OVERSEER® Technical Manual

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

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Animal intakes

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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.

Scientific contribution to model development:

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

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Animal intakes

1. Introduction

1.1. Background

OVERSEER calculates nutrient intakes for an animal enterprise by first calculating the energy requirements for the enterprise using a standard metabolic model (Animal metabolic energy requirements chapter). This is converted to dry matter (DM) intake based on the feed from different sources consumed by the animals and default values for their metabolisable energy (ME) contents. Based on the DM intakes and nutrient contents of the different feed sources, nutrient intake is calculated. The reasons for using this method, rather than using pasture DM production and utilisation are outlined in the Animal model chapter.

Dry matter intake is used in the estimation of methane emissions from enteric, dung, and effluent (Calculation of methane emissions chapter).

Nutrient intake is partitioned between nutrients required for products (based on user-provided production data) and excreta. Excreta is then distributed to farm structures where dung and urine are deposited, and can be processed in an effluent management system where excreta may be returned to blocks as effluent. The remainder is partitioned between urine and dung which is then deposited onto blocks as dung or urine.

A schematic diagram showing the relationship between animal intakes (ME, DM, and nutrients), and other sub-models is shown in Figure 1. When undertaking the calculations, the following interactions can occur:

- Animal ME requirements, and hence estimation of ME supplied by pasture, are dependent on the feed quality (average ME content of the diet). As blocks can have different ME contents, the average ME content of the diet is dependent on the allocation of pasture DM to blocks and the block ME contents. The allocation of pasture DM intake for some settings of relative productivity is dependent on total DM intake for an enterprise, which is driven by animal ME requirements.
- In a given month, the estimated ME requirements supplied by pasture is dependent on ME supplied by supplements and crops. To reduce feeding errors, the allocation of supplements to animal enterprises and between months also takes into account the estimated ME requirements supplied by pasture.
- Nutrient intake is dependent on block nutrient concentrations, which vary with fertiliser and effluent inputs. Effluent inputs are dependent on estimated pasture nutrient intakes.

Therefore an iterative process is used to minimise the amount of recalculations required, but ensures the major effects of any interactions are captured.

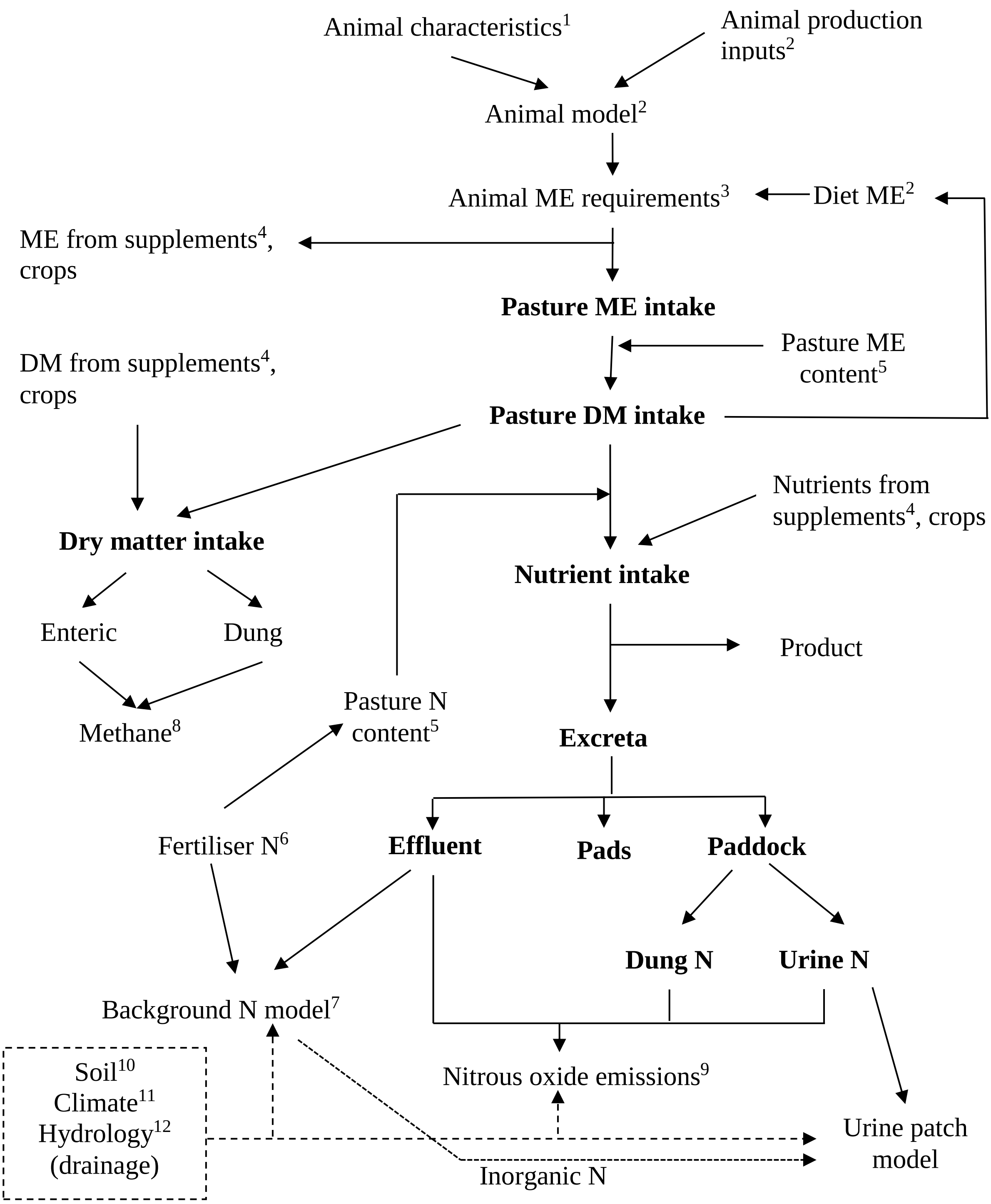

Figure 1. Relationships between sub-models and metabolisable energy (ME), dry mater (DM) and nutrient intakes (shown in bold), with a focus on nitrogen (N), with relevant Technical Manual chapters indicated by superscripts ([1]Animal characteristics, [2]Animal model, [3]Metabolic energy requirements of animals, [4]Supplements, [5]Characteristics of pasture, [6]Characteristics of fertilisers, [7]Crop N sub-models, [8]Methane emissions, [9]Nitrous oxide emissions, [10]Characteristics of soils, [11]Climate, [12]Hydrology).

1.2. Workings of the technical manual

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

When describing equations in this manual, units are shown using ( ) and cross-references to other equations and sections within this chapter 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 for each option is shown on the right hand side. Multiplication is depicted by a '*'. The variable and parameter names used are generally shortened names of the model property, and this naming convention is similar to the convention used in the OVERSEER engine model.

Error messages that are generated are shown in italics, and insertions into the error message text are shown between angle brackets < >.

1.3. Abbreviations, chemical symbols, and subscripts

<u>Abbreviations</u>

DM Dry matter (kg DM)

ME Metabolisable energy (MJ)

<u>Chemical symbols:</u>

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

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

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

block a given block, which is an area of the farm with similar characteristics and management, as defined in the Introduction chapter.

2. ME intakes

Animal ME requirements are estimated for each animal enterprise each month (Animal model chapter). The animal ME requirements are assumed to be met by feed supplied as supplements (brought in, farm grown or from storage), then crops and lastly pasture. When crops and supplements are entered by the user, it is assumed that ME from these sources is 'known', and hence the unknown is ME supplied by pasture. This approach assumes that poor feed utilisation within the animal is not occurring, for example due to parasites. In this case, animal production and hence ME requirements may be low and hence the estimated ME supplied by pasture is low, whereas in practice a higher amount of feed may be consumed and voided.

As feed offered on wintering pad/animal shelters or feed pads, or in the milking shed, is specified by the user, this feed is assumed to meet animal ME requirements first after storage and utilisation losses are accounted for. This principle is also encapsulated in the default allocation of supplements (Supplement chapter) and crops (unpublished).

2.1. ME supplied by pasture

Animal ME requirements that are estimated to be supplied by pasture and supplements consumed on the farm (pasturesupMEintake, MJ ME/month) is estimated as the difference between animal ME requirements, and ME supplied by feed (supplements and crops) consumed in the milking shed, on a feed pad and/or on wintering pad/animal shelters, and crops consumed either in situ or on another block due to cut and carry. Thus:

Equation 1: $$\text{pasturesupMEintake} = \text{MEIntake}_{\text{antype, mon}} - \text{MEMilkShed} - \text{MEFeedpad} - \text{MEWinpad} - \text{MEFcrop}$$

MEIntake is the animal ME requirements (MJ ME/month) [Animal model chapter].

FoodMilkShed is the ME in feed offered in the milking shed (MJ ME/month) [Equation 2].

FoodFeedpad is the ME in feed offered on the feed pad (MJ ME/month).

FoodWinpad is the ME in feed offered on the wintering pad/animal shelter (MJ ME/month).

MEFcrop is the ME in crops consumed either in situ or on another block if cut and carried (MJ ME/month) [Equation 3].

