OVERSEER® Technical Manual

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

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Characteristics of animals

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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.

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Characteristics of animals

1. Introduction

This chapter describes traits about animals used in OVERSEER, specifically dairy cows, dairy cow replacements, sheep, beef, deer, and dairy goats. The characteristics listed within this chapter are used for the following purposes (with relevant chapter name in parenthesis):

- Determination of animal metabolic energy requirements sub-model (Animal metabolic energy requirements chapter), which is used to determine pasture dry matter (DM) intake and hence nutrient intake.
- Derivation of change in animal weights over time used as an input to the metabolic requirement sub-model (Animal model chapter).
- Estimation of product nutrient removal using the nutrient concentrations of the product or live weight nutrient concentrations and the live weight removed. This is used in the nutrient budget, and the estimation of the amount of nutrients in excreta.
- Estimation of embodied greenhouse gas emissions for animal transportation using animal weights.

Many of the inputs required for these sub-models are not readily available. This document describes how default values are estimated.

1.1. 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 sub-model. This technical chapter is part of a series of technical manuals currently under development to explain the inner working of the OVERSEER engine.

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

2. Animal breeds and classes

The breeds of animals recognised within each animal enterprise are shown in Table 1. The breed is used to determine default characteristics such as standard reference weights, or default milk protein and fat levels for dairy cows.

Table 1. The breeds for each animal enterprise.

Enterprises	Breeds
Dairy	Friesian, F x J cross, Jersey, Ayrshire
Beef	Angus, Ayshire, Beef Type, Blonde, Charolais, Chianina, Dairy-beef cross, Friesian, Friesian X jersey, Hereford, Jersey, Limousine, Maine Anjou, Simmental, South Devon
Sheep	Border Leicester, Cheviot, Coopworth, Corriedale, Dorset Down, East Friesian, Finn, Merino, Oxford, Perendale, Poll Dorset, Romney, Southdown, Suffolk, Texel
Deer	Fallow, Red, Hybrid, Elk
Goats	Alpine, Nubian, Saanen, Toggenburg, Other

With each animal enterprise, a range of classes of animals is recognised. These classes are also used to identify animals that are breeding or trading, an important component of the greenhouse gas product emissions sub-model. Each class has characteristics of sex, whether they are mixed aged mob or not, whether the mob is allowed to become pregnant and to lactate, and whether the animals are from animals weaned on farm.

Animal numbers can be entered monthly using the stock reconciliation option. For each enterprise, mobs of animal are entered by selecting the breed and class, and entering the number of animal presence on the farm each month.

Each animal class can have inputs of weight and the source and fate of animals, or inputs are assumed from the class. Weights are used to determine base animal weights and growth rates that are used as inputs into the animal metabolic requirement sub-model (Animal Model chapter), and to estimate embodied CO_2 associated with transport of animals. Each animal class has a source and fate associated with them. The source and fate determine whether live weight is brought in or sold from the farm, and hence the net nutrients that leave the farm as product. It is also used in the greenhouse gas sub-model to determine embodied CO_2 emissions associated with transport. For sheep and beef animal enterprises, the option for selecting whether hoggets or heifers respectively are mating is also available.

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

- mature live weight — mature live weight (kg) (see section 4.2). Optional input.
- live weight start — 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 live weight start or age start must be entered for growing (non-breeding mob) animals.
- live weight end — weight (kg) at the end of the year can be entered, or is estimated by carcass weight dived by typically dressing out percentage, or is estimated from age at the end of the year, mature weight and a typical age live weight distribution. Optional input.

- Carcass weight — if fate is sold works, then average carcass weight (kg) can be entered. Optional input.
- Age start — age for the first entry of animal numbers in a column. Either live weight start or age start must be entered for growing (non-breeding mob) animals.
- Source — options are 'Brought', 'On-farm' or 'Weaned'. On-farm animals should also be reflected in the end of another column of older age animals that remain on farm. Must be selected for growing (non-breeding mob) animals.
- Fate — options are 'Sold store', 'Sold works' or 'Remain on-farm'. Animals that remain on farm at the end of the year should also be reflected in the beginning of another column of older age animals. Must be selected for growing (non-breeding mob) animals.

The way these inputs are used are defined in the Animal Model chapter of the Technical Manual. There are corresponding default source and fates for other methods of inputting data.

Table 2. For each class, of sex, whether they are mixed aged mob or not, whether the mob is allowed to become pregnant and to lactate, and whether the animals are animals weaned from animals on farm.

Classes	Breeding mob	Sex	Mixed age	Gestating	Lactating	Weaned on farm
Dairy cows						
Milking herd 1	✓	Female	✓	✓	✓	
Milking herd 2	✓	Female	✓	✓	✓	
Milking herd 3	✓	Female	✓	✓	✓	
Replacements	✓	Female		✓		
Breeding bulls mixed age	✓	Male				
Calves	✓	varies[1]				✓
Sheep						
Breeding ewes Mixed age	✓	Female	✓	✓	✓	
Breeding ewes	✓	Female		✓	✓	
Breeding replacements	✓	Female		✓[2]		✓
Breeding rams mixed age	✓	Male	✓			
Lambs		varies[1]				
Ewes and Hoggets		Female				
Wethers		Castrates				
Rams		Male				
Beef						
Breeding cows mixed age	✓	Female	✓	✓	✓	

Breeding cows	✓	Female		✓	✓	
Breeding replacements	✓	Female		✓[2]		✓
Breeding bulls mixed age	✓	Male	✓			
Weaners		varies[1]				
Heifers and cows		Female				
Steers		Castrates				
Bulls		Male				
Dairy grazing milking cows		Female	✓	✓		
Dairy grazing replacements		Female				
Deer						
Breeding hinds mixed age	✓	Female	✓	✓	✓	
Breeding hinds	✓	Female		✓	✓	
Breeding replacements	✓	Female		✓		✓
Breeding stags	✓	Male	✓			
Weaners		varies[1]				
Hinds		Female				
Stags Mixed age		Male				
Stags		Male				
Dairy goats						
Does milking	✓	Female	✓	✓	✓	
Does milking all year	✓	Female	✓	✓	✓	
Replacements	✓	Female		✓		✓
Breeding Bucks	✓	Male	✓			

[1] Varies means that the user can select female, male, or mixed sex.
[2] Gestation occurrence depends on age. For sheep and beef, gestation can also be set so that hoggets (< 1 year) or heifers (< 2 years) can be mated.

3. Ages

Ages of animals at different stages of growth are used primarily in the animal (Animal Model chapter) and animal metabolic requirement sub-model (Animal metabolic energy requirements chapter). These are:

- Mean weaning age (section 3.2).
- Minimum age for gestation to start (Table 3).
- Minimum age for lactation to start (Table 3). This was set at about two months prior to the age of first lactation.
- Age (months) when animals become mature (Table 3), which was set to five years for all animal types. Once animals become mature, age-related weight gain is assumed zero, but seasonal changes in weight may be modelled.

- Average age (days) of mixed age flock/herd (Table 3).

In addition, the default day in year that animals are born (section 3.1) or weaned (section 3.3) is also required. The day in year is based on a 365-day year, with 1 being January 1st, and February 29th in a leap year ignored.

Table 3. Age of animals for different stages.

	Minimum age for gestation (days)	Minimum age for lactation (days)	Age at maturity (months)	Average age of mixed age mob (months) [a]
Dairy cow	385	670	60	48
Sheep	155	305	60	48
Beef	385	670	60	60
Deer	437	670	60	72
Dairy goats	155	300	60	48

[a] Nicol and Brookes (2007, Appendix first table).

3.1. Mean birthday

Mean birth date (day in year) can be entered as part of multiple calving times for dairy cows, or in the monthly stock reconciliation form for sheep, beef and deer. Otherwise, a default day of the year is used as shown in Table 4 for dairy cows, or Table 5 for sheep, beef, deer, and dairy goats.

Table 4. Regionally based mean calving day[a] (day in year) for dairy cow animals.

Region	Mean calving day	Date
Northland	195	14th July
Auckland	201	20th July
Waikato / Coromandel	201	20th July
BOP	201	20th July
Central Plateau	201	20th July
King Country/Taihape	201	20th July
Taranaki	207	26th July
Manawatu/Wanganui	209	28th July
Wellington	209	28th July
East Coast North Island	209	28th July
West Coast South Island	218	6th August
Nelson	218	6th August
Marlborough	218	6th August
Canterbury	218	6th August
Otago	218	6th August
Southland	218	6th August
High Country (> 300 m)	218	6th August

[a] Source: Livestock Improvement Corporation (2006). Data was only available for the regions Northland, Auckland, BOP/East Coast, Taranaki, Wellington/Hawkes Bay and South Island, and represent spring calving.

Table 5. Mean birth day in year and date[a] for sheep, beef, deer, and dairy goats.

Animal type	Day in year	Date
Sheep	258	8th September
Beef	288	15th October
Deer fallow	1	1st January
Deer others	335	1st December [b]
Dairy goats	196	15th July

[a] No defined source unless indicated. Derived from expert opinion.
[b] Deer master (2006).

3.2. Weaning age

Weaning age (days) can refer to the age young animals are no longer fed milk, or the age animals are removed from the mothers.

For dairy cows, dairy calves are assumed to be fully weaned from milk at 90 days (about 13 weeks). The proportion of the replacement diet that is milk decreases over time. The age animals are removed from the mothers is assumed to be four days.

Similarly, for dairy goats, all kids are assumed to be removed from the mother four days after birth.

For non-dairy animals, age young animals are no longer fed milk and the age animals are removed from the mothers is the same. Hence weaning age is when milk is no longer a dietary component for the young animals, and lactation of the mother ceases. The proportion of the pre-weaned animal's diet that is milk decreases over time.

Table 6. Mean weaning age (days). [a]

Animal type	Weaning age (days)
Sheep	84
Beef	168
Deer	100 [b]
Dairy goats	4

[a] No defined source unless indicated. Derived from expert opinion.
[b] Deer master (2006).

Within the animal sub-model (Animal Model chapter), weaning age (days) is estimated as:

Equation 1: weaningage = meanweaningday - meanbirthday
meanbirthday is the meanbirthday (day in year) [section 3.1].
meanweaningday is the mean weaning day (day in year) [section 3.3].

