.8)$

AddME (MJ ME/month) is as in Equation 101.

For sheep, it is assumed that about 20% of the ME is from young (less than one year) animals, and that all animals are crossbred. Hence:

Equation 104: $MEYoung_{mon} = \sum(AddME * 0.2)$

AddME (MJ ME/month) is as in Equation 101.

and

Equation 105: $pCrossbred = 1$

The ME requirements (MJ ME/month) used to estimate embodied CO_2 emissions associated with wintering off is estimated as:

Equation 106: $MEWinterOff_{antype,\ mon} = MEmonth_{mon} * GrazeoffProp_{antype,\ mon} / 100)$

MEmonth (MJ ME/month) is as in Equation 99.

GrazeoffProp is the user entered proportion (%) of time animals are grazed off.

7.2. Live weight

This section describes the changes in live weight for each enterprise, which are then added to the enterprise-based changes (section 3.5).

The default values were based on average meat sold off farm as carcass weight when MAF (now MPI) monitor farms were modelled using Stockpol, a precursor of FARMAX. As actual farm data was not available, the modelled farms were based on an interpretation of MAF (now MPI) monitor farm data (pers. comm. O Montes, AgResearch, 2007).

The amount of live weight sold (kg) per RSU (kg/RSU/year) is estimated as the area weighted average across blocks. Thus:

Equation 107: $lwtSold = \sum_{block}(CarcassSold / (pdress / 100) * EntAreabl_{antype})$

CarcassSold is the carcass weight sold based on block characteristics (kg/RSU) [Table 9].

pdress is the dressing out rate percentage [Characeristics of Animals chapter].

$EntAreabl_{antype}$ is an block area enterprise (ha) [Equation 8].

Table 9. Estimated carcass weight sold (kg/RSU) and the proportion of weight sold that is from the breeding mob (pbreed) for a range of farm systems.

System	Carcass weight sold	pbreed
Sheep merino	9.5	0.7
Sheep, steep	12.7	0.5
Sheep, otherwise	14.3	0.3
Beef finishing block	32	0
Beef, otherwise	15	0.3
Deer finishing	38	0
Deer otherwise	17	0.3

The amount of live weight breed on the farm per RSU (kg/RSU/year) was not included in the original analysis, and hence this is assumed to be proportional to the live weight sold, that is:

Equation 108: $lwtbreed = \sum_{block}(CarcassSold / (pdress / 100) * EntAreabl_{antype} * pbreed)$

CarcassSold is the carcass weight sold (kg/RSU) [Table 9].

pdress is the dressing out rate percentage [Characeristics of Animals chapter].

$EntAreabl_{antype}$ is the enterprise block area (ha) [Equation 8].

pbreed is the proportion of weight sold that is from the breeding mob [Table 9].

When RSU's are entered, the animal enterprise is assumed to be breeding units and hence no live weight is brought in. On finishing blocks, it is assume that the animals finished came from the breeding mobs. Thus:

Equation 109: $lwtbrought_{antype} = 0$

The live weight raised on farm (kg/year) is therefore the live weight sold plus the live weight increase in the breeding mobs. Thus:

Equation 110: $liveweightonfarm_{antype} = (lwtSold_{antype} + lwtBreed_{antype}) / EntArea_{antype} * RSU_{antype}$

lwtSold is the amount of live weight sold (kg.ha/RSU/year) [Equation 107].

lwtBreed is the amount of live weight gain by the breeding mob (kg.ha/RSU/year) [Equation 108].

$EntArea_{antype}$ is an area enterprise (ha) [Equation 9].

RSU is the entered RSU for sheep, beef or deer enterprises, or calculated RSU for the 'Other' enterprise [section 7.6]

The live weight gain from the breeding mob (kg/year) is estimated as:

Equation 111: $liveweightonfarmBreeding_{antype} = lwtBreed_{antype} / EntArea_{antype} * RSU_{antype}$

lwtBreed is the amount of live weight gain by the breeding mob (kg.ha/RSU/year) [Equation 108].

$EntArea_{antype}$ is an area enterprise (ha) [Equation 9].

RSU is the entered RSU for sheep, beef or deer enterprises, or calculated RSU for the 'Other' enterprise [section 7.6].

The amount of live weight sold can then be estimated as:

Equation 112: $totalLwtSold_{antype} = lwtSold_{antype} / EntArea_{antype} * RSU_{antype}$

lwtSold is the amount of live weight sold (kg.ha/RSU/year) [Equation 107].

