OVERSEER®

OVERSEER® Technical Manual

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

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Distribution of farm data to block scale

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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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1. Introduction

The fertiliser recommendation models in early Outlook, and early versions of Overseer required the block stocking rate as an input. By definition, stocking rate is an estimate pasture intake or production. Anecdotal evidence indicated that although these models required block stocking rates, most users did not know how to distribute stocking rate, which is estimated a farm level, to individual blocks, particularly when there were multiple enterprises on the farm. Anecdotal evidence did indicate that they had some concept of the amount of pasture produced on a block, or the amount of time animals could be grazed on that block (grazing days). This method was developed by the author as a means to allow block stocking rates to be determined, and was subsequently expanded to distribute estimated pasture intake by each animal enterprise to blocks.

The Animal intakes chapter describes how the amount of pasture dry matter (DM) that is consumed each month is estimated for each animal enterprise on a total farm basis. This intake is then distributed to each animal enterprise on each block (section 2) to give intake on a per-hectare basis. This is then used to estimate nutrient intake from each block (Animal intakes chapter).

Nutrients consumed on one part of the farm and deposited on another represents internal transfer of nutrients within the farm, blocks and/or lanes, i.e. nutrients consumed on blocks and deposited on lanes or yards is a transfer of nutrients from the block to the lanes or yards. The estimation of the amount of excreta deposited, and its distribution to and from different farm structures (i.e. effluent management system, races, yards, and wintering pads/animal shelters), occurs at a farm scale and is described in the Animal intakes chapter. The remaining excreta is deposited on blocks, and the distribution to blocks is described in section 4.1 and 4.2. This information is used in crop N model and nutrient budget calculations. The nutrient that are transferred from blocks to farm structures blocks is described in section 4.3 and used in the nutrient budget.

The amount of product removed and animal supplements provided to animals is also estimated at a farm scale (Animal models chapter). These are then associated with a block as described in section 4.4 and 4.5.

1.1. Workings of the technical manual

The aim of the technical manual is to provide a level of detail so that users of OVERSEER can clearly see the underlying principles and sources of data used to build the components of the 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.

Within the manual, a variable with subscripts implies that the option variable has values for multiple options, for example, $var_{block, mon}$ means that variable var has values for each block and each month (mon). A summation is indicated by the symbol Σ. The summation is over all options unless followed by a subscript before the variable name, in which case the summation is only over those variables, for example, $\Sigma_{block, mon} var_{block, antype, mon}$ means the variable var is summed over each occurrence of block and mon, to give values for each occurrence of antype.

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

1.2. Abbreviations, chemical symbols, and subscripts

Abbreviations

DM Dry matter (kg DM)

ME Metabolisable energy (MJ)

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.

Subscripts

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. Distribution of animal DM intake to blocks

Animal pasture DM intake (i.e. DM consumed) is distributed between blocks based on relative block production, relative annual intake of each animal enterprise on a block, block pasture utilisation and supplement removal, so that animal intake is maintained. Block relative productivity can be expressed on either an animal basis, where the relativity is based on animal intake such as grazing days, on a pasture basis, where the relativity is based on pasture production on the block such as relative yield, or on measurements of pasture production. The relationship between the two (animal basis or pasture basis), is that pasture production equals animal intake divided by pasture utilisation plus any supplements removed,

or that animal intake equals pasture production less any supplements removed, with the result multiplied by pasture utilisation.

Hence the underlying assumptions when distributing intake are that:

- Total animal intake is maintained.
- Pasture intake is distributed such that relative pasture production between blocks is the same as the relative block productivity that is estimated based on user inputs.
- Distribution of animal intake is consistent with the blocks animals are on and proportional to the total intake of each animal enterprise on a block.

The second and third options are not always consistent with each other, especially when block relativity is expressed on a pasture basis. In these cases an approximate solution is derived.

An additional condition is, that for a given month, the amount of DM intake allocated to an animal enterprise across all blocks must be similar to the amount of intake estimated for that animal enterprise in the animal intake sub-model. If this does not occur, an alternative solution based on using relative block productivity based on animals on block is offered to the user. Sometimes, this alternative solution doesn't work, in which case an error condition is generated.

