OVERSEER® Technical Manual

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

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Supplements

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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.

Contents

Supplements

1. Introduction

1.1. Types of supplements

Animal supplements are defined as feed other than grazed pasture or farm-grown crops that is grown for animal feed. Feed is defined as material that is fed to animals to supply energy and nutrients for growth and production. Farm-grown crops are crops grown on either a fodder or cropping block for the purpose of feeding to animals, either by grazing in-situ or harvesting and then feeding out.

Four categories of supplements are recognised in OVERSEER:

- Imported supplements – these are feed products that are produced beyond the farm boundary and can be fed in the milking shed (in-shed), on pads or on blocks (paddocks). They are supplements brought in and fed that year.
- Farm-grown supplements – pasture based supplements (hay, silage, baleage) removed from pastoral and cut and carry blocks. These can be fed in the milking shed, on pads or on blocks, or placed in storage or exported.
- Supplements fed from a long-term store (storage supplements). These are pasture based farm-grown supplements that have been placed in storage (were not feed in the year they are made) but are now being fed in the current year. Storage should only apply when OVERSEER is used with annual management.
- Left-over supplements. Dairy goats are selective feeders (‘Characteristics of pasture’ chapter), and on many farms, dairy goat utilisation of supplements is lower than for other animal enterprises. The left over (unutilised) supplements are often fed to other animal enterprises. Left-over supplements from the wintering pad/animal shelter or from paddocks are managed separately.

OVERSEER also accounts for supplements, typically minerals, fed for animal health reasons or as a means of balancing a diet. They differ from feed supplements in that there is no Dry Matter (DM) or Metabolic Energy (ME) associated with them (section 8).

1.2. Linkages between Supplement sub-model and other sub-models

The role of supplements is showing in a schematic diagram (Figure 1) and as explained in Introduction chapter. Supplements supply ME, and therefore can be used to meet animal ME requirements. Pasture ME intake is estimated as the difference between animal ME requirements, and ME supplied by supplements and crops. The DM and nutrients contents of supplements are included in the ‘animal pasture intake’ and ‘animal nutrient intake’ sub-models. Total DM intake (DM from supplements, crops, and pastures) is used in the estimation of methane (Methane emissions chapter). Total nutrient intake (nutrients from supplements, crops, and pastures) is first used for products (growth, milk, wool, velvet), and the remainder is excreted as dung or urine.

The 'greenhouse gas' sub-model (Carbon dioxide, embodied and other gaseous emissions chapter) uses information on supplements to estimate embodied CO_2 and energy emissions associated with making, transporting and feeding of supplements. This sub-model requires information for each animal enterprise on a total farm basis.

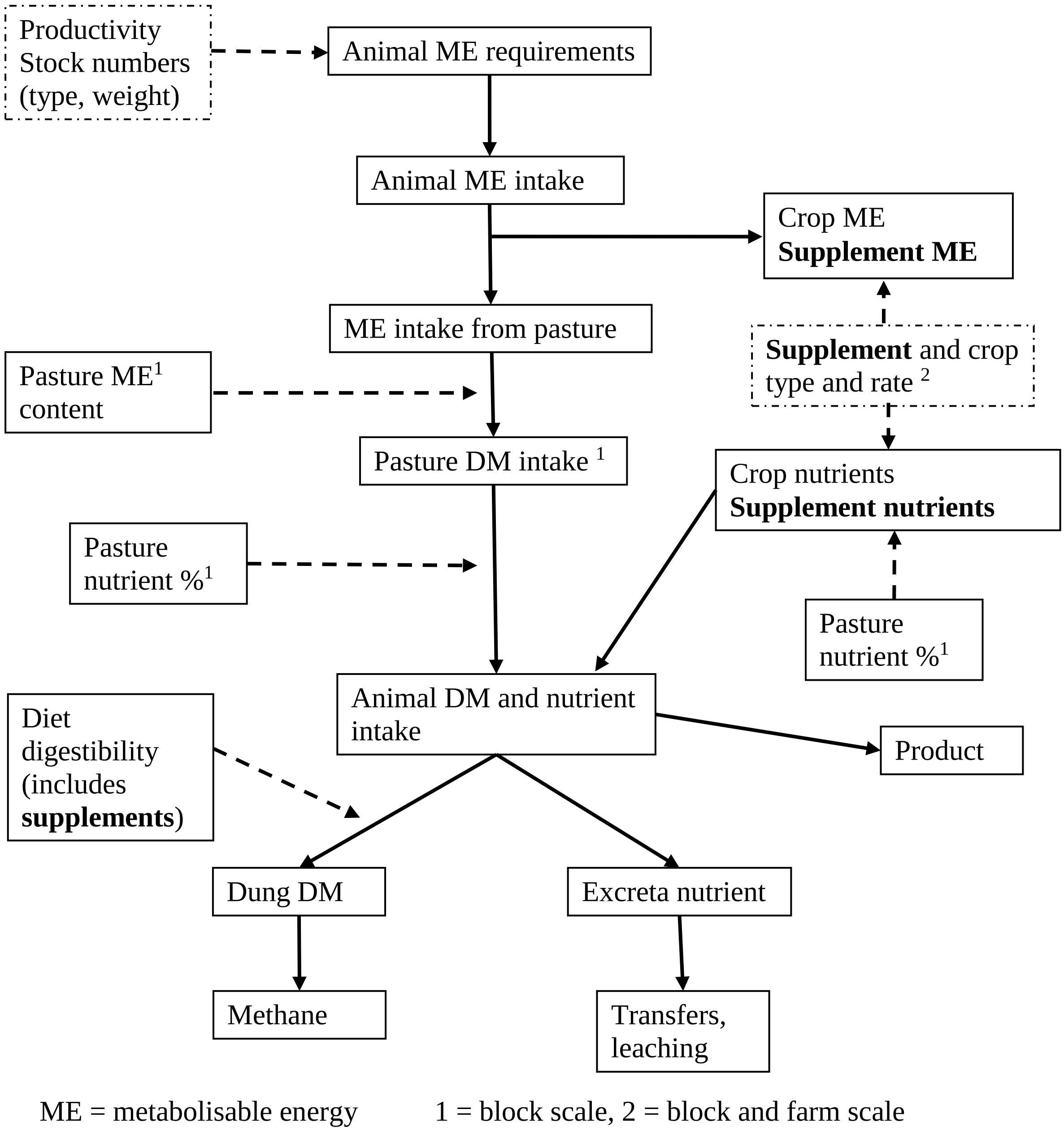

Figure 1. Simplified relationship between animal intake sub-models and supplements. Dotted boxes are typical user inputs and dotted lines represent data inputs.

1.3. Supplement movements

The making, purchasing and feeding of supplements represents a potential transfer of nutrients around a farm. A schematic diagram is shown in Figure 2 and summarised in Table 1. Supplement contents are distributed according to a user specified destination, and this can either be animal enterprise, blocks, structure (i.e. animal shelter, feed pad, or milking shed).

Thus, for example, farm-grown supplements (e.g. hay, silage, baleage) grown on pastoral or cut and carry blocks can be removed and fed out onto pads (in-shed feeding, feed pad, wintering pad), placed in long-term storage or exported off farm. This represents a transfer of nutrients out of a block. Exporting also represents a transfer of nutrients out of the farm. Imported supplements represent a net import of nutrient into the farm, which can then be transferred to blocks (a transfer of nutrients) or pads. The distribution methods are described in more detail in section 5.

The energy, DM and nutrient contents of the supplements consumed is also transferred to the animal enterprise that eats them. These are used in the animal intake sub-models. As the intake sub-model is on a monthly time scale, the supplements that are distributed to an animal enterprise are also distributed on a monthly time scale. This is described in more detail in section 5.7.

Table 1. Summary of transfers of each supplement category.

Supplement	Transferred from	Move to	Transfer to
Imported	Off farm	Pads[1]	Animal enterprise Pad type
		Block	Animal enterprise Block fed on
Farm-grown	From block made on	Pads	Animal enterprise Pad type
		Block	Animal enterprise Block fed on
		Stored	Long term storage
		Exported	Off farm
Stored	Long-term storage	Pads	Animal enterprise Pad type
		Block	Animal enterprise Block fed on
Left-over	Pad or block with dairy goats	Pads	Animal enterprise (not dairy goats) Pad type
		Block	Animal enterprise (not dairy goats) Block fed on

[1] refers to wintering pad/animal shelter, feed pad, and in-shed feeding.

When calculating these transfers:

- Supplement DM, ME, and nutrients are distributed to an animal enterprise on a total basis (kg DM, MJ ME, kg nutrient respectively) and are used in the estimation of animal intakes. They cannot be on a per ha basis as animals may be in farm structures.

- Supplement DM, ME and nutrients distributed to blocks are on a per ha basis (kg DM/ha, MJ ME/ha, kg nutrient/ha respectively). Transfers in and out of blocks are estimated on a per ha basis to align with other block calculations.
- Supplement weight inputs are on a total basis as they are frequently fed direct to animals, and the transfer to animals is on a total basis. Farm-grown supplements are also on a total area to avoid confusion about what area should be used or pastoral blocks with fodder crops rotating through them. The unit of tonnes is used to reduce the size of the number.

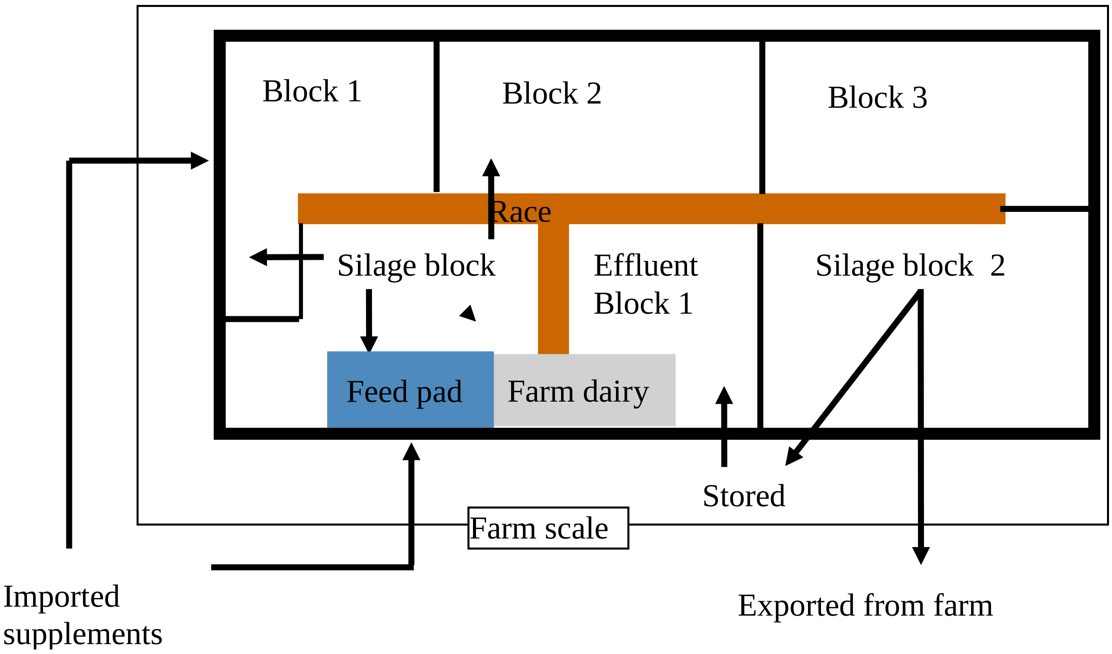

Figure 2. Schematic representation of some nutrient transfers due to the movement of supplements around a farm.

1.4. Individual supplement transfers

The ME, DM and nutrient contents of an individual supplement is described in section 4. Each component of an individual supplement is then distributed as in the schematic diagram shown in Figure 3. As noted in section 1.3, ME, DM, and nutrients contents of supplements fed on a pad are assigned to an animal enterprise and the structure they are fed on. In contrast, ME, DM, and nutrients contents of supplements fed on a block are assigned to an animal enterprise and the block they are fed on.

Farm-grown supplements can be exported or placed in long-term storage. When fed out, they are treated as a storage supplement. Supplements fed to dairy goats can be left over and these are then treated as a left over supplement. These supplements are treated the same as other supplements with the exceptions noted below.

Storage loss and supplement utilisation are included in the analysis. The proportion of supplements not utilised (not eaten by the animal) is defined by the wastage. Storage and wastage are defined in more detail in sections 2.3 and 2.4 respectively. Unutilised supplements remain in blocks if fed on blocks, or enter the effluent management system if fed on pads or in-shed. For dairy goats, the unutilised supplements can be fed to other animals, that is, they become left-over supplements.

Supplements placed in long term storage can be fed out again. As the storage loss is included when farm-grown supplements are placed in storage, there is no storage loss associated with supplements fed out of long-term storage. Left-over supplements are also assumed to have no storage loss.