$EntArea_{antype}$ is an area enterprise (ha) [Equation 9].

RSU is the entered RSU for sheep, beef or deer enterprises, or calculated RSU for the 'Other' enterprise [section 7.6].

The live weight that is sold can be sold either to works or store. It is assumed the farm is a breeding unit so it is assumed that live weight sold is evenly split between sold to works and sold to store. Thus:

Equation 113: $liveweightSoldWorks_{antype} = totalLwtSold_{antype} * 0.5$

Equation 114: $liveweightSoldStore_{antype} = totalLwtSold_{antype} * 0.5$

liveweightSold is the amount of live weight sold (kg/year) [Equation 112].

For sheep, the live weight sold (kg/year) is split evenly between mutton and lamb. Thus:

Equation 115: $lwtsoldmutton = liveweightSold_{antype} * 0.5$

Equation 116: $lwtsoldlamb = liveweightSold_{antype} * 0.5$

liveweightSold is the amount of live weight sold (kg/year) [Equation 112].

For deer, it is assumed that 5 kg/year male live weight is sold for every kg/year of antler or velvet sold. Thus:

Equation 117: liveweightsoldMaleDeer = (velvet + antler) * 5

If animals are grazed-off over winter, then the live weight associated with grazing off for each animal enterprise (kg/year) is estimated as:

Equation 118: liveweightWinterOff[ansys] = animalwt * animalnumber * maxgrazeoff / 100

animalwt is the standard reference weight (SRW, kg) of Romney, Beef type and Red deer for sheep, beef and deer enterprises respectively [Characteristics of Animals chapter].

Maxgrazeoff is the maximum value of GrazeoffProp, the user entered proportion (%) of time animals are grazed off.

where:

Equation 119: animalnumber = RSU / RSUperanimal

RSU is the entered RSU for sheep, beef or deer enterprises, or the calculated RSU for the 'Other' enterprise [section 7.6].

RSUperanimal is RSU per animal [section 3.8].

Weight is not considered for the 'Other' animal enterprises.

7.3. Number of breeding animals

The number of breeding animals is estimated from RSU as:

Equation 120: $BreedingNumber_{antype} = RSU_{antype} / RSUperanimal_{antype}$

RSU is the entered RSU for sheep, beef or deer enterprises.

RSUperanimal is RSU per animal [section 3.8].

7.4. Percentage intake by male beef animals

For beef animals, the percentage of RSU's that are male animals is entered by the user.

7.5. Product allocations

The allocation of greenhouse gas emissions allocated to product (milk, wool, velvet) or live weight gain (panimal) is used in greenhouse gas reporting requires estimates of the number of breeding animals, the replacement rate, mature weight and weaning weight.

Weaning weight (kg) is estimated as:

Equation 121: $weaningwt = matureweight * femalewt_{weanage}$

femalewt is the proportion of mature live weight at weaning age [Characteristics of Animals chapter].

where mature weight is taken as the standard reference weight (SRW) for the breed shown in Table 10 (Characteristics of Animals chapter).

Table 10. Default breeds and replacement rates (%) used estimate product allocations when RSU is entered.

	Breed	Replacement rate
Sheep	Romney	28
Beef	Beef type	20
Deer	Red deer	24

The number of animals reared is estimated as:

Equation 122: $NumberReared_{antype} = BreedingNumber * (1 - ReplacementRate/100)$

BreedingNumber is the number of breeding animals [Equation 120].

ReplacementRate is the replacement rate (%) [Table 10].

Product allocation is not considered for the 'Other' animal enterprise.

7.6. Other enterprise RSU

RSU for 'Other' enterprises is the sum of numbers of animals entered times the RSU shown in Table 2 (section 2.3.2) or the user-defined RSU if this option is used.

Equation 123: $RSU_{other} = \sum(Number_{class} * RSUOtherAnimal_{class})$

Number is the entered number of animals for each class

RSUOtherAnimal is the RSU equivalent shown in Table 2 [section 2.3.2], or the user entered value for a user defined class of animal.

The distribution for 'Other' animal enterprise is assumed to be the same as sheep as no other information was found.

The 'Other' enterprises is assumed to be small in number and probably represent hobby farms. Hence, it is assumed that live weight sold is minimal, and hence is ignored. Product allocation is also ignored.

8. Animal products

Animal products consist of milk, wool, antlers, and velvet (enterprise specific products) which can be entered by the user, and net animal live weight leaving the farm. The latter is estimated using the change in stock numbers and their live weights.