If the calculated mean weaning age is less than zero, then it is recalculated as:

Equation 2: weaningage = 365 - meanbirthday + meanweaningday

3.3. Mean weaning day

For non-dairy animals, mean weaning day (day in year) is calculated from the entered date of weaning (day and month), or a default is estimated as:

Equation 3: Mean weaning day = meanbirthday + weaningage
meanbirthday is the meanbirthday (day in year) [section 3.1].
weaningage is the weaning age (days) [section 3.2].

If mean weaning day is greater than 365, then mean weaning day is recalculated as:

Equation 4: Mean weaning day = 365 - Mean weaning day

Mean weaning day is not required for dairy animals.

4. Weights

4.1. Standard reference weight or SRW

Input: Animal type

Sex

SCA (1994) defined standard reference weight (SRW, kg) as the weight of the animal when it reaches mature skeletal size and has a mid-range condition score. A similar definition was used for dairy cattle (Board on Agriculture and Natural Resources, 2001), with the additional criteria that the empty body contains 25% fat which corresponded to a mid-range condition score. Values for female animals are listed in Table 7 to Table 11.

For dairy goats, little information was found. Unpublished information suggests that in New Zealand, milking goats enter the herd at about 40 kg, and reach a maximum weight, after 4-5 years, of between 80 and 100 kg. This suggests that the published SRW for milking goats of 40-60 kg for Cashmere (cited in SCA 1994) or Angora (McGregor 2005) are lower than for milking goats. Hence, the higher weights shown in Table 11 were used.

The relationship between female SRW and male SRW, wethers SRW or steers SRW was supplied by Litherland (AgResearch, pers. comm.). Mobs that were not sexed, such as a mob of female and male lambs, are labelled mixed sex. The relationships for sheep were also applied to dairy goats.

For dairy cows

Equation 5:	SRW	= SRWf	female
		= 1.3902* SRWf + 9.8131	male
		= (SRWf * 0.5) + (1.3902 * SRWf + 9.8131) * 0.5	mixed sex

SRWf is the female breed standard reference weight [Table 7].

For sheep

Equation 6:	SRW	= SRWf	females
		= 1.3 * SRWf	males
		= 1. 1464 * SRWf + 0.2115	wethers
		= (SRWf * 0.5) + (1. 1464 * SRWf + 0.2115) * 0.5	mixed sex

SRWf is the female breed standard reference weight [Table 8].

For beef

Equation 7:	SRW	= SRWf	females
		= 1.3902 * SRWf + 9.8131	male
		= 1.1121* SRWf + 7.8505	steers
		= (SRWf * 0.5) + (1.3902 * SRWf + 9.8131) * 0.5	mixed sex

SRWf is the female breed standard reference weight [Table 9].

For deer

Equation 8:	SRW	= SRWf	females
		= 1.33 * SRWf	male Elk

= (SRWf * 0.5) + (1.33 * SRWf) * 0.5 mixed sex Elk
= 3.0442 * SRWf - 61.253 male other
= (SRWf * 0.5) + (3.0442 * SRWf - 61.253) * 0.5 mixed sex other

SRWf is the female breed standard reference weight [Table 10].

For dairy goats

Equation 9: SRW = SRWf female
= 1.33* SRWf male
= (SRWf * 0.5) + (1.33 * SRWf) * 0.5 mixed sex

SRWf is the female breed standard reference weight [Table 11].

Table 7. Female standard reference weight (SRWf, kg) [a] for dairy cow breeds.

Breed	SRWf (kg)
Friesian	525
Friesian – jersey cross	495
Jersey	405
Ayrshire	415

[a] No defined source. Derived from expert opinion.

Table 8. Female standard reference weight (SRWf, kg)[a] for sheep breeds.

Breed	SRWf (kg)
Border Leicester	76
Cheviot	50
Coopworth	73
Corriedale	63
Dorset Down	79
East Friesian	82
Finn	63
Merino	53
Oxford	84
Perendale	60
Poll Dorset	76
Romney	66
Southdown	53
Suffolk	79
Texel	73

[a] Litherland (AgResearch, pers. comm.).

Table 9. Female standard reference weight (SRWf, kg)[a] for beef breeds.

Breed	SRWf (kg)
Angus	570
Ayrshire	415
Beef Type	640
Blonde	710
Charolais	710
Chianina	710
Dairy-beef cross	640
Friesian	525
Friesian X Jersey	495
Hereford	570
Jersey	405
Limousin	640
Maine Anjou	790
Simmental	710
South Devon	710

[a] Litherland (AgResearch, pers. comm.), except for dairy cow breeds, which are the same as in Table 7.

Table 10. Female standard reference weight (SRWf, kg)[a] for deer breeds.

Breed	SRWf (kg)
Fallow	55
Red	100
Hybrid	120
Elk	280

[a] No defined source, Derived from expert opinion.

Table 11. Female standard reference weight (SRWf, kg)[a] for dairy goat breeds.

Breed	SRWf (kg)
Alpine	61
Nubian	61
Saanen	61
Toggenburg	54
Other	60

[a] See text for source.

4.2. Mature 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). This weight may not be reached on-farm, or before slaughter occurs if the animals are sold before being fully mature.

Mature weight for mixed age animals is the maximum weight within the year (excluding the conceptus[1]). This is usually the weight in autumn.

Mature weight can be entered by the user, otherwise a default value (SRW, section 4.1) is used. The mature weight would typically be greater than or equal to the standard reference weight. For dairy cow animals, mature weights in Table 12 were similar to standard reference weights presented in Table 7. Given this, for other animals except dairy goats, mature weight is assumed to be the standard reference weight (section 4.1).

For dairy goats, mature weight (Table 11) was based on unpublished data from a farm survey reported by Carlson *et al.* (2010, 2011). The standard reference weights for goats presented in Table 9 are lower than the mature weights from the survey, and hence separate default weights are used for mature and standard reference weights.

Table 12. Dairy cow female mature weight.[a]

Breed	Mature weight (kg)
Friesian	540
Friesian – jersey cross	490
Jersey	415
Ayrshire	No data

[a] Source: Livestock Improvement Corporation (2010).

Table 13. Dairy goat female mature weight.[a]

Breed	Mature weight (kg)
Alpine	79
Nubian	79
Saanen	79
Toggenburg	70
Other	79

[a] Source: see text.

4.3. Average mob weight

Input: Breed

[1] The embryo, chorionic sac, placenta, and foetal membranes in the uterus.

The maximum value throughout the year of the average weight of animals in a mixed age mob is the average mob weight, or herd weight (kg) is the average weight of animals in a mixed age herd and is estimated as:

Equation 10: herdweight $= cowherdweight_{breed} * matureweight / SRW$ dairy cow
$= matureweight$ mixed age

cowherdweight (kg) [Table 14].

matureweight (kg) is defined in section 4.2.

SRW is the standard reference weight (kg) [section 4.1].

For dairy goats, the average herd animal weight was about 60 kg (survey reported by Carlson *et al*. 201 and 2011, Pomroy *et al*. 1987) and is similar to SRW weights (Table 11). Hence, the used of mature weight, which defaults to SRW, was assumed to be adequate.

Table 14. Dairy cow herd weight for female mature weight. [a]

Breed	Herd weight (kg)
Friesian	462
Friesian – jersey cross	439
Jersey	374
Ayrshire	380

[a] Source: Livestock Improvement Corporation (2006. Table 4.6, averaged over ages 2-6 year).

4.4. Birth weight

Input: Animal type

SRW

Mature weight for dairy cow

Birth weight (kg) is estimated for dairy cows using the method shown in Equation 11 that was derived from cow and calf birth weight data in a Dexcel feed requirement brochure for dairy, and the equations from Freer *et al*. (2006) for sheep and beef, and from Nicol and Brookes (2007, page 21) for deer were used. Birth weights are determined for singles (all breeds), and for individual animals from twins (sheep and beef), and from triplets and quadruplets (sheep).

For singles:

Equation 11: $birthwt_1$ $= 0.1 * MatureWeight - 10$ dairy cows
$= 0.100 * fRS * SRW$ sheep
$= 0.070 * fRS * SRW$ beef
$= 3.1351 * Ln(SRW) - 7.2375$ deer
$= MatureWeight * 0.07$ dairy goats

SRW is the standard reference weight (kg) [section 4.1].

MatureWeight is the mature weight (kg) [section 4.1].

fRS is a factor to adjust birt weight for animal size [Equation 15].

If twins, then:

Equation 12: $birthwt_2$ = 0.085 * fRS * SRW — sheep
= 0.055 * fRS * SRW — beef

If triplets, then:

Equation 13: $birthwt_3$ = 0.070 * fRS * SRW — sheep

If quadruplets, then:

Equation 14: $birthwt_4$ = 0.055 * fRS * SRW — sheep

The constant 0.55 for $birthwt_4$ was extrapolated from the constants for $birthwt_{1..3}$.

To account for birth weight of lambs or calves being larger in larger ewes or cows respectively, birth weight is adjusted by the factor fRS, which is estimated as:

Equation 15: fRS = (1 - 0.33 + 0.33 * RS)

This factor has been re-written as (1 – 0.33 * (1-RS)).

4.5. Weaning weight

A weaning weight (kg) can be supplied by the user; otherwise a default weaning weight can be estimated (Equation 16). The equation to estimate weaning weight for deer was derived from data in Nicol and Brookes (2007, Appendix, Table headed: Values for birth weight and mature live weight …).

Equation 16: Weaningwt = supplied value — or
= birthwt1 + (WeaningAge * 0.5) — dairy cows
= femaleweight * $Monthlwt_{mon}$ — otherwise

birthwt1 is the birth weight (kg).

weaningAge is the age at weaning (days) [section 3.2].

femaleweight is the female mature weight, or a female mature weight. estimated from male mature weight using the relationships to estimate SRW [section 4.1].

monthlwt is the monthly age weight factor [see section 4.7, Table 16] for the month mon, where mon is the interger value of (LacLen / 30) + 1.

LacLen is the lactation length (days) [section 5.1].

