OVERSEER®

# OVERSEER® Technical Manual

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

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# Characteristics of fertilisers

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# Preface

## OVERSEER® Nutrient Budgets

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

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

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

## This technical manual

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

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

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

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

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

## Contents

# Characteristics of fertiliser

## 1. Introduction

### 1.1. Fertiliser within OVERSEER

Within OVERSEER, fertilisers are defined as material applied to supply nutrients for plant growth. Fertilisers include synthetic and natural inorganic fertilisers (sometimes referred to as ‘conventional' fertilisers), lime and organic material. However, this definition of fertiliser within OVERSEER excludes farm produced effluent, which is modelled separately.

Fertiliser use within OVERSEER is reported in block and farm nutrient budget reports as the amount of nutrient applied for all fertilisers, and for each component (inorganic, lime and organic). In addition, the nitrogen (N) from any dicyandiamide (DCD) applied to paddocks is also shown as a fertiliser input for convenience. Fertilisers can be added to pastoral and cut and carry blocks, and blocks with arable, vegetable, fodder and fruit crops.

The effects of the use of fertilisers containing N and phosphorus (P) on N and P cycling are modelled in OVERSEER. For example, as the rate of inorganic N fertiliser rates increase, the N concentration in pastures increase and therefore the grazing animals consume a higher N content in their diet, resulting in increased N intake and hence excreta deposited on farm. Depending on the time and place of deposition, this can result in increases in N leaching. However, the major impact of applying inorganic N fertiliser on N leaching is to increase pasture production, which can be grazed directly or conserved as feed, and is captured through animal production inputs, and hence N intake. OVERSEER also takes into account the contribution inorganic and organic N fertiliser makes to background (non-urine patch leaching), and this is reported in OVERSEER as ‘leaching – other’. Within the crop sub-models, N fertiliser is a contributor to the soil N pools, and a portion of the soil N pools, may leach under some conditions. These processes will be discussed in more detail in the Nitrogen chapter of the Technical Manual (under development). The impact of N fertiliser use on N volatilisation is discussed in this document (section 3.1.4). The impact of P fertiliser use on P runoff will be discussed in more detail in the Phosphorus chapter of the Technical Manual (under development).

For all nutrients, fertiliser inputs contribute to the soil pool and hence affect pasture nutrient concentrations, and hence intake and nutrient transfers, and may contribute to potentially leachable soil pools. The N and P runoff sub-model uses a monthly time step, and hence fertiliser inputs are required on a monthly time step. This was applied across all fertilisers so that compound fertilisers (those containing N or P and other nutrients) could be added using the same mechanisms as N and P fertilisers.

Fertiliser inputs also have an embodied manufacturing, transport and spreading carbon dioxide ($CO_2$) and energy emissions. These are incorporated into the embodied carbon dioxide ($CO_2$) emission sub-models as described in the chapter ‘Carbon dioxide, embodied and other gaseous emissions’ of the Technical manual.

A schematic diagram is shown in Figure 1 to illustrate the relationship of fertiliser with relevant sub-models within OVERSEER. The majority of the calculations involving fertiliser as outlined in the chapter are undertaken within the block that the fertilisers are applied, and the results have units of per ha.