Therefore, a procedure was developed to distribute animal intake of pasture (kg DM/animal enterprise) as described in the Animal intakes chapter is distributed to each block animal enterprises are on to obtain block pasture intake and pasture production (kg DM/ha/year) for a given block. The procedure is:

1. Estimate pasture utilisation for a block (section 3.2)
2. Estimate block relative productivity for each block (section 3.1).
3. Estimate animal pasture intake and production for each block:
    - If the block relative productivity was expressed on an animal basis then as described in section 2.2.
    - Otherwise if the block relative productivity was expressed on a pasture basis then as described in section 2.3.
    - Allocate block pasture intake to each animal enterprise grazing that block for each month as in section 2.5.
4. If the error condition described in section 2.4 occurs then:
    - The option to use Relative block productivity based on animals on block is made available. If selected then estimate the monthly pasture intake for each animal enterprise and block, and allocate this to animal pasture intake and production for each block using the method described in section 2.6.
    - If the error condition described (in section 2.4) still occurs then no solution is found.
5. Prepare the pasture production report (section 2.7).

2.1. Outputs

The output from these procedures, if no errors occur, are:

consume	animal consumption (intake) of pasture DM per block (kg DM/ha/year).
DMpasture	pasture production per block (kg DM/ha/year).
pastureDMIntakeBl	pasture DM production for a given animal enterprise, block and month (kg DM/ha/month).

2.2. Relative block production on an animal basis

Animal intake of green pasture (kg DM/ha/year), and block pasture production (kg DM/ha/year) when relative block production is on an animal basis is estimated as:

Equation 1: $consume_{block} = \Sigma_{antype}\ blockintake_{antype}$

Equation 2: $DMpasture_{block} = \Sigma_{antype}(blockintake_{antype} * pastureutilisation_{block}) + supDMout_{block}$

blockintake is the intake per block for a given animal enterprise (kg DM/ha/year [Equation 4].

pastureutilisation is the annual pasture utilisation rate for a block [section 3.2].

supDMout is the amount of supplement harvested from a block (kg DM/ha/year) [Supplements chapter].

In addition, the intake for each animal enterprise, which is used when allocating DM intake to months (section 2.5), is estimated as:

Equation 3: $antype\_consume_{block,\ antype} = blockintake_{antype}$

The uptake per block (kg DM/ha/year) for a given animal enterprise is estimated as:

Equation 4: $blockintake_{antype} = \sum_{mon} pastureDMintake_{antype,\ mon} * reldist_{block,antype} / (\Sigma_{block} reldist_{block,antype}) * area_{block}$

pastureDMintake is the estimated DM intake of pasture for a given animal enterprise in a given month based on intake (kg DM/month) [Animal intakes chapter].

reldist is the relative distribution factor for block and each animal enterprise [Equation 5].

area is the block area (ha).

The relative distribution factor for each block for each animal enterprise is estimated as:

Equation 5: $reldist_{block,antype} = BlockRel_{block} * blockSU_{block,\ antype} / 100 * area_{block} / areagrazed$

BlockRel is the relative block productivity [section 3.1].

blockSU is the relative yearly intake of each animal enterprise on a block (%) [Animals chapter].

area is the block area (ha).
areagrazed is the area of blocks grazed (ha) [section 3.4].

2.3. Relative block production on a pasture basis

When relative block production is on a pasture basis, the DM intake for animals needs to be distributed to blocks consistent with the initial assumptions. As relative block productivity is on a pasture basis, supplement removal also has to be considered when distributing animal intake. This is achieved by an iterative procedure which adjusts block pasture production. In most cases the solution is approximate, but is considered close enough so as not to not effect results.

Initially, the procedure followed is the same as that used when relative block production was assessed using animal-based assessment (section 2.2).

An additional procedure is undertaken to adjust block pasture production. This involves estimating a correction factor, calculating the pasture production given the correction factor, and estimating to what degree the desired pasture production is achieved (Errorcheck). The correction factor is adjusted according to two correction factors (correction and oldcorrection) and their associated error checks (Errorcheck and olderrorcheck).

If the number of stock enterprises is one, or no supplement is removed from any pastoral blocks, then the correction is set to zero. In these cases a single iteration is sufficient to achieve the desired distribution.

When at least one block has had supplement removed, the solution is the minimum value of a V response curve. The following steps are followed to find a solution:

1. Set the factor correction to 0.7, and the factor oldcorrection to 0.5.
2. Estimate oldErrorcheck using oldcorrection
3. Start an iteration loop where in each loop:
    - Estimate Errorcheck using correction. Pasture intake is also estimated using an iterative process using 10 loops.
    - Estimate the new correction factor (section 2.3.2).
    - Estimate Errorcheck using oldcorrection.
    - At the end of the loop, Errorcheck (and hence DM intake and DM production for each block) is estimated using the most recent estimate for correction factor.