8.1. Wool production

Wool production (greasy as sold) can be entered by the user, or is. If not, it is estimated. Wool production from Merino and Corriedale sheep breeds is assumed to be lower than other breeds; production from lambs is assumed to be about 20% lower. Thus, wool production per stock unit (kg wool/RSU) is estimated as:

Equation 124: WoolprodSU = woolmature * (1-plamb) + woolmature * plamb * 0.8

plamb is the proportion of ME requirements by lambs

Woolrate is the wool production of mature animals, weighted for breed (kg/RSU).

The wool production of mature animals, weighted for breed (kg/RSU) is estimated as:

Equation 125: woolmature = 4.83 * pCorriedale +
4.46 * pmerino +
5.1 * pCrossbred

pCorriedale, pmerino and pCrossbred is the proportion of ME requirements by Corriedale, merino or other breeds [section 3.6].

The wool production per stock unit is based on Beef and Lamb economic reports.

Total farm wool production (kg/year) is estimated as:

Equation 126: $\text{Woolproduction} = \text{WoolprodSU} * \text{RSU}_{\text{sheep}}$

RSU is the entered RSU for sheep.

8.2. Nutrient output in animal products

Product nutrients include the amount of nutrients in farm products milk, wool, velvet, and antler. These are sold from the farm during the year.

Animal live weight also contains nutrients. Nutrients in live weight changes due to growth are used in the nutrient intake sub-model. Nutrients in net live weight removed from the farm are included in the nutrient budget product removals.

For each animal enterprise, total product nutrients that are used in the intake model (kg nutrients/year) is estimated as

Equation 127: $\text{ProductNut}_{\text{antype, nut}} = \text{Prod}_{\text{nut}} + \text{lwtonfarm}_{\text{nut}}$

prod is the nutrients removed from the farm as milk, wool, velvet or antler (kg nutrient /year) [section 8.2.1].

lwtonfarm is the nutrients in live weight gain that occurred on the farm (kg nutrient /year) [section 8.2.2].

For each animal enterprise, total product nutrients removed from the farm (kg nutrients/year) is estimated as

Equation 128: $\text{ProductRemoved}_{\text{antype, nut}} = \text{Prod}_{\text{nut}} + \text{lwtloss}_{\text{nut}}$

prod is the nutrients removed from the farm as milk, wool, velvet or antler (kg nutrient /year) [section 8.2.1].

lwtloss is the nutrients in live weight sold from the farm (kg nutrient /year) [section 8.2.2].

and total nutrient intake due to live weight gain on the farm for each enterprise (kg nutrients/year) is estimated as:

Equation 129: $\text{ProductLW}_{\text{antype, nut}} = \text{lwtonfarm}_{\text{nut}}$

lwtonfarm is the nutrients in live weight gain that occurred on the farm (kg nutrient /year) [section 8.2.2].

8.2.1. Enterprise specific products

For nutrients other than acidity, product nutrient outputs ($Prod_{nut}$) are calculated using the entered or estimated production amounts, and the nutrient content of those products. Thus:

Equation 130:

$$Prod_{nut} = milkvolume * milkbulkdensity * Cmilk_{nut} \quad \text{for dairy cows}$$
$$= wool * Cwool_{nut} \quad \text{for sheep}$$
$$= velvet * Cvelvet_{nut} + antler * Cantler_{nut} \quad \text{for deer}$$
$$= milkvolume * milkbulkdensity * Cgoatmilk_{nut} \quad \text{for dairy goats}$$
$$= 0 \quad \text{otherwise}$$

milkvolume is the annual or estimated milk volume (litres/year)

Milkbulkdensity is the density of milk (litres/kg) [Characteristics of Animals chapter].

wool is the entered or estimated annual amount of wool sold (kg/year) [section 8.1].

velvet or antler is the entered amount of velvet or antler sold (kg/year).

Cmilk, Cwool, Cvelvet, Cantler and Cgoatmilk are product nutrient concentrations (kg/kg) [Characteristics of Animals chapter].

8.2.2. Live weight

Nutrients that accumulate in animals as a consequence of live weight due to growth or are used in the nutrient intake sub-model and are estimated as:

Equation 131:

$$lwtonfarm_{nut} = liveweightonFarm_{antype} * Canimal_{antype,\ nut} / 100$$

liveweightonFarm is the amount of live weight associated with growth on the farm (kg).

Canimal is the concentration of nutrient in animal live weight (%) [Charactersitics of Animals chapter].