1.5. Summary of chapter sections

The sections in this chapter covers the following topics:

- Section 2 describes the supplement inputs within OVERSEER.
- Section 3 describes supplement characteristics for each supplement category.
- Section 4 describes how the values for supplement properties that are distributed are estimated.
- Section 5 describes how each supplement is distributed around the farm.
- Section 6 describes how the timing of supplements fed to animals is estimated.
- Section 7 describes the calculation of additional outputs from the supplement sub-model that are used elsewhere in OVERSEER.
- Section 8 describes how Animal health supplementation is calculated and distributed to blocks and animal enterprises.

1.6. 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 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.

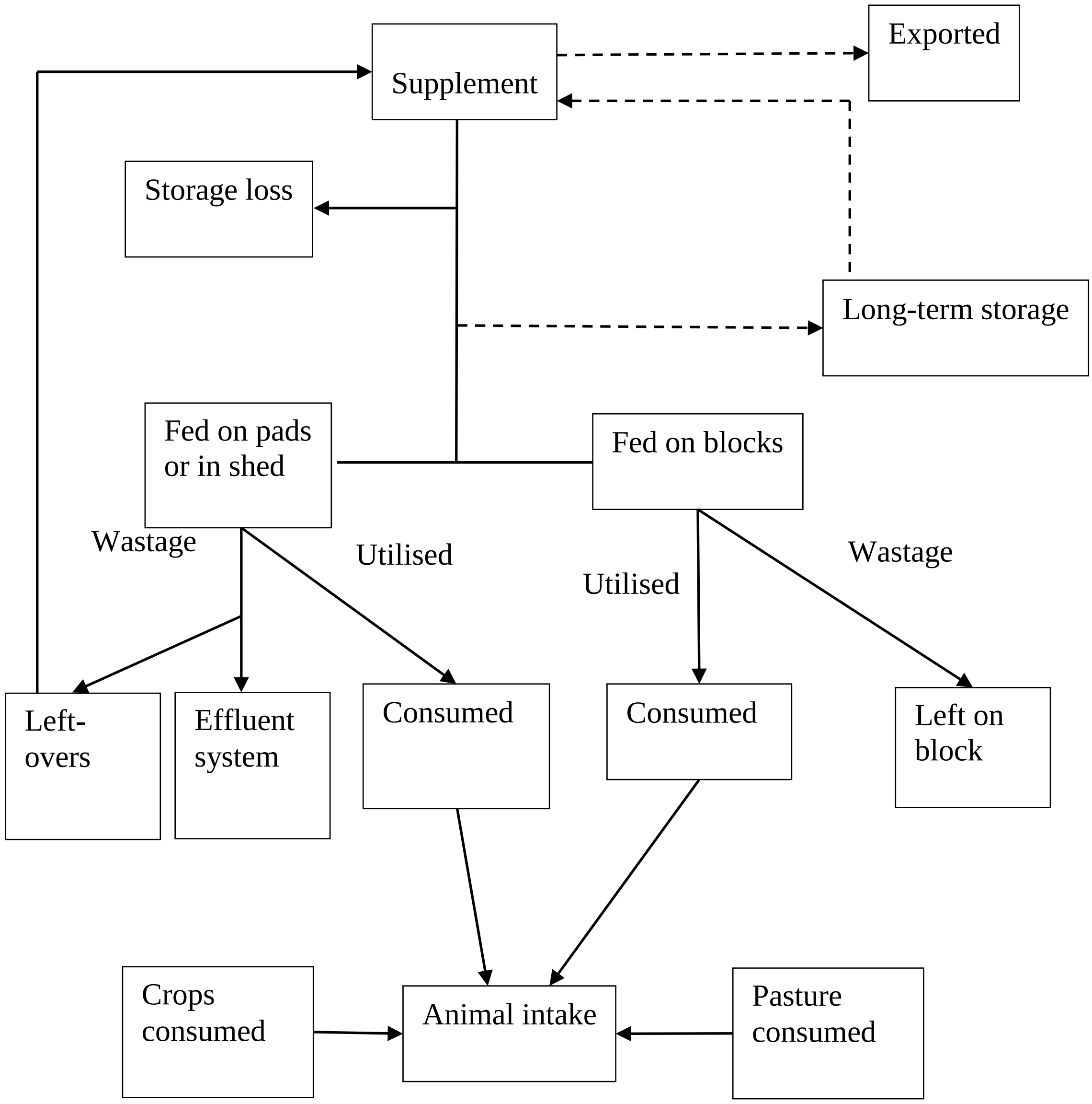

Figure 3. Schematic representation of some nutrient transfers due to the movement of supplements around a farm.

1.7. Abbreviations, chemical symbols, and subscripts

Abbreviations

DM dry matter (kg)

MJ mega joules, unit of energy

ME metabolisable energy

Chemical symbols:

N, P, K, S, Ca, Mg, Na, and Cl refer to the nutrients nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, sodium and chlorine respectively.

<u>Subscripts</u>

mon month

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 acidity.

sup individual supplement entry.

block a given block as defined in the Introduction chapter.

antype animal enterprises within OVERSEER (dairy, dairy replacements, sheep, beef, deer, dairy goats, other)

2. Supplement inputs

2.1. Entering supplement weights

OVERSEER requires supplement amounts on a tonne basis. For farm grown supplements, a supplement amount calculator is provided (Section 2.1.1). For imported supplements, the weight (tonnes) of supplement entering the farm gate is entered, and whether this is a wet weight or dry weight selected. For pasture based supplements (hay, silage, baleage), the supplement amount calculator (section 2.1.1) can be used.

2.1.1. Supplement amount calculator

The supplement amount calculator estimates the dry weight of pasture based supplements (hay, baleage, and silage) that are imported, farm grown pasture supplements, or pasture that is direct fed. The calculator does not distinguish between pasture types except for lucerne.

The supplement calculator uses the inputs shown in Table 2.

Table 2. Inputs for the supplement calculator

Input	Comments
Weight	weight (tonnes).
DryWeightBasis	weight on dry weight basis (Y/N).
Silage method	direct cut or wilted (for silage only).
Bales	number.
BaleEquivalents	number of 20 kg DM standard bales.
Bale type	square or round bales.
Bales size	height, width, and depth (cm) for square bales. Height and diameter (cm) for round bales.
Volume	cubic metres (m^3).
NumberCuts	number.
NumberCutsAut	number, lucerne only.
AreaCut	selected or defaults to block area for farm-grown supplements.

Additional input items are shown in Table 3. As this is the only means of adding farm-grown supplements, options are provided to indicate the use of silage stacks and whether effluent from the stack is contained. The latter is included as a reminder that leachate from silage stacks can be a point source of pollution. The calculator also contains options to indicate whether the silage is covered in plastic. Supplement wrapping information is used to estimate the embodied plastic energy and CO_2 emissions from plastics (section 7.4).

Table 3. Additional supplement calculator inputs.

Items	Comments
Supplements wrapped or covered in plastic	shown for all supplements.
Silage stack used	only shown for silages.
Effluent from stack contained	only shown for silages stored in a silage stack.

The ‘Silage stack used’ and ‘Effluent from stack contained’ option should be used for imported silages that are stored on farm (e.g. pasture imported and stored in a stack) to capture leachate losses from the stacks.

2.2. Blocks supplements can be fed on

OVERSEER allows imported, stored and supplements removed from a pastoral or cut and carry block to be fed on the following blocks:

- pastoral blocks.
- fodder crop blocks.
- fruit crop blocks if sward type ‘Full pasture’ ‘Herbicide strip’ and the ‘Source of animal information’ option selected is ‘Farm stock – see Enterprises numbers panel’.
- crop blocks if the crop is grazed by animals, the ‘Source of animal information’ option selected is ‘Farm stock – see Enterprises numbers panel’ and grazed defoliation occurs in the current year, or if the pre-crop option selected is ‘Pasture’ and this extends into

the current year, and the ‘Source of animal information’ option selected is ‘Farm stock – see Enterprises numbers panel’.

2.3. Storage loss

A report on supplement use prepared by van der Weerden *et al.* (2009) contained a summary of storage losses collated by P. Hedley (Dairy NZ), and is repeated in the Table 4. This data is based on P. Hedley’s own knowledge and best estimates from scientists and industry experts.

The data was based on a qualitative assessment of storage losses, with categories of ‘excellent, very good, average, and poor’. Definition of the storage losses categories (Table 5), were also taken from van der Weerden *et al.* (2009), as supplied by P. Hedley. The definition for concentrates was also assumed to apply to whole grains.

It was assumed that storage loss from hay, silages, and straws were the same (referred to as grass silage general type), and concentrates and whole grain losses were the same. Whole grain was separated out to capture the additional loss due to lack of digestion. All other supplements (green feeds, vegetables, by-products) were treated the same as palm kernel.

Table 4. Supplement storage losses (from van der Weerden *et al.* (2009) based on P Hedley summary).

Supplement general type	Storage condition			
	No storage	Excellent	Average	Poor
Grass Silage	0	5	12	30
Maize & Cereal Silage	0	6	12	30
Concentrates	0	0	5	15
Whole grain	0	0	5	15
Other (Palm Kernel)	0	0	12	20

For supplements placed in storage, any loss due to storage is included when farm-grown supplements are placed in storage. Therefore, storage loss is not estimated for stored supplements that are fed out.

Table 5. Definitions of storage conditions (source: P. Hedley (DairyNZ) as reported by van der Weerden *et al.* (2009)).

Supplement	Storage condition		
	Excellent	**Average**	**Poor**
Grass Silage	- Bunker with concrete floor. - Well consolidated stack, air-tight. - Inoculants used. - Covered. - Grass harvested at optimum DM.	- Bunker with concrete floor. - Well consolidated stack, air-tight. - Covered. - No inoculants used *or* - Harvested when grass too dry.	- Permeable floor (e.g. soil). - Stack not air-tight, due to either poor consolidation or poorly covered. - No inoculants used.
Maize & Cereal Silage	- Concrete floor. - Non-permeable sides. - Well consolidated stack, air-tight. - Inoculants used. - Covered. - Cereal silage harvested at optimum DM (38%).	- Concrete floor. - No sides. - Well consolidated stack, air-tight. - Covered. - No inoculants used *or* - Harvested when crop too dry.	- Permeable floor (e.g. soil). - Stack not air-tight, due to either poor consolidation or poorly covered. - No inoculants used *or* - Harvested when crop too dry.
Concentrates	- Silo storage over concrete base. - No storage losses.	- Silo storage over concrete base. - Fresh products only.	- Silo not used. - Moisture can spoil supplement. - Grains have high percentage of fines. - Expired product.
Other (Palm Kernel)	- Bunker with concrete floor. - Dry storage: under cover. - Sweepings can be recovered.	- Bunker with concrete floor. - No roof or covering.	- Bunker with permeable floor (e.g. soil). - No roof or covering

2.4. Supplement feed utilisation and wastage

Feed wastage is defined as feed that is given to the animal but is not eaten or ingested – it is left where the feed was given. Supplement utilisation is the proportion feed that is given to the animal that is eaten or ingested.

Knowledge on supplement utilisation has been collated by P. Hedley of Dairy NZ. The information was made available for a report on supplement use prepared by van der Weerden *et al.* (2009). This report contained a summary of supplement wastage rates (proportion feed that is given to the animal that is not eaten or ingested) and is repeated in Table 6. This data is based on Hedley's own knowledge and best estimates from scientists and industry experts. The data was based on a qualitative assessment of utilisation, with wastage rates estimated for categories of excellent, average, and poor for supplements fed out on pasture (as defined in Table 7), and very good and poor for supplements fed in bins (as defined in Table 8). The definition for concentrates was also assumed to apply to whole grains.

Table 6. Wastage rate (%) for each supplement utilisation categories when feeding supplements out in the paddock or in bin for each supplement general type (from van der Weerden *et al.* (2009) based on P. Hedley (DairyNZ) summary).

Supplement general type	Feeding Out Paddock[1]			Feeding Out Bins[2]	
	Excellent	Average	Poor	Very Good	Poor
Grass Silage	10	20	40	7	25[3]
Maize & Cereal Silage	15	22	40	7	25[3]
Concentrates	25	30	50	5	25
Whole grain[4]	25	30	50	5	25
Other (Palm kernel extract)	25	30	50	10	25

[1] Includes losses at the stack face and when loading the wagon.
[2] Bins implies the use of a feed-trough for Palm kernel extract (PKE) fed in the paddock or feed pad for forages or in-shed feeding for concentrates.
[3] Excludes refusal in the bin for rotten silage.
[4] See text below on additional losses from feeding concentrates and grains.

Feeding whole grains can lead to undigested grain passing through the animal. This feed is eaten by the animal but not utilised, and is passed out in the dung. For this reason, whole grains are typically crushed to improve utilisation. OVERSEER assumes that all 'whole grains' fed directly or as part of a concentrate diet are crushed.

It is assumed that the wastage values shown in Table 6 apply to all animal enterprises except dairy goats. If utilisation category is not selected by the user, then utilisation category is assumed to be 'average' when feeding out on paddocks and 'very good' when feeding out in bins.

For dairy goats, utilisation of supplements fed on pasture or in the wintering pad/animal shelter can be specified as part of the left-over feed inputs. By default, dairy goat utilisation is set at 60%, or wastage at 40%). The fate of left-over supplements (those not utilised) is described in section 5.6. Given this, in the rest of this chapter, wastage is referred to 'unutilised', that is feed not utilised by the animal enterprise it is fed to.