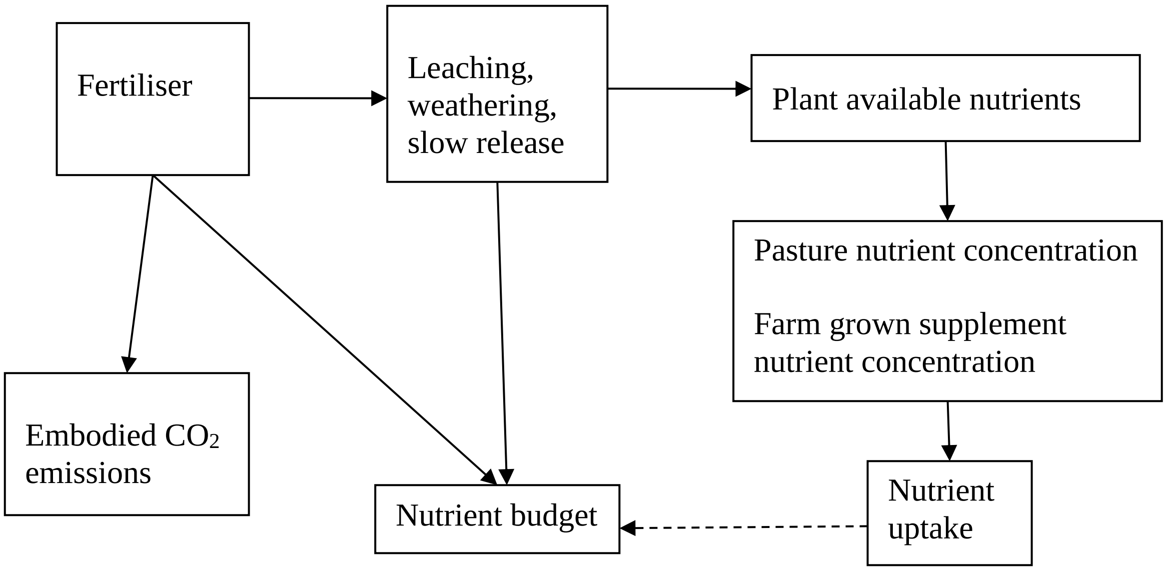


**Figure 1: Simplified relationship between fertiliser and other sub-models. Dotted lines indicate that the relationship is via several intermediary steps.**

## 1.2. Classification of nutrient forms available within inorganic fertilisers

Table 1 below shows the form of nutrients within inorganic fertilisers available within OVERSEER, and Table 2 shows the sub-models where the amount of nutrients in each from are used in the calculations. The classification for form was based on the effect on acidification (de Klein et al., 1997). For P, the only form considered in the phosphorus runoff loss model is RPR.

For K, Ca, and Na, the form of nutrient that is applied is not used within OVERSEER.

**Table 1: Nutrient forms available within OVERSEER.**

| Nutrient | Form |
|---|---|
| N | Urea |
| | Diammonium phosphate (DAP) |
| | Other ammonium ($NH_4$) forms |
| | Nitrate ($NO_3$) forms |
| | Mixed forms[1] |
| P | Super |
| | DAP / Dicalcium phosphate (DCP) |
| | Rock |
| | Other |
| S | Sulphate |
| | Elemental |
| Mg | Serpentine |
| | Magnesium oxide |
| | Dolomite |
| | Other |

[1]mixed refers to a mix of ammonium and nitrate forms.

**Table 2: Sub-models which use the amount of nutrient in a given form as an input.**

| Nutrient | Sub-model |
|---|---|
| N | Volatilisation |
| | Acidity from leaching |
| | Atmospheric loss |
| P | Acidity from fertiliser |
| | P runoff |
| S | Acidity from fertiliser |
| Mg | Greenhouse gas emissions |

For N fertilisers with other mixes, such as DAP and other $NH_4$ form, the form should be the dominant form in the product. Otherwise, the selection of form is arbitrary, but for consistency, the first form on the list is selected.

## 1.3. Workings of the technical manual

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

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

### 1.4. Abbreviations, chemical symbols and subscripts used

Abbreviations

$CO_2$ carbon dioxide.

DM dry matter

Chemical symbols

N, P, K, S, Ca, Mg, and Na refer to the nutrients nitrogen, phosphorus, potassium, sulphur, calcium, magnesium, and sodium respectively. Acidity refers to the change in acidity.

Subscripts

application given fertiliser data entry in the interface.

nut nutrients.

mon month of application.

form form of inorganic fertiliser as defined in section 1.2.

block block the fertiliser is applied to.

Some calculated variables are used outside the block that the fertilisers is applied, that is at a farm level, and these have a block subscript.