Metabolisable energy supplied by feed that is consumed in the milking shed is estimated as:

Equation 2: $$\text{MEMilkShed} = (\text{supinMEMilkShed}_{\text{antype}} + \text{supfarmMEMilkShed}_{\text{antype}} + \text{supstoreMEMilkShed}_{\text{antype}}) * \text{SuppMilkShedTiming}_{\text{antype, mon}} + \text{CropMEMilkShed}_{\text{antype, mon}}$$

supinMEMilkShed is the ME in brought in supplements consumed in the milking shed (MJ ME/month) [Supplements chapter].

supfarmMEMilkShed is the ME in farm-grown supplements consumed in the milking shed (MJ ME/month) [Supplements chapter].

supstoreMEMilkShed is the ME in stored supplements consumed in the milking shed (MJ ME/month) [Supplements chapter].

SuppMilkShedTiming is proportion of total supplement consumed each month for each animal enterprise for in shed feeding [Supplements chapter].

CropMEMilkShed is the ME in farm-grown crops consumed in the milking shed (MJ ME/month) [unpublished].

A similar method is used to estimate ME from supplements and crops consumed on the feed pad (MEFeedpad) and the wintering pad/animal shelter (MEWinpad). For wintering pad/animal shelters, the amount of left-over supplements from dairy goat feeding is also included.

The ME in crops consumed either in situ or on another crop when cut and carried is estimated as:

Equation 3: $MEFcrop = CropMEOnCrop_{antype,\ mon} + CropMEOnPdk_{antype,\ mon}$

CropMEOnCrop is the ME supplied by crops consumed in situ (MJ ME/month) [unpublished].

CropMEOnPdk is the ME supplied by crops consumed on another block when cut and carried (MJ ME/month) [unpublished].

At this stage, error checks to determine whether feed has been supplied to wintering pad/animal shelters is undertaken (section 2.2.1). A series of errors checks are then undertaken if pasture ME intake is less than zero (section 2.2.2). If there is an error, the model still continues calculations to supply data for the animal diagnostic reports, but sets pasturesupMEintake to zero. Only the first occurrence of an error is reported. Additional errors will be sequentially reported once the prior one is resolved.

If there is no error, the ME supplied by supplements (brought in, farm-grown and stored) that are consumed on blocks is deducted from pasturesupMEintake to give the ME intake that is estimated to be supplied by pasture. Thus:

Equation 4: $pastureMEintake = pasturesupMEintake - Suppinfarm - SuppStorefarm – - SuppFarmMade$

pasturesupMEintake is the ME intake estimated to come from pasture and supplements consumed on blocks (MJ ME/month) [Equation 1].

Suppinfarm is the ME intake estimated to come from brought in supplements consumed on blocks (MJ ME/month) [Equation 5].

SuppStorefarm is the ME intake estimated to come from stored supplements consumed on blocks (MJ ME/month).

SuppFarmMade is the ME intake estimated to come from farm grown supplements consumed on blocks (MJ ME/month).

The ME estimated to be supplied from brought in supplements consumed on blocks (MJ/month) is estimated as:

Equation 5: $Suppinfarm = supinMEfarm_{antype} * SuppInPastureTiming_{antype,\ mon} + supinMEfarmMon_{antype,\ mon}$

supinMEfarm is the ME supplied by brought in supplements when timing is not specified (MJ ME/month) [Supplements chapter].

SuppInPastureTiming is the estimated monthly distribution for supplements consumed on pasture (MJ ME /month) [Supplements chapter].

supinMEfarmMon is the ME supplied by brought in supplements when timing is specified (MJ ME /month) [Supplements chapter].

ME supplied by left over supplements from dairy goat feeding that are consumed on farm are added ME estimated to be supplied from brought in supplements to give:

Equation 6: $Suppinfarm = Supinfarm + supLeftMEfarmMon_{antype, mon}$

supLeftMEfarmMon is the ME supplied by left-over supplements from dairy goats that are fed to another animal enterprise on a blocks (MJ ME /month) [Supplements chapter].

Similar estimates of ME intake supplied by stored (SuppStorefarm) and farm grown (SuppFarmMade) supplements are made as described in Equation 5.

A series of errors checks are then undertaken as described in section 2.2. If estimated ME intake supplied by pasture (pastureMEintake) is less than zero, that is the ME supplied by supplements and crops exceeds animal ME requirements (section 2.2.3), an error is reported. Additional error checks are made to identify animals not on pasture that consumed either too much or insufficient ME from ME supplied by supplements and crops (section 2.2.4), that sufficient feed has been fed to animals on wintering pad/animal shelters (section 2.2.5), and that animals are on a block if pasture is consumed (section 2.2.6). If there is an error pastureMEintake is set to zero. As before, if there is an error, the model still continues calculations to supply data for the animal diagnostic reports, but sets pasture ME to zero. Only the first occurrence of an error is reported.

The estimated ME supplied from different sources are used to populate outputs for the animal diagnostic reports (section 2.3). The ME supplied by pasture is used to estimate pasture DM intake (section 3.1.2).

2.2. Feeding error checks

This section lists the checks for feeding that are undertaken while estimating ME intakes. Additional checks are made when DM and nutrient intake are estimated, and within the calculation phase.

As a general rule, checks are made to ensure that feed supplied is within 10% of animal requirements on a yearly basis, and within 20% on a monthly basis. The wider allowance on a monthly basis accounts for any distribution errors between months because a monthly model is being used. Note that the model still uses the amount of feed supplied in the remainder of the calculations used to generate animal feeding reports. However, if the entered supplementary feed or crop yields are higher than actual, pasture production will be lower.

2.2.1. Feed supply to wintering pad/animal shelters

For a given month and animal enterprise, if 100% of animals are on a wintering pad/animal shelter and they are not grazing pasture, and if no feed is allocated to the wintering pad/animal shelter for that month (MEWinpad is zero) then the following error message is generated:

For <animal enterprise> in <month> no feed was assigned to wintering pad/animal shelter.

If estimated pasture ME intake is less than zero, that is, ME from feed consumed in the milking shed, on the feed pad or as crops exceeds animal ME requirements, then the error message above is extended by adding:

> *ME supplied by supplements fed in the milking shed or on the feed pad, or as crops were more than the animal ME requirements.*

2.2.2. Negative pasture ME intakes (excluding supplements fed on pasture)

At this stage, only feed consumed on farm structures or crops has been included in the calculations. Given that animals can be completely housed (on a wintering pad/animal shelter), a check is made to ensure sufficient feed has been allocated to meet animal ME requirements while on the wintering pad/animal shelter. To allow for some buffering for a given month, a message is only generated if the feed supplied (ME from feed consumed in the milking shed, on the feed pad or wintering pad/animal shelter, or farm grown crops) is greater than 1.2 times the animal ME requirements (that is there is a 20% additional allowance). The generated error message is:

> *For <animal enterprise> in <month>, ME supplied in feed fed in the shed, on pads and as crops exceeded animal ME requirements by <factor>%.*

where factor is:

Equation 7: factor = (FoodMilkShed + MEFeedpad + MEWinpad + MEFcrop) / MEIntake * 100

MEMilkShed, MEFeedpad, MEWinpad, and MEFcrop is ME of feed consumed in the milking shed, on the feed pad, on the wintering pad/animal shelter, or from crops respectively (MJ ME/month) [section 2.1].

MEIntake is animal ME requirements (MJ ME/month) [Animal model chapter].

The message is extended depending on whether all animals are on the wintering pad/animal shelter (section 2.2.2.1) or otherwise (section 2.2.2.2).

2.2.2.1. *All animals fed on wintering pad/animal shelter*

If 100% of animals are on the wintering pad/animal shelter and they are not grazing pasture in the given month, then if the proportion of feed ME from a crops consumed on a wintering pad/animal shelter is greater than 50% of the total feed ME consumed on the wintering pad/animal shelter (MEWinPad), then the error message is extended by adding:

> *The feed was predominately from <source>. Note that storage losses are not included. Check crop yield, distribution of crops to animals or consider increasing grazing time on fodder crop if this message persists.*

If the proportion of feed ME from a source (brought in, farm grown or stored supplements) consumed on a wintering pad/animal shelter is greater than 50% of the total feed ME consumed on the wintering pad/animal shelter, then the error message is extended by adding:

The feed was predominately from <source>. Check supplement rates and supplement utilisation.

Otherwise the message is extended by adding:

Check supplement rates and supplement utilisation, or crop yield and distribution of crops to animals.

2.2.2.2. *Mixed locations*

If no feed has been allocated to the wintering pad/animal shelter (MEWinpad is zero) then the error message is extended by adding:

No feed was assigned to wintering pad.

Otherwise an indication of the source of feed is indicated in the message. If half the total ME in feed is supplied by ME from crops, the error message is extended by adding:

The feed was predominately from crops. Note that storage losses are not included. Check crop yield, distribution of crops to animals or consider increasing grazing time on fodder crop if this message persists.

If feed was predominately consumed in either the milking shed, feed pad or animal shelter (> 70% of feed ME was consumed in that location) then the error message is extended by adding:

The feed was predominately fed in the <location>.

The message is extended further in a manner similar to section 2.2.2.1 if the proportion of feed ME from a source (brought in, farm grown or stored supplements) fed on a location was greater than 50% of the total feed ME supplied.

2.2.3. Negative pasture intake

If pasture intake is negative, then the following error message is generated:

Supplements and crops fed on pads and in the paddock are more than estimated animal intakes for <animal enterprise> in <month> (Source of supplementary feed).

The percentage contribution from each feed source (MEMilkShed, MEFeedpad, MEWinpad, FoodFcrop, Suppinfarm, SuppStorefarm SuppFarmMade, section 2.1) is then added to the error message.