The net amount of nutrients in live weight of animals removed from the farm is estimated from the net change in live weight, which is the difference between brought on and sold live weights. The net change may be negative if the live weight of animals brought on is greater than that sold, resulting in an accumulation of nutrients on the farm. The net amount of nutrients in live weight removed from the farm is estimated as:

Equation 132:

$$lwtloss_{nut} = (liveweightsoldWorks_{antype} + liveweightsoldStore_{antype} - liveweightbrought_{antype}) * Canimal_{antype,\ nut} / 100$$

liveweightsoldWorks is the amount of live weight sold to the works (kg) .[section 3.5].

liveweightsoldStore is the amount of live weight sold store (kg).[section 3.5].

liveweightsoldbrought is the amount of live weight brought on to the farm (kg).[section 3.5].

Canimal is the concentration of nutrient in animal live weight (%) [Charactersitics of Animals chapter].

8.2.3. Acidification from products

The removal of product can result in a change in the amount of hydrogen ions (H+) in the block or farm, resulting in acidification of the soil. The acidification rate as a consequence of product removal is a function of excess cations consumed (de Klein *et al*., 1997). The unit of change is $kmol^+$/ha/year, which is approximately the same as kg H^+/ha/year, the reporting unit that is used. The change in acidity due to product removal for non-dairy animals is estimated for each block and summed as:

Equation 133: $animalout_{antype,\ H} = \Sigma_{block}(0.15 * Cplant_H * consume_{block,\ antype} * EntAreaBl_{block})$

0.15 is the proportion of excess cations removed in products [de Klein *et al*., 1997].

$Cplant_H$ is estimated plant excess cations (EC, $cmol^+$/kg DM) [Characteristics of Pasture chapter].

consume is DM consumed by an animal enterprise from a block (kg DM/ha/year).

EntAreaBl is the enterprise area (ha) [section 3.7].

The acidity sub-model assumes that 15% of excess cations consumed by non-dairy animals is removed as products. As most of this product is live weight, then there should also be some product removal associated with net live weight changes for dairy animals, although this will be minimal for systems that bring in replacements as two year olds. The acidity removed as product removal is not adjusted for live weight leaving the farm.

Excess cations removed in product is calculated using the methods described by de Klein *et al*. (1997). Thus, for dairy cows, the change in acidity due to removal of milk is estimated from excess cations in milk as:

Equation 134: $Prod_{dairy,\ H}$ = milkvolume * ECmilk

milkvolume is the annual dairy cow milk volume (litres/year).

ECmilk is the excess cation content of milk (0.000054 kmol/litre) [deKlein *et al*., 1997].

It is assumed that the same principle applies to dairy goats, hence

Equation 135: $Prod_{dairygoats,\ H}$ = GoatMilkVolume * ECmilk

GoatMilkVolume is the annual goat milk volume (litres/year)

9. Proportion of excreta nutrients in urine

For a given nutrient, the proportion of excreta nutrient in the urine (Purine) is estimated as:

Equation 136:

Purine = ((11.9 * NutConcDiet * 100) + 29.9) / 100	N
= 0	P
= 0.88	K
= (NutConcDiet – 0.114 /100) / NutConcDiet	S
= 0.04	Ca
= 0.13	Mg

= 0.65 Na

NutConcDiet is the concentration of nutrient in the diet (kg nutrient/kg DM).

where the derivation of the equations for nitrogen (N) and sulphur (S) are described in sections 9.1 and 9.2 respectively, and the derivation of the estimated proportions for the other nutrients are described in section 9.3.

9.1. For Nitrogen

Ledgard *et al*. (2003) summarised the proportion of N intake excreted as urinary N and developed a linear relationship between the proportion of N intake and dietary N concentrations for dairy cattle. This relationship was used in the earliest version of the model, and in the New Zealand Greenhouse Gas emission inventory.

The second approach assumes that if the concentration of N in dung is constant, the proportion of excreta N as urine N on a fixed concentration in the dung can be estimated as:

Equation 137: $Purine_N = (NConcDiet – ConcDung /100) / NConcDiet$

For dairy cattle, a reasonable fit to the data was obtained assuming dung N concentrations was 0.9 g per 100 g DM eaten for cattle, and the fit was similar to that using the equation Ledgard *et al*. (2003) as shown in Figure 6

Barrow and Lambourne (1962) indicated that the average N concentration in sheep dung was 0.835 g per 100 g DM eaten. Burgraaf (pers. comm. AgResearch) indicated dung concentrations of 0.72 g per 100 g DM eaten for sheep in the absence of tannin. The relationship using the equation of Ledgard *et al*. (2003) gave a similar fit as assuming dung had fixed N concentrations of 0.835 and 0.72 g per 100 g DM eaten were used (Figure 7).