If a weaning weight is not included in the parameters sent to the animal metabolic requirement sub-model procedure, then the following is assumed:

Equation 17: Weaningwt = birthwt1 + (WeaningAge * 0.5) — dairy cows
= 20 — sheep
= 120 — beef

= 31.351 * Ln(SRW) - 97.375 deer
= 16 dairy goats

SRW is the standard reference weight (kg) [section 4.1].

4.6. Live weight variation within year for mature animals

Inputs: Herdweight = maximum weight during year once animals are mature

DayLactation = days since lactation started

For dairy animals, the change in weight over time for a lactating mature dairy cow was based on the weight changes measured at a Waikato research dairy farm (No 2 dairy, Dexcel) and are shown in Figure 1. This indicated that the maximum decrease in weight was about 15% of maximum weight, that the weight decrease started about 30 days after lactation started, and that minimum weight occurred about 120 days after lactation. However, it was considered that the decrease in weight was larger than typically occurred on dairy farms, and the duration shorter. Hence, maximum proportional decrease in weight is set to 0.1 and number of days from start of lactation that minimum weight occurs was set to 100 days.

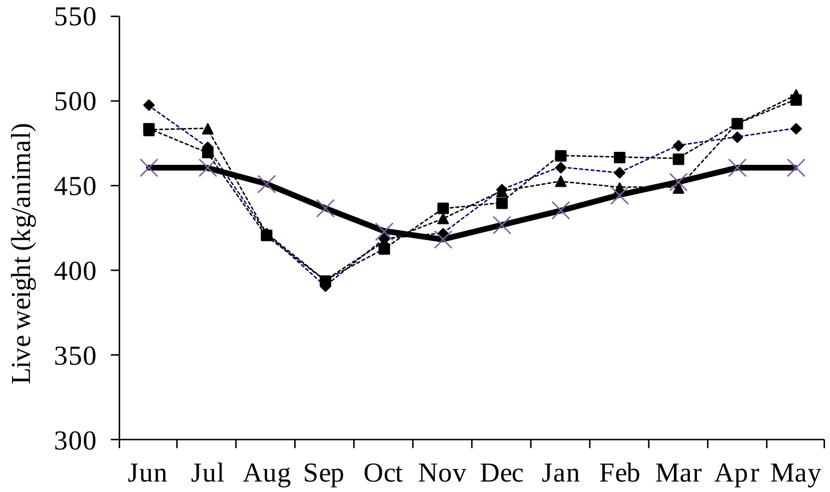


Figure 1. Live weight (kg/animal) over 3 years for a dairy herd in the Waikato (dotted lines), and fitted model (solid bold line) assuming a base weight of 461 kg/animal.

To allow the timing of weight change to respond to differences in lactation length, the day since the start of lactation that the minimum weight occurs, and the size of the decrease in weight was made proportional to the lactation length. Thus day since the start of lactation that the minimum weight occurs is estimated as:

Equation 18: LowPoint = 100 * Lactlen / 263

Lactlen is the lactation length [section 5.1].

263 is the average lactation length for No2 dairy.

and the proportional decrease is estimated as:

Equation 19: Decrease = 0.1 * Lactlen / 263

The change in live weight (kg/day) is then estimated as:

Equation 20: MatureLwtChange := (endlwt - startlwt) / $DaysInMonth_{mon}$

endlwt is the weight at Lactday, where lactday is the number of days of the lactation to the end of the month or end of lactation [Equation 21 or Equation 22].

startlwt is the weight at Lactday, where lactday is the number of days of the lactation at the beginning of the month or start of lactation [[Equation 21 or Equation 22].

If the point in time (lactday) is less than the day since the start of lactation that the minimum weight occurs, weight is estimated as:

Equation 21: Weight = HerdWeight - (HerdWeight * Decrease) / LowPoint * Lactday

Herdweight (kg) is the maximum weight of mature animals [section 4.3].

Decrease is the maximum proportional decrease is the live weigth [Equation 19].

Lowpoint is the day since the start of lactation that the minimum weight occurs [Equation 18].

Lactday is the day since start of lactation.

Otherwise weight is estimated as:

Equation 22: Weight = HerdWeight - (HerdWeight * Decrease) + (HerdWeight * Decrease) / (Lactlen - LowPoint) * (Lactday - LowPoint)

The proportion of a lactating female sheep, beef or deer animal maximum weight within a year for a given month was estimated by combining the weight data from Nicol and Brookes (2007), Fennessey *et al.* (1981), Fleming (1996), and Woodford and Nicol (2004). The proportion of mature weight is based on animal weight less the conceptus. Thus, when estimating the proportions, it was assumed that female weight declined nearly linearly from mating to immediately post-birth, and the difference was the conceptus. The value of 1 represents the maximum weight (excluding conceptus), or the mature weight (see section 4.1) and typically occurs at about mating time.

The result of this analysis is shown in Table 15 and in Figure 2.

For male mature animals, it was assumed that mature weight was constant over the year (the proportion of mature weight was constant) except for stags, where the maximum weight was the weight before mating started.

For sheep, the proportion of mature weight for each month was similar for 55 and 65 kg mature ewes. Therefore, any difference due to the base weight of ewes was ignored.

For dairy goats, it was assumed that live weight variation within year for mature animals was minimal. It has been noted that goats tend to be fed well all year round as they do not have the reserves for large weight changes (Carlson, AgResearch, pers. comm.).

Table 15. Proportion of mature weight for given month for ewes, beef cows, hinds and stags.

	Ewe	Beef cow	Hinds	Stags	Dairy goats
January	0.936	1	0.872	0.98	1
February	0.934	0.978	0.921	1	1
March	0.982	0.945	1	0.95	1
April	1	0.913	1	0.90	1
May	0.995	0.880	1	0.84	1
June	0.957	0.860	1	0.83	1
July	0.957	0.870	0.973	0.81	1
August	0.989	0.891	0.947	0.80	1
September	0.856	0.910	0.921	0.84	1
October	0.892	0.930	0.895	0.88	1
November	0.924	0.956	0.868	0.91	1
December	0.926	1	0.842	0.94	1

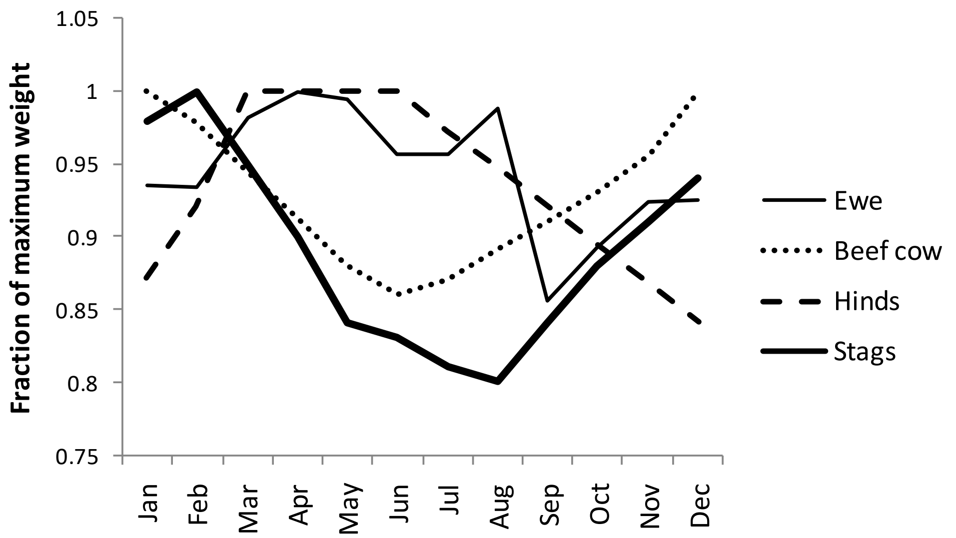


Figure 2. Proportion of mature weight for sheep, beef, and deer.

4.7. Proportion of mature weight at a given age

For animal mobs entered using the stock reconciliation method, the proportion of mature weight at a given age is used to estimate the default weight gains if beginning and end weights are not entered, or default age if weights are entered but not age.

The proportion of mature weight at a given age for sheep and beef animals (Table 16, Figure 3a) was estimated from data in Nicol and Brookes (2007, Appendix second table), and Fleming (1996). The growth curve was adjusted so that live weight always increases over time. The value at 0 represents weaning weight.

For sheep, the monthly weight factors were similar for a target weight of 55 and 65 kg mature ewes (Fleming 1996). Therefore, mature ewe weight changes were ignored.

For beef, there was an indication that beef animals (mature weight of 450 kg) had a different growth curve than dairy-beef animals (Fleming 1996). This difference has been ignored. For a given age, steers (castrated) are about 10% heavier and bulls 20% heavier than heifers (Fleming 1996). It is assumed that this occurs as mature weights of these sexes are higher, rather than the proportion of mature weight at a given age differing with sex. The curve for dairy cows was based on dairy beef animals in Fleming (1996).

For deer, data from Nicol and Brookes (2007) and SU (stock units) data from Woodford and Nicol (2004) was use to estimate the proportions shown in Table 16 and Figure 3b. The stag growth rates came from Fennessey *et al.* (1981).

For dairy goats, the growth curve is based on birth weight, weaning month, age and typically weights at mating (Carson, AgResearch pers. comm., based on data from Stubbs and Abud), and weights from a weight gain study reported on an unrecorded internet site (Figure 4). The weights in New Zealand appear to be higher than those reported overseas. The pattern of live weight change over the first eight months was similar for Carlson (2010) and the farm survey (Figure 4).

Table 16. Proportion of mature weight at a given age for dairy cow, sheep and beef animals, and for deer breeds (Red, Hybrid, Elk) and stags.