Currently, the iteration loop is only cycling through once. Additional loops would improve the solution, but occasionally a stray solution occurred. Given that the solution appears adequate, a single iteration has been adopted.

2.3.1. Estimating pasture distribution

2.3.1.1. *Estimating closeness of fit*

The closeness of fit is estimated for each enterprise as the difference between animal DM intake based on the animal intake sub-model, and pasture DM intake from each block, estimated by this sub-model. This is estimated as:

Equation 6: $Errorcheck_{antype} = \Sigma((\Sigma_{mon}pastureDMintake_{antype, mon} / \Sigma pastureDMintake_{antype, mon}) - ((DMpasture_{block} * blockSU_{block, antype} /100) / sumpasture_{antype}))$

pastureDMintake is the estimated DM intake of pasture for a given animal enterprise in a given month based on intake (kg DM/month) [Animal intakes chapter].

DMpasture is the block DM pasture production estimated in section 2.3.1.2.

sumpasture is the pasture production associated with each animal enterprise (kg DM/ha/year) [Equation 7].

blockSU is the relative yearly intake of each animal enterprise on a block (%) [Animals chapter].

The pasture production associated with each animal enterprise (kg DM/ha/year) is estimated as:

Equation 7: $sumpasture_{antype} = \Sigma (blockintake / pastureUtilisation_{block} + supDMout_{block} * blockSU_{block, antype} /100)$

blockintake is the estimated DM intake for an animal enterprise on a given block (kg DM/ha/year).

$pastureutilisation_{block}$ is the annual pasture utilisation rate for a block [section 3.2].

supDMout is the amount of supplement harvest from a block (kg DM/ha/year) [Supplements chapter].

blockSU is the relative yearly intake of each animal enterprise on a block (%) [Animals chapter].

2.3.1.2. *Estimating pasture intake*

Pasture intake and production is estimated using an iterative loop whereby pasture intake is estimated and this is used to estimate a relative distribution. The latter, along with the block base relative distribution factor is used to re-estimate pasture intake. This loop is undertaken 10 times.

Equation 8: $DMpasture_{block} = \Sigma(blockintake_{antype} * pastureutilisation_{block}) + supDMout_{block}$

Equation 9: $consume_{block} = \Sigma blockintake_{antype}$

blockintake is the DM intake for an animal enterprise for each block (kg DM/ha/year) [Equation 10].

pastureutilisation is the annual pasture utilisation rate for a block [section 3.2].

supDMout is the amount of supplement harvested from a block (kg DM/ha/year) [Supplements chapter].

where DM intake for an animal enterprise for each block (kg DM/ha/year) is estimated as:

Equation 10: $blockintake_{antype} = (\sum_{mon} pastureDMintake_{antype, mon}) * reldist_{block,antype} / (\Sigma reldist_{antype}) / area_{block}$

pastureDMintake is the estimated DM intake of pasture for a given animal enterprise in a given month based on intake (kg DM/month) [Animal intakes chapter].

reldist is the relative distribution factor for each block for each animal enterprise [Equation 11].

area is the block area (ha).

In addition, the intake for each animal enterprise, which is used for Equation 12, is estimated using the method in Equation 3.

Relative distribution factor for each block and animal enterprise is estimated as:

Equation 11: $reldist_{block,antype} = SrelBlockPasture_{block} * blockSU_{block, antype} / 100 * area_{block} / areagrazed * fsup$

SrelBlockPasture is the base relative distribution [section 2.3.1.3].

blockSU is the relative yearly intake of each animal enterprise on a block (%) [Animals chapter].

area is the block area (ha).

areagrazed is the area grazed (ha) [section 3.4].

fsup is a factor to account for supplements removed [Equation 12].

If supplements are removed from a block, the factor that accounts for this when estimating relative block distribution is estimated as:

Equation 12: $fsup = (1 – (supDMout_{block} * blockSU_{block, antype} / 100 * pastureutilisation_{block} / blconsume_{block} * correction_{antype})) * pastureutilisation_{block}$

supDMout is the amount of supplement harvest from a block (kg DM/ha/year) [Supplements chapter].

blockSU is the relative yearly intake of each animal enterprise on a block (%) [Animals chapter].

$pastureutilisation_{block}$ is the annual pasture utilisation rate for a block [section 3.2].

blconsume is total pasture consumed by each animal enterprise on the block where the pasture consumed in the calculated value from section 2.2 (kg DM/ha/year).

correction is the value fed into the procedure [section 2.3.1].

The factor has a minimum value of 0.001. If supplements are not removed, the factor is set to 1.