Lastly the following is added to the end of the error message:

Check the amount of supplements brought in and fed on pasture, timing of that feeding (Advanced pasture supplement feeding, imported options), or time that animals are removed from pasture (wintering pad/animal shelter or grazing off), and supplement utilisation. Also check the amount of supplements from storage and timing of that feeding (Advanced pasture *supplement feeding, internal options), or time that animals are removed from pasture (wintering pad/animal shelter or grazing off), and supplement utilisation. Consider reducing supplement inputs if this message persists. Note that animal requirements are met first from supplements fed on pads - if these are changed then supplements fed on pasture may also need to be modified.*

2.2.4. Animals not on pasture

If animals are not on pasture for the given month, a check is made to confirm that the non-pasture contribution is greater than 90% and less than 110% of animal ME requirements less that supplied by pasture. Note that this check is done before supplements consumed on pasture is included, and hence a buffer of 10% is used. Thus the ratio is estimated as:

Equation 8: $\text{ratio} = (\text{MEIntake}_{\text{antype, mon}} - \text{pastureMEintake}) / \text{MEIntake}_{\text{antype, mon}}$

MEIntake is animal ME requirements (MJ ME/month) [Animal model chapter].

pastureMEintake is the ME in pasture consumed (MJ ME/month) [Equation 4].

The following message is generated if the ratio is less than 0.8:

Insufficient feed has been supplied to <animal enterprise> when not on pasture for the month of <month>. Only <ratio> '% was supplied.

or if ratio is greater than 1.2, the following message is generated:

Too much feed has been supplied to <animal enterprise> when not on pasture for the month of <month>. <ratio> % was supplied.

2.2.5. Checks for feed supply on wintering pad/animal shelters

In a given month, if all animals are on wintering pad/animal shelter, and time grazing pasture is zero or the option ‘Wintering pad only’ is selected, then a check is made that sufficient feed has been offered. A buffer of 20% is allowed. Account is taken of feed already supplied to the feed pad and milking shed. Thus the check is:

Equation 9: $\text{check} = \text{MEWinpad} / (\text{MEIntake}_{\text{antype, mon}} - \text{MEMilkShed} - \text{MEFeedpad})$

MEFeedpad and MEWinpad is ME in feed consumed on the feed pad or wintering pad/animal shelter respectively (MJ ME/month) [section 2.1].

MEIntake is animal ME requirements (MJ ME/month) [Animal model chapter].

If check is less than 0.8, then the following error message is generated:

Insufficient feed supplied to <animal enterprise> on wintering pad/animal shelter when the 'Pad/shelter only' feeding regime is selected. Only <ratio> % were supplied. Supplements need to be diverted to the wintering pad/animal shelter.

2.2.6. Check that animals are on a block

Animals can be allocated to specific blocks with the farm, and for specific months. If pasture intake is estimated (pastureMEintake > 0) but average pasture ME content is zero, because the animals are not on any blocks consuming pasture, then the following error message is generated:

> *Animals are defined as being on blocks but they are not allocated to any block for <animal enterprise> for the month of <month>. Check monthly grazing option for each block.*

2.3. Outputs

2.3.1. Data outputs

The amount of ME supplied by pasture (MEintakePasture, MJ ME/month) is used in the allocation routines and reporting and is:

Equation 10: $MEIntakePasture_{antype,\ mon} = pastureMEintake$

pastureMEintake is the amount of ME supplied by pasture for a given animal enteprise in a given month (MJ ME/month) [Equation 4].

2.3.2. Animal reports: ME source report

In the animal reports, ME supplied by different feed sources are reported based on the outputs shown in Table 1.

Table 1. Outputs used to develop the ME source animal report.

Description	Variable	Source
From fresh pasture	pastureMEintake	Equation 4
From farm-grown and stored supplements (hay, silage and baleage)	MEIntakeSuppFarm	Equation 11
From brought in fodder supplements (hays, silages, straws and maize silage)	MEIntakeSuppFodd	Equation 12
From other brought in supplements and left-over supplements	MEIntakeSuppOther	Equation 14
From farm grown crops	MEIntakeCrops	Equation 16

The ME supplied by feed from farm-grown and stored supplements (hay, silage and baleage) are estimated as follows. Unless otherwise specified, the terms in these equations are defined in section 2.1:

Equation 11: $MEIntakeSuppFarm_{antype,\ mon} = SuppFarmMade +$
$supfarmMEMilk_{antype} * SuppMilkTiming_{antype,\ mon} +$
$supfarmMEFP_{antype} * SuppFPTiming_{antype,\ mon} +$
$supfarmMEWP_{antype} * SuppWPTiming_{antype,\ mon} +$
$SuppStorefarm +$

$supstoreMEMilk_{antype} * SuppMilkTiming_{antype, mon} +$
$supstoreMEFP_{antype} * SuppFPTiming_{antype, mon} +$
$supstoreMEWP_{antype} * SuppWPTiming_{antype, mon}$

The ME supplied by feed from brought in fodder supplements (hays, silages, straws and maize silage) is estimated as:

Equation 12: $MEIntakeSuppFodd_{antype, mon} = SuppfeedIn * SuppMEFodderRatio + suppinMEfarmMonFod_{antype, mon}$

SuppfeedIn is the amount of ME in supplements brought in where timing is not specified (MJ ME/month) [Equation 13].

SuppMEFodderRatio is the proportion of ME supplements that are hay or silage [Supplements chapter].

suppinMEfarmMonFod is the amount of ME in supplements brought in that are hay or silage where timing is specified (MJ ME/month) [Supplements chapter].

and where:

Equation 13: $SuppfeedIn = suppinMEMilk_{antype} * SuppMilkTiming_{antype, mon} + suppinMEFP_{antype} * SuppFPTiming_{antype, mon} + suppinMEWP_{antype} * SuppWPTiming_{antype, mon} + suppinMEfarm_{antype} * SuppInPastureTiming_{antype, mon}$

The ME supplied by non-fodder feeds from brought in supplements and left-over supplements is estimated as:

Equation 14: $MEIntakeSuppOther_{antype, mon} = Suppfeed2 – MEIntakeSuppFodd_{antype, mon}$

where:

Equation 15: $Suppfeed2 = Suppfeed + suppinMEfarmMon_{antype, mon} + supLeftMEfarmMon_{antype, mon} + supLeftMEWPMon_{antype, mon}$

The ME supplied by farm grown crops is estimated as:

Equation 16: $MEIntakeCrops_{antype, mon} = CropMEMilkShed_{antype, mon} + CropMEFeedpad_{antype, mon} + CropMEWinpad_{antype, mon} + CropMEOnCrop_{antype, mon} + CropMEOnPdk_{antype, mon}$

2.3.3. Animal reports: ME place report

In the animal reports, ME supplied by different sources of feed that are consumed in different locations within the farm are reported based on the outputs shown in Table 2.

Table 2. Outputs used to develop the ME place animal report.

Source	Description	Variable
Milking shed - Imp sup	Imported supplements consumed in the milking shed.	MEIntakeMilk1 [1]
Milking shed - Farm sup	Farm-grown supplements consumed in the milking shed.	MEIntakeMilk2 [1]
Milking shed - Crop	Cut and carry crops consumed in the milking shed.	MEIntakeMilk3 [1]
Feed pad - Imp sup	Imported supplements consumed on the feed pad.	MEIntakeFeed1 [1]
Feed pad - Farm sup	Farm grown supplements consumed on the feed pad.	MEIntakeFeed2 [1]
Feed pad - Crop	Cut and carry crops consumed on the feed pad.	MEIntakeFeed3 [1]
Wintering - Imp sup	Imported supplements consumed on the wintering pad/animal shelter.	MEIntakeWin1 [1]
Wintering - Farm sup	Farm grown and left over supplements consumed on the wintering pad/animal shelter.	MEIntakeWin2 and MEIntakeWin4 [1]
Wintering - Crop	Cut and carry crops consumed on the wintering pad/animal shelter.	MEIntakeWin3 [1]
Imp sup	Other imported supplements consumed while animals are on pasture or crops.	MEIntakePast1 [2]
Farm sup	Other farm grown and stored supplements consumed while animals are on blocks.	MEIntakePast2 [2]
Pasture - Crop	Cut and carry crops consumed while animals are on blocks.	MEIntakePast3 [2]
Pasture - Left-overs	Left-over supplements that are consumed while animals are on pasture.	MEIntakePast4 [2]
Pasture	Fresh pasture.	MEIntakePasture [3]
On crops	In situ grazing of crops.	CropMEOnCrop [4]

[1] See Equation 17 to Equation 19.
[2] See Equation 21 to Equation 24.
[3] See Equation 4.
[4] Unpublished.