Table 7. Definitions of supplement utilisation when feeding out into paddocks (source: P. Hedley (DairyNZ) as reported by van der Weerden *et al.* (2009)).

Supplement	Level of utilisation		
	Excellent	**Average**	**Poor**
Grass Silage	- Feeding out under dry weather conditions. - No wastage when loading wagon, silage not run over.	- Fed out in dry to moderately wet conditions. - Loading and stack management average. - Silage average quality 10.0 – 10.5 MJME/kg DM.	- Fed out in wet conditions. - Poor quality affecting palatability. - High wastage loading wagon.
Maize & Cereal Silage	- Feeding out under dry weather conditions. - No wastage when loading wagon. - High quality silage 10.8 ME plus. - Fed out fresh on new break just before cows moved on. - No evidence or very little of maize left in the paddock.	- Fed in dry to moderately wet conditions. - Loading and stack management average – not a tight clean face, some loose maize. - Silage average quality 10.0 – 10.5 MJME/kg DM. - Silage not always fed onto fresh pasture. - Evidence of maize on ground in paddock.	- Fed in the wet. - Poor stack management, very loose face and lot of loose maize at stack face around stack; evidence of spoiled silage. - Poor loading of wagon, maize on ground. - Silage not fed fresh onto break, or under fence lines. - Burn lines of maize evident. - Poor quality <10.0 ME/kg DM.
Other (Palm Kernel)	- Feeding out under dry weather conditions. - Loading directly into bin.	- Fed on a trailer in paddocks. - Bins over-filled, spillage.	- Mixed in a feed out wagon or fed directly on top of supplement in the paddock.

Table 8. Definitions of supplement utilisation when feeding out into bins (source: P. Hedley (DairyNZ) as reported by van der Weerden *et al.* (2009)).

Supplement	Level of utilisation	
	Very Good	**Poor**
Grass Silage	- Feeding out under dry weather conditions. - Loading directly into bin. - No evidence of spilt silage around stack. - Excellent stack management.	- Poor quality, not as palatable <10.0 MJME/kg DM. - Poor stack management and loading of silage into bins.
Maize & Cereal Silage	- Feeding out under dry weather conditions. - Loading directly into bin. - Excellent stack management, tight face.	- Fed out day in advance, bins not emptied at each feed, leading to spoiling of feed. - Low quality feed <10.0 MJME/kg DM. - Poor stack management, very loose face and lot of loose maize at stack face around stack; evidence of spoiled silage.
Concentrates (Fed in Shed)	- Feeding out under dry weather conditions. - Loading directly into bin.	- Concentrate not fresh, low palatability. - Concentrates not eaten each milking and left in bins. - Unsuitable concentrate (e.g., too finely ground, not cracked, etc.).
Other (Palm Kernel)	- Refer to paddock feeding (Table 7).	- Refer to paddock feeding (Table 7).

3. Supplement characteristics

3.1. Characteristics

3.1.1. General Characteristics

Supplements have the characteristics of

- DM content (%) is the proportion of wet weight that remains after removal of moisture using standard drying conditions.
- ME content (MJ ME/kg DM) is an estimate of the energy in the diet that is available for maintenance and production in ruminant animals, that is, the energy in the feed use for metabolic purposes. This is estimated from other constituents of the feed rather than a measured value.

- Digestibility (%) is the proportion of the feed that can be digested by ruminants. Digestibility reduces as the plant matures due to increased levels of structural cell-wall carbohydrates (cellulose and hemicellulose) and lignin.
- Nutrient concentrations (%) of N, P, K, S, Ca, Mg, Na and Cl on a dry matter basis. Data on concentrations of nutrients other than N or P for many supplements are limited.
- Supplement general type (section 3.1.2).

Each imported supplement also has default embodied energy and CO_2 emissions. This is outlined in more detail in the 'Carbon dioxide, embodied and other gaseous emissions' chapter.

The default data for imported, farm-grown, and storage and left-over supplements are provided in sections 3.2.1, 3.3, and 3.4 respectively. For imported supplements, user defined characteristics can be defined (3.2.2).

3.1.2. Supplement general type

Supplements have a supplement general type that is used to estimate supplement storage and feed wastage rates (sections 2.3 and 2.4). The classification of each default imported supplements is shown in Table 9.

Table 9. Supplement general types (from van der Weerden *et al.* (2009) based on P.Hedley (DairyNZ) summary).

Supplement general type	Comments
Grass Silage	Imported: all hays, silages except those noted below, and straws. All farm-grown and stored supplements.
Maize & Cereal Silage	Imported: maize, cereal, triticale, and barley milky dough silages (whole crop cereal silage (WCCS)).
Concentrates	Concentrates, and supplements that do not fit the other categories.
Whole grain	Imported: all grains except soya bean meal extract.
Other (Palm Kernel)	Imported: all greens, vegetables and by-products, soya bean meal extract.

An additional general type, whole grain, was added to provide the option to take account of whole grains that are eaten but pass through the animal undigested. OVERSEER assumes all whole grains are crushed.

3.1.3. Chloride levels

For supplements, excess cations, which are used in the lime maintenance sub-model, are estimated from supplement nutrient concentrations. Estimation of excess cations require concentrations of N, P, K, S, Ca, Mg, Na, and Cl. In general, chloride values are not well known.

For farm-grown supplements, deKlein (pers. comm.) noted that 'Cl concentrations are higher on pasture (1-1.2%) because K is applied as Muriate of Potash (KCl), whereas hay and silage paddocks often receive effluent which has high K but lower Cl concentrations'. Typical Cl concentrations on hay and silage samples from Feedtech were lower (0.1-0.6%). Therefore, farm-grown supplement Cl concentrations, including lucerne, were set at 1.1% if more than 10 kg K/ha fertiliser had been applied, and 0.5% otherwise.

3.2. Imported supplements

3.2.1. Default characteristics

The characteristics of imported feed supplements in the internally database are shown in Table 10. These were derived from typical (not necessarily average) values of feeds measured by a commercial feed testing company (FeedTech). Data for corn grits/hominy came from the Nutritional Requirements of Dairy Cattle (1989).

Table 10. Characteristics of imported supplements

Name	DM content (%)	Nutrient content (%) N	P	K	S	Ca	Mg	Na	Cl	ME content (MJ ME/kg DM)	Digestibility (%)
Hays											
Pasture good quality hay	85	2.40	0.36	2.00	0.31	0.5	0.20	0.15	0.5	9.2	63
Pasture average quality hay	85	1.60	0.39	1.80	0.34	0.53	0.20	0.15	0.5	8.5	58
Pasture poor quality hay	70	1.12	0.39	1.50	0.34	0.55	0.20	0.15	0.5	7.5	51
Lucerne good quality hay	85	3.36	0.30	2.40	0.30	1.40	0.30	0.15	0.5	9.0	62
Lucerne average quality hay	85	2.88	0.30	2.20	0.30	1.40	0.30	0.15	0.5	8.5	58
Lucerne poor quality hay	70	2.56	0.30	2.00	0.30	1.40	0.30	0.15	0.5	7.5	51
Silages											
Pasture good quality silage	22.5	2.90	0.25	2.50	0.22	0.50	0.18	0.14	0.6	11.0	75
Pasture average quality silage	25	2.40	0.35	2.00	0.23	0.52	0.18	0.14	0.5	10.0	68
Pasture poor quality silage	35	1.60	0.30	1.50	0.23	0.50	0.18	0.14	0.5	9.0	62
Baleage	35	1.60	0.30	2.00	0.23	0.50	0.17	0.14	0.4	10.0	68
Maize silage	33	1.14	0.20	0.92	0.10	0.18	0.12	0.14	0.1	10.5	72
Cereal silage	33	1.60	0.30	2.00	0.17	0.30	0.18	0.14	0.2	10.0	68
Triticale silage	33	1.60	0.30	2.00	0.17	0.30	0.18	0.14	0.2	10.0	68
Lucerne silage	28	3.68	0.30	2.40	0.30	1.40	0.30	0.15	0.5	10.0	68
Barley milky dough silage	33	1.60	0.30	2.00	0.17	0.30	0.18	0.14	0.2	10.0	68
Straws											
Barley straw	85	0.64	0.07	1.80	0.17	0.30	0.23	0.14	0.4	7.5	51
Wheat straw	85	0.64	0.07	0.18	0.17	0.30	0.23	0.14	0.4	7.5	51
Oat straw	85	0.54	0.10	1.70	0.17	0.30	0.23	0.14	0.4	7.5	51
Ryegrass straw	85	0.96	0.18	1.20	0.17	0.30	0.23	0.14	0.4	7.5	51
Pea straw	85	1.28	0.20	1.40	0.17	0.30	0.23	0.14	0.4	7.5	51
Corn stover	85	0.80	1.80	1.20	0.15	0.30	0.16	0.03	0.1	7.5	51
Greenfeeds											
Annual ryegrass	14	4.16	0.30	3.00	0.22	0.5	0.18	0.14	0.2	12.5	86
Turnips	10	3.20	0.26	2.00	0.11	0.35	0.11	0.09	0.6	13.0	89

Name	DM content (%)	Nutrient content (%) N	P	K	S	Ca	Mg	Na	Cl	ME content (MJ ME/kg DM)	Digestibility (%)
Kale	15	2.72	0.26	2.00	0.11	0.35	0.11	0.09	0.6	12.5	86
Rape	12	2.60	0.26	2.00	0.11	0.35	0.11	0.09	0.6	12.5	86
Oats leafy	18	2.08	0.30	2.00	0.17	0.30	0.18	0.14	0.2	12.5	86
Oats milky dough	25	1.28	0.25	1.90	0.17	0.30	0.18	0.14	0.2	8.5	58
Sorghum	14	1.92	0.10	1.80	0.17	0.30	0.18	0.03	0.2	9.0	62
Japanese millet	14	1.92	0.10	1.80	0.17	0.30	0.18	0.03	0.2	9.0	62
Maize greenfeed	22	1.10	0.18	0.92	0.09	0.16	0.14	0.01	0.1	9.5	65
Sulla	15	3.80	0.30	2.40	0.30	1.40	0.30	0.15	0.4	10.0	68
Vegetables											
Potatoes	20	1.70	0.30	2.17	0.09	0.20	0.10	0.09	0.28	12.5	86
Onions	10	1.60	0.30	2.17	0.09	0.20	0.10	0.09	0.6	12.0	82
Cabbage	9	3.20	0.26	2.00	0.11	0.35	0.11	0.09	0.6	13.0	89
Carrots	13	1.52	0.35	2.80	0.17	0.40	0.20	0.104	0.5	13.3	91
Kiwifruit	15	0.80	0.09	0.46	0.02	0.05	0.03	0.12	0.1	12.0	82
Squash	25	1.60	0.30	2.17	0.09	0.20	0.10	0.09	0.5	13.0	89
Apples	18	0.60	0.09	0.46	0.02	0.05	0.03	0.12	0.1	11.9	82
Apple pomace	65	1.10	0.14	0.46	0.02	0.16	0.06	0.12	0.1	13.0	89
Grape pomace	38	1.12	0.06	0.62	0.02	0.61	0.03	0.09	0.1	13.0	89
Citrus pulp	20	1.12	0.12	0.79	0.08	1.84	0.17	0.09	0.1	12.6	86
Grains											
Barley grain	88	2.00	0.40	0.47	0.17	0.09	0.12	0.06	0.2	13.0	89
Wheat grain	88	1.92	0.48	0.52	0.11	0.05	0.13	0.02	0.1	13.5	92
Oats grain	88	1.87	0.48	0.39	0.21	0.08	0.13	0.06	0.2	12.0	82
Maize grain	88	1.30	0.30	0.37	0.12	0.03	0.13	0.03	0.1	13.5	92
Peas	88	4.10	0.40	1.00	0.15	0.10	0.16	0.05	0.2	13.2	90
Soya bean meal (extracted)	88	8.80	0.79	2.30	0.48	0.30	0.31	0.03	0.1	13.3	91
Brewers grain	25	4.00	0.55	0.09	0.32	0.33	0.16	0.23	0.2	11.5	79
ByProducts											
Bran	88	2.72	1.38	1.56	0.25	0.13	0.60	0.04	0.1	10.8	74
Pollard	88	2.72	1.38	1.56	0.25	0.13	0.6	0.04	0.1	11.0	75

Name	DM content (%)	Nutrient content (%)								ME content (MJ ME/kg DM)	Digestibility (%)
		N	P	K	S	Ca	Mg	Na	Cl		
Avonfeed	88	3.52	0.28	0.21	0.39	0.06	0.05	0.06	0.1	12.9	88
Lucerne meal	85	3.20	0.30	2.4	0.30	1.40	0.30	0.15	0.4	10.0	68
Molasses	75	0.72	0.11	3.84	0.47	1.00	0.43	0.22	3.0	11.8	81
Palm kernel meal	88	2.72	0.62	1.36	0.50	0.06	0.30	0.10	0.03	11.6	79
Canola	88	2.72	1.04	1.36	1.25	0.67	0.60	0.10	0.03	11.0	75
Copra	88	3.20	0.54	1.36	0.50	0.06	0.30	0.10	0.03	12.9	88
Cottonseed meal	88	3.68	0.89	1.39	0.34	0.21	0.58	0.04	0.04	13.5	92
Fishmeal	88	11.09	4.17	0.91	0.53	8.02	0.20	0.85	0.55	11.0	75
Proliq	38	1.20	1.40	5.9	4.00	1.30	0.26	2.40	3.2	11.3	77
Corn grits /hominy	88	1.84	0.57	0.65	0.03	005	0.26	0.09	0.1	13.5	92

3.2.2. User-defined characteristics

Imported user-defined supplements can be entered by the user. The data required is DM content (%), ME content (MJ ME/kg DM) and/or digestibility (%), nutrient concentrations (%), and supplement general type (section 3.1.2).