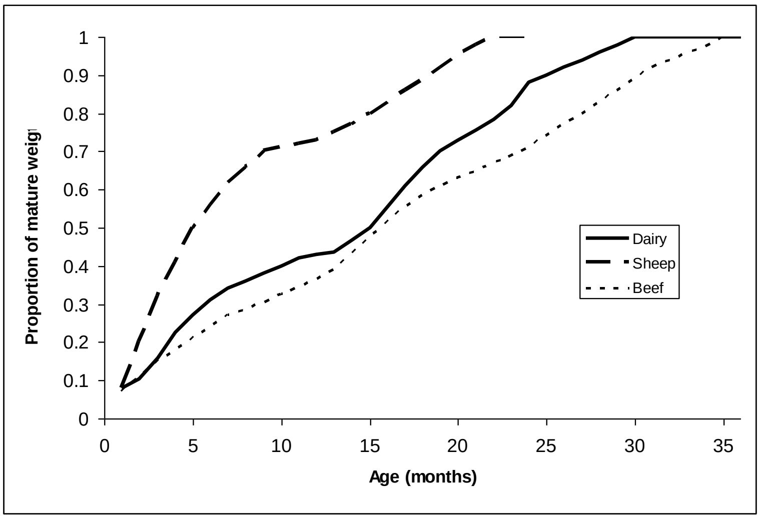
Index	Dairy cows	Sheep	Beef	Red	Hybrid	Elk	Stag	Dairy goats
0	0.08	0.08	0.07	0.07	0.066	0.04	0.07	0.042
1	0.10	0.14	0.09	0.185	0.168	0.11	0.16	0.0825
2	0.12	0.20	0.11	0.30	0.27	0.18	0.25	0.123
3	0.16	0.32	0.15	0.392	0.344	0.214	0.35	0.196
4	0.225	0.41	0.18	0.433	0.381	0.311	0.356	0.262
5	0.27	0.50	0.21	0.467	0.413	0.332	0.36	0.322
6	0.31	0.56	0.24	0.508	0.4444	0.346	0.37	0.375
7	0.34	0.62	0.27	0.525	0.463	0.361	0.385	0.423

Index	Dairy cows	Sheep	Beef	Red	Hybrid	Elk	Stag	Dairy goats
8	0.36	0.66	0.288	0.542	0.481	0.371	0.39	0.466
9	0.38	0.70	0.305	0.575	0.50	0.389	0.40	0.504
10	0.40	0.71	0.325	0.617	0.537	0.429	0.407	0.538
11	0.42	0.72	0.345	0.683	0.593	0.458	0.52	0.569
12	0.43	0.73	0.365	0.742	0.662	0.497	0.593	0.596
13	0.435	0.75	0.39	0.808	0.711	0.542	0.61	0.620
14	0.465	0.77	0.43	0.842	0.74	0.564	0.63	0.641
15	0.50	0.80	0.475	0.851	0.778	0.66	0.644	0.660
16	0.555	0.83	0.515	0.853	0.809	0.682	0.68	0.677
17	0.61	0.86	0.555	0.854	0.84	0.696	0.72	0.692
18	0.66	0.89	0.585	0.856	0.859	0.71	0.746	0.706
19	0.70	0.92	0.61	0.857	0.878	0.721	0.747	0.719
20	0.73	0.95	0.63	0.89	0.896	0.739	0.748	0.731
21	0.755	0.98	0.65	0.895	0.896	0.778	0.749	0.742
22	0.785	1	0.67	0.895	0.896	0.807	0.75	0.752
23	0.82	1	0.69	0.895	0.896	0.847	0.751	0.763
24	0.88	1	0.71	0.895	0.896	0.847	0.752	0.773
25	0.90		0.74	0.895	0.896	0.872	0.8	0.783
26	0.92		0.77	0.921	0.921	0.921	0.86	0.793
27	0.94		0.8	0.95	0.95	0.95	0.911	0.803
28	0.96		0.83	0.97	0.97	0.97	0.92	0.813
29	0.98		0.86	0.993	0.993	0.993	0.93	0.824
30	1		0.89	0.994	0.994	0.994	0.99	0.835
31	1		0.92	0.995	0.995	0.995	0.991	0.846
32	1		0.94	0.996	0.996	0.996	0.992	0.858
33	1		0.96	0.997	0.997	0.997	0.993	0.870
34	1		0.975	0.998	0.998	0.998	0.994	0.882
35	1		1	0.999	0.999	0.999	0.995	0.894
36	1		1	1	1	1	1	0.907
37								0.919
38								0.932
39								0.944
40								0.955
41								0.966
42								0.976
43								0.985
44								0.993
45								0.999
46								1
47								1
48								1

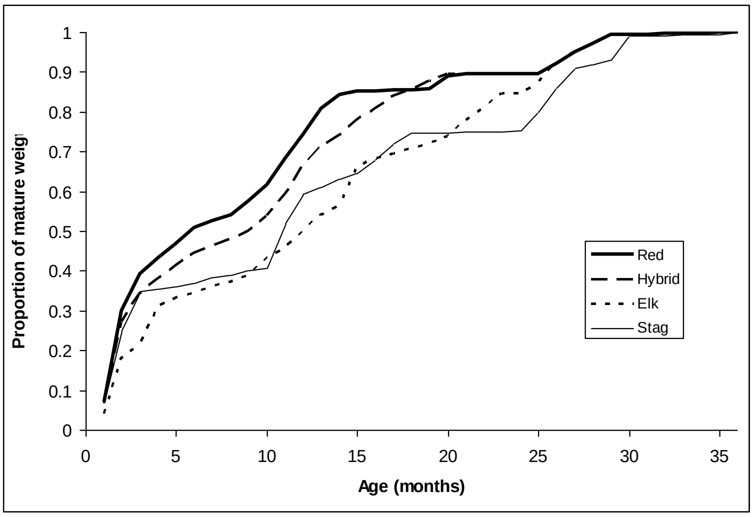
Table 17. Interpretation of curve data.

Index [a]	Age range (months)	x-axis (months) [b]	Age [c]
0	0 (Birth weight)		
1	>0-1	0.5	1
2	>1-2	1.5	2
3	>2-3	2.5	3
4	>3-4	3.5	4
5	>4-5	4.5	5

[a] Index in Table 16.
[b] age data extracted from relationships in Figure 3 and Figure 4.
[c] age (months) that is entered on the interface.



a)



b)

Figure 3. Estimated proportion of mature weight at a given age for dairy cow, sheep, and beef (a) and for deer breeds (red, hybrid, elk) and stags (b).

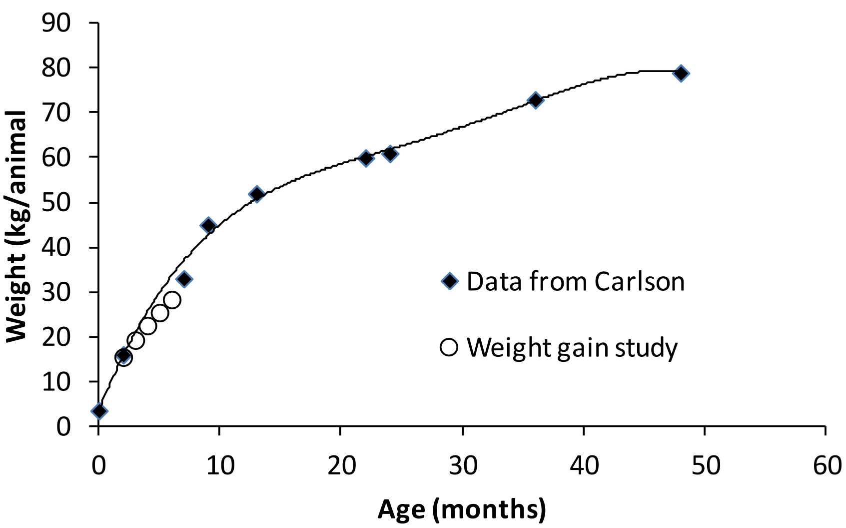


Figure 4. Weight (kg/animal) of dairy goats at a given age.

4.8. Dressing out rate

The ratio between carcass weight (as displayed on freezing works killing sheets) and live weight is the dressing out rate. The user can enter a final weight of a mob leaving the farm as a carcass weight and dressing out rate is used to convert this to live weight.

Equation 23: liveweight = carcassweight * dressrate / 100
Carcassweight is the entered carcass weight (kg).
Dressrate is the dressing out prescentage [Table 18].

Dressing out rate for sheep, beef and deer (Table 18) was taken from Fleming (1996, section A-97). Dressing out rate for dairy cows was set to be the same as beef and for dairy goats the same as sheep. For deer, Fleming (1996) had dressing out percentage (carcass weight x 100/ live weight) varying with weight. Thus, a dressing out percentage was assigned to deer breeds based on the SRW for the breed (Table 19).

Table 18. Dressing out percentage.

Breed	Dressing out %
Dairy cows	55
Sheep, <= 12 months old	45
Sheep, > 12 month old	50
Beef	55
Deer	Table 19
Dairy goats	50

Table 19. Deer dressing out percentage.

Breed	Dressing out %
Fallow	52
Red	54
Hybrid	56
Elk	58

5. Lactation

5.1. Lactation length

For dairy cows, lactation length (days) can be estimated from the difference between mean calving and drying off dates if entered, or can be entered directly in the monthly stock reconciliation form. Otherwise, a default lactation length is used:

For dairy cows, lactation length is estimated as:

Equation 24: Lactation length = DiffcalveDry if calving date data entered
= enter value if lactation length entered
= regionally based lactation length [Table 20]

where

Equation 25: DiffcalveDry = dryoffday – StartCalveDay

Dryoffday is the day in year that drying off occurred, determined from the entered mean drying off date.

StartCalveDay is the day in year for median calving, determined from the entered mean start calcving date.

If dryoffday > StartCalveDay, then

Equation 26: DiffcalveDry = 365 - StartCalveDay + dryoffday

Table 20. Regionally based default lactation length for dairy cows. [a]

Region	Lactation length (days)
Northland	264
Auckland	268
Waikato / Coromandel	268
BOP	264
Central Plateau	264
King Country / Taihape	268
Taranaki	266
Manawatu/Wanganui	270
Wellington	270
East Coast North Island	270
West Coast South Island	268
Nelson	268
Marlborough	268
Canterbury	268
Otago	268
Southland	268
High Country (> 300 m)	268

[a] Source: Livestock Improvement Corporation, 2006. Data was only available for the regions Northland, Auckland, BOP/East Coast, Taranaki, Wellington/Hawkes Bay and South Island.

For sheep, beef and deer, lactation length is estimated as the difference between mean birth day and mean weaning day.

Equation 27: Lactlength = MeanWeaningday – Meanbirthday

MeanWeaningday is the mean weaning day (day in year) [section 3.3].