The ME supplied from feed consumed in the milking shed, or on feed pad or wintering pad/animal shelter from brought in supplements, farm grown and stored supplements, and crops is estimated. The ME supplied from feed consumed in the milking shed is estimated as follows. Unless otherwise specified, the terms in the equations are defined in section 2.1:

Equation 17: $\text{MEIntakeMilk1}_{\text{antype, mon}} = \text{supinMEMilk}_{\text{antype}} * \text{SuppMilkTiming}_{\text{antype, mon}}$

Equation 18: $\text{MEIntakeMilk2}_{\text{antype, mon}} = (\text{supfarmMEMilk}_{\text{antype}} + \text{supstoreMEMilk}_{\text{antype}}) * \text{SuppMilkTiming}_{\text{antype, mon}}$

Equation 19: $\text{MEIntakeMilk3}_{\text{antype, mon}} = \text{CropMEMilkShed}_{\text{antype, mon}}$

Similar calculations are done for feed pads and wintering pad/animal shelters. For wintering pad/animal shelters and pasture, ME from left over imported supplements, farm grown and stored supplements, and crops are included as:

Equation 20: $\text{MEIntakeWin4}_{\text{antype, mon}} = \text{supLeftMEWPMon}_{\text{antype, mon}}$

For animals on blocks, the ME supplied by brought in supplements, farm grown and stored supplements, farm-crop crops and left over supplements consumed on the blocks is estimated as:

Equation 21: $\text{MEIntakePast1}_{\text{antype, mon, 1}} = \text{supinMEfarm}_{\text{antype}} * \text{SuppInPastureTiming}_{\text{antype, mon}} + \text{supinMEfarmMon}_{\text{antype, mon}}$

Equation 22: $\text{MEIntakePast2}_{\text{antype, mon, 2}} = \text{SuppStorefarm} + \text{SuppFarmMade}$

Equation 23: $\text{MEIntakePast3}_{\text{antype, mon, 3}} = \text{CropMEOnPdk}_{\text{antype, mon}}$

Equation 24: $\text{MEIntakePast4}_{\text{antype, mon, 4}} = \text{supLeftMEfarmMon}_{\text{antype, mon}}$

3. DM intakes

Dry matter (DM) intake uses a similar methodology to that used to estimate ME supplied by pasture (section 2.1). The main difference is that ME intake from pasture is estimated from the difference between animal ME requirements and ME supplied by supplements and crops, whereas DM intake is estimated from DM supplied by supplements, crops, and pasture.

DM intake is not needed for feed allocations so is estimated at the same time as nutrient intake.

3.1. Monthly intake

3.1.1. Dry matter intake

DM intake is estimated using a similar approach as for ME intake [section 2.1] in that DM from supplements and crops is defined by user inputs. Thus, DM intake variables (kg DM/month) for each animal enterprise each month is estimated as:

Equation 25: $\text{DMIntake}_{\text{antype, mon}} = \text{pastureDMintake} + \text{FoodMilkShed} + \text{FoodFeedpad} + \text{FoodWinpad} + \text{FoodFcrop} + \text{Suppinfarm} + \text{Suppstorefarm} + \text{SupFarmGrown}$

pastureDMintake is the pasture DM intake for a given animal enterprise in a given month (kg DM/year) [section 3.1.2].

FoodMilkShed, FoodFeedpad, FoodWinpad, FoodFcrop, Suppinfarm, Suppstorefarm, and SupFarmGrown are estimated using the same methods as for ME intake [section 2.1], except using the DM version of the variables (kg DM/month).

3.1.2. Pasture DM intake

Pasture DM intake (pastureDMintake, kg DM/month) for a given animal enterprise in a given month is estimated as ME intake from pasture divided by the weighted average pasture ME content. Thus:

Equation 26: $\text{pastureDMintake} = \text{pastureMEintake} / \text{pastureME}_{\text{antype, mon}}$

pastureMEintake is the ME intake from pasture (MJ ME/month) [Equation 4].

pastureME is the ME content of the pasture consumed (MJ ME/kg DM) [Animal model chapter].

3.2. Error checks

If there is no feed consumed by animals in the milking shed (FoodMilkShed = 0) but the user has selected that animals are consumed in the milking shed, then the following error message is generated:

> *<animal enterprise> animals are fed in the milking shed but no supplements or crops are been fed to these animals, or the feed from crops already exceeds animal requirements for the month of <month>.*

If there is no feed consumed by animals on the feeding pad (FoodFeedpad = 0) but animals are on the feed pad, then the following error message is generated:

> *<animal type> animals are on the feed pad but no supplements or crops are been fed to these animals, or the feed from in-shed feeding or from crops already exceeds animal requirements for the month of <month>.*

If DM intake is zero but animal ME intake is greater than zero, then the following message is generated:

> *There was no DM available for the month of <month> to feed to <animal enterprise> animals. This may occur if growth rates or pasture or crops are zero between harvests, and no supplements are been fed.*

3.3. DM outputs

3.3.1. Dry matter intakes

The primary output is DM (DMIntake, kg DM/month; Equation 25). In addition, for sheep, DM intake by young sheep is used in the estimation of methane emissions (Calculation of methane emissions chapter) and is estimated as:

Equation 27: $\text{DMIntakeYoungSheep}_{\text{mon}} = \text{DMIntake}_{\text{sheep, mon}} * \text{MEyoung}_{\text{mon}} / \text{MEIntake}_{\text{sheep, mon}}$

DMIntake is estimated DM intake for sheep for the given month (kg DM/month [Equation 25].

MEyoung is the ME requirements for young sheep for the given month (MJ ME/month) [Animal model chapter].

MEIntake in the ME requirements for sheep for the given month (MJ ME/month) [Animal model chapter].

Dry matter intake for each species in the 'Other' enterprise is also used in the estimation of methane emissions. Dry matter intake for the 'Other' enterprise is distributed between species based on the ratio of ME intake, expressed as revised stock units (RSU), for each species (non-dairy goats, camelids, horses or others). Thus:

Equation 28: $DMIntake_{sp} = \sum(DMI_{other} * RSUsp / \sum(RSUsp))$

RSU is the estimated RSU for each species [Animal model chapter].

sp is either other goats, camelids, horses or others.

3.3.2. Animal reports: DM source

The animal reports includes a report showing DM intake from different sources. The variables associated with each source is shown in Table 3.

Table 3. Variables used to assemble the DM source animal report.

Source	Description	Variable	Source
Milking shed	DM consumed in the milking shed (all sources of feed).	FoodMilkShed	Section 3.1.2
Feed pad	DM consumed on the feed pad (all sources of feed).	FoodFeedpad	Section 3.1.1
Wintering/shelter	DM consumed on the wintering pad/animal shelter (all sources of feed).	FoodWinpad	Section 3.1.1
Fresh pasture	DM consumed as fresh pasture.	pastureDMintake	Section 3.1.2
Imported supplement	DM consumed as brought-in supplements and left-over supplements fed on blocks.	Suppinfarm	Section 3.1.1
Farm grown supplement	DM consumed as farm-grown, stored supplements and left-over supplements fed on blocks.	SupFarmgrown+ Suppstorefarm	Section 3.1.1
Crops	DM consumed from crops grown on the farm.	FoodFcrop	Section 3.1.1
Total	Total from all sources for each month.	DMI	

4. Nutrient intake

Nutrient intake uses a similar methodology to that used to estimate ME supplied by pasture. The main difference is that ME from pasture is estimated from the difference between animal ME requirements and ME supplied by supplements and crops, whereas nutrient intake is estimated from nutrients supplied by supplements, crops, animal health supplements and pasture.

4.1. Monthly intake

4.1.1. Total nutrient intake

Total nutrient intake for an animal enterprise each month (kg nutrient/month) is estimated as:

Equation 29: Nutintake = nutpasture
+ NutMilkShed
+ NutFeedpad
+ NutWinpad
+ NutFcrop
+ NutSuppinfarm
+ NutSuppstorefarm
+ NutSupout
+ AHsup

nutpasture is the amount of nutrient in consumed pasture (kg nutrient/month) [section 4.1.2].

NutMilkShed, NutFeedpad, NutWinpad, NutFcrop, NutSuppinfarm, NutSuppstorefarm, and NutSupout are estimated using the method in section 2.1 except that the 'nut' variable is used (kg nutrient/month). NutWinpad also includes nutrients in animal health supplements allocated to wintering pad/animal shelters [section 4.1.3].

AHsup is the amount of nutrient supplied in animal health supplements (kg nutrient/month) [section 4.1.3].

4.1.2. Pasture nutrient intakes

Pasture nutrient intake for a given animal enterprise for a given month is the total intake (kg nutrients) from pasture from blocks the animal enterprise are on. The intake from a given block is the DM intake for the given enterprise on that block multiplied by the nutrient concentration in pasture for that block. Thus:

Equation 30: $\text{nutpasture} = \sum_{block}(\text{pastureDMintakeBl}_{block,\ antype,\ mon} * \text{area}_{block} * \text{pastconc} / 100)$

pastureDMintakeBl is the pasture DM intake for the given animal enterprise for a given month from a given block (kg DM/ha/month).

area is the block area (ha).

pasture concentration is the monthly concentration of N and P, or annual average concentration of the other nutrients for a given block (%) [Characteristics of pasture chapter].

4.1.3. Animal health supplements

The amount of animal health supplements (drench, dusting, salt blocks) supplied is allocated between months based on ME intake. In practice, drench in particular is probably supplied in certain months, such as magnesium (Mg) drench in spring for dairy cows.

Animal health supplements may be administered anywhere on the farm. However, as animals may also be on pads in months when animal health supplements is supplied, a method to allocate animal health supplements to wintering pad/animal shelters is required. Animal health supplements are therefore split between those that are allocated to the wintering pad/animal shelters, and those that are allocated to pasture. The former is estimated as:

Equation 31: AHsupWP = AHsupIntake * (NutWinpad + NutMilkShed) /Nutintake

AHsupIntake is the amount of nutrients supplied as animal health supplements (kg nutrient/month) [Equation 33].