After undertaking the 10 iterations, the estimated closeness of fit of the relative DM pasture production to the block relativity productivity is estimated (section 2.3.1.1).

2.3.1.3. *Base relative distribution*

For each block, base relative distribution is estimated as:

Equation 13: $SrelBlockPasture_{block} = OldSrelBlockPasture_{block} * blockcorrection_{block}$

where the correction factor is estimated as:

Equation 14: $blockcorrection_{block} = (BlockRel_{block} / \Sigma\ BlockRel) / (DMpasture_{block} / \Sigma\ DMpasture_{block})$

BlockRel is the relative block productivity [section 3.1].

DMpasture is the Pasture DM production from the previous iteration (kg DM/ha/year).

OldSrelBlockPasture is estimated as:

Equation 15: $OldSrelBlockPasture_{block} = DMpasture_{block} / \Sigma(DMpasture_{block} * area_{block})$

DMpasture is the pasture DM production as calculated in from section 2.2 which is based on animal based estimate of relative block productivity (kg DM/ha/year).

area is the block area (ha).

As pasture DM production is based on the first calculation [section 2.2], the initial value is the same each time the closeness of fit is estimated.

2.3.2. Estimating new correction factor

If the assessment of relative block production is based on pasture production, then the factor correction is set for each animal enterprise using a linear extrapolation, i.e.

Equation 16: $correction_{antype} = oldcorrection_{antype} + (Errorcheck_{antype} - OldErrorcheck_{antype}) * slope$

Equation 17: $slope = (correction_{antype} - oldcorrection_{antype}) / (Errorcheck_{antype} - OldErrorcheck_{antype})$

When at least one block has had supplement removed, the solution is the minimum value of a V response curve. Hence, to ensure that analysis is on one side of the line, correction factors are reduced to provide a linear extrapolation to the minimum value. Thus:

Equation 18: $oldcorrection_{antype} = correction_{antype} * 0.8$

and new value of correction is multiplied by 0.9.

2.4. Error condition

A check is made to ensure that for each month and enterprise the amount of DM intake from all blocks aligns with the monthly amounts of DM intake of each animal enterprise. Thus for each month and animal enterprise:

Equation 19: $ratio = pastureDMintake_{antype,mon} / sumBlock$

where

Equation 20: $sumBlock = \Sigma_{antype,\ mon} pastureDMIntakeBl_{block,\ antype,\ mon} * area_{block}$

If ratio is greater than 1.05 or ratio is less than 0.95, then the following error message is generated:

> *Pasture DM could not be allocated to blocks due to block relative productivity, animal distribution between blocks, and monthly distribution of animals on blocks for <animal enterprise>. Try changing the animal distribution method to 'Based on animals on block'.*

2.5. Distribution of pasture intake to months

The pasture consumption (intake) for each animal enterprise and month is estimated as described in section 2.2, 2.3 and 2.6. This is then allocated to each month. Initially, for a given animal enterprise, the pasture DM intake from each block is allocated to each month (kg DM/month), based on the total pasture DM intake each month for an animal enterprise, that is:

Equation 21: $pastureDMIntakeBl_{block,\ antype,\ mon} = antype\_consume_{block,\ antype} * area_{block} * ratio$

antype_consume is pasture consumed by the intake for each animal enterprise (kg DM/ha/year) [Equation 3].

area is the block area (ha).

ratio is the allocation proportion [Equation 22].

The allocation proportion is estimated as:

Equation 22: $ratio = pastureDMintake_{antype,\ mon} / \sum pastureDMintake_{antype,\ mon}$

pastureDMintake is the estimated DM intake of pasture for a given animal enterprise in a given month based on intake (kg DM/month) [Animal intakes chapter].

For each animal enterprise, the monthly allocation is adjusted so that:

- the sum of intake across blocks for a given month is similar to the pasture intake estimated for that month when calculating animal intakes.
- the sum of intake across months for a given block is similar to the pasture intake distributed to that block.

For each iteration, the sum of intake across blocks for a given month is estimated and then the monthly intake is adjusted by multiplying by prop, which is estimated as:

Equation 23: $prop = pastureDMintake_{antype,mon} / SumMonIntake_{antype, mon}$

pastureDMintake is the estimated DM intake of pasture for a given animal enterprise in a given month based on intake (kg DM/month) [Animal intakes chapter].

SumMonIntake is the sum of pastureDMIntakeBl for each month for a given animal enterprise (kg DM/ha/month).