Meanbirthday.is the mean birth day (day in year) [section 3.1].

if MeanWeaningday > Meanbirthday, otherwise

Equation 28: Lactlength = 365 - Meanbirthday + MeanWeaningday

Dairy goats milking mobs can be either milked all year, or dry off at the end of the season. Lactation length (days) is estimated as:

Equation 29:	Lactation length	= 365	if milked all year
		= enter value	if lactation length entered
		= 270	otherwise

5.2. Milk composition

For dairy cows, milksolids (fat plus protein, kg) is a compulsory input and milk fat (kg) amount is an optional user input. If milk fat amount is entered, then fat and protein content (%) is estimated as:

Equation 30: Milk fat% = milkfat / (milkyield * milkdensity) * 100
Equation 31: Milk protein% = (milksolids - milkfat) / (milkyield * milkdensity) * 100
milkfat is the entered milk fat amount (kg).
milksolids is the amount of milksolids (kg).
milkdensity is the density of milk (kg/l) [section 5.3].
milkyield is the volume of milk (l) [section 5.4].

The default milk fat and protein contents are shown in Table 21.

Table 21. Dairy cow breed based default fat and protein contents (%).[a]

Parameter	Unit	Friesian	Friesian – jersey cross	Jersey	Ayrshire
Fat content of milk	%	4.44	5.06	5.80	4.45
Protein content of milk	%	3.60	3.86	4.14	3.61

[a] Source: Livestock Improvement Corporation (2010).

Data from No 2 dairy, where milk fat, protein and lactose was measured regularly, indicates that milk fat showed a seasonal pattern whereby it was higher at the beginning and end of lactation. Changes in milk content during lactation have not been included.

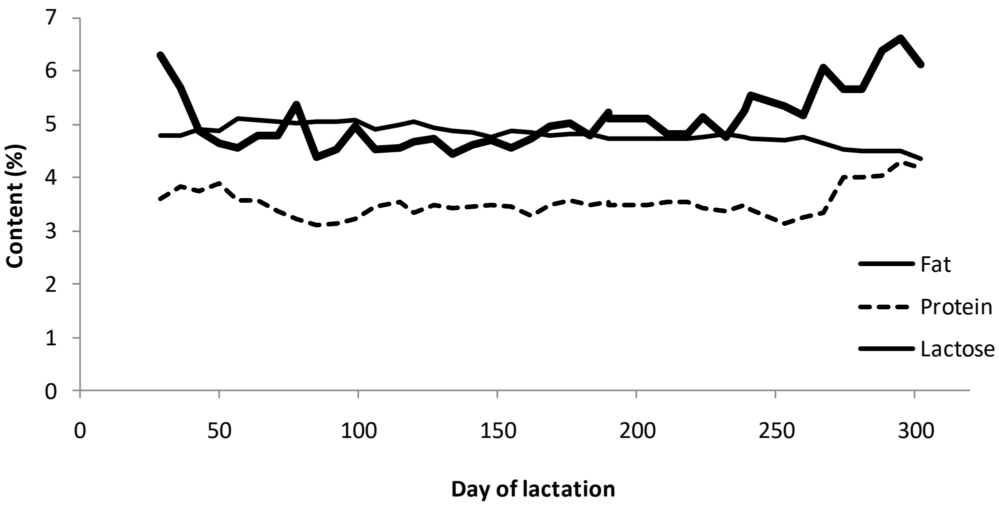


Figure 5. Variation in milk fat, protein and lactose with day of lactation for dairy cows.

Sheep and beef milk composition was based on mean values from several sources (Table 22). Moore (1966) and Corbett (1968) indicated that in merinos, milk fat content increased over time but this variation has been ignored.

Table 22. Milk fat and protein contents for sheep and beef milk (%).

Breed	Fat%	Protein%	Fat%	Protein %
	Sheep		Beef	
Freer *et al*. (2006)		4.5		3.2
Silver (1961)	6.24	5.4	3.65, 4.45	3.13, 3.77
Berger (2013)	6.6	5.8		
Oddy (1978[a])	6.5, 5.6	3.9, 4.5		
Moore (1966[b])	5.7-7.2			
Corbett (1968[b])	7.39-9.08	5.02-5.57		
Melton *et al.* (1967[c])			2.68-2.82	8.64-8.94
MAF (2011)	8.0		4.62-4.95	3.45-3.76

[a] feed high wheat and 50% wheat diet.
[b] Merinos, content increased over time.
[c] For Angus, Charolais, and Hereford cows.

For deer, Landete-Castillejos *et al*. (2003) reported that Iberian red deer milk contained 11.5% fat, 7.6% protein, 5.9% lactose, and 26.7% DM. Silver (1961) reported that for four deer studies on reindeer, unspecified deer breed and two studies on white-tailed deer, milk contained 15.1-22.5% fat, 10.3-11.92% protein, 2.2-3.8 % lactose, and an additional study with mule deer had 8.3% fat. Silver (1961) also indicated that protein and fat content in deer milk was higher than in cow and sheep milk. Both Mueller and Sadleir (1977) and Arman *et al.* (1973) had similar average contents, but their studies showed milk fat and protein increased by nearly 50% and lactose content more than halved over 20 weeks of lactation. Based on this data, default values of 15% fat and 10% protein for deer were adopted.

For dairy goats, production records (milk volume in litres/month, and milk fat, milk protein and lactose (kg/month)) for 50 indoor and outdoor suppliers were available over a 2-year period (DGC, data not published). Milk fat and protein contents tended to be slightly higher for indoor than outdoor goat herds, higher earlier in lactation, and higher later in lactation for indoor herds (Figure 6). Changes in milk content during lactation or differences between indoor and outdoor herds have not been included.

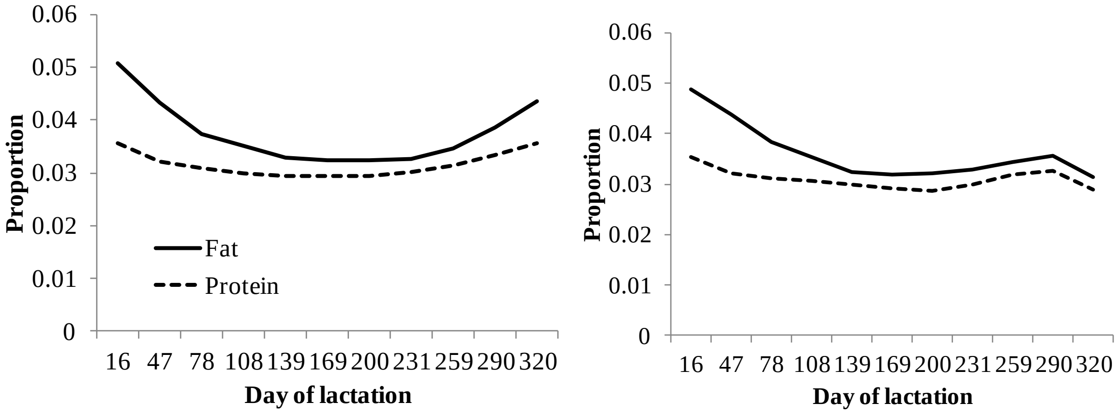


Figure 6. Milk fat and protein content for indoor (left) and outdoor (right) dairy goat mobs.

The default values for milk fat and protein content are shown in Table 23 and Table 24 respectively.

Table 23. Milk fat content (%).

Animal	Milk fat%
Dairy cow	Table 21
Sheep	6.5
Beef	4.5
Deer	15.0
Dairy goats	3.68

Table 24. Milk protein content (%).

Animal	Milk protein %
Dairy cow	Table 21
Sheep	5.5
Beef	3.5
Deer	10.0
Dairy goats	3.12

For dairy cows, total milk fat and milk protein (kg/year) can be estimated as shown in Equation 32 and Equation 33 for reporting.

Equation 32: milkfat = Milk fat%/ (Milk fat%+ Milk protein%) * milksolids
Equation 33: milkprotein = milksolids - milkfat

5.3. Milk density

Measured data from a research dairy farm in a Waikato dairy trial (unpublished data) gave a milk density of 1.033 kg/l. Wells (2001) reported an average of 1.032 kg/l. Therefore, the density of dairy milk was assumed to be 1.032 kg/l, and to apply to milk from all animal types.

5.4. Total milk volume and weight

Total annual milk volume (l/year) is estimated as:

Equation 34: Milk volume = milksolids * milk ratio
milksolids is the entered milk solids (kg).
milk ratio is a breed based conversion factor for dairy cows [Table 25].

For dairy cows, milksolids is fat plus protein amount, and for dairy goats, the sum of fat, protein and lactose amounts. The difference in definitions reflected the different reporting values from factories.

The weight of milk (kg) can be estimated as milk volume (l) multiplied by the milk density (kg/l).

5.5. Production per animal

Production per animal of solids, fat and milk volume (Table 25) are used to distribute milk production between herds.

Table 25. Dairy cow breed based average production.

Parameter	Unit	Friesian	Friesian – jersey cross	Jersey	Ayrshire
Milk ratio[b]	l milk/kg milksolid	12.52	11.32	10.10	12.46
Milk solids [b]	kg/year/cow	329	291	329	295
Milk fat [b]	kg/year/cow	180	169	185	162
Milk volume [b]	l/year/cow	4169	2975	3773	3695

[a] Source: ratio of milk volume (litres) and milksolids (kg) (Livestock Improvement Corporation (2006, Table 4.6, averaged over ages 2-6).
[b] Source: Livestock Improvement Corporation (2006. Table 4.6, averaged over ages 2-6).

5.6. Daily milk yield

For dairy cows and dairy goats, an annual milk yield is entered. The daily milk yield (kg milk/day) is estimated as:

Equation 35: Daymilkyield = milkvolume * milkdensity * $PropLact_{day}$

Milkvolume is the annual milk volume (l milk/year) [section 5.4].
Milkdensity is the milk density density (kg/l) [section 5.3].
PropLact is the proportion of annual milk produced each day [section 5.4].

Milk volume can be either total volume, volume per mob or volume per cow or dairy goat.