NutWinpad is the amount of nutrients consumed on the wintering pad/animal shelters (kg nutrients/month) [section 4.1.1].

NutMilkShed is the amount of nutrients consumed in the milking shed (kg nutrients/month) [section 4.1.1].

Nutintake is the total amount of nutrients consumed (kg nutrients/month) [section 4.1.1].

otherwise:

Equation 32: AHsupWP = AHsupIntake * NutWinpad /Nutintake

and is added to nutrients consumed on the wintering pad/animal shelters (NutWinPad). The amount of animal supplement intake on blocks (AHsup, kg nutrient) is estimated as the difference between the amount of nutrients supplied as animal health supplements per month, and the amount allocated to the wintering pad/animal shelters.

The amount of nutrients supplied as animal health supplements (kg nutrients/month) is estimated as:

Equation 33: $AHsupIntake = AnimalHealth_{antype, nut} * MEIntake_{antype, mon} / \sum_{mon} MEIntake_{antype, mon}$

AnimalHealth is the amount of nutrients supplied to animals as drench, dusting and salt blocks [Supplements chapter].

MEIntake is the ME requirements for a given animal enterprise in a given month (MJ ME/month) [Animal model chapter].

4.1.4. Soil ingestion

Grace and Healy (1974) indicated that grazing sheep and cattle ingest annually up to 65 kg soil and 600 kg soil respectively. On an annual basis, soil is less than 2% of intake (Healy 1972). Healy (1972) indicated that soil type, stocking rate, earthworms, and management can affect the amount of soil ingestion. It is probable that most of this ingestion occurs in winter under wet conditions, and under restricted feed supplies. Thus, the highest rate of ingestion is likely to occur on poorly drained soils, under rotational grazing or when sacrifice paddocks[1] are used, and when animals are grazing fodder crops, particularly those with bulbs such as fodder beet, swede, and turnips. The intake of soil in these situations can be substantial. Under these conditions, nutrients in ingested soils could be a significant proportion of animal nutrient intake over winter.

In most cases, there is little transfer of nutrients out of the block by animals during this period. Hence, ingested soil nutrients are returned to the pasture in faeces. The exception could be when pads are used in conjunction with grazing over winter. Soil ingestion has been ignored and is not accounted for by the model.

4.2. Error checks

For nutrients other than acidity, if the nutrients supplied in feed consumed in the milking shed is zero (NutMilkShed is zero) but animals are entered as being in the milking shed for the given month, then the following error message is generated:

> *Animals are in the milking shed but no <nutrient> was present in supplements or crops fed to them for the month of <month> to feed to <animal enterprise> animals.*

A similar message under similar conditions is also generated for feed pads. However, for wintering pad/animal shelters, the condition determining whether or not animals are present is firstly, whether animals are entered as being on the pad for the given month if the 'Winter pad' only management option is selected, or secondly, if animals are entered as being on the pad but grazing time is zero for the given month if the 'Winter pad plus grazing' management option is selected.

Otherwise, if nutrient intake is less than or equal to zero, the following error message is generated:

> *There was no nutrients available for <nutrient> for the month of <month> to feed to <animal enterprise> animals. This occurs when animals are not on pasture, fed supplements or on a crop for the month listed.*

4.3. Outputs

The following nutrient outputs are used:

- Nutintake (Equation 29) is used to estimate excreta (section 5.1).
- The difference between total of animal health supplements and animal health supplements linked to wintering pad/animal shelters (AHsupWP, Equation 31 or Equation 32) is used to allocate to individual blocks.

[1] Sacrifice paddock is a paddock animals spend time in winter, and due to the soil type and wetness of the paddocks, the pasture is sacrificed – that is, the paddock needs to be re-grassed.

5. Excreta nutrients and its distribution

For each animal enterprise, month and nutrient, the amount of excreta nutrient is estimated (section 5.1). Excreta nutrients for each animal enterprise for each month are distributed to the farm structures lanes, farm dairy, feed pad and standoff/loafing pads but excluding the wintering pad/animal shelters (sections 7.1.3 to 7.1.7), and to the wintering pad/animal shelters (section 7.3). The cumulative output per animal enterprise is used in effluent management calculations (section 5.4.2). The remaining excreta is deposited on blocks (section 5.4.3) and used in the nitrogen loss models (Urine patch and Crop based N sub-models chapters). Nutrients transferred in and out of blocks in the gut of animals is estimated (section 7.4) and used when developing block nutrient budgets.

5.1. Nutrients

Excreta is estimated as intake less nutrients required for products removed from the farm that are produced with a calendar year (milk, wool, velvet), and nutrients associated with live weight gain during the year (product nutrients). The later may differ from product nutrient output from the block, which is the result of total live weight brought and sold that may be accumulated over several years.

5.1.1. Product nutrients

For dairy systems (dairy cows and dairy goats), nutrients in milk removed from the farm are assumed to occur when animals are lactating, and to be evenly distributed over time. In practice, nutrients required for milk production may come from storage (e.g. calcium), and more would be required earlier in the lactation. Nutrients for non-milk products removed from the farm (wool, velvet, antler) and nutrients required for live weight gain are estimated on an annual basis and allocated between months based on animal ME requirements. The loss or gain of nutrients due to monthly changes in live weight in mature animals is ignored. The model assumes that poor utilisation of nutrients within the animal, for example in parasitized animals, does not occur.

Thus, for dairy systems, product nutrients each month (kg nutrient/month) is estimated as:

Equation 34: $$\text{productloss}_{nut} = (\text{ProductNut}_{antype,\ nut} - \text{ProductLW}_{antype,\ nut}) * \text{Ratiolactation}_{mon} / \sum \text{Ratiolactation}_{mon} + \text{ProductLwt}_{antype,\ nut} * \text{MEIntake}_{antype,\ mon} / \sum \text{MEIntake}_{antype,\ mon}$$

ProductNut is the nutrient content in products (milk, wool, velvet, antler) sold for a given animal enterprise (kg nutrient/year) [Animal model chapter].

ProductLwt is the nutrient content in live weight gain for a given animal enterprise (kg nutrient/year) [Animal model chapter].

Ratiolactation is the proportion of the month animals are lactating [Animal model chapter].

MEIntake is the ME requirements of a given animal enterprise in a given month (MJ ME/month) [Animal model chapter].

For other animal enterprises, all product nutrients are allocated between months based on animal ME requirements.

The product nutrients for a given animal enterprise are modified if wintering pad/animal shelters are also present (section 7.3.2).

5.1.2. Excreta nutrients

The amount of excreta nutrient (kg nutrient/month) is estimated as:

Equation 35: $excreta_{nut} = nutintake_{nut} - productloss$

nutintake is nutrient intake for the given month (kg nutrient/month) [Equation 29].

productloss is the amount of product nutrients (kg nutrient/month) [Equation 34].

5.2. Error checks: Product nutrients greater than intake

On a yearly basis, for each animal enterprise total product nutrients (kg nutrient/year) is estimated as:

Equation 36: $totproductloss_{antype,\ nut} = \sum productloss$

and total annual intake is estimated as:

Equation 37: $totNutIntake_{antype,\ nut} = \sum nutintake$

If total product nutrients is greater than total annual intake, the following error message is generated:

> *Total product loss is greater than nutrient intake for <animal enterprise> and nutrient <list of nutrient>. This typically occurs when supplement nutrient contents are low. Please check.*

An enterprise fed only user-defined supplements for which a nutrient content has not been entered is one known cause triggering this error message.

This message is added as a comment (i.e. it is not a fatal message preventing generation of nutrient budgets).

5.3. Nutrient distribution

Excreta nutrients for each animal enterprise for each month are distributed to the farm structures lanes, farm dairy, feed pad and standoff/loafing pads but excludes the wintering pad/animal shelters (sections 7.1.3 to 7.1.7). Excreta nutrients are then distributed to the wintering pad/animal shelters, including adjusting distribution to lanes (section 7.3). The cumulative output per animal enterprise is used in effluent management calculations (section 5.4.2). The remaining excreta is deposited on blocks (section 5.4.3) and used in the nitrogen loss models (Urine patch and Crop based N sub-models chapters). Nutrients transferred in and out of blocks in the gut of animals is estimated (section 7.3 for wintering pad/animal shelters, and section 7.4 for blocks) and used when developing block nutrient budgets.

5.4. Outputs

5.4.1. Accumulations

The amount of excreta N is reporting in the animal reports, and is:

Equation 38: $ExcretaN_{antype, mon} = excreta_N$

$excreta_N$ is the amount of excreta N (kg N/month) [Equation 35].

The annual product nutrients associated with a wintering pad/animal shelter is used to distribute nutrients between blocks, and to derive the farm nutrient budget. It is estimated as:

Equation 39: $productfeedpad_{antype, nut} = \sum productWP$

productWP is the amount of product nutrients that are supplied by feed consumed on the winering pad/animal shelter (kg nutrient/month) [Equation 75].

5.4.2. Excreta to effluent management system

Total yearly nutrients transferred for each animal enterprise are used in the effluent management system calculations and are estimated as:

Equation 40: $nuttolane_{antype, nut} = \sum(tolane_{nut} + tolaneWP_{nut})$

Equation 41: $nuttoeffluent_{antype, nut} = \sum(toeffluent_{nut} + toeffluentWP_{nut})$

Equation 42: $nutfromfeedpad_{antype, nut} = \sum toFP_{nut}$

Equation 43: $nutfromstandoff_{antype, nut} = \sum tostandoff_{nut}$

Equation 44: $nutfromwinpad_{antype, nut} = \sum toWP_{nut}$

toeffluent, tolane, toeffluentWP, tolaneWP, tostandoff, toFP and toWP are the distributed excreta (kg nutrient/month) [section 7.1.3 and 7.3].