The ME content and N or crude protein content tend to be correlated, in that lower ME content pastures tend to have lower N contents (Characteristics of pasture chapter). Digestibility is also correlated with ME content. Within OVERSEER, feed intake increases as ME content decreases, but N intake decreases as the N content is also lower. Given this interaction, ME content, digestibility, and nutrient contents (particularly N) come from the same source.

3.3. Farm-grown supplements

Farm-grown supplements DM, digestibility and ME contents for hay and silage are based on values for average quality hay and silages and baleage for imported supplements (Table 10) as shown in Table 11. Wilted silage is assumed to have the same DM content, digestibility and ME as baleage. Direct feed pasture is assumed to have the same digestibility and ME content as silage as they are harvested at similar stages of growth.

Table 11. Estimated DM content (%), digestibility (%) and ME content (MJ ME/kg DM) for farm-grown supplements.

Supplement	DM content	Digestibility	ME content
Hay	85	58	8.5
Baleage	35	68	10
Silage - wilted	35	68	10
Silage - not wilted	25	68	10
Direct feed	25	68	10

The concentration of nutrients (%) in supplements removed from a block are assumed to be related to the nutrient concentrations in pasture. The nutrient concentrations in pasture are dependent on soil tests, fertiliser, and other nutrient inputs. This relationship depends on the age of maturity of the pasture at harvest.

Thus for supplements derived from pasture other than lucerne:

Equation 1: $SupNutConc_{nut} = PastureNutConc_{nut} * fmaturity_{suptype, nut}$

PastureNutConc is pasture nutrient concentration (%) [Characteristics of pasture chapter].

fmaturity is a maturity factor [Table 12].

suptype is hay, baleage or silage.

Maturity factor (Table 12) takes account of the decrease in nutrient contents as pasture stem content increases. Cornforth and Sinclair (1984) indicated that nutrient concentrations are lower in hay and silage than grazed pasture, and lower in hay than silage.

For supplements removed from lucerne blocks, the nutrient concentrations for average quality lucerne hay or silage for imported supplements (Table 10) are used. As there was not data for

Lucerne baleage in Table 10, it was assumed that lucerne baleage have the same nutrient concentrations as lucerne silage.

Table 12. Estimated maturity factor for correcting annual average pasture nutrient concentration to that expected in hay or silage for each supplement removal type.

Supplement	N	P	K	S	Ca	Mg	Na	Acidity[1]
Hay	0.60	0.90	0.7	0.90	0.8	0.8	0.8	1
Baleage	0.86	0.93	0.8	0.93	0.9	0.9	0.9	1
Silage	0.86	0.93	0.8	0.93	0.9	0.9	0.9	1

[1] adjusting pasture Cl^- levels, used in the calculation of excess cations (section 2.4).

3.4. Storage and left-over supplements

Storage supplements are assumed to have the same characteristics as farm-grown supplements.

For left-over supplements, the amount of DM, ME and nutrients are determined from the supplements that were originally fed to dairy goats.

4. Individual supplement calculations

This section describes how the contents of an individual supplement that are distributed around the farm and to animal enterprise are estimated .

4.1. Individual supplement amounts

For each supplement record, the amount of supplement DM (kg/year) is estimated as:

Equation 2: suppDM = supprate * 1000 * fDW

supprate is the weight of supplement (Tonnes/year) entered or estimated from the supplement calcuator [section 2.1.1].

1000 converts tonnes to kg.

fDW is factor to convert between dry weight and wet weight [Equation 3].

and

Equation 3: fDW = 1 if rate on dry weight basis

= DMcontent / 100 if rate on wet weight basis

where supplement type is the user selected supplement, and DMcontent is the DM content (%) of the supplement as detailed in section 3.2 (Table 10) for imported supplements, section 3.3 for farm-grown supplements, and section 3.4 for stored and left-over supplements.

The total amount of ME supplied by a supplement (MJ ME/year) is estimated as:

Equation 4: $suppME = suppDM * MEcontent_{supplement\ type}$

where ME content is the ME content (MJ ME/kg DM) detailed in section 3.2 (Table 10) for imported supplements, section 3.3 for farm-grown supplements, and section 3.4 for stored and left-over supplements.

The total amount of nutrient in a supplement (kg nutrient/year) is estimated as:

Equation 5: $suppnut_{nut} = suppDM * conc_{supplement\ type,\ nut}$

where conc is the nutrient concentration (%) as detailed in section 3.2 (Table 10) for imported supplements, section 3.3 for farm-grown supplements, and section 3.4 for stored and left-over supplements.

4.2. Individual supplement storage and utilisation

Section 4.1 provides the amount of supplement DM, ME or nutrient imported, removed from a block (farm-grown supplement) or removed from storage. The amounts that animals consume is lower than this due to storage and wastage losses. For the calculations, this is combined into a single term for supplements fed in the milking shed, feed pad or wintering pads (UtilStoreBin), and for supplements feed on paddocks (UtilStorePdk), as:

Equation 6: UtilStoreBin = (1 - StLoss) * (1 - WasteBin)
Equation 7: UtilStorePdk = (1 - StLoss) * (1 - Wastepdk)

StLoss = StorageLoss / 100

StorageLoss is the storage loss (%) for the general type of the supplement [section 2.6].

100 converts % to a proportion.

WasteBin = WasteBins / 100

WasteBins is the wastage (%) when using bins for the general type of the supplement [section 2.4].

Wastepdk = WastePaddock / 100

WastePaddock is the wastage (%) when fed in paddocks for the general type of the supplement [section 2.4].

4.3. Estimating supplement weight

The dry weight, (DW, tonnes DM) of supplement can be entered directly, or is estimated from wet weight as:

Equation 8: DW = weight * suppDMcontent

weight is the entered wet weight (tonnes).

where DM content is the DM content (%) of the supplement as detailed in section 3.2 (Table 10) for imported supplements, section 3.3 for farm-grown supplements, and section 3.4 for stored and left-over supplements. Note that supplements are added using units of tonnes/year (section 1.3).

If the dry or wet weight is not known, the supplement calculator provides alternative methods to estimate the dry weight (tonnes DM) of hay, silage, or baleage. The calculator allows three alternative methods, listed in order of preference because the inherent accuracy of each method:

- Estimate weight based on bale size or bale equivalents.
- Estimate weight from volume of material.

- Estimate weight from number of cuts.

The following details the calculations. Given a standard bale equivalent is 20 kg DM (McGimpsey *et al*., 1994), then if number of bales and bale equivalents are entered, DW (tonnes DM) of supplement is estimated as:

Equation 9. DW = Bales * BaleEquivalents * 20 / 1000

Bales is the entered number of bales.
Bale equivalents is the bale size, based on a standard bale of 20 kg DM.
20 is the weight (kg) of a standard bale.
1000 converts kg to tonnes.

If volume is entered, DW (tonnes DM) of supplement is estimated as:

Equation 10. DW = Volume * Density / 1000

Volume is the enterd volume of supplement (m^3).
Density is the density of the supplement (kg DM/m^3) [section 4.3.1].
1000 converts kg to tonnes.

If the number of bales and dimension of bales is entered, DW (tonnes DM) of supplement is estimated as:

Equation 11. DW = Bales * EstVol * Density / 1000

Bales is the entered number of bales.
Estvol is the estimated volume (m^3).
Density is the density of the supplement (kg DM/m^3) [section 4.3.1].
1000 converts kg to tonnes.

where the estimated volume (m^3) of the bales is calculated as:

Equation 12. Estvol= height / 100 * width / 100 * depth / 100 square bale
= height / 100 * pi * radius^2 round bale

pi is the mathmatical number pi.
height, width and depth (cm) are entered dimensions for a square bale.
height and diameter are entered dimensions (cm) for a round bale.
radius (m) estimated as:
radius = diameter / 100 / 2
100 converts cm to m.

The least preferred method of estimating DW (tonnes DM) of supplement is based on the number of cuts:

Equation 13. DM = NumberCuts * AreaCut * harvestWeight / 1000
+ NumberCutsAut * AreaCut * harvestWeightAut / 1000

NumberCuts is the entered number of cuts. For lucerne, this is split between spring/summer, and autumn.
Areacut (ha) is the entered block area (farm-grown supplements) or the entered area imported supplements were cut from (imported supplements).

harvestWeight is the weight harvested (kg DM) [Table 14].

harvestWeightAut is the weight harvested in autumn for lucerne (kg DM) [Table 14].

1000 converts kg to tonnes.

4.3.1. Supplement density

The density (kg DM/m^3) is based on a survey of contractors and is shown in Table 12 (van der Weerden *et al.*, 2009).

Table 13. Typical densities (kg DM/m^3) for a range of supplement methods.

Condition	Density
Direct feeding	210
Silage	210
Balage, square bales	155
Balage, other	133
Hay, square bales	186
Hay	156

4.3.2. Supplement harvest weight

The typical harvest weight (kg DM/harvest) per cut is based on a survey of contractors (van der Weerden *et al.,* 2009) and is shown in Table 14.

Table 14. Typical harvest weights (kg DM/harvest) for a range of pasture types and supplement methods.

Pasture type	Condition	Typical harvest weight
Lucerne	Autumn cut	3000
	Spring and summer cut	1500
Other	Silage and direct feeding	3300
	Balage, square bales	2300
	Balage, other	3600
	Hay, square bales	3300
	Hay	5100

5. Supplement distribution

As noted in section 1.3, the movement of supplements represents a movement of nutrients around the farm, and the feeding of supplements are an important part of the animal intake sub-models (section 1.2).

This section describes the methods that are used to distribute supplements around the farm.

5.1. Supplements made on a block

The amount of supplements made on a block (kg DM/ha/year) is estimated as:

Equation 14: $supDMout = \Sigma_{sup}(suppDM / area_{block})$

suppDM is the amount of DM made for each supplement sup (kg DM/year) [section 4.1].

area is block area (ha).

5.2. Distribution to farm structures

Supplements allocated to in shed feeding, feed pads, or wintering pad are distributed to the animal enterprise. The loss due to storage or wastage is removed to provide estimates of DM (SupSssDMpad), ME (SupSssMEpad), or nutrients (SupSssnutpad) available for intake. Thus:

Equation 15: $SupSssDMpad_{antype} = \Sigma_{sup}(suppDM * UtilStoreBin)$

Equation 16: $SupSssMEpad_{antype} = \Sigma_{sup}(suppME * UtilStoreBin)$

Equation 17: $SupSssnutpad_{antype, nut} = \Sigma_{sup}(suppnut * UtilStoreBin)$

SupSss is either imported, farm-grown or stored supplements.

pad is either the milking shed (in-shed feeding), feed pad or wintering pad.

antype is the animal enterprise the supplement is to be fed to (user defined).

sup is an individual supplement fed to animal enterprise antype.

suppDM, suppME and suppnut are the amounts for each supplement sup [section 4.1].

UtilStoreBin accounts for storage and utilisation losses [section 4.2].

For each supplement, the unutilised portion is estimated as:

Equation 18. $pUnutil = (1 - StLoss) * WasteBin$

StLoss is the storage loss for the general type of the supplement [section 4.2].

WasteBin is the wastage when using bins for the general type of the supplement [section 4.2].

The unutilised supplements fed to dairy goats on wintering pads can be fed to other animal enterprises (left-over supplements). If left-overs are fed to other animal enterprises, then the amounts of DM (supDMLO, kg DM/month), ME (supMELO, MJ ME/month) and nutrients (supnutLO, kg nutrients/month) that are transferred to left-over supplement and re-distributed as outlined in section 5.6.1, are estimated as:

Equation 19: $supDMLO = \Sigma_{sup}(suppDM * pUnutil)$

Equation 20: $supMELO = \Sigma_{sup}(suppME * pUnutil)$

Equation 21: $supNutLO_{nut} = \Sigma_{sup}(suppnut_{nut} * pUnutil)$

sup is an individual supplement fed to animal enterprise antype.

suppDM (kg DM/year), suppME (MJ ME/year), and suppnut (kg nutrient/year) are the amounts for each supplement item [section 4.1].

pUnutil is the proportion of supplement unutilised [Equation 18].