Next, the sum of intake across months for a given block is estimated and then the monthly intake (pastureDMIntakeBl) is adjusted by multiplying by prop, which is estimated as:

Equation 24: $prop = (antype\_consume_{block, antype} * area_{block}) / SumBlockIntake_{block}$

antype_consume is pasture consumed by the intake for each animal enterprise (kg DM/ha/year) [Equation 3].

area is the block area (ha).

SumBlockIntake is the sum of pastureDMIntakeBl for each month for a given animal enterprise (kg DM/ha/month).

Lastly, the amount of pasture DM intake per block, animal enterprise and month is converted to a per-hectare basis by dividing by the block area.

2.6. Relative block productivity based on animals on block

Monthly pasture intake for each animal enterprise on each block (kg DM/ha/month) is estimated as:

Equation 25: $pastureDMintakeBl_{block, antype, mon} = pastureDMintake_{antype, mon} * reldist_{block} / \Sigma reldist_{block} / area_{block}$

pastureDMintake is the estimated DM intake of pasture for a given animal enterprise in a given month based on intake (kg DM/month) [Animal intakes chapter].

reldist is the relative distribution to each block [Equation 26].

area is the block area (ha).

The distribution of total intake for each animal enterprise and month is based on the block relative productivity and area, that is:

Equation 26: $reldist_{block} = area_{block} * BlockRel_{block}$

area is the block area (ha).

BlockRel is the relative block productivity [section 3.1].

The error condition in section 2.4 is rechecked, and if there is no error then animal DM intake and production are estimated at a block level, that is:

Equation 27: $consume_{block} = \Sigma_{antype, mon} pastureDMintakeBl_{block, antype, mon}$

Equation 28: $DMpasture_{block} = \Sigma_{antype, mon} pastureDMintakeBl_{block, antype, mon} / pastureutilisation_{block}$

pastureDMintakeBl is pasture intake for each animal enterprise on each block each month (kg DM/ha/month) [Equation 25].

pastureutilisation is the annual pasture utilisation rate for a block [section 3.2].

Bug: supplement removal from the block needs to added on

and the intake for each animal enterprise on each block is estimated as:

Equation 29: $\text{anconsume}_{\text{block, antype}} = \Sigma_{\text{mon}}\text{pastureDMintakeBl}_{\text{block, antype, mon}}$

The relative uptake for each block is then recalculated as:

Equation 30: $\text{blockSU}_{\text{block, antype}} = \text{anconsume}_{\text{block, antype}} / \text{consume}_{\text{block}} * 100$

2.7. Pasture production report

The pasture production report shows the items in Table 1 for each block.

Table 1. Items in pasture production report.

Definition	Units	Variable
On-farm fresh pasture intake	kg DM/ha/year	$\text{consume}_{\text{block}}$
Utilisation	%	$\text{pastureUtilisation}_{\text{block}} * 100$
Supplements removed	kg DM/ha/year	$\text{supDMout}_{\text{block}}$
Pasture growth	kg DM/ha/year	$\text{DMpasture}_{\text{block}}$

For crop blocks, supplement removal from pasture is not allowed. However, there are two methods of estimating pasture growth – one is based on growth curves which are used to estimate nutrient uptake, and the other is based on animal intake (as in this section). For crop blocks, the supplements removed is replaced by the difference between pasture production estimated using the growth curve and pasture production estimated using animal intake. Hence the supplements removed item is set to:

Equation 31: $\text{diff} = \text{CropPastureYield}_{\text{block}} - \text{consume}_{\text{block}} / (\text{pastureutilisation}_{\text{block}})$

CropPastureYield is the pasture yield estimated from growth curves (kg DM/ha/year).

consume is animal consumption (intake) of pasture DM per block (kg DM/ha/year).

pastureutilisation is the annual pasture utilisation rate for a block [section 3.2].

Pasture growth is replaced by the estimated pasture production plus the difference.

3. Properties

3.1. Relative block productivity

Relative block productivity is standardised by dividing by the largest value to ensure all values are less than or equal to 1. Hence it is the relative difference between input values rather than their absolute values that is important.

The relative block productivity of pastures is estimated for each block as:

Equation 32: $BlockRel_{block} = blinter_{block} / maxinter$

blinter is the block relativity [section 3.1.1].

maxinter is the maximum value of blinter across all blocks.

3.1.1. Block relativity

For pastoral blocks, the block relativity is 1 if the user selected method for determining the relative productivity of grazed block is 'No difference between groups', if. If the user selected method is 'Relative yield (from soil, fertiliser inputs), the block relativity is based on relative yield estimated using soil test and fertiliser input data (Characteristics of pasture chapter), otherwise it is block relative yield as entered by the user. The entered block relativity can be on an animal basis or a pasture production basis.