Monthly transfers of N are used in the effluent management and N models (Crop based N-models), and is determined as:

Equation 45: $nuttoeffluentN_{mon} = \sum (toeffluent_N + toeffluentWP_N)$

Equation 46: $nutfromfeedpadN_{antype, mon} = \sum toFP_N$

Equation 47: $nutfromstandoffN_{antype, mon} = \sum tostandoff_N$

Equation 48: $nutfromwinpadN_{antype, mon} = \sum toWP_N$

The monthly deposition of excreta P on the wintering pad/animal shelter is used in the P runoff loss model, and is determined as:

Equation 49: $nutfromwinpadP_{antype, mon} = toWP_P$

5.4.3. Excreta deposited on blocks

The amount of excreta nutrient distributed on pasture for a given animal enterprise each month for each nutrient (kg nutrient/month) is thus:

Equation 50: $toBlocks = excreta - toeffluent - tolane - toeffluentWP - tolaneWP - tostandoff - toFP - toWP$

excreta is the amount of nutrient in excreta for a given nutrient, animal enterprise and month (kg nutrient/month).

toeffluent, tolane, toeffluentWP, tolaneWP, tostandoff, toFP and toWP are the distributed excreta (kg nutrient/month) [section 7.1.3 and 7.3].

The proportion of excreta deposited on pasture that is urine is estimated (Animal models chapter). For nitrogen and sulphur, the proportion in urine is dependent on the dietary concentration. The amount of dung and urine deposited on blocks for a given animal enterprise in a given month is thus estimated as:

Equation 51: $blockdungnut_{antype, nut, mon} = toBlocks * (1 - PUrine)$

Equation 52: $blockurinenut_{antype, nut, mon} = toBlocks * Purine$

toBlocks is the amount of excreta deposited on blocks (kg nutrient/month) [Equation 50].

Purine is the proportion of excreta deposited on pasture that is urine [Animal model chapter].

Note that the distribution of dung and urine to individual blocks is estimated separately.

6. Dung dry matter and its distribution

6.1. Dry matter

DM in dung is estimated using the method reported in the New Zealand Greenhouse Gas Inventory (Ministry of the Environment, 2011) such that:

Equation 53: $dungDM = \sum(DMintake_{source} * (1 - digestibility_{source})/100)$

DMintake is the amount of DM intake from all sources for a given animal enterprise in a given month (kg DM/month) [Equation 25].

digestibility is the average digestibility of the source (%).

The source of feed's DM intake and digestibility values used are shown in Table 4. Feeds of multiple types may come from each source so weighted average digestibilities are used (section 6.2).

Table 4. Dry matter (DM) intake and digestibility variables of different sources.

Source	DM [1]	Digestibility [2]
Supplements fed on structures		
In-shed feeding	FoodMilkShed	DigestMilkShed
Feed pad	FoodFeedpad	DigestFeedpad
Wintering pad/animal shelter	FoodWinpad	DigestWinpad
Crops fed on blocks and grazed in situ		
Crops	FoodFcrop	CropAnimalwtDigest
Supplements fed on blocks		
Brought in supplements	Suppinfarm	Digestsuppin
Farm grown supplements	Supout	suppoutwtDigest
Stored supplements	Suppstorefarm	suppstorewtDigest
Fresh pasture		
Pasture	pastureDMintake	pasturedigest

[1] section 3.1.1 and 3.1.2.
[2] section 6.2.

6.2. Digestibility

Digestibility for milking shed is estimated as:

Equation 54: $$\text{DigestMilkShed} = \frac{(\text{suppinwtDigest}_{antype} * \text{suppinDMMilk}_{antype}) + (\text{suppfarmwtDigest}_{antype} * \text{suppoutDMMilk}_{antype}) + (\text{CropwtDigest}_{antype} * \sum \text{CropDMMilkShed}_{antype,\ mon})}{\text{suppinDMMilk}_{antype} + \text{suppoutDMMilk}_{antype} + \sum \text{CropDMMilkShed}_{antype,\ mon}}$$

Similar calculations are undertaken for feed consumed on the feed pad and wintering pad/animal shelters.

Crop digestibility is the weighted average digestibility of crops consumed on blocks or in situ to a given animal enterprise.

The digestibility of supplements consumed on blocks is detailed in the Supplements chapter. The weighted average digestibility of pasture is detailed in the Animal model chapter. This can vary with crop and supplement allocation as the pasture distribution between blocks can vary with allocation, and hence the weighted average, if digestibility varies between blocks.

6.3. Dung DM distribution

DM dung each month for each animal enterprise is distributed as described in section 7.1.3 and 7.3, where excreta is dung DM. The amount of dung DM deposited on blocks is then estimated as:

Equation 55: $$\text{toBlock} = \text{dungDM} - \text{tolane} - \text{tolaneWP} - \text{toeffluent} - \text{toeffluentWP} - \text{toFP} - \text{tostandoff} - \text{toWP}$$

dungDM is the amount of dung DM as excreta (kg DM/month) [section 6.1].

tolane, tolaneWP, toeffluent, toeffluentWP, toFP, tostandoff and toWP is the distributed amount of dung DM (kg DM/month) [section 7.1.3 and 7.3].

6.4. Outputs

The amount of dung DM deposited in different locations for each animal enterprise is used to estimate methane emissions (Calculation of methane emissions chapter), and are estimated as:

Equation 56: $dungtolane_{antype} = \sum(tolane + tolaneWP)$

Equation 57: $dungtoeffluent_{antype} = \sum (toeffluent + toeffluentWP)$

Equation 58: $dungfromfeedpad_{antype} = \sum toFP$

Equation 59: $dungfromstandoff_{antype} = \sum tostandoff$

Equation 60: $dungfromwinpad_{antype} = \sum toWP$

Equation 61: $dungBlock_{antype} = \sum toBlock$

tolane, tolaneWP, toeffluent, toeffluentWP, toFP, tostandoff and toWP is the distrbuted amount of dung DM (kg DM/month) [section 6.3].

toBlock is the amount of dung DM deposited on blocks (kg DM/month) [section 6.3].

The distribution of dung DM deposited on blocks to individual blocks is estimated separately.

7. Excreta distribution

Excreta may be deposited in different places on a farm. The following broad categories of transfer are defined:

- Rate of deposition of excreta in different parts of the farm. These are defined in section 7.1 and modified in section 7.3 if wintering pad/animal shelter is present.
- Transfer of nutrients between structures on the farm. These include transfers in and out of blocks, and are used to derive block and farm nutrient budgets (section 7.4).

Transfers from block to block and between structures are, in effect, the transfer of nutrients carried in the gut of animals. Two other transfers are recognised in the model but are covered in other chapters. They are included here for completeness, being:

- Direct deposition of dung and/or urine directly into watercourses. This represents the transfer of nutrients from a block to a stream.
- Internal block transfer, that is, the transfer of nutrients from the main part of the paddock to areas of accumulation such as camp sites, and around troughs, gateways and fence lines.

This section describes the deposition rates of excreta for yards, farm dairies, feed pads, standoff/loafing pads, and wintering pad/animal shelters, and the transfer of excreta between farm structures.

The distribution of dung DM follows a similar methodology as for nutrients.

7.1. Deposition rates

7.1.1. Time based system

Deposition rates on farm dairy and feed pads are based on those reported by Ledgard and Brier (2004), which were based on the assumption that, on a herd basis, the proportion of time spent in an area (farm dairy or feed pad) equated to the proportion of excreta deposited in that area. Bagshaw (2002) also noted that for beef animals, the percentage of time spent near riparian strips and percentage of dung deposited in that area was the same. This approach assumes that, animals of an enterprise deposit excreta evenly through the day, and the distribution of dung and urine is the same.

Ledgard and Brier (2004) quoted a study by Zegwaard that indicated that 4.7% of defecations occurred in yard/shed areas whereas the time was 5.7%. Although this indicates little difference in the whole farm pattern, it does represent 18% less nutrients on yards than if a time based system is used. However, this study is based on little data. Betteridge *et al*. (2013) reported that"

> *'All cows urinated at some time during the night, and urinary N loads were typically higher than during daytime. At about sunrise all cows would stand and urinate relatively large N loads, but thereafter, loads were smaller and urination frequency was higher. After entering a new break, urinary N loads increased over the next 10 h, reflecting the increasing amount of N excreted from freshly eaten pasture.'*

Using the time-based method may be under or overestimating nutrient transfer and this may be important for estimation of effluent application rates, effluent block size, greenhouse gas emissions, and maintenance fertiliser nutrient calculations.

The model has used a time-based system to estimate deposition rates.

7.1.2. Feed sources

The model assumes that feed from different sources is evenly mixed in the gut of animals and does not consider the source of nutrients when estimating excreta distribution. Hence nutrient is not preferentially transferred based on subsequent locations animals are moving to. For example, a low N feed consumed in the milking shed moves with animals onto pasture (transferred in the gut of the animals to blocks). Animals then consume pasture before using the lane to return to the milking shed (farm dairy). The model while accounting for the low N feed does not consider its source, i.e. the milking shed, when estimating excreta distribution. The low N feed is added to all feed sources and is not preferentially deposited on pastures because pasture is the next location animals are in. The excreta deposited on the lane is assumed to be based on the whole diet.