Otherwise, unutilised supplements from supplements fed in the milking shed, or fed on feed pad and the wintering pad/barn are added to effluent management system. This assumes that the unutilised supplements falls on the floor and is moved with excreta as part of the cleaning process. The amount transferred is accumulated as:

Equation 22. $suppnutUnUtilpad_{antype,\ nut} = \Sigma_{sup}\ (suppnut * pUnutil)$

pad is either the milking shed (in-shed feeding), feed pad or wintering pad.

antype is the animal enterprise the supplement is to be fed to (user defined).

sup is an individual supplement fed to animal enterprise antype.

suppnut (kg nutrient/year) are the amounts for each supplement item [section 4.1].

pUnutil is the proportion of supplement unutilised [Equation 18].

If utilisation is low, this can represent a substantial addition of nutrients to effluent.

5.3. Distribution of supplements to blocks

Similar to farm structures, supplements fed on blocks are distributed to animal enterprises. The loss due to storage or wastage is removed to provide estimates of DM, ME, or nutrients available for intake. For paddock fed supplements, the supplements can be allocated to a specific animal enterprises, or to blocks with the supplement subsequently allocated to animal enterprises on those blocks(s). In addition, the timing of supplement feeding can be specified.

For supplements fed in paddocks, supplement transferred to blocks before utilisation is included (that is, storage loss has been calculated), but animals eat only the utilised supplement. Thus, unutilised supplements remain in the block and unutilised nutrients are dealt with as part of a balancing procedure when block nutrient budgets are finalised.

5.3.1. Specified blocks

Supplements can be fed on specified blocks if that block is one of the allowed block types (section 2.1), or on all pastoral blocks. These can also include cropping blocks.

The distribution of supplements around multiple blocks is based on the area weighted for the proportion of intake of the animal enterprise. This can create bias if the amounts per ha going to different blocks are not similar, or if there are differences in the time animals are on different blocks, for example, pastoral v crop blocks.

Supplements are distributed to the animal enterprise on a total basis by looping through each block and assigning the individual supplement components to each animal enterprise on that block as:

Equation 23: $suppSssDMfarm_{antype} = \sum(suppDM * pSupp * UtilStorePdk)$

Equation 24: $suppSssMEfarm_{antype} = \sum(suppME * pSupp * UtilStorePdk)$

Equation 25: $supSssnutfarm_{antype,\ nut} = \sum(suppnut * pSupp * UtilStorePdk)$

SupSss is either imported, farm-grown or stored supplements.

antype is the animal enterprise the supplement is to be fed to (user defined).

suppDM (kg DM/year), suppME (MJ ME/year), and suppnut (kg nutrient/year) are the amounts for each supplement item [section 4.1].

pSupp is the proportion of the supplement allocated to an animal enterprise [Equation 26 or Equation 28].

UtilStorePdk accounts for storage and utilisation losses [section 4.2].

The proportion of the supplement allocated to an animal enterprise (pSupp) when one of the blocks specified is a fodder crop or cropping block is estimated monthly as:

Equation 26: $pSupp = factorcrop_{block, antype, mon}/sumfactorcrop$

area is the block area (ha).

factorcrop is proportion of supplement allocated to an animal enrerprise on a given block the supplement is fed on per month Equation 27].

100 converts % to proportion.

where factorcrop is estimated for each month and animal enterprise is on the block as

Equation 27: $factorcrop_{block, antype, mon} = MEintake_{antype, mon} * SupSU_{block, antype} /100 * area_{block}$

area is the block area (ha).

SupSU is the percentage of block intake consumed by a given animal enterprise [section 5.7].

antype is the animal enterprise the supplement is to be fed to as they are on the specifed block.

100 converts % to proportion.

If animals are not on pasture for a given month, factorcrop is multiplied by 1.3 to favour supplement feeding on the crops to ensure animal requirements are met.

Otherwise if a fodder crop or cropping block is not specified then pSupp is estimated as:

Equation 28: $pSupp = area_{block}/suparea * SupSU_{block, antype} / 100$

area is the block area (ha).

suparea is the sum of the areas of the blocks that the supplements are fed on.

SupSU is the percentage of block intake consumed by a given animal enterprise [sectio n 5.7].

antype is the animal enterprise the supplement is to be fed to as they are on the specifed block.

100 converts % to proportion.

Supplement dry matter is used to estimated total dry matter consumed on a block. The units for blocks are per ha. Thus, supplement DM (kg DM/ha/year) is distributed to the pastoral blocks where the animal enterprises are fed as:

Equation 29: $suppSssDMconsume_{block} = \sum((suppDM * pSupp * UtilStorePdk) / area_{block})$

area is the block area (ha) to obtain per ha units.

pSupp is the proportion of the supplement allocated to an animal enterprise [Equation 28].

UtilStorePdk accounts for storage and utilisation losses [section 4.2].

suppDM (kg DM/year) is the amounts for each supplement item [section 4.1].

Nutrients added to a block are a net transfer, and hence utilisation is not included, but storage loss is. It is assumed that the individual supplement is distributed evenly across the included blocks. Thus:

Equation 30: $suppSssnutblock_{block,\ nut} = \sum(supnut * (1 - StLoss) / area_{block})$

suppnut (kg nutrient/year) are the amounts for each supplement item [section 4.1].

StLoss is the storage loss for the general type of the supplement [section 4.2].

area is the block area (ha) to obtain per ha units.

The unutilised supplements fed to dairy goats on wintering pads can be fed to other animal enterprises (left-over supplements) (section 5.6.1). The amounts of DM, ME and nutrients for each supplement that is transferred are estimated as shown in Equation 19, Equation 20, and Equation 21, except pUnutil is calculated as in Equation 39. Otherwise, unutilised supplements are left on the block and incorporated as part of the block balancing procedures.

5.3.2. Timing specified

If the user enters the proportion of supplement fed per month, then the following variables are estimated following a similar procedure as above except the calculation is on a monthly basis.

$suppSssDMfarmMon_{antype,\ mon}$

$suppSssMEfarmMon_{antype,\ mon}$

$suppSssnutfarmMon_{antype,\ nut,\ mon}$

5.3.3. Unutilised supplements

For supplements not fed to dairy goats, the unutilised supplements DM (suppDMUntilblock, kg DM/ha/year) and nitrogen (suppNUntilblock, kg N/ha/year) are accumulated for each block. These are used as inputs in the crop N model (Crop based nitrogen sub-model chapter).

5.4. Distribution to storage

Farm-grown supplements can be placed in long-term storage. These are treated as a transfer out of the block but a transfer into the farm storage pool. Storage losses are included at this stage. Thus, the amount of DM (kg DM/year) placed in long-term storage (supDMStorage) is estimated as:

Equation 31: $supDMStorage = \Sigma_{sup}(suppDM * (1 – StLoss))$

sup refer to supplements placed in storage.

suppDM (kg DM/year) is the DM weight for each supplement sup [section 4.1].

StLoss is the storage loss for the general type of the supplement sup [section 4.2].

and the amount of nutrient (kg nutrient/year) placed in storage (supStorageNut) is estimated as:

Equation 32: $supStorageNut_{nut} = \Sigma_{sup}(suppnut * (1 – StLoss))$

sup refer to supplements placed in storage.

suppnut (kg nutrient/year) is the amounts for each supplement sup [section 4.1].

StLoss is the storage loss for the general type of the supplement sup [section 4.2].

5.4.1. Specified animal enterprise

Supplements can be fed to specified animal enterprises on pastoral blocks. Supplements are distributed to an animal enterprise on a total basis so that intakes can be estimated as:

Equation 33: $supSssDMfarm_{antype} = \sum_{sup}(suppDM * UtilStorePdk)$

Equation 34: $supSssMEfarm_{antype} = \sum_{sup}(suppME * UtilStorePdk)$

Equation 35: $supSssnutfarm_{antype, nut} = \sum_{sup}(suppnut * UtilStorePdk)$

SupSss is either imported, farm-grown or stored supplements.

antype is the animal enterprise the supplement is to be fed to (user defined).

sup is an individual supplement fed to animal enterprise antype.

suppDM (kg DM/year), suppME (MJ ME/year), and suppnut (kg nutrient/year) are the amounts for a supplement sup [section 4.1].

UtilStorePdk accounts for storage and utilisation losses [section 4.2].

Supplement DM is used as part of the wider calculation to estimate total DM consumed on a block. The units for blocks are on a per ha basis. The distribution of supplements around multiple blocks is based on the area weighted for the proportion of intake of the animal enterprise. Thus, supplement DM consumed on a given pastoral block (kg DM/ha/year) where the animal enterprises being fed are present is estimated as:

Equation 36: $suppSssDMconsume_{block} = \sum_{sup}(suppDM * suparea_{block} / \sum suparea_{block} / area_{block} * UtilStorePdk)$

SupSss is either imported, farm-grown or stored supplements.

sup is an individual supplement fed to animal enterprise antype.

suppDM (kg DM/year) is the DM amount for a supplement sup [section 4.1].

area is the block area (ha) of the block supplement is fed on to give per ha output.

suparea /∑suparea defines the allocation between blocks [Equation 37].

UtilStorePdk accounts for storage and utilisation losses [section 4.2].

and where suparea is estimated for pastoral blocks as:

Equation 37: $suparea_{block} = area_{block} * BlockSU_{block, antype}/100$

BlockSU is the percentage of block intake utilised by a given animal enterprise.

area is the block area (ha).

antype is the animal enterprise the supplement is to be fed to (user defined).

100 converts percentage to proportion.

Nutrients added to a block are a net transfer, and hence wastage is not included, but storage loss is. Thus, nutrients added to a block (suppSssnutblock) are estimated as:

Equation 38: $suppSssnutblock_{block, nut} = \sum_{sup}(suppnut * (1 - StLoss) * suparea_{block} / \sum_{block} suparea_{block} / area_{block})$

SupSss is either imported, farm-grown or stored supplements.

suppnut (kg nutrient/year) are the amounts for each supplement item [section 4.1].

StLoss is the storage loss for the general type of the supplement [section 4.2].

$suparea_{block} / \sum_{block} suparea$ is the proportion of supplement allocation to the block [Equation 37].

area is the block area (ha) of the block supplement is fed on to give per ha output.

For each supplement, the unutilised portion is estimated as:

Equation 39. $pUnutil = (1 - StLoss) * WastePdk$

StLoss is the storage loss for the general type of the supplement [section 4.2].

WastePdk is the wastage when supplements are fed on paddocks for the general type of the supplement [section 4.2].

The unutilised supplements fed to dairy goats on wintering pads can be fed to other animal enterprises (left-over supplements) (section 5.6.1). The amounts of DM, ME and nutrients for each supplement that is transferred are estimated as shown in Equation 19, Equation 20, and Equation 21, except pUnutil is calculated as in Equation 39. Otherwise, unutilised supplements are left on the block and incorporated as part of the block balancing procedures.

5.5. Distribution off farm

Farm-grown supplements can be exported off farm. This is assumed to occur before storage, and hence storage losses are zero. The amount of DM (kg DM/year) exported (supExportDM) is estimated as:

Equation 40: $supExportDM = \Sigma_{sup} (suppDM)$

sup refer to farm-grown supplements that are exported.

suppDM (kg DM/year) is the DM weight for each supplement sup [section 4.1].

and the amount of nutrient (kg nutrient/year) exported (supExportNut) is estimated as:

Equation 41: $supExportNut_{nut} = \Sigma_{sup} (suppnut)$

suppnut (kg nutrient/year) is the amount of nutrient for each supplement sup [section 4.1].

5.6. Distribution of left-over supplements

Dairy goat left-over supplements that are fed on a wintering pad can be added to the effluent system, compost system, exported, or fed to another animal enterprise.

If indicated by the user, dairy goat left-over supplements are fed to other animal enterprises on the farm or accumulated as compost or exported off farm.

5.6.1. Left-over supplements from dairy goats on pads

Dairy goat left-over supplements from supplements fed on a wintering pad/animal shelter can be added to the effluent management system, compost system, exported, or fed to another animal enterprise.

Nutrients from left-over supplements fed on a wintering pad that can be added to the effluent system are accumulated as:

Equation 42: $SupSssNutUnUtilWP_{nut} = \sum(supnutLO_{nut})$

SupSss is for farm-grown supplements, or stored and imported supplements.

supnutLO is the left-over nutrient amount (section 5.1).

Nutrients from left-over supplements composted are estimated as:

Equation 43: $SupSssNutComposted_{nut} = \sum(supnutLO_{nut})$

Nutrients from left-over supplements exported off-farm are estimated as:

Equation 44: $SupSssNutReexported_{nut} = \sum(supnutLO_{nut})$

If left-over supplements are fed to other animal enterprises, then DM, ME and nutrients are distributed monthly based on the timing of feeding to dairy goats on the wintering pad/animal shelter. These left-over supplements can be fed to animals on either a wintering pad/animal shelter, or to animals on pastoral blocks.

Equation 45: $supDM = supDMLO * Util_{antype} * leftoverprop_{antype} /100$

Equation 46: $supME = supMELO * Util_{antype} * leftoverprop_{antype} /100$

Equation 47: $supNut = supnutLO * Util_{antype} * leftoverprop_{antype} /100$

supDMLO, supMELO, and supnutLO is the unutilised (left-over) supplements when dairy goats are fed supplements in the shed or on pads (section 5.1).