For fodder crop blocks, the relative block productivity is the area weighted average relative block productivity of those pastoral blocks the fodder crop rotates though, multiplied by the proportion of the pasture yield expected given the months pasture is grown. Thus, for fodder crop blocks:

Equation 33: $blinter_{block} = PastFodRelProd * PropYearPast_{block}$

PastFodRelProd is the weighted average relative block productivity for the pastoral blocks the fodder crop rotates though.

PropYearPast is the proportion of annual yearly growth that pasture is growing on the fodder crop block [section 3.1.2].

A similar approach is used for fruit crop and cropping blocks, except that the weighted average relative block productivity from all pastoral blocks is used, or if no pastoral blocks are present, then a value of 1. Thus for fruit crop and cropping blocks,

Equation 34: $blinter_{block} = AvPastureInter * PropYearPast_{block}$

AvPastureInter is the weighted average relative block productivity for pastoral blocks.

PropYearPast is the proportion of annual yearly growth that pasture is growing on the crop block [section 3.1.2].

3.1.2. Proportion of annual growth

The proportion of annual yearly growth that pasture is growing on the block is 1 if the distribution of animal DM intake is based on block animal distribution (section 2.2), otherwise it is estimated as the sum of the proportion of annual pasture production estimated in a given month (Monproppasture, Characteristics of pasture chapter) for months that

animals graze the block. If animals are grazing the block in a given month, a minimum value of 0.04 is used to cover times when no growth occurs but animals are present grazing accumulated pasture.

3.2. Pasture utilisation

The average pasture utilisation for a given block can be entered, otherwise it is estimated for the block as:

Equation 35: $pastureutilisation_{block} = \Sigma(DefUtilisation_{type} * ratio * blockSU_{block, antype})$

DefUtilisation is the default pasture utilisation.

ratio is a factor representing grazing pressure.

blockSU is the relative yearly intake of each animal enterprise on a block [Animals chapter].

The default pasture utilisation is assumed to be 0.85 for dairy enterprise, 0.75 for dairy replacements, and 0.70 for all other enterprises.

The factor for grazing pressure is a measure of the relative grazing pressure between blocks. It is assumed that grazing pressure is higher on beef and deer finishing blocks so pasture utilisation is higher, hence the factor for grazing pressure is set to 1.15. On merino blocks, it is assumed that grazing is less intensive and so pasture utilisation is lower at 0.95. Otherwise, the factor is set to 1.

3.3. Total block consumption

Distribution of nutrients to blocks is assumed to be proportional to the amount of feed (DM) eaten on the block, which is estimated as:

Equation 36: $blconsume_{block, antype, mon} = anconsume * area_{block}$

consume is the consumption of a given animal enterprise each month (kg DM/month) [section 2].

area is the entered block area (ha).

The consumption of a given animal enterprise each month (kg DM/month) is estimated as:

Equation 37: $consume = pastureDMIntakeBl_{block, antype, mon} + CropDMOnCropBlock_{block, antype, mon} + inDMblock_{block} * inPastureTiming_{antype, mon} / 100 * BlockSU_{block, antype}/100 + outDMblock_{block} * outPastureTiming_{antype, mon} / 100 * BlockSU_{block, antype} /100 + storeDMblock_{block} * storePastureTiming_{antype, mon} / 100 * BlockSU_{block, antype} /100$

pastureDMIntakeBl is the pasture DM intake from each block for each animal enterprise each month (kg DM/ha/month) [section 2.5].

CropDMOnCropBlock is the DM intake from crops feed on a block for each animal enterprise each month (kg DM/ha/month) [unpublished].

spDMblock is the intake of supplements fed on blocks (sp = in, out or store) (kg DM/ha/year) [Supplements chapter].

spPastureTiming is the proportion of supplement fed each month (sp= in, out or store) (%) [Supplements chapter].

blockSU is the relative yearly intake of each animal enterprise on a block (%) [Animals chapter].

Bug: Feed from crops or supplements where timing is specified have not been included.

3.4. Area grazed

The area grazed is the sum of block areas that have animals eating pasture.

4. Distribution of nutrients to blocks

Dung and urine deposited by each animal type each month are distributed between blocks in proportion to the feed consumed on each block.