7.1.3. Lanes and raceways

Deposition rates for the lane are based on those reported by Ledgard and Brier (2004). These are reduced for once-a-day milking and adjusted to account for variation in lactation length.

For once-a-day milking, there is only one trip to the shed per day. In theory, this would half the amount of time on the lanes but as there was no data, a conservative estimate of the reduction of 0.7 was used. These are estimated on an annual basis to simplify calculations.

The amount of time dairy animals spend on a laneway is also expected to increase as the length of lanes increase. Currently, the transfer factors used in the model are based on typical values. The model takes no account of differences in herd management within yards. Practical experience indicates that for a similar sized herd and milking platform, the amount of dung deposited in yards can vary greatly between farms.

For dairy cows, the transfer rate to lanes is estimated as:

Equation 62: LaneTransfer = 0.35 * $\text{RatioLactation}_{mon}$ * OADracefactor

0.35 is the base transfer rate, assuming cows spent about 50 minutes per day on the race for twice a day milking.

RatioLactation is the proportion of the month animals are lactating [Animal model chapter].

OADracefactor is 1, 0.8, 0.97, 0.97, 0.93, 0.9 for the for OADMilk options of 'Never', 'All season', 'During calving', 'During drying off', 'During calving and drying off', 'Half of season' respectively.

The transfer rate for dairy goats is assumed to be zero as the housing and milking shed are assumed to be closely associated. Transfers may be adjusted if wintering pad/animal shelters are present (section 7.3.4).

For sheep, beef and deer, transfer rate to lane and yards was assumed to be 0.01 (1%) of excreta, except if the farm is merinos (extensive) in which lanes are assumed to be non-existent and hence the transfer rate is zero.

7.1.4. Farm dairy

Ledgard and Brier (2004) estimated the percentage of a cow's day spent in the farm dairy as:

Equation 63: %time = ((Hc/Sn) +1) * tr / 2 * Md / 1440 * 100

Hc is the number of lactating cows in the whole herd.

Sn is the number of clusters.

tr is the time (minutes) taken to milk a row or for rotary platforms, for one platform.

2 accounts for the average or median cow.

Md is the number of milkings per day.

1440 is the number of minutes in a day.

Based on survey data, they used an Hc/Sn of 11.5 to 1, a milking time of 9 minutes to give an average percentage of a cow's day spent in the farm dairy of 7.8%. Ledgard and Brier (2004) indicated that the estimated time in a shed, and hence the deposition rate was dependent on herd size, average milking time and cup numbers, as well as management, such as splitting large herds when milking. Time can be difficult to estimate if the herd has stragglers, or if split herd milking and the herds overlap. In addition, shed management and quality can also affect the amount of excreta deposition on the yards. These factors have not been included.

This time-based approach was used rather than using effluent nutrient concentrations, because it was easy to track and conserve nutrients, and as pointed out elsewhere, effluent nutrient concentrations can be highly variable over time (Longhurst *et al*., 2000). A concentration-based system would require taking multiple samples for nutrient analysis over both time and space, and making flow measurements. Sims *et al*. (2005) noted that:

> *'Of significance was the increase in the production intensity and kW capacity of equipment in the sheds (Table 7). Newer sheds have been built not just to meet current cow numbers but for future predicted increases in cow milked. New sheds built less than ten years ago were better designed to cope with increased cow numbers in a farmer's five to ten years strategic plan rather than just meeting their current carrying capacity. Those farms that have not updated, or partly updated their shed designs have also increased their milk production but continue to use sheds designed for less cow numbers, squeezing through the cows by using increased milking times.'*

The effect of shed capacity or design on milking times has not been considered.

For dairy cows and goats, the transfer rate in a given month is estimated as:

Equation 64: $\text{transferOADshed} = 0.078 * \text{RatioLactation}_{mon} * \text{OADshedfactor}$

0.078 is the average proportion of a cow's day spent in the farm dairy [Ledgard and Brier, 2004].

RatioLactation is the proportion of the month animals are lactating [Animal model chapter].

OADshedfactor is 1, 0.7, 0.95, 0.95, 0.90, 0.85 for the for OADMilk options of 'Never', 'All season', 'During calving', 'During drying off', 'During calving and drying off', 'Half of season' respectively.

The factor for once a day milking is more conservative than that of Ledgard and Brier (2004) because it is possible that milking times may increase with once a day milking. Although the deposition rate is estimated for each month, an annual factor for once a day milking is used to simplify calculations.

For other animal enterprises, transfer to effluent, is zero.

7.1.5. In shed feeding

When animals are fed in the milking shed, it is assumed that the animals are there for the same time as for milking, and hence there is no additional excreta deposition.

7.1.6. Feed pad to effluent

The rate of deposition of excreta on feed pads is also based on time. The transfer rate is only estimated for the dairy cow enterprise each month, and is estimated as:

Equation 65: $\text{FeedpadTransfer} = (\text{FeedpadTime}_{mon} / 24) * \text{FeedpadProp}_{mon} / 100)$

FeedpadTime is the entered time on the feed pad (hours).

FeedpadProp is the entered proportion of animals on the feed pad (%).

For other animal enterprises, transfer to a feed pad is zero.

7.1.7. Standoff pads

The transfer rate to standoff /loafing pads for dairy cows is also based on time and is estimated each month as:

Equation 66: EffStandoffTransfer = (StandoffTime$_{mon}$ / 24) * StandoffProp$_{mon}$ / 100)

StandoffTime is the entered time on the standoff/loafing pad (hours).

StandoffProp is the entered proportion of animals on the standoff/loafing pad (%).

A 2-hour period on the feed pad gives a similar transfer rate as the transfer rate to the farm dairy, that is, 2 hours on a feed pad plus milking, approximately doubles the amount of effluent compared to milking only.

For other animal enterprises, transfer to a standoff is zero.

7.2. Deposition amounts

The amount of excreta (nutrients of dung DM) deposited on lanes, farm dairy, standoff pads, and feed pads are estimated as:

Equation 67: tolane = excreta * LaneTransfer

Equation 68: toeffluent = excreta * FDETransfer

Equation 69: toFP = excreta * FeedPadTransfer

Equation 70: toStandoff = excreta * StandoffTransfer

excreta is excreta nutrients or dung for a given animal enterprise for a given month (kg/month).

LaneTransfer, FDETransfer, FeedPadTransfer and StandoffTransfer are the deposition rates on a given farm structure (section 7.1).

The transfers to lanes and effluent are modified if wintering pad/animal shelters are also present (section 7.3).

7.3. Distribution to wintering pad/animal shelters

7.3.1. Feed

If all the animals are on a wintering pad/animal shelter and there is no grazing, but animals are fed in the milking shed, then the nutrients or DM must be transferred to the wintering pad/animal shelter. This is generalised so that the amount of feed that is associated with the wintering pad/animal shelter is estimated as:

Equation 71: WinpadIn = WinpadFeed + MilkShedFeed * propmilkshed

WinpadFeed is the amount of nutrients or DM consumed on the feed pad (kg/month) [section 3.1.1 or 4.1.1].

MilkShedFeed is the amount of nutrients or DM consumed in the milking shed (kg/month) [section 3.1.1 or 4.1.1].

propmilkshed is the proportion of feed in the milking shed associated with the feeding pad [Equation 72].

where the proportion of feed in the milking shed that is associated with the wintering pad/animal shelter estimated as:

Equation 72: $propmilkshed = (WinPadProp_{antype, mon} / (100 - GrazeoffProp_{antype, mon}))$

WinPadProp is the entered proportion of animals on the wintering pad/animal shelter (%).

GrazeoffProp if the entered proportion of animals grazed off (%) [Animal model].

The ratio of intake (nutrients or DM) associated with a wintering pad/animal shelter is estimated as:

Equation 73: $ratio = WinpadIn / totalintake$

WinpadIn is the amount of feed that is associated with the wintering pad/animal shelter (kg/month) [Equation 71].

totalintake is the total amount of DM or nutrient intake for the given animal enterprise and month (kg/month) [section 3.1.1 or 4.1.1].

7.3.2. Proportion of time on wintering pad/animal shelter

The proportion of animals on the wintering pad/animal shelter for each animal each month is estimated as:

Equation 74: $propwinpad = WinPadProp_{antype, mon} / 100 * (1 + GrazeoffProp_{antype, mon} / 100)$

WinPadProp is the entered proportion of animals on the wintering pad/animal shelter (%).

GrazeoffProp if the entered proportion of animals grazed off (%) [Animal model].

Note that the grazing off option only applies when animal numbers are entered using RSU or peak cow number entry methods.

7.3.3. Product nutrients

If all the animals are on a wintering pad/animal shelter and there is no grazing, then the product nutrients (section 5.1.1) must be supplied by feed consumed on the wintering pad/animals shelters. This has been generalised so that the amount of product nutrients supplied by feed consumed on the wintering pad/animals shelters is estimated as:

Equation 75: $productWP = productloss * ratio$

productloss is the amount of product nutrients that are supplied by feed consumed on the wintering pad/animal shelter (kg nutrient/month) [Equation 34].

ratio is the proportion of intake that is associted with the wintering pad/animal shelter (section 7.3.1).