Util is the utilisation of supplements by the animal enterprise the left-over supplements are fed to.

leftoverprop is the proportion (%) of left-over supplements fed to a given animal enterprise (user specified).

100 converts percentage to proportion.

The supplements can be fed to other animal enterprises, to animals that are on the wintering pad/animal shelter (destin = WP) or to animals that are on blocks (Destin = Farm). Leftover supplement DM and ME is allocated to animal enterprises as:

Equation 48: $supLeftDMDestinMon_{antype, mon} = \sum supDM * SuppWPTiming_{dairygoats, mon}$

Equation 49: $supLeftMEDestinMon_{antype, mon} = \sum supME * SuppWPTiming_{dairygoats, mon}$

Destin is WP or Farm

SupDM is the supplement DM fed to animal enterprise antype (kg DM) [Equation 45].

SupME is the supplement ME fed to animal enterprise antype (MJ ME) [Equation 46].

SuppWPTiming defines the monthly distrbution of supplements fed on wintering pads/animal shelters [Equation 69].

Left-over nutrients fed to animals (kg nutrient/year) are distinguished between those whose original source was farm-grown supplements, and those that are imported or storage supplements. Thus if the source was farm-grown supplements, and the left-over supplement is fed to animals on a wintering pad/animals shelter, then the amount of left-over nutrients fed to the animals on a wintering pad/animals shelter (supFarmLeftNutWPMon) is estimated as:

Equation 50: $supFarmLeftNutWPMon_{antype, mon, nut} = \sum(supNut * UtilBin * SuppWPTiming_{dairygoats, mon})$

antype is animal enterprise the left –over supplements are fed to.

supNut is the supplement nutrient fed to animal enterprise (kg nutrient) [Equation 47].

UtilBin is utilising from bins [Equation 51].

SuppWPTiming defines the monthly distrbution of supplements fed on wintering pads/animal shelters [Equation 69].

and where

Equation 51: $UtilBin = 1 – WasteBins/100$

WasteBins is the wastage (%) when using bins for the general type of the supplement [section 2.4].

Unutilised supplements are accumulated (SupFarmLeftNutUnUtilWP) as:

Equation 52: $SupFarmLeftNutUnUtilWP_{antype, nut} = csupNut * (1 - UtilBin)$

antype is animal enterprise the left –over supplements are fed to.

supNut is the supplement nutrient fed to animal enterprise (kg nutrient) [Equation 47].

UtilBin is utilising from bins [Equation 51].

If the left-over supplement is fed to animals on blocks, then the amount of left-over nutrients fed to the animals on blocks (supFarmLeftNutfarmMon) is estimated as:

Equation 53: $supFarmLeftNutfarmMon_{antype, nut, mon} = supNut * UtilPdk * SuppWPTiming_{dairygoats, mon}$

supNut is the supplement nutrient fed to animal enterprise (kg nutrient) [Equation 47].

UtilPdk is utilising in blocks [Equation 54].

SuppWPTiming defines the monthly distrbution of supplements fed on wintering pads/animal shelters [Equation 69].

and where

Equation 54: $UtilBin = 1 – WastePaddock /100$

WastePaddock is the wastage (%) when feeding on paddocks for the general type of the supplement [section 2.4].

and the supplement nutrients transferred to a block (kg nutrient/ha) as:

Equation 55: $supFarmleftnutblock_{block,\ nut} = supNut * suparea_{block} / \sum suparea / area_{block}$

supNut is the supplement nutrient fed to animal enterprise (kg nutrient) [Equation 47].

area is the block area (ha).

and where suparea is estimated for pastoral blocks as:

Equation 56: $suparea = area_{block} * BlockSU_{block,\ antype}/100$

BlockSU is the percentage of block intake consumed by a given animal enterprise.

area is the block area (ha).

A similar calculation procedure is undertaken for imported and storage supplements, to give the variables shown in Table 15.

Table 15. Variables estimated for left-over supplements for imported and storage supplements.

Variable	Description	Equivalent equation
supNutUnUtilWP	Left-over supplements fed on a wintering pad	Equation 42
supNutComposted	Left- over supplements composted	Equation 43
supNutReexported	Left- over supplements exported	Equation 44
supLeftNutWPMon	Left-over supplements fed to animals on a wintering pad/animals shelter	Equation 50
supLeftNutUnUtilWP	Unutilised supplements	Equation 52
supLeftNutFarmMon,	Left-over supplements fed to animals on paddocks	Equation 53
supLeftNutBlock.	nutrients transferred to a block when left-over supplements are fed to animals on blocks	Equation 55

5.6.2. Left-over supplements from dairy goats fed on blocks

Left-over supplements from supplements fed to dairy goats that are fed on a blocks are assumed to be consumed by non-dairy goat animals on the block they were fed. Hence, there is no associated transfer from the block.

However, an estimate is required of the supplement DM, ME and nutrients consumed by each animal enterprise the left over supplement is fed to, which is estimated as:

Equation 57: $supDM = supDMLO * Util * leftoverprop_{antype} /100$

Equation 58: $supME = supMELO * Util * leftoverprop_{antype} /100$

Equation 59: $supnut = supnutLO * Util * leftoverprop_{antype} /100$

supDMLO, supMELO, and supNutLO is the unutilised (left-over) supplements when dairy goats are fed supplements on blocks [section 5.4.1 and 5.3.1].

Util is the utilisation of supplements by the animal enterprise the left-over supplements are fed to.

leftoverprop is the proportion (%) of left-over supplement fed to a given animal enterprise (user specified).

100 converts percentage to proportion.

If the source of left-over supplements was farm-grown supplements that were fed to dairy goats, then the nutrients consumed from left-over supplements by an animal enterprise (kg nutrient/year) is estimated as:

Equation 60: $supGrowLeftNutfarmMon_{antype,\ nut,\ mon} = supNut * UtilPdk * SuppWPTiming_{dairygoats,\ mon}$

supNut (kg nutrient/year) [Equation 59].

UtilPdk is the utilisation of supplements in the block by the animal enterprises the left-over supplements are fed to.

SuppWPTiming defines the monthly distribution of supplements fed on wintering pads/animal shelters [Equation 69].

A similar calculation procedure is undertaken for imported and storage supplements, to give the variable supLeftNutfarmMon.

5.7. Animal distribution on blocks where supplements are fed

SupSU is the percentage of intake consumed by a given animal enterprise on a given block. Initially, on pastoral blocks, this is assumed to be the same as BlockSU. On fodder crop and cropping blocks, SupSU for a block is estimated as:

Equation 61: $SupSU_{block,\ antype} = blocksupSU_{antype} / \sum blocksupSU_{antype}$

where for each block:

Equation 62: $blocksupSU_{antype} = MEintake_{antype,\ mon} * propmon$

where propmon is the proportion of animals consuming pasture or the crop in a given month, as entered by the user. For cropping blocks, only crops or pasture consumed in the reporting year are considered.

If the distribution of crops or supplements results in under or over feeding error messages, then supSU is recalculated for both pastoral and fodder crop and cropping blocks to be based on the available ME that is to be met by supplements. Available ME each month for each animal enterprise is estimated as animal ME intake (Animal Model Technical Manual) less ME fed as in-shed feeding, on feed or wintering pads, as supplements brought in or removed from store, or supplements where the timing is specified.

6. Time of supplement feeding

The animal intake sub-models require supplement inputs on a monthly basis. Currently OVERSEER does not require supplements to be entered on a monthly basis, or for the time supplements are fed as an input. The time supplements are fed, entered as the month a proportion of the total weight of supplement is fed, is available as an optional input.

When user-specific timing is not entered, default timings (proportion of supplements fed each month) are estimated and yearly totals are allocated to monthly supplement feeding rates. In calculating the default timing, it is assumed initially that animal ME requirements in a given month are met from crops first, then supplements fed in-shed (section 6.1), on a feed pad (in section 6.2), wintering pad (in section 6.3) or imported and farm-grown supplements fed on blocks (sections 6.4 and 6.5). The calculation is done in this order as crops have the most restrictive inputs (yield and month of defoliation are entered), whereas supplement amounts can be allocated to a wider number of months. It is not necessarily a reflection of the order of feeding. This assumption becomes increasingly important as the proportion of supplements and crops in the diet increases, and can lead to messages that animals are been under- or over-fed. If this message does occur, then the allocation of supplements is re-calculated .

6.1. In-shed feeding

The timing of supplements fed in the milking shed to each animal enterprise assumes that the amount fed is in proportion to the animal ME requirements, less that supplied by crops. Timing (proportion of total supplement fed each month for each animal enterprise) for in shed feeding (SuppMilkTiming) is estimated as:

Equation 63: $\text{SuppMilkTiming}_{\text{antype, mon}} = \text{prop}_{\text{mon}} / \sum \text{prop}_{\text{mon}}$

where prop_{mon} is estimated as:

Equation 64: $\text{prop}_{\text{mon}} = \text{MilkShedmonthProp}_{\text{antype, mon}} * (\text{MEIntake}_{\text{antype, mon}} - \text{supCrop}_{\text{mon}})$

antype is the animal enterprise the supplement is fed to.

MilkShedmonthProp is the entered percentage of animals fed in the milking shed each month.

MEIntake is animal ME intake (MJ ME/mon) [Animal model chapter].

supCrop (MJ ME/month) is the supplement ME supplied by crops [Equation 65].

where supplement ME supplied by crops (supCrop) is estimated as:

Equation 65: $\text{supCrop}_{\text{mon}} = \text{CropMEMilkShed}_{\text{antype, mon}} + \text{CropMEfeedpad}_{\text{antype, mon}} + \text{CropMEwinpad}_{\text{antype, mon}} + \text{CropMEonpdk}_{\text{antype, mon}} + \text{CropMEOnCrop}_{\text{antype, mon}}$

where CropMEMilkShed, CropMEfeedpad, CropMEwinpad, CropMEonpdk and CropMEOnCrop is ME from crops fed to animals in the milking shed, feed pad, wintering pad/animal shelter, or to animals after cut and carry to another block, or grazed in situ, respectively.

Animal metabolic energy requirements are dependent on diet ME content, which in turn is dependent on the supplement amount and time of feeding. To initialise the timing so that animal intake can be estimated, prop_{mon} is set to MilkShedmonthProp.

6.2. Feed pad

Timing of supplements fed on the feed pad follows a similar pattern to that for the milking shed (section 6.1), except that supplements fed in the milking shed are removed prior to estimating timing for fed pads. Thus the proportion of supplements fed on the feed pad each month (SuppFPTiming) is estimated as:

Equation 66: $SuppFPTiming_{antype, mon} = prop_{mon} / \sum prop_{mon}$

where $prop_{mon}$ is estimated as:

Equation 67: $prop_{mon} = FeedPadmonthProp_{antype, mon} * (MEIntake_{antype, mon} - supCrop_{mon} - supMilk_{mon})$

FeedPadmonthProp is the entered percentage of animals fed each month on the feed pad.

supMilk (MJ ME/month) is the supplement ME supplied by supplements fed in the milking shed [Equation 68].

MEIntake is animal ME intake (MJ ME/mon) [Animal model chapter].

supCrop (MJ ME/month) is the supplement ME supplied by crops [Equation 65].

Supplement ME supplied by supplements fed in the milking shed (supMilk) is estimated as:

Equation 68: $supMilk_{mon} = (suppinMEMilk_{antype} + suppgrowMEMilk_{antype} + suppstoreMEMilk_{antype}) * SuppMilkTiming_{antype, mon}$

suppinMEMilk, suppgrowMEMilk, suppstoreMEMilk is ME fed to animals in the milking shed from imported, farm-grown or stored supplements respectively [section 5.1].

SuppMilkTiming is the timing of supplements fed in the milking shed [Equation 63].

6.3. Wintering pad/barn

Timing of supplements fed on the wintering pad/barn follows a similar pattern to that for the milking shed (section 6.1), except assuming that supplements fed in the milking shed and feed pad are used to meet animal requirements first. Supplements are allocated by identifying supplements that must be fed on the wintering pad, and supplements that can be fed at other times. Thus, for each animal enterprise on the farm:

Equation 69: $SuppWPTiming_{antype, mon} = prop_{mon} / \sum prop_{mon}$

If the sum of MustEat is greater than the amount of supplement (brought in, farm-grown or from stores) that can be fed on a wintering pad (supwinpad) or if all the animals on the wintering pad, then:

Equation 70: $prop_{mon} = MustEat_{mon}$

otherwise

Equation 71: $prop_{mon} = supallocated * CanEat_{mon} / \sum CanEat$

where

Equation 72: supallocated = supwinpad - ∑MustEat

Initially, the amount of ME animals must consumed as 100% of them are on the wintering pad when animals are present on the pad all month is estimated as:

Equation 73: $Musteat_{mon} = AvailME_{antype, mon} * WinpadmonthProp_{antype, mon} /100$

WinPadmonthProp is the entered percentage of animals fed each month on the winering pad/animal shelter.

otherwise:

Equation 74: $CanEat_{mon} = AvailME_{antype, mon} * WinpadmonthProp_{antype, mon} /100$

where the available ME that can be met by supplements (MJ ME/month) is estimated as:

Equation 75: $AvailME_{mon} = MEIntake_{antype, mon} - supcrop_{antype, mon} – supMilk_{antype, mon} - suppFP_{antype, mon}$

MEIntake is animal ME intake (MJ ME/mon) [Animal model chapter].

supCrop (MJ ME/month) is the supplement ME supplied by crops [Equation 65].

supMilk (MJ ME/month) is the supplement ME supplied by supplements fed in the milking shed [Equation 68].

supFP (MJ ME/month) is the supplement ME supplied by supplements fed on the feeding pad [Equation 76].

where supplement ME supplied by supplements fed on the feed pad is estimated as:

Equation 76: $suppFP_{mon} = (suppinMEFP_{antype} + suppgrowMEFP_{antype} + suppstoreMEFP_{antype}) * SuppFPTiming_{antype, mon}$

suppinMEFP, suppgrowMEFP, suppstoreMEFP is ME fed to animals on feed pads from imported, farm-grown or stored supplements respectively [section 5.1].