For sheep and beef, daily milk yield daily milk yield is estimated using a method supplied by Litherland (AgResearch, pers. comm.). For sheep, the effect of multiple young (MLE), different breeds and available pasture are factored into the estimation of daily milk yield (Litherland, AgResearch, pers. comm.). Thus daily milk yield (kg milk/day/animal) for sheep is estimated as:

Equation 36: Daymilkyield = (1.01
* EXP(0.41 * LN(DayLactation) - 0.0287 * DayLactation)
* MLE * BFM * 1000
+ (0.4144 * ($PastureMass_{slope, sheeep}$ * 1000 -1300))
+ (-1 * $10E^{-4}$ * ($PastureMass_{slope, sheeep}$ * 1000 - $1300)^{2}$)) / 1000

DayLactation is the number of days since the start of lactation.
PastureMass is the pasture mass at grazing (T DM/ha) [section 7.3].
EXP is the natural exponential, and LN the natural logarithim.

The multiplier for the effect of multiple young on lactation (MLE) is estimated as:

Equation 37: MLE = 1.002884363 * $prop_1$ + 1.287356551 * $prop_2$
+ 1.368048232 * $prop_3$
+ 1.368048232 * $prop_4$

$Prop_n$ is the proportion of animals with 1, 2, 3 or 4 young [section 6.6].

The multiplier for the effect of different breeds on lactation (BFM) for a single animal was originally written as:

Equation 38: BFM = 1 + (Breedeffect * (3 * (N-1)/(N+1))

However, this can be translated in the equation shown above for a mob-based mode to give:

Equation 39: BFM = $prop_1$ + (1 + Breedeffect) * $prop_2$
+ (1 + (Breedeffect * 1.5) * $prop_3$
+ (1 + (Breedeffect * 1.8) * $prop_4$

Breedeffect	= 0.2EastFriesian
= 0.1	RomneyEFcross
= 0.01	otherwise

$Prop_n$ is the proportion of animals with 1, 2, 3 or 4 young [section 6.6].

There was no information for the effect of quadruplets on MLE. A plot of the constants indicated that the constants were reaching a plateau after triplets and hence the same constant was used for quadruplets as for triplets.

Daily milk yield (kg milk/day/animal) for beef animal (Litherland, AgResearch, pers. comm.) is estimated as:

Equation 40: $\text{Daymilkyield} = 4.26 * \text{DayLactation}^{0.113} * (\text{EXP}((-4.95\ 10^{-3}) * \text{DayLactation})) + (6.51\ 10^{-4} * (\text{PastureMass}_{\text{slope, beef}} * 1000 + 200)) + (2.9110^{-1} * \text{BC})$

DayLactation is the number of days since the start of lactation.
PastureMass is the pasture mass at grazing (T DM/ha) [section 7.3].
BC is a breeding condition (assumed to be 1).
EXP is the natural exponential.

For deer, a different approach was adopted as outlined in the Animal metabolic energy requirements chapter as no information was found for annual milk yield.

5.7. Daily distribution of milk yield

For dairy cows, the proportion of annual milk yield that occurred on a given day of lactation was based on three years of data from Number 2 dairy farm in the Waikato (Figure 7). The average lactation length was 263 days. If the day of lactation is less than the lactation length, the proportion of annual milk that was produced on that day is estimated as:

Equation 41: $\text{Prop}_{\text{day}} = (-0.00000003891 * \text{DayLactation}^2 + 0.0000016361 * \text{DayLactation} + 0.0044999) * 263 / \text{lactlen}$

DayLactation is the number of days since the start of lactation.
lactlen is the lactation length (days) [section 5.1].

A minimum value based on the value at 300 days lactation (0.001489) was set for mobs with greater than 300 days lactation.

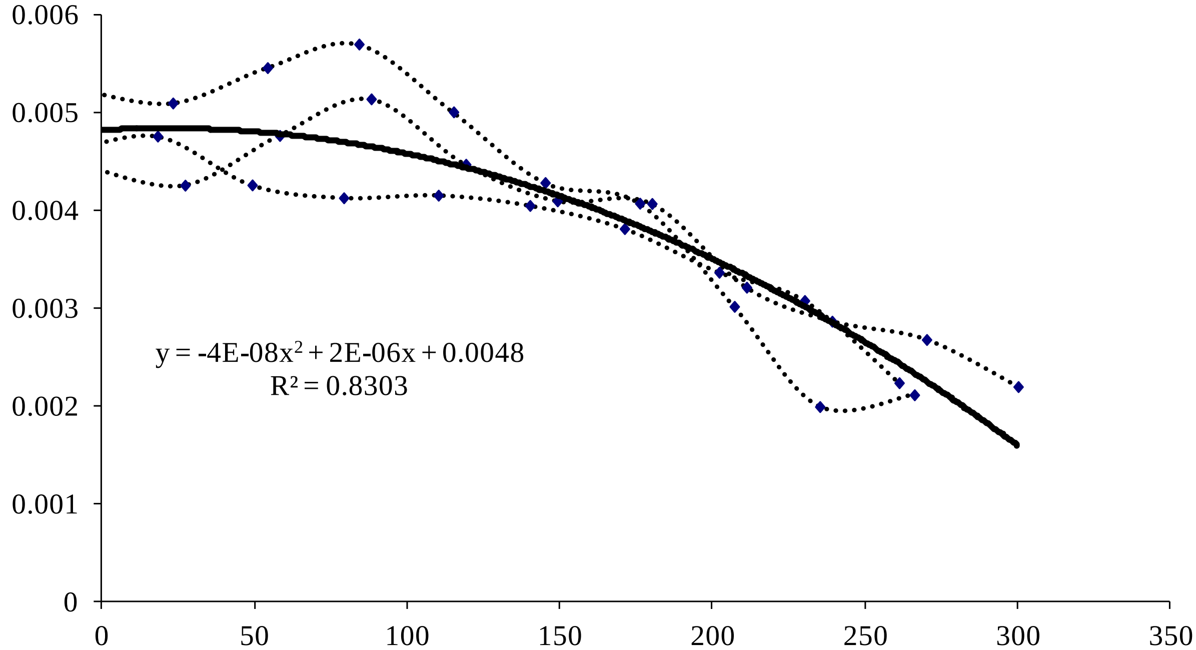


Figure 7. Proportion of annual dairy cow milk solids produced each day for three lactations, and fitted regression line (solid line) over the 3 years.

Lactation curves for dairy goats indicated that the curve differed for indoor or outdoor goats (Figure 8; DGC, data not published).

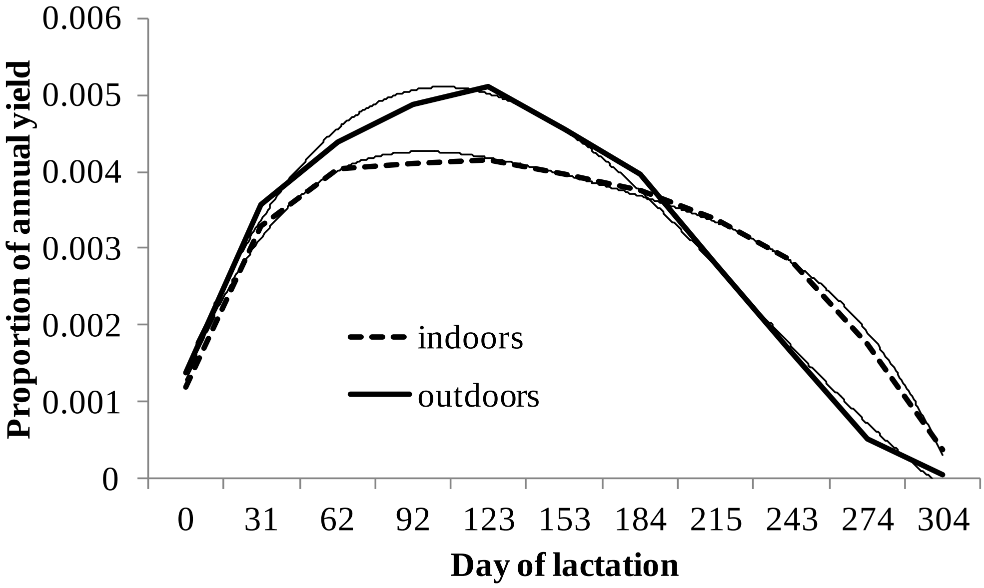


Figure 8. Proportional of annual milk yield on a given day of lactation for indoor (left) and outdoor (right) dairy goat mobs (bold line is measured data, thin line is regression line).

The proportion of annual milk that was produced on a given day was estimated for indoor goats (*Equation 42*, $r^2 = 0.9948$) and outdoor goats (*Equation 43*, $r^2 = 0.993$) based on monthly data from a survey of dairy goat milk suppliers (unpublished data).

Equation 42: $$Prop_{day} = -0.0000041603 * DayLactation^4 + 0.00010616 * DayLactation^3 - 0.0010350 * DayLactation^2 + 0.0042948 * DayLactation + 0.0020866$$

DayLactation is the number of days since the start of lactation.

Equation 43: $$Prop_{day} = 0.000020013 * DayLactation^3 - 0.00051572 * DayLactation^2 + 0.0033751 * DayLactation - 0.0014657$$

A minimum value based on the value at 300 days lactation (0.0005) was set for mobs with greater than 300 days lactation but not all year, and 0.003 for mobs milked all year (365 days + lactation).

This daily proportion was then standardised so that the total added up to 1. Thus:

$$PropLact_{day} = Prop_{day} / \sum PropLact_{day}$$

5.8. Monthly distribution of milk yield

The proportion of milk produced each month is used in the metabolic model to estimate ME requirements for lactation for a mob. This is achieved by assigning the proportion of annual milk production that occurs in a given day to a day in the year, and then to month of the year. The result is then standardised to ensure annual lactation is fully accounted.

For dairy, it is assumed that cows starting lactating over a 42 day period. To accommodate this, there is an initial start-up period of 42 days. Over the first 42 days, the proportion of annual milk production that occurs in a given day is estimated as:

Equation 44: $Lactday_{day} = prop_{21} * i/42$

day is the day number in the year.

prop is the proportion of lactation on day 21 [section 5.7].

i is the day number.

For dairy goats, it is assumed that lactation starts on the mean kidding day.