For dung DM distribution, productloss is zero.

7.3.4. Deposition rates

If all animals are on a wintering pad/animal shelter in a given month, then transfers to the farm dairy and lane, must come from feed consumed on the wintering pad/animal shelter. This implies that any transfers must come from the wintering pad/animal shelter, not from blocks.

7.3.4.1. *Lanes*

The transfer to lanes are considered when estimating the transfer rates:

- If the feeding regime is 'Wintering pad only', then transfer to lanes for animals using the wintering pad/animal shelter is reduced to zero as there would be less walking. This includes dairy animals that are in lactation, as it is assumed that wintering pad/animal shelters are close to the milking shed.
- If the feeding regime is 'Wintering pad plus grazing' then for animals on the wintering pad/animal shelter:
  - For lactating dairy cows, there is no difference in the transfer to lanes as it is assumed that walking from the block to the wintering pad/animal shelter or the farm dairy is the same distance and takes the same time as walking from the blocks to the farm dairy.
  - For non-lactating dairy cows, it is assumed that the distance and time, and hence deposition rates, for animals walking from the wintering pad/animal shelter to grazing is the same as lactating animals walking from blocks to the farm dairy.
  - For non-dairy, it is assumed that the distance and time, and hence deposition rates, for animals walking from the wintering pad/animal shelter to grazing is the same as lactating dairy animals walking from blocks to the farm dairy.

Hence, for non-lactating dairy cows and non-dairy cow enterprises, the transfer to lanes is increased as:

Equation 76: $tolane = tolane + excreta * LaneTransfer_{dairy} * propwinpad$

tolane is the amount of dung DM or excreta nutrients deposited on lanes and raceways [section 7.2].

excreta is the amount of dung DM or excreta nutrients [section 5.1.2].

LaneTransfer is the deposition rate on lanes for Dairy animals while lactating [section 7.1.3].

propwinpad is the proportion of time animals are on the wintering pad/animal shelter [section 7.3.2].

The deposition on lanes associated with feed consumed on the wintering pad/animal shelter is estimated as:

Equation 77: $tolaneWP = tolane * ratio$

tolane is the amount of dung DM or excreta nutrients deposited on lanes and raceways [section 7.2].

ratio is the proportion of intake that is associted with the wintering pad/animal shelter [section 7.3.1].

The amount of excreta deposited on lanes (kg/month) when wintering pad/animal shelters are not being used is reduced as:

Equation 78: tolane = tolane * (1 - ratio)

If the management method is 'Wintering pad only', then tolaneWP is zero.

7.3.4.2. *Farm dairy*

The amount of excreta deposited on laneways (kg/month) when wintering pad/animal shelters are not being used is reduced as:

Equation 79: tolane = tolane * (1 - propwinpad)

For farm dairy effluent, the amount of excreta that comes from wintering pad/animal shelters is assumed to be proportional to the total feed supplied that is consumed on the wintering pad/animal shelters. Hence:

Equation 80: toeffluentWP = toeffluent * ratio

toeffluent is the amount of excreta deposited on laneways (kg/month) when wintering pad/animal shelters are not present.

ratio is the proportion of intake that is associted with the wintering pad/animal shelter [section 7.3.1].

Similar to lanes, the amount of excreta deposited on the farm dairy (kg/month) when wintering pad/animal shelters are not being used is reduced as:

Equation 81: toeffluent = toeffluent * (1 - ratio)

7.3.4.3. *Transfers between blocks*

When animals are on wintering pad/animal shelter and also grazing, then feed consumed on the wintering pad/animal shelter can be transferred in the gut to be deposited on the block as excreta. Conversely pasture consumed on the block can be transferred in the gut and deposited as excreta on the wintering pad/animal shelter. The model uses a time basis approach to estimate these transfers. The transfer from the pasture to the wintering pad/animal shelter is estimated as:

Equation 82: PastureToWinpad = PastEaten * propwinpad

propwinpad is the proportion of animals on the wintering pad/animal shelter [section 7.3.2].

PastEaten is the non-wintering pad intake.

where the amount of nutrients in pasture eaten is estimated as:

Equation 83: PastEaten = totalintake – WinpadIn

totalintake is the total amount of DM or nutrient intake for the given animal enterprise and month (kg/month) [section 3.1.1 or 4.1.1].

WinpadIn is the amount of feed that is associated with the wintering pad/animal shelter (kg/month) [Equation 71].

The transfer from the wintering pad/animal shelter to the pasture is estimated as:

Equation 84: $\text{WinPadTopasture} = \text{WinpadExcreta} * \text{WinPadGrazeTime}_{antype, mon} / 24 * \text{propwinpad}$

WinpadExcreta is the excreta not accounted for (kg/month] [Equation 85].

WinPadGrazeTime is the entered time animals are grazing pasture (hours).

propwinpad is the proportion of animals on the wintering pad/animal shelter [section 7.3.2].

The amount of excreta not accounted for is estimated as:

Equation 85: WinpadExcreta = excreta - tolane - toeffluent - toFP - tostandoff - tolaneWP

excreta is the amount of excreta nutrients or dung DM [section 6.1 or 5.1.2].

tolane, toeffluent is amount of excreta nutrients or dung DM (kg/month) deposited on lanes and raceways of the farm dairy [Equation 79 and Equation 81].

toFP and tostandoff are amounts of excreta nutrients or dung DM (kg/month) deposited on feed pads or standoff/loafing pads [section 7.2].

tolaneWP is the amount of excreta nutrients or dung DM (kg/month) deposited on lanes and raceways associated with wintering pad/animal shelters [section 7.3.4.1].

7.3.5. Excreta deposited on the wintering pad/animal shelter

The excreta left on the wintering pad/animal shelter is used in the effluent management calculations. If the feeding regime is ‘Wintering pad plus grazing’ then the excreta deposited is estimated as:

Equation 86: toWP = WinpadIn + PastureToWinpad - WinPadTopasture - productWP – tolaneWP - toeffluentWP

WinpadIn is the amount of feed that is associated with the wintering pad/animal shelter (kg/month) [Equation 71].

PastureToWinpad is the transfer from pasture to wintering pad/animal shelter (kg/month) [*Equation 82*].

WinPadTopasture is the transfer from wintering pad/animal shelter to pasture (kg/month) [*Equation 84*

productWP is the product nutrients associated with the wintering pad/animal shelter (kg/month) [section 7.3.3].

tolaneWP is the amount of excreta nutrients or dung DM (kg/month) deposited on lanes and raceways associated with the wintering pad/animal shelter [section 7.3.4.1].

toeffluentWP is the amount of excreta nutrients or dung DM (kg/month) deposited on the farm dairy associated with wintering pad/animal shelters [section 7.3.4.1].

Otherwise, if the feeding regime is 'Wintering pad only' it is estimated as:

Equation 87: toWP = WinpadIn - productWP – toeffluentWP - tolaneWP

WinpadIn is the amount of feed that is associated with the wintering pad/animal shelter (kg/month) [Equation 71].

7.4. Block transfers

The transfer of nutrients to farm structures (lanes, farm dairy, feed pads) presents a transfer of nutrients out of a block. Feed eaten in the milking shed or on feed pads is transferred back to the blocks in the gut of animals. This approach used, assumes that nutrients in feed consumed in the milking shed or on the feed pad are transferred to the blocks in the gut of animals, hence there is a transfer of nutrients from the milking shed or feed pad to the block (Equation 89). Conversely, any nutrients in excreta deposited on the farm structures are transferred as nutrients mixed in the gut, and thus is a transfer from the block back to the feed pad (Equation 88). There can also be transfers of nutrients between blocks and wintering pad/animal shelters. These are included in a block nutrient budget.

The amount of nutrients transferred from a block in the gut of animals is estimated as:

Equation 88: TransFromBlock = tolane + toeffluent + toFP + tostandoff

tolane, toeffluent is amount of excreta nutrients or dung DM (kg/month) deposited on lanes and raceways of farn dairy [Equation 79 and Equation 81].

toFP and tostandoff are the amount excreta nutrients or dung DM (kg/month) deposited on deed pads of standoff/loafing pads [section 7.2].

All nutrients in feed consumed in the milking shed or on the feed pad is assumed to be consumed and transferred back to blocks. Thus:

Equation 89: TransToBlock = MilkShed * (1 - propmilkshed) + Feedpad

MilkShed is the amount of nutrients or DM in feed consumed in the milking shed (kg nutrient/month) [section 4.1.1 or 3.1.1].

propmilkshed is the proportion of feed in the milking shed that is associated with the wintering pad/animal shelter [Equation 72].

Feedpad is the amount of nutrients or DM in feed consumed on the feed pad (kg nutrient/month) [section 4.1.1 or 3.1.1].

These, as well as the transfers between wintering pad/animal shelters and blocks, are accumulated as the allocation to individual blocks is dependent on total consumption, and is thus estimated separately. Hence:

Equation 90: $\text{TransFromBlock}_{\text{antype, nut, mon}} = \sum \text{TransFromBlock}$

Equation 91: $\text{TransToBlock}_{\text{antype, nut, mon}} = \sum \text{TransToBlock}$

Equation 92: $\text{nutpasttowinpad}_{\text{antype, nut, mon}} = \sum \text{PastureToWinpad}$

Equation 93: $\text{nutwinpadtopasture}_{\text{antype, nut, mon}} = \sum \text{WinPadTopasture}$

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