Given these results, the equation of Ledgard *et al*. (2003) was used as shown in Equation 136 for N, but assuming a maximum value of 0.8 to prevent anomalous results when dietary N concentrations are extreme.

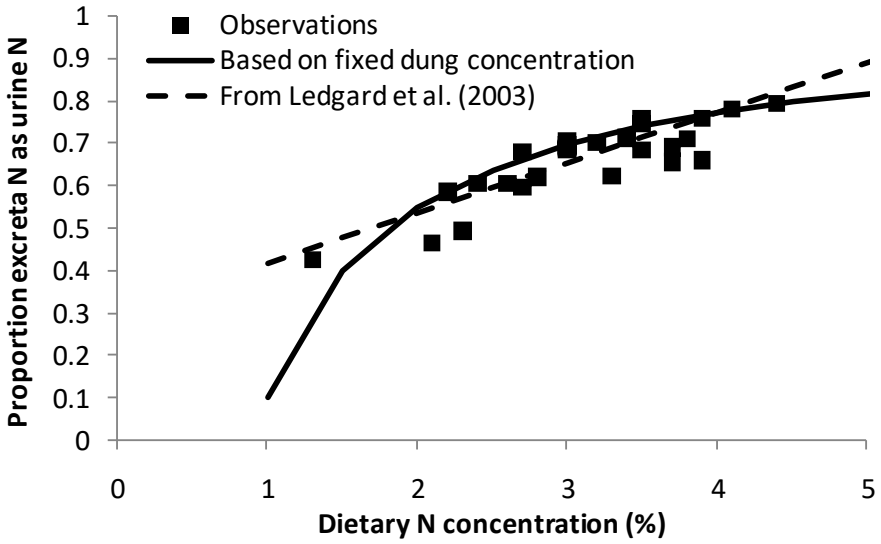

Figure 6. Relationship between dietary N concentration and the proportion of excreta N as urine N for dairy cows and cattle using data summarised by Ledgard *et al*. (2003) and a fixed dung concentration of 0.9%.