SuppFPTiming defines the monthly distrbution of supplements fed on feed pads [Equation 66].

6.4. Imported supplements on pasture

Imported supplements fed on pasture are assumed to occur outside of winter. Hence, initially it is assumed that imported supplements are not fed out on pasture in April, May, and June, or if the proportion of animals grazed off or on wintering pad/animals shelters is 100%. In the other months, the proportion of the supplement fed is estimated as:

Equation 77: $prop_{mon} = MEIntake_{antype, mon} - supCrop_{mon} - supMilk_{mon} - supFP_{mon}- supWP_{mon})$

supMilk is supplement ME (MJ ME/month) fed in shed [Equation 68].

supFP is supplement ME (MJ ME/month) fed on feed pad [Equation 76].

supWP is supplement ME (MJ ME/month) fed on wintering pad/animal shelter [Equation 78].

MEIntake and supCrop are defined in section 6.1

where

Equation 78: $suppWP_{mon} = (suppinMEWP_{antype} + suppgrowMEWP_{antype} + suppstoreMEWP_{antype}) * SuppWPTiming_{antype,\ mon}$

suppinMEWP, suppgrowMEWP, suppstoreMEWP is ME fed to animals on wintering pads/animal shelters from imported, farm-grown or stored supplements respectively [section 5.1].

SuppWPTiming defines the monthly distrbution of supplements fed on wintering pads/animal shelters [Equation 69].

A check is made to determine whether the amount of supplement fed in a month is greater than the amount of ME left to be met by supplements. Thus, the check is:

Equation 79: $suppinMEfarm_{antype} * prop_{mon} / \sum prop_{mon} > prop_{mon}$

and if true, prop is re-calculated using *Equation 77* for all months. The proportion of total imported supplement fed on pasture that is fed each month for each animal enterprise is estimated as:

Equation 80: $SuppInPastureTiming_{antype,\ mon} = prop_{mon} / \sum prop_{mon}$

For the first loop through timing calculations when MEIntake has not been estimated, $prop_{mon}$ is set to 1/12, that is, equal proportions are fed each month.

6.5. Farm-grown supplements on pasture

The allocation is undertaken up to three times in the calculation, first to provide initially allocation of farm grown supplements for the initial estimation of the animal ME requirements (section 6.5.1), then after ME requirements are estimated (section 6.5.2). The allocation is then re-estimated once the allocation of crop ME is known.

6.5.1. Initial estimates

If total ME supplied to an animal enterprise from crops and supplements fed in shed or on a pad (TotalsuppME) is higher than total animal ME requirements, then Equation 90 is used to estimate the proportion of farm grown supplements fed on a block each month (SuppgrowPastureTiming). TotalsuppME (MJ ME/year) is estimated as:

Equation 81: $TotalsuppME_{antype} = \sum(SupSssMEpad_{antype}) + \sum_{mon}(supCrop_{mon} + suppSssMEfarmMon_{antype,\ mon})$

SupSss is either imported, farm-grown or stored supplements [Equation 16].

pad is either the milking shed (in-shed feeding), feed pad or wintering pad.

supCrop is ME supplied by crops (MJ ME/month) [Equation 65].

suppSssMEfarmMon is the is ME supplied by supplements (MJ ME/month) when timing is specified [section 5.3.2].

If the total animal ME requirements have not been calculated (initial calculation), it is assumed that farm-grown supplements are preferential allocated to meet winter requirements. An estimated of the proportion of supplement fed each month (prop) is calculated as:

Equation 82: $prop_{mon}$ = 0.2 month May, June, July
= 0.4 / 9 otherwise

6.5.2. Standard allocation

In subsequent calculations, farm-grown supplements are first preferentially allocated to months in the order June, May, July, April, August, March, September, February, October, January, November, and December. This assumes that farm-grown supplements are used to meet winter ME requirements, and then are progressively allocated to months outside winter. This is achieved by estimating proportion of supplement fed each month (prop) using an iterative process. The proportion of supplement fed in a month is assumed to be zero if animals are off pasture during to the use of wintering pads/animal shelters or are grazed-off, or the available amount of animal ME requirements that can be met by farm-grown supplements(section 6.5.3). is zero. Otherwise, on the first iteration, $prop_{mon}$ is estimated as:

Equation 83: $prop_{mon}$ = 0.2 * $rgrazetime_{mon}$ May, June, July
= 0.1 * $rgrazetime_{mon}$ August

where the time spent grazing is estimated as:

Equation 84: $ratiograzetime_{mon} = 1 - WinPadmonthGrazeTime_{antype, mon} / 24$
WinPadmonthGrazeTime is the time (hours/day) animals are grazing when on wintering pads or animals shelters.

Otherwise, for subsequent iterations, an additional month in the sequence listed above is include, and the proportion of supplement fed for an included month is increased by:

Equation 85: $prop_{mon}= prop_{mon-1} + 0.2 * ratio *rgrazetime_{mon}$
$ratiograzetime_{mon}$ is the proportion of the time animals spend grazing [Equation 84].

where ratio is estimated as:

Equation 86: $ratio = (availME_{mon} - suppgrowMEfarm_{antype} * prop_{mon-1}) / availME_{mon}$
availME is the available amount of animal ME requirements that can be met by farm-grown supplements (MJ ME/month) [section 6.5.3].
suppgrowMEfarm is the amount of farm-grown supplement ME to be allocated (MJ ME/year).

Ratio has the effect of decreasing the rate of increase as a higher proportion of the available ME is met by supplements. The proportion is constrained such that the amount of supplement ME allocated in a month, supME (MJ ME/month), which is:

Equation 87: $supME_{mon} = suppgrowMEfarm_{antype} * prop_{mon}$

is greater than the available ME that can be met by farm-grown supplements, then the estimated proportion of supplement fed each month is fixed at:

Equation 88: $prop_{mon} = availME_{mon} / suppgrowMEfarm_{antype}$

The total amount of ME allocated to farm-grown supplements (totalsupME) is estimated as the sum of supME. If totalsupME is greater than suppgrowMEfarm, then the iterations are stopped. The proportion (prop) is then adjusted so that estimated amount of supplement fed equals the amount of supplement available for feeding, that is:

Equation 89: $prop2_{mon} = prop_{mon} * suppgrowMEfarm_{antype} / totalsupME$

If totalsuppin is greater than animal ME intake then:

Equation 90: $prop2_{mon} = MEIntake_{antype, mon} / \sum MEIntake_{antype, mon}$

MEIntake is the amount of farm-grown supplement ME to be allocated (MJ ME/year).

To finish and to ensure timing adds up to one, the proportion of supplement fed each month is calculated as:

Equation 91: $SuppgrowPastureTiming_{antype, mon} = prop2_{mon} / \sum prop2_{mon}$

6.5.3. Available ME

The available amount of animal ME requirements that can be met by farm-grown supplements is estimated as:

Equation 92: $availME_{mon} = MEIntake_{antype, mon} – FoodMilkShed - FoodFeedpad - FoodWinpad - FoodFcrop - Suppinfarm - SuppStorefarm – Suppgrowfarm$

MEIntake is animal ME intake (MJ ME/mon) [Animal model chapter].

and where

Equation 93: $FoodMilkShed = (suppinMEMilk_{antype} + suppgrowMEMilk_{antype} + suppstoreMEMilk_{antype}) * SuppMilkTiming_{antype, mon} + CropMEMilkShed_{antype, mon}$

suppinMEMilk, suppgrowMEMilk and suppstoreMEMilk is the amount of supplement energy (MJ ME/month) allocated for in-shed feeding [Equation 16].

SuppMilkTiming is the proprotion of supplement fed each month supplements for in-shed feeding [section 6.1].

CropMEMilkShed (MJ ME/month) is the amount of crop energy fed for in-shed feeding.

Equation 94: $FoodFeedpad = (suppinMEFP_{antype} + suppgrowMEFP_{antype} + suppstoreMEFP_{antype}) * SuppFPTiming_{antype, mon} + CropMEFeedPad_{antype, mon}$

suppinMEFP, suppgrowMEFP and suppstoreMEFP is the amount of supplement energy (MJ ME/month) allocated to the feed pad [Equation 16].

SuppFPTiming is the proportion of supplement fed each month on the feed pad [section 6.2].

CropMEFeedPad (MJ ME/month) is the amount of crop energy fed on the feed pad.

Equation 95: $FoodWinpad = (suppinMEWP_{antype} + suppgrowMEWP_{antype} + suppstoreMEWP_{antype}) * SuppWPTiming_{antype, mon} + CropMEWinPad_{antype, mon}$

suppinMEWP, suppgrowEWP and suppstoreMEWP is the amount of supplement energy (MJ ME/month) allocated to the wintering pad/animals shelter [Equation 16].

SuppWPTiming is the proprotion of supplement fed each month on the wintering pad/animals shelter [section 6.3].

CropMEWinPad (MJ ME/month) is the amount of crop energy fed on the wintering pad/animals shelter.

Equation 96: $FoodFcrop = CropMEOnCrop_{antype, mon} + CropMEOnPdk_{antype, mon}$

CropMEOnCrop(MJ ME/month) is the amount of enery consumed in situ on a crop.

CropMEOnCrop(MJ ME/month) is the amount of enery consumed from crops fed on blocks.

Equation 97: $Suppinfarm = suppinMEfarm_{ntype} * SuppInPastureTiming_{antype, mon} + suppinMEfarmMon_{antype, mon} + supLeftMEfarmMon_{antype, mon}$

suppinMEfarm is the amount of imported supplement energy (MJ/year) fed on block [section 5.4.1 or 5.3.1].

SuppFPTiming is the proprotion of imported supplement fed each month on the feed pad [section 6.4].

suppinMEfarmMon is the amount of imported supplement energy (MJ/year) fed on blocks when timing is specified [section 5.3.2].

supLeftMEfarmMon is the amount of left over supplement energy (MJ/year) [section 5.6].

Equation 98: $SuppStorefarm = suppstoreMEfarm_{ntype} * SuppStorePastureTiming_{antype, mon} + suppstoreMEfarmMon_{antype, mon}$

SuppStorefarm is the amount of stored supplement energy (MJ/year) fed on block [section 5.4.1 or 5.3.1].

SuppFPTiming is the proprotion of stored supplement fed each month on the feed pad [section 6.4].

suppinMEfarmMon is the amount of stored supplement energy (MJ/year) fed on blocks when timing is specified [section 5.3.2].

Equation 99: $Suppgrowfarm = suppgrowMEfarmMon_{antype, mon}$

suppgrowMEfarmMon is the amount of farm-grown supplements energy (MJ/year) fed on blocks when timing is specified [section 5.3.2].

Note that Suppgrowfarm is included as the distribution is already known and this section is about identifying the distribution of the last remaining feed source.

7. Additional supplement characteristics

7.1. Farm-grown supplement nutrients removed from block

Total amount of farm-grown supplement nutrients, harvested and removed from a block, are displayed as a block output in the nutrient budget. This is estimated as:

Equation 100: $SupRemovedFromBlock_{block, nut} = \sum_{sup}(suppnut_{nut} / area_{block})$

sup is individual farm-grown supplements.

Suppnut is nutrient amount for farm-grown supplements [Equation 5].

area is block area (ha) supplement is removed from.

7.2. Total imported supplement nutrients

Total amount of imported supplement nutrients used in a farm nutrient budget is estimated as:

Equation 101: $SupBroughtInNut_{nut} = \sum_{sup}(suppnut_{nut})$

sup is individual imported supplements.

Suppnut is nutrient amount (kg nutrient) for individual imported supplements [Equation 5].

7.3. Average digestibility of supplements in the diet

The quantity of dung DM produced by each animal enterprise is estimated monthly as the sum of dry mater intake times (1-digestibility) of each dietary component. The dung DM is an input into estimating methane emissions (Methane chapter). To include supplements in this analysis, an average digestibility of the supplements fed to each animal enterprise is required, and this is estimated as:

Equation 102: $SssDigest_{antype} = SsswtDigest_{antype} / totalDM_{antype}$

where

Equation 103. $SsswtDigest_{antype} = \Sigma_{sup}(suppDM * SupDigest * UtilStorexxx)$

Sss refers to imported, farm-grown or stored supplements.

antype is the animal enterprise the supplement was fed to.

suppDM is the amount of DM (kg DM) for each supplement item [section 4.1].