4.1. Excreta

The amount of excreta dung and urine nutrients deposited on a block by each animal enterprise each month (kg nutrient/ha/month) is estimated as:

Equation 38: $bldung_{block,\ nut,\ mon,\ antype} = \Sigma(blockdungnut_{antype,\ nut,\ mon} * ratio / area_{block})$

Equation 39: $blurine_{block,\ nut,\ mon,\ antype} = \Sigma(blockurinenut_{antype,\ nut,\ mon} * ratio / area_{block})$

blockdungnut is the amount of excreta dung deposited on blocks for each animal enterprise, nutrient and month (kg nutrient/month) [Animal intakes chapter].

blockurinenut is the amount of excreta urine deposited on blocks for each animal enterprise, nutrient and month (kg nutrient/month) [Animal intakes chapter].

ratio is the distribution proportion [Equation 40].

area is the block area (ha).

The distribution proportion is estimated as:

Equation 40: $ratio = blconsume_{block,\ antype,\ mon} / \Sigma_{block} blconsume_{block,\ antype,\ mon}$

blconsume is the DM intake on each block for each animal enterprise and month (kg DM/ha/month) [section 3.3]

4.2. Excreta re-distribution between blocks

If crops are grazed for only some hours during the day (restricted grazing), then some of the excreta from the consumption of feed on that block is transferred to the blocks the animals spend the remainder of their time on. It is assumed that this transfer of nutrients is proportional to time, and that the transfer is to pastoral blocks. Thus for each crop block on which there is restricted grazing of a crop, for each nutrient, month and animal enterprise, the amount of nutrient transferred out of the crop block (kg nutrient/ha/year) is estimated as:

Equation 41: transferurine = $blUrine_{block, nut, mon, antype}$ * (1 - Grazetime/24)

Equation 42: transferdung = $blDung_{block, nut, mon, antype}$ * (1 - Grazetime/24)

blurine is the amount of nutrient in excreta urine deposited on a block by each animal enterprise each month (kg nutrient/ha/month) [section 4.1].

blurine is the amount of nutrient in excreta dung deposited on a block by each animal enterprise each month (kg nutrient/ha/month) [section 4.1].

block is the cropping block.

Grazetime is the entered time when the crop is grazed (hours/day).

The transferred nutrient is removed from urine and dung deposited on the crop block.

The transferred excreta is then added to the pastoral blocks that the animals are on when not on the crop. The distribution of total excreta on the receiving pastoral blocks is assumed to be proportional to the distribution of the total amount of urine-N deposited on receiving blocks. This assumption may under or over-estimate the transfer rates to particular blocks if some pastoral blocks are being used as sacrifice paddocks, because sacrifice blocks are not identified. It is assumed that dung N and other nutrients follow the same pattern as urine N in the model, an assumption used elsewhere.

This is achieved by multiplying the transfer amount by the area of the crop block (to get the total nutrient amount). The transferred amount is then distributed to each pastoral block depending on the amount of dung or urine already deposited, and then divided by the receiving block area to give kg nutrient/ha transferred. This is added to the receiving block dung and urine amounts (bldung and blurine). Thus, for each pastoral block, the amount added (kg nutrient/ha/month) for each animal enterprise is estimated as:

Equation 43: addurine = transferurine * $area_{cropblock}$ * ($ratio_{block2}$ / Σ_{block}ratio) / $area_{block2}$

Equation 44: adddung = transferdung * $area_{cropblock}$ * ($ratio_{block2}$ / Σ_{block}ratio) / $area_{block2}$

area is the entered block area (ha).

cropblock refers to the block the crop is grown in.

block2 refers to a pastoral block.

ratio is the amount of urine N deposited on a pastoral block (kg N/month) [Equation 45].

The distribution to each pastoral block is based on ratio, which for each block is the amount of urine N deposited on the block times the block area. Thus ratio is estimated as:

Equation 45: $ratio_{block2} = blurine_{block2, nitrogen, mon, antype}$ * $area_{block2}$

blurine is the amount of N in excreta urine deposited on a block by each animal enterprise each month (kg nutrient/ha/month) [section 4.1].

block2 refers to a pastoral block.

area is the block area (ha) for the receiving pastoral block.

4.3. Nutrient transfers

Nutrient transfers from blocks to farm structures, such as raceways, pads and farm dairies, are allocated back to a block based on the amount of feed consumed on each block. The amount of nutrients transferred is described in the Effluent management chapter.

For a given amount transferred to a structure (animalNutMonth, kg nutrient/month), the amount transferred from a given block (BlockDist, kg nutrient/year) is estimated as:

Equation 46: $BlockDist_{block, nut} = \Sigma_{antype, mon} animalNutMonth_{antype, nut, mon} * ratio$

animalNutMonth is the farm scale nutrient transfer of interest (kg nutient/month) [Animal intakes chapter].

ratio is the proportion allocated to a given block [Equation 47 or Equation 48].