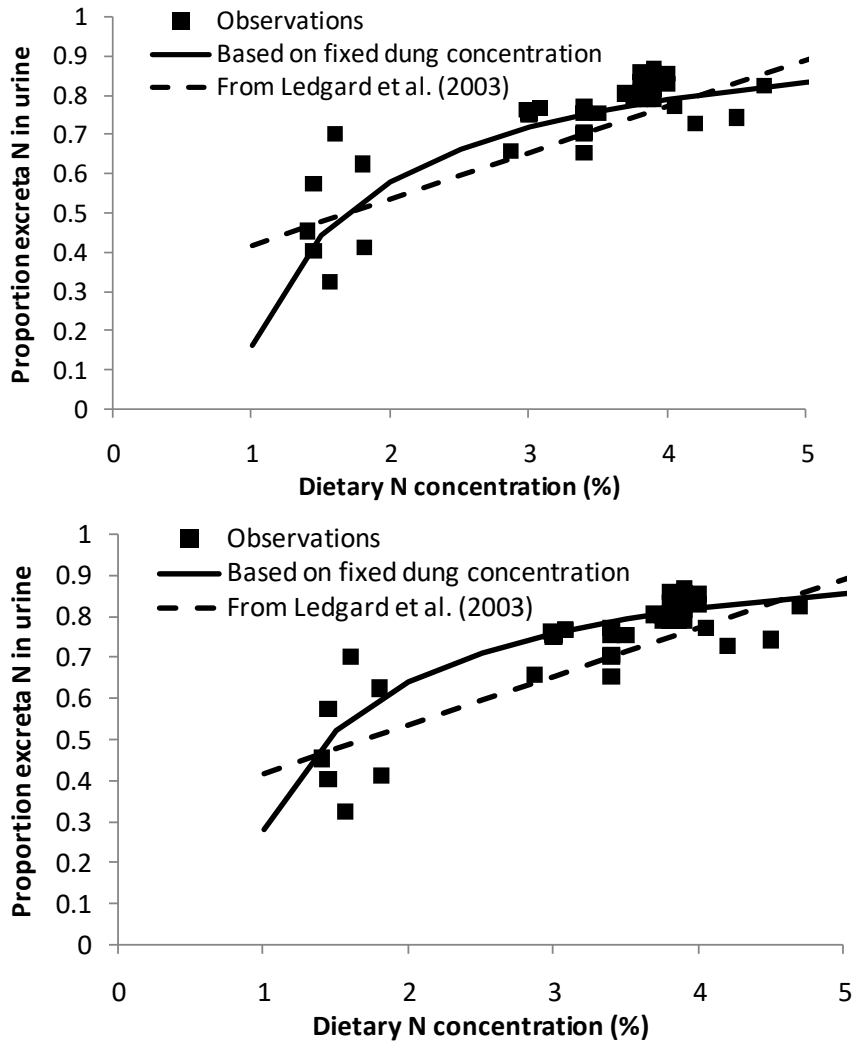

Figure 7. Relationship between diet N concentration and the proportion of excreta N as urine N for sheep using data summarised by Ledgard *et al.* (2003) and Burgraaf (pers. comm., AgResearch) and a fixed dung concentration of 0.835% (top) and 0.72% (bottom).

Tannins reduce the proportion of N in urine by 0.1 to 0.2 (Burgraaf, pers. comm., AgResearch) depending on the amount and type of condensed tannin in the diet. The presence of tannin increased N in dung from 0.72 to 1.0 g per 100 g DM eaten for sheep. The effect of tannins on N in urine is not accounted for by OVERSEER.

9.2. For Sulphur

The approach, assuming a constant dung concentration, gave reasonable results for N so the same approach has been applied to S. Barrow and Lambourne (1962) indicated that the proportion of dietary S excreted in urine varied from 6 to 90%. They also reported dung S concentration of 0.114g per 100 g DM eaten, and assuming that dung S is constant, proportion of S partitioned into urine can be estimated as:

Equation 138: $Purine_S = (SConcDiet - 0.114/100) / SConcDiet$

SConcDiet is the concentration of sulphur in the diet (kg S/kg DM).

0.114 is the sulphur content of dung (g per 100 g DM)

100 converts g per 100 g DM to kg S/kg DM

The relationship is shown in Figure 8. Goh and Nguyen (1997) reported a value of 0.6 for proportion of excreta S in urine, which corresponds to dietary S concentration using the above approach of 0.3%, which is reasonable for a pasture receiving S fertiliser.

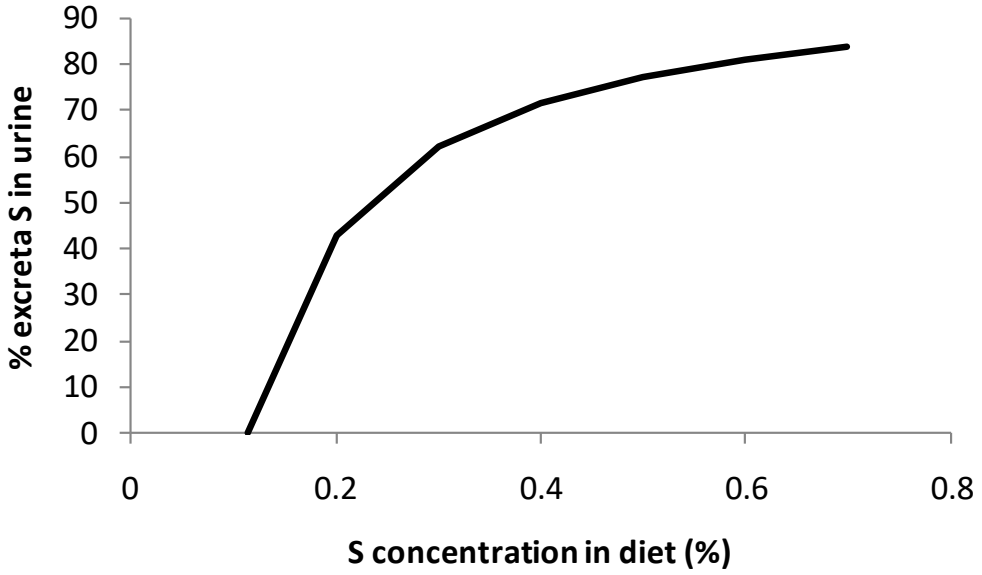

Figure 8. Relationship between diet S concentration and the proportion of excreta S as urine S and a fixed dung concentration of 0.114%.

9.3. Other nutrients

Data for other nutrients is based on data summarised by During (1972) for dairy cows. It is assumed that this also applies to other animal enterprises. A similar approach to that used for N and S could be applied if relevant data is located.

10. Acknowledgements

We wish to thank Mike Freeman and Geoff Mercer for reviewing this chapter.

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