SupDigest is digestibility as a proportion for the supplement [section 2].

UtilStorexxx is UtilStoreBin or UtilStorePdk as appropriate [section 4.2].

and

Equation 104. $totalDM_{antype} = \Sigma_{sup} (suppDM * UtilStorexxx)$

7.4. Estimating embodied emissions

Supplements contribute to the embodied energy and carbon dioxide (CO_2) emissions, used in the estimation of farm and product greenhouse gas emissions.

For imported supplements, for consistency the total embodied costs are considered to be the same as the embodied costs of exporting the supplement.

7.4.1. Dry matter for plastic embodied CO_2 emissions

Plastics have an embodied energy and CO_2 emissions (Carbon dioxide, embodied and other gaseous emissions chapter), and embodied rates are based on a per kg supplement. If plastic covering or wrapping is checked for farm-grown supplements, then the amount of DM used to estimate embodied energy and CO_2 emissions is estimated. Note that for supplements fed out from storage, the storage conditions and hence the use of plastic is included as part of the farm-grown supplement specifications and hence do not need to be considered.

The embodied CO_2 emissions for plastics are based on DM of the supplements covered in plastic. It is assumed that less plastic is used for silage stacks and this is about a 1/3 of that used for wrapping bales. Hence, the amount of DM from farm-grown supplement covered in plastic is estimated as:

Equation 105: $SupDMWrap = \sum_{sup}(DMstack_{sup} + DMnonstack_{sup})$

DMstack = suppDM/3 if silage stacks are used.

DMnonstack = suppDM otherwise.

suppDM is the dry weight (kg DM) of an individual farm-grown supplement made [section 4.1].

Imported silage stored on-farm in silage stacks is not included in estimating SupDMWrap.

7.4.2. Wet weights

The embodied carbon dioxide emissions, used in the estimation of farm and product greenhouse gas emissions, requires an estimate of supplement wet weight to calculate embodied feeding and transport emissions. Wet weight is ascribed to each animal enterprise. This is estimated as (kg FW /year):

Equation 106: $suppSssWetWeight_{antype} = suppDM_{supplement} / (DMcontent_{supplement} / 100)$

suppDM is the DM amount (kg DM) for each supplement item [section 4.1].

DMcontent is the DM content of the supplement [section 4.3 for farm-grown supplements and section 3.4 for stored and section 3.1.3].

and where supDM is the dry weight of an individual farm-grown supplement made [section 4.1] and is estimated for imported supplements, farm-grown supplements that are not exported or placed in storage, and stored supplements that are fed out.

Note that wet weights of left-over supplements are not included as they have already been accounted for in the primary supplement source. The embodied feeding and transport emissions for feeding out left-over supplements are assumed to be negligible. This would be the condition if the left-over supplements are fed directly to other animals, for example, at the end of a conveyor system.

7.5. Nutrient loss in storage

Supplement nutrients lost through storage are added to the farm nutrient budget as immobilised nutrients. For silage made on blocks, some of the storage loss is assumed to leach if the stack is not contained. Thus:

Equation 107: $SupNutStorageLoss_{nut} = \sum_{sup} suppnut_{nut} * StLoss * (1 – Rleach)$

Equation 108: $SilageStackleachnut = \sum_{sup} suppnut_{nut} * StLoss * RLeach$

Suppnut is nutrient amount (kg nutrient)for farm-grown supplements [Equation 5].

StLoss = StorageLoss / 100

StorageLoss is the storage loss (%) for the general type of the supplement [section 3.1.2].

RLeach is the leaching rate.

It was assumed that 10% of nutrients lost while in storage were lost as leachate if the stack was not contained. Thus:

Equation 109: RLeach = 0.1 for silage supplements removed when stack leachate is not contained

= 0 otherwise

Imported silage stored on-farm in an unlined silage stacks is not included in leachate losses.

8. Animal health supplementation

Animal health supplements can be added as a salt product (blocks, licks or bags), as total amount of product added as dusting or drenching, or as dusting on feed and drench on an animal enterprise basis. Nutrients in animal health supplements are included in animal nutrient intake. They are distributed around the farm as part of the animal intake sub-model.

8.1. Allocation to animal enterprise

For each animal enterprise, the amount of nutrients added as animal health supplements (kg nutrient/year) is estimated as:

Equation 110: $AnimalHealth_{antype, nut} = salt_{nut} + total_{nut} + dust_{nut} + drench_{nut}$

The amount of nutrients in salt products (kg nutrient/year) is estimated as:

Equation 111: $salt_{nut} = \Sigma(Rsalt * Csalt_{nut} /100 * unit)$

Rsalt is the entered number of units (bags, blocks, etc).

Csalt is the nutrient concentrations (%) of material selected as defined in section 8.2.

unit is the size of block, bag etc (kg) as defined in section 8.2.

100 converts percentage to proportion.

If total animal health supplements is entered, then the amount of nutrient (kg nutrient/year) is:

Equation 112: $total_{Mg}$ = 0.6 * TotalMgO + 0.145 * TotalMgCl + 0.099 * TotalMgSO4
Equation 113: $total_{S}$ = 0.13 * TotalMgSO4
Equation 114: $total_{Na}$ = 0.39 * TotalSalt
Equation 115: $total_{Ca}$ = 0.33 * TotalLimeFlour
Equation 116: $total_{N}$ = TotalN * 0.46
Equation 117: $total_{P}$ = TotalP

where TotalMgO (kg MgO/year), TotalMgCl (kg $MgCl_2$/year), TotalMgSO4 (kg $MgSO_4$/year), TotalSalt (kg NaCl/year), TotalLimeFlour (kg lime flour/year), Total N (kg urea/year) and Total P (kg P/year) are entered weights of material drench used, either for drenching, or dusting, and the constants are the proportion of the nutrient in the respective products.

For a dairy cow enterprise, a drenching regime can be entered. The amount of nutrient supplied is estimated as:

Equation 118.: $drench_{Mg}$ = conc * Mgrate * Mgweek * SR * 7 / 1000
Equation 119: $drench_{S}$ = conc2 * Mgrate * Mgweek * SR * 7 / 1000

conc	= 0.099	$MgSO_4$ (Epsom salts)
	= 0.145	$MgCl_2$
	= 0.6	MgO
conc2	= 0.13	Epsom salts
	= 0	otherwise

Mgrate is the entered weekly drenching rate (g material/cow/day).
Mgweek is the entered number of weeks dosage occurs.
conc and conc2 is the proportion of Mg or S respectively in the drenching materials.
7 is the number of days in the week.
1000 converts g to kg.
SR is the number of milkers on a total farm basis.

Similarly, nutrients from drenching salt or lime flour are estimated as:

Equation 120: $drench_{Na}$ = 0.39 * Narate * Naweek * SR * 7 / 1000
0.39 is the proportion of Na in salt (NaCl).
Narate is the entered weekly drenching rate (g material/cow/day).
Naweek is the entered number of weeks dosage occurs.
7, 1000 and SR are defined in Equation 118.
Equation 121: $drench_{Ca}$ = 0.33 * Carate * Caweek * SR * 7 / 1000
0.33 is the proportion of Ca in limeflour ($CaCO_3$).
Carate is the entered weekly drenching rate (g material/cow/day).
Caweek is the entered number of weeks dosage occurs.
7, 1000 and SR are defined in Equation 118.

The amount of nutrient supplied for dusting is estimated as:

Equation 122: $dust_{Mg}$ = 0.6 * Mgdustrate

Equation 123: $dust_{Na} = 0.39 * Nadustrate$

Equation 124: $dust_{Ca} = 0.33 * Cadustrate$

where Mgdustrate (kg MgO/year), Nadustrate (kg salt/year) and Cadustrate (kg lime flour/year) are the entered dusting rate, and 0.6, 0.39 and 0.33 are the proportions of Mg, Na or Ca in magnesium oxide (MgO), salt (NaCl) and lime flour ($CaCO_3$) respectively.

8.2. Salt block characteristics

Salt for animal health supplementation is typically purchased as blocks, licks or in bags. The range of products, with the unit weight and nutrient concentrations, is shown in Table 16.

Table 16. Unit weight and nutrient content of salt blocks.

Type	Unit weight (kg)	Nutrient content (%) N	P	K	S	Ca	Mg	Na	Cl
Summit multimineral block	20	0	0	0	0	0	0	34.8	54.5
Summit multimineral Littlix	2.5	0	0	0	0	0	0	34.8	54.5
Summit multimineral bag	25	0	0	0	0	0	0	34.8	54.5
Summit magnesium block	20	0	0	0	0	0	4.81	33.4	52.1
Summit magnesium bag	25	0	0	0	0	0	4.81	33.4	52.1
Summit copper	20	0	0	0	0	0	0	38	59
Summit Amaize	25	0	0	0	0	18	4.9	7.6	4.9
Summit Ag Salt	25	0	0	0	0	0	0	38	59
Summit liquimin	25	0	0	0	0	0	0.95	35	55

9. Outputs

The output variables listed in Table 17 are described in this chapter and are used in other technical manual chapters. Variables associated with the distribution of left-over supplements is covered in section 5.6.

Table 17. Output variables and description from the supplements sub-model.

Variable [1]	Description	Section
Dry matter (DM)		
$suppSssDMpad_{antype}$	Supplements allocated to in shed feeding, feed pads, or wintering pad are distributed to the animal enterprise (kg DM/year).	5.2
$suppSssDMfarm_{antype}$	DM in supplements fed on blocks (kg DM/year).	5.3.1
$suppSssDMfarmMon_{antype, mon}$	DM supplied by supplements when timing is not specified (kg DM/month).	5.3.2
$suppSssDMconsume_{block}$	Supplement DM (kg DM/ha/year) consumed	5.3.1

Variable [1]	Description	Section
	on a given block.	
$supDMout_{block}$	Supplement DM made on a block (kg DM/ha/year).	5.1
supDMStorage	DM in farm grown supplement placed in storage (kg DM/year).	5.4
supDMExport	DM in farm grown supplement exported from the farm (kg DM/year).	5.5
supDMWrap	DM supplements covered in plastic (kg DM/year).	7.4.1
Metabolisable energy (ME)		
$SuppSssMEpad_{antype}$	ME from supplements allocated fed on pads (MJ ME/year).	5.2
$suppSssMEfarm_{antype}$	ME from supplements fed on blocks (MJ ME/year).	5.3.1
$suppSssMEfarmMon_{antype, mon}$	ME supplied by brought in supplements when timing is not specified (MJ ME/month).	5.3.2
Nutrients		
$suppSssNutpad_{antype, nut}$	Supplements allocated to in shed feeding, feed pads, or wintering pad are distributed to the animal enterprise (kg nutrient/year).	5.2
$suppSssNutFarm_{antype, nut}$	Nutrients in supplements fed on blocks (kg nutrient/year).	5.3.1
$suppSssNutFarmMon_{antype, mon, nut}$	Nutrients supplied by brought in supplements when timing is not specified (kg nutrient/month).	5.3.2
$suppSssnutblock_{block, nut}$	Nutrients added to a block as supplements (kg nutrient/ha/year).	5.3.1
supNutStorage	Nutrients in farm grown supplement placed in storage (kg nutrient/year).	5.4
supNutExport	Nutrients in farm grown supplement exported from the farm (kg nutrient/year).	5.5
$supRemovedFromBlock_{block, nut}$	Total amount of nutrients in farm-grown supplement harvested and removed from a block (kg nutrient/ha/year).	7.1
$supBroughtInNut_{nut}$	Total amount of imported supplement nutrients (kg nutrient/year).	7.2
$SupNutStorageLoss_{nut}$	Supplement nutrients lost through storage (kg nutrient/year).	7.5
$AnimalHealth_{antype, nut}$	Nutrients supplied to animals as drench, dusting and salt blocks.	8.1
$suppnutUnUtilpad_{antype, nut}$	Nutrients in unutilised supplements from a pads (kg nutrient/year).	5.2
Timing		
SuppMilkTiming	Proportion of total supplement consumed each month for each animal enterprise for in shed feeding.	6.1
SuppFPTiming	Proportion of total supplement consumed each month for each animal enterprise for in	6.2

Variable [1]	Description	Section
	shed feeding.	
SuppWPTiming	Proportion of total supplement consumed each month for each animal enterprise for in shed feeding.	6.3
SuppInPastureTiming	Monthly distribution for supplements consumed on pasture (MJ ME /month).	6.4
Other outputs		
$suppSssDigest_{antype}$	Average digestibility of the supplements fed to each animal enterprise.	7.3
$suppSssWetWeight_{antype}$	Wet weight is ascribed to each animal enterprise.	7.4.2

[1] Suss is either imported, farm-grown or stored supplements.
pad is either the milking shed (in-shed feeding), feed pad or wintering pad.

10. References

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