If the amount consumed has been estimated then the ratio is estimated as:

Equation 47: $ratio = BlConsume_{block, antype, mon} / \Sigma_{antype, mon} BlConsume_{block, antype, mon}$

BlConsume is the amount of DM consumed (kg DM/ha/month) [section 3.3].

Otherwise, if the amount consumed has not been estimated (initial allocation) then the ratio is based on the area, that is:

Equation 48: $ratio = BlAreaConsume_{block, antype, mon} / \Sigma_{block} BlAreaConsume_{block, antype, mon}$

BlAreaConsume is the area of a block where animals are grazing pasture in a given month (ha).

4.4. Product

Nutrients in animal products leaving the farm are estimated at the farm scale (Animal model chapter), but the nutrients in products are from nutrients ingested on blocks or on wintering pads/animal shelters. The allocation of nutrients in product removed to each block is based the amount of feed consumed on each block, adjusted for an expected conversion rate to product. Thus on finishing blocks, it is assumed that two times more nutrient ends up as product than on non-finishing blocks. On sheep merino and steep hill blocks, it is assumed that less nutrients will end up in product.

The amount of product nutrients allocated to each block (AnimalProduct, kg nutrient/ha/year) is estimated for each block as:

Equation 49: $AnimalProduct_{block, nut} = \sum_{antype}(ProductRemoved_{antype, nut} * ratio_{block, antype} * ratioFP_{antype, nut}) / area_{block}$

ProductRemoved is the total amount of product nutrient removed from the farm (kg nutrient/year) [Animal model chapter].

ratio is the distribution ratio between blocks and animal enterprises [Equation 50].

ratioFP is the proportion of product nutrients removed that came from blocks [Equation 54].

area is the block area (ha).

The distribution ratio between blocks and animal enterprises is estimated as:

Equation 50: $ratio_{block, antype} = reldist_{block, antype} / \sum_{antype}(reldist_{block, antype})$

reldist is the distribution ratio [Equation 51].

Where for each block and animal enterprise:

Equation 51: $reldist_{block,\ antype} = \sum_{mon} (BlConsume_{block,\ antype,\ mon}) * aninter_{block,\ antype}$

BlConsume is the amount of DM consumed (kg DM/ha/month) [section 3.3].

aninter is the expected conversion rate to product [Equation 52 or Equation 53].

For each block, and animal enterprise, the factor for expected conversion rate to product for beef and deer finishing blocks is estimated as:

Equation 52: $aninter = (1 + 1 * blockSU_{block,\ antype} / 100)$

blockSU is the relative yearly intake for beef or deer on a block [Animals chapter].

For sheep merino and steep hill blocks, the factor is estimated as:

Equation 53: $aninter = (0.66 + (1 - 0.66)* (1 - blockSU_{block,\ sheep} / 100))$ merino

$= (0.88 + (1 - 0.88) * (1 - VblockSU_{block,\ sheep} / 100))$ steep hill

blockSU is the relative yearly intake of sheep on a block [Animals chapter].

Otherwise the factor for expected conversion rate to product is 1. The ratio of total product removed that comes from blocks is based the amount of animal intake as this is used to estimate product nutrient intake associated with the wintering pad/animal shelter. This is estimated as:

Equation 54: $ratioFP_{antype,\ nut} = (productnut_{antype,\ nut} - productfeedpad_{antype,nut}) / antype\_productnut_{antype,\ nut}$

productnut is the total amount of product nutrient used in the intake model (kg nutrient/year) [Animal model chapter].

productfeedpad is the total amount of product nutrient that is associated with consumption on winteringpads/aniaml shelters (kg nutrient/year) [unpublished].

4.5. Drenches

The method used for drenches is similar to that used for product. This assumes that when drench is allocated to blocks, the distribution is also adjusted for an expected conversion rate to product. Thus:

Equation 55: $DrenchBlock_{block,\ nut} = \sum_{antype}((AnimalHealth_{antype,\ nut} - DrenchWinpad_{antype,\ nut}) * ratio / area_{block}$

AnimalHealth is the amount of nutrients added as animal health supplements (kg nutrient/year) [Supplements chapter].

DrenchWinpad is the amount of nutrients added as animal health supplements that are associated with witnering pads/animal shelters (kg nutrient/year) [unpublished].

ratio is the distribution ratio between blocks and animal enterprises [Equation 50].

area is the entered block area (ha).