5.9. NE content of milk

The net energy (NE) value of milk is used in the determination of metabolisable energy requirements for lactation in lactating animals (Animal metabolic energy requirements chapter). The NE value for dairy cow milk can be calculated from the milk's fat and protein content according to Tyrrell and Reid (1965 (see their Table 4, equation 2, on page 1219). Tyrrell and Reid (1965) expressed the energy value of milk in kilocalories per pound of milk (energy per unit mass of milk). Conversion of units to MJ/kg requires the ratio of 4.1868 J per calorie and 0.4536 kg per pound, or a factor of 0.00923. An analysis of Grainger *et al*. (1983) suggested that the Tyrell and Reid (1965) calculation compared well with measurements in New Zealand. Thus, NE content of milk (MJ/kg milk) in dairy cows is calculated as (Equation 45).

Equation 45: $NEmilk = (0.376 * Cmilkfat) + (0.209 * Cmilkprotein) + 0.948$

Cmilkfat is the milk fat content (%) [section 5.8].

Cmilkprotein is the milk protein content (%) [section 5.8].

Using data from a Waikato research dairy farm (No 2 dairy, unpublished) and applying Equation 45 indicated that NE for milk was higher at the beginning and the end of lactation. This pattern implies that NE of milk are 10-20% higher in autumn than if an average value is used. Changes in NE of milk during lactation have not been included.

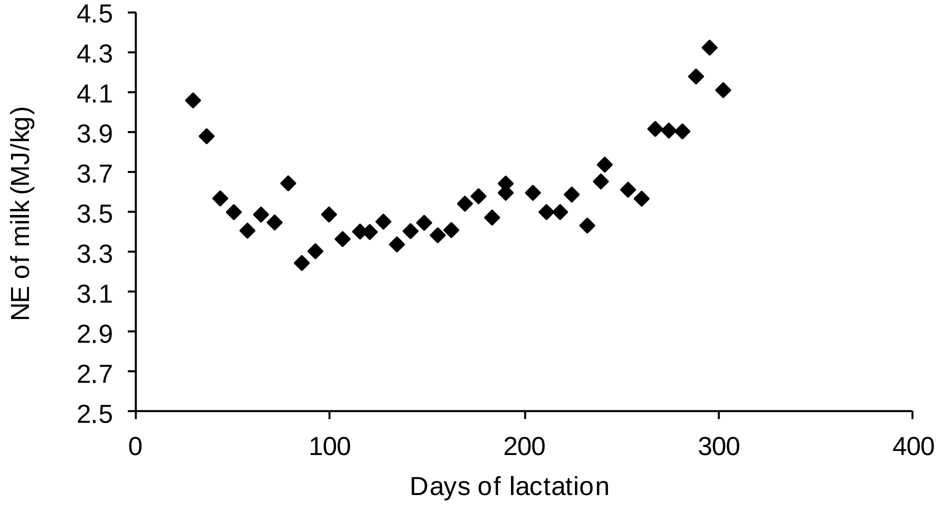


Figure 9. Average variation in milk NE (MJ/kg milk) during the lactation period on a Waikato research dairy farm.

The estimation of NEmilk (MJ/l milk) for sheep and beef is taken from Nicol and Brookes (2007) (Equation 46).

Equation 46: NEmilk = (0.376 * Cmilkfat) + (0.209 * Cmilkprotein) + 0.976
Cmilkfat is the milk fat content (%) [section 5.8].
Cmilkprotein is the milk protein content (%) [section 5.8].

For deer, NEmilk is not required as a different approach was adopted as outlined in the Animal metabolic energy requirements chapter as no information was found for annual milk yield.

For dairy goats, Tedeschi *et al* (2010) reported that on average using this equation for sheep over-predicts goat requirements by 5%. SCA (1994) reported that goats milk NE was similar to that of dairy cows. Therefore, Equation 46 was adopted for dairy goats, but NE content was multiplied by 0.95.

6. Reproduction and rearing

6.1. Conception rate

The conception rate is the number of mature animals that conceive over those that are mated. Typically, the number conceived is based on scanning results. Conception rate is not used in the model.

6.2. Birth rate

Birth rate is defined as the number of young born divided by the number of breeding animals mated, and is estimated as:

Equation 47: birthrate = weaning rate / (survivalrate / 100)
weaningrate is weaning rate [
Survivalrate as shown in zzz

Baker *et al*. (1981) reported hogget lambing rate averaged 30% or 6 years, giving 24% weaning rate. McCall and Hight (1981) indicated that hogget lambing rate was dependent on hogget (yearling) live weight, varying from about 10% at 25kg live weight to 90% at 45 kg live weight. Expert opinion also indicated that hogget lambing rate was related to mature ewe lambing rate (Webby, AgResearch, pers. comm.). Therefore a relationship between mature breeding ewes and hogget lambing percent was developed assuming a minimum hogget lambing rate of 24% (Figure 10) for mature breeding ewes lambing rates of less than 160%. When mature breeding ewes lambing rate exceeded 160%, hogget lambing rate is estimated as:

Equation 48: hoggetbirthrate = 0.641649 * ewebirthrate
ewebirthrate is the mature breeding ewes birth rate [section 6.2].
0.641649 is the hogget lambing percent at 160% mature ewe lambing rate (102%) divided by 160.

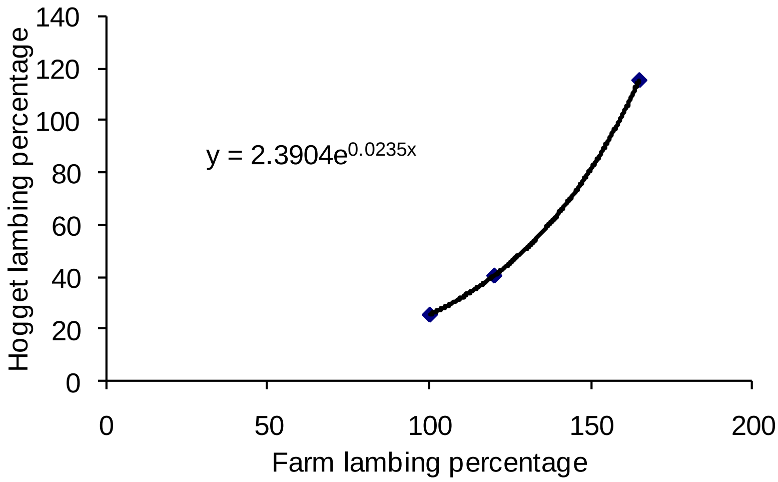


Figure 10. Relationship between mature breeding ewes and hogget lambing percent.

6.3. Weaning rate

Weaning rate is defined as the number of weaned animals divided by the number of breeding animals mated.

Weaning rate for mature stock is a compulsory input for monthly stock reconciliation for sheep, beef, and deer. To simplify calculations, this is defined as number weaned dived by the number of animals in July. The metabolic requirement sub-model assigns default values if weaning rate is not entered based on Table 26, for example, when stocking rates are entered as stock units.

Table 26. Default weaning rate for mature animals.

Animal type	Weaning rate born (%)
Dairy cow	100
Sheep	125[a]
Beef	83[b]
Deer	72[c]
Dairy goats	100

[a] No defined source. Derived from expert opinion.
[b] Fleming (1996).
[c] based on data reported in Deer Manual (2006) .

Beef heifer calving rate was assumed to be 90% of mature animal calving rate, based on 77% calves weaned/cow mated (Beef + lamb 2006).

In a summary of data, Deer Master (2000) indicated an average weaning rate of 72%, with R2 hinds having a weaning rate about 90% of mixed aged hinds.

6.4. Survival rate

The difference between weaning rate and mating rate, that is breeding animals that are mated but fail to produce any progeny (dry animals), can be due to:

- inability to become pregnant (dry/dry),
- successfully become pregnant but lose their progeny prior to birth,
- successfully give birth but lose their progeny prior to weaning (wet/dry),
- or die during pregnancy.

The survival rate is defined as the proportion of animals born that are weaned, that is, weaning rate divided by birth rate. Survival rate is an indication of the number of wet/dry animals. The birth rate is an indication of the number of dry/dry animals, and those that became successfully become pregnant but lose their progeny prior to birth.

The survival rate to weaning was reported as 72% by Baker *et al*. (1981), and about 78% by McCall and Hight (1981). In contrast, Beef + Lamb (2012) indicated survival rates of 78-94% for singles and twins, and Woodford and Nicol (2004) indicated that the pregnancy rates (presumably at birth) where about 15% and 8% higher than weaning rates in sheep and beef animals respectively. A value of 85% has been adopted for sheep.

Beef + lamb (2006) indicated an in-calf rate of 85% and 77% calves weaned/cow mated, given a survival rate of 90%. Data reported by Deer manual (2006) indicated that the survival rate for deer averaged 87%.

Table 27. Default survival rates for animals born to mature animals. [a]

Animal type	Survival rate (%)
Dairy cow	100
Sheep	85
Beef	90
Deer	87
Dairy goats	100

[a] See text for source of data.

6.5. Number of dries

The difference between weaning rate and mating rate, that is breeding animals that are mated but fail to produce any progeny (dry animals), can be due to:

- inability to become pregnant (dry/dry),
- successfully become pregnant but lose their progeny prior to birth,
- successfully give birth but lose their progeny prior to weaning (wet/dry),
- or die during pregnancy.

Dries are breeding animals that are mated but fail to produce young due to failure of the breeding animal to become pregnant, loss of young during lactation, or death of the breeding animal during pregnancy. For animals other than sheep, the dry rate is the difference between 100 and the birth rate. Thus, the default dry rate is 0, 8%, and 17% for dairy cows and goats, beef and deer respectively. A value of 8% was assumed for sheep.

6.6. Proportion of singles, twins, triplets and quadruplets

For sheep, estimates of the proportion of singles, twins, triplets and quadruplets ($prop_1$ ... $prop_4$) are made based on curves from Fleming (1996, Fig 1.13, p A-60) and are reproduced in Figure 11. It was assumed that 'Number of Lambs Born/Ewe' is the same as the birth rate (section 6.2, and that if the birth rate was 100 or less, then all lambs were single.

Thus, for sheep, when lambing percentage (PercentBorn), as defined under reproductive performance (section 6.4), was greater than 100% and less than 240% then

Equation 49: $prop_1 = 0.5164 * PercentBorn/100^2 - 2.3561 * PercentBorn/100 + 2.8679$
Equation 50: $prop_2 = -0.9478 * PercentBorn/100^2 + 3.4823 * PercentBorn/ 100 - 2.5846$
Equation 51: $prop_3 = 0.3106 * PercentBorn/100^2 - 0.7495 * PercentBorn/ 100 + 0.4189$
Equation 52: $prop_4 = 1 - prop_1 - prop_2 - prop_3$

In addition, $prop_1$ was greater than 19%, and $prop_2 \ldots prop_4$ were greater than zero. Otherwise, for sheep when lambing percentage is less than or equal to 100%, and for all other animal species, $prop_1$ is 1, and $prop_2$, $prop_3$, and $prop_4$ are zero.

The proportion of singles, twins, triplets and quadruplets weaned is estimated as

Equation 53: $propwean_n = prop_n * survivalrate/100 / \sum(prop_n * survivalrate/100)$

Beef + Lamb (2012) indicated survival rates of 78-94% for singles and twins, and 58-82% for triplets. Therefore, the survival rate shown in section 6.4 is used for singles and twins, and 75% for triplets and quads.

For other animal types, it is assumed that there are no twins, triplets or quadruplets (i.e. $prop_2$ ... $prop_n$ = 0, and $prop_1$ is the birth rate.

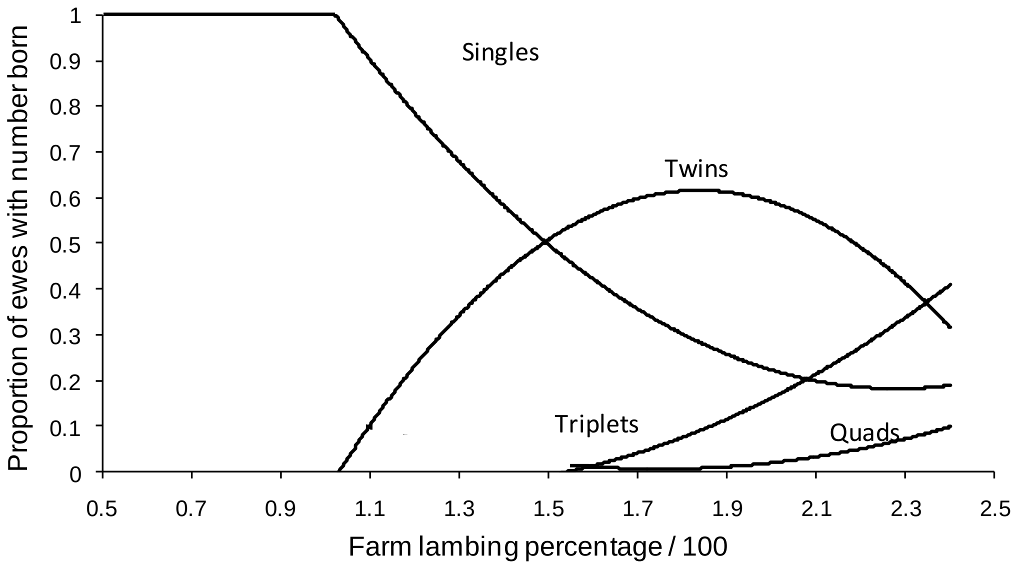


Figure 11. Proportion of mob with multiple births for sheep (from Fleming 1996).

6.7. Gestation length

Gestation length (Table 28) was taken from Freer *et al*. (2006) for dairy cows, cattle, and sheep and from Fleming (1996) for deer. Fleming (1996) reported average period of 233 days for red deer and 229 days for fallow deer. The difference between deer breeds was ignored.

Table 28. Gestation length for each animal type.

Animal type	Gestation length (days)
Dairy cows	285
Sheep	150
Beef	285
Deer	233

6.8. Breeding herd replacement rates

Replacement rate is defined as the proportion of breeding mature animals (those over 2years, excluding hoggets, heifers, or replacement animals) that are culled each year. OVERSEER assumes that the cull rate and replacement rate are the same.

For dairy cows, herd replacement can be entered, or if it is not entered then a default of 23% is used. For sheep, beef, and deer, replacement rate is a compulsory input for monthly stock reconciliation.

The default replacement rates (Table 29) is used to initially populate the replacement rate in the 'generate breeding animal option' (see Animal Model chapter).

Table 29. Replacement rates (%).

Breed	**Replacement rate %**
Dairy cows	23
Sheep	20
Beef	15
Deer	18
Dairy goats	18

7. Grazing

The animal characteristics in the grazing section are all used in the metabolic requirement sub-model (Animal metabolic energy requirements chapter).

7.1. Average slope

The average slope represents that average topography of blocks grazed by an animal type and is estimated as:

Equation 54: $Avslope_{antype} = INTEGER(\sum_{block} Slopearea / \sum_{block} area)$

$\sum_{block}$ is for blocks that antype are present on.

area is the block area (ha).

anytype is the animal type.

and where for each block Slopearea is estimated as:

Equation 55: $Slopearea = Topography * area$

Topography is the integer value to denote topography.

area is the block area (ha).

7.2. Walking distances while grazing (Hk and Vk)

Hk and Vk are parameters used in the metabolic requirement sub-model (Animal metabolic energy requirements chapter) and are the average horizontal and vertical distance walked (km) by an animal during grazing. They exclude items such as walking to yards by dairy cows. The values shown in Table 30 were taken from Nicol and Brookes (2007, Appendix – activity costs).

Table 30. Average horizontal and vertical distance walked by an animal during grazing (km).

Parameter	Flat	Rolling	Easy Hill	Steep Hill
Horizontal distance (Hk)	0.5	1.0	1.5	2.0
Vertical distance (Vk)	0	0.1	0.15	0.2

7.3. Pasture mass at grazing

Inputs average slope – see section 7.1

animal type

The amount of pasture mass (Tonnes/ha) on offer to animals at time of grazing (PastureMass) is used in the metabolic requirement sub-model (Animal metabolic energy requirements chapter). The values (Table 31) were taken from Nicol and Brookes (2007, Appendix – Costs of grazing). The value for easy hill was extrapolated between rolling/easy hill and hard hill values in Nicol and Brookes (2007).

Table 31. Pasture mass at grazing (tonnes/ha).

Animal	Flat	Rolling	Easy Hill	Steep Hill
Dairy cows	2.5	2.5	2.5	2.5
Dairy cow replacements	2.2	2.0	1.9	1.8
Sheep	1.8	1.5	1.4	1.2
Beef	2.2	2.0	1.9	1.8
Deer	2.0	1.8	1.7	1.5
Dairy Goats	1.8	1.5	1.4	1.2

8. Product nutrient concentrations

8.1. Live weight nutrient concentrations

Live weight nutrient concentrations are used to estimate product nutrient removal. They were based on Longhurst (1995), who found limited data for live weight nutrient concentrations, particularly for deer and for nutrients other than N and P. Live weight nutrient concentrations for dairy goats and other animals were assumed to be the same as for sheep.

It was assumed that nutrient concentrations in live weight gain were the same.

Table 32. Animal live weight nutrient concentrations (%).

Animal	N	P	K	S	Ca	Mg	Na
Dairy cow	3.26	0.8	0.22	0.39	1.64	0.04	0.09
Sheep	3.40	0.7	0.23	0.40	1.44	0.04	0.10
Beef	3.26	0.8	0.22	0.39	1.64	0.04	0.09
Deer	3.71	0.9	0.22	0.41	1.85	0.04	0.10

8.2. Enterprise specific products nutrient concentrations

Enterprise specific products (milk, wool, velvet, and antler) nutrient concentrations are used to estimate product nutrient removal. Product nutrient concentrations were based on Longhurst (1995), who found limited amounts of data for product nutrient concentrations, particularly for deer and for nutrients other than N and P.

Dairy cow milk nutrient concentrations in Table 33 are on a weight of whole milk basis. Differences in protein, fat, and DM content are known to occur between breeds (LIC data) and herds although it is unclear how this affects total milk composition. OVERSEER does not respond to different milk protein contents. The concentrations for dairy goats are assumed to be the same as for dairy cows.

For wool, R, Sumner (AgResearch, pers. comm.) supplied data for greasy wool, scoured wool and wool wax and squint (Table 34). Greasy wool has higher P, K, and Mg concentrations than scoured wool, probably because of the presence of wax and squint. Longhurst (1995) reported a range of values, with values similar to either greasy or scoured wool. Wool input is also on a wet basis. Therefore, the nutrient content of greasy wool on a wet weight basis was used. Longhurst (1995) also reported nutrient concentrations that were within the range of values reported by Sumner. It is also suspected that Na levels in greasy wool are considerable higher due to the sweat content and hence a high concentration was used.

Table 33. Product nutrient concentrations (kg/kg).

Product	N	P	K	S	Ca	Mg	Na
C_{milk}	0.0057	0.00095	0.0014	0.0003	0.0012	0.00012	0.0004
C_{wool}	0.132	0.00016	0.0022	0.023	0.0004	0.0001	0.005
C_{velvet}	0.092	0.052	0.0023	0.0196	0.090	0.0012	0.002
C_{antler}	0.148	0.102	0.0009	0.0377	0.18	0.002	0.0035
$C_{milkgoats}$	0.0057	0.00095	0.0014	0.0003	0.0012	0.00012	0.0004

Velvet is typically cut at 60 days. The concentration of nutrients at the base of the velvet was assumed to be similar to that of hard antler, and at growing tip the concentrations would be closer to the whole body or live weight figures. Therefore, the concentration of nutrients in velvet reported in Table 33 is the mean of venison and antler reported by Longhurst (1995).

Table 34. Elemental content (kg/kg) of wool products on an oven dry basis assuming fleece is 12% moisture content (R Sumner, pers. com.).

Product	N	P	K	S	Ca	Mg
Greasy wool	0.150	0.00018	0.0025	0.026	0.00045	0.00010
Scoured wool	0.160	0.00010	0.0012	0.029	0.00040	0.00007
Wool wax & suint	0.120	0.00042	0.0064	0.017	0.00060	0.00019

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