## 2. Fertiliser inputs

### 2.1. Entry of fertiliser into OVERSEER

Fertiliser inputs are entered into OVERSEER at the block level. Fertiliser inputs for a given month can be entered using five possible methods:

- Inorganic fertiliser products (pre-defined or user-defined)
- Soluble inorganic fertiliser nutrients
- Inorganic fertiliser nutrients by form
- Lime (pre-defined or user-defined)
- Organic fertiliser

More than one method of input can be used in a given month, and more than one fertiliser product can be added per month. The range of methods available for entering fertiliser information caters for different uses of OVERSEER. For inorganic fertilisers, soluble fertiliser or fertiliser forms tend to be used to model science-based farm systems, whereas many farmers and consultants tend to use the fertiliser products.

### 2.1.1. Fertiliser products

The OVERSEER fertiliser database contains a list of fertiliser products for which chemical composition has been supplied by manufacturers. The list of products currently available and their nutrient contents and forms of nutrients are shown in Appendix 1. In addition, the user can set up a list of products in a user-defined database (section 2.1.6).

When entering fertiliser products, the user selects the product type and the amount applied to a block with a known area (ha). Nutrient contents (N, P, K, S, Ca, Mg, and Na) are extracted from the database for the product chosen and are stored with the input data file at the time a save occurs. The extracted nutrient contents and along with the amount entered is used by the sub-model to estimate the rate of nutrient applied. Thus, the original extracted nutrient contents are used if the product is deleted from the list, or the nutrient contents of products within the list are changed.

### 2.1.2. Soluble fertiliser nutrients

Soluble fertiliser nutrients are fertiliser nutrients added as predetermined forms, which are:

- N as urea,
- P and S as superphosphate,
- K as potassium chloride and
- Mg as serpentine superphosphate.

Hence, soluble fertilisers have the forms listed in Table 1 of 'Nurea', 'Psuper', 'Sulphate' and 'Serpentine' for N, P, S, and Mg respectively. Fertiliser nutrient rate is entered as kg/ha/application for each form.

### 2.1.3. Fertiliser nutrients by form

Fertiliser nutrients can come in many different forms. The nutrient forms that can be directly entered are shown in Table 1. Fertiliser nutrient rate is entered as kg/ha/application for each nutrient form.

### 2.1.4. Lime

Lime applications are entered for two time periods, current or reporting year, and previous years. If lime is applied within the reporting year then this is entered the same as fertiliser; by selecting the type of material and amount applied. If lime has been applied in the last 5 years, then this also can be accounted for by ticking the box 'Specify last previous lime application (if within the last 5 years)', where again type of lime material and amount is required. Similar to fertiliser products, nutrient contents are extracted from the database for the product chosen and are stored with the input data file at the time a save occurs. The extracted nutrient contents and along with the amount entered is used to estimate the rate of nutrient applied. Thus, the original extracted nutrient contents are used if the product is deleted from the list, or the nutrient contents of products within the list are changed. Methodologies related to lime applications are outlined in Section 4.

### 2.1.5. Organic fertilisers

Organic based fertilisers can be entered into OVERSEER. A variety of organic types of material can be accounted for, including compost/mulches, dairy factory effluent, piggery effluent, imported dairy effluent, and other organic material. Depending on what type of organic material is entered a variety of information will be required i.e. amount, DM content and nutrient concentrations. Methodologies related to organic fertiliser applications are outlined in Section 5.

### 2.1.6. User defined

User defined fertilisers, lime and organic material can be entered into OVERSEER.

A user defined fertiliser and lime product requires the same information as the internal database. For inorganic fertilisers, this includes the contents (%) of N, P, K, S, Ca, Mg, and Na in the fertiliser, and the form of those nutrients for N, P and Mg, and the percentage of S as elemental S. For lime, only the contents (%) of N, P, K, S, Ca, Mg, and Na in the lime are required. Only a single user defined lime can be entered.

OVERSEER also has a database of nutrient contents for dairy factory lactic acid whey, sulphuric acid whey and cheese whey. There is also the option for a user-defined dairy factory effluent, where the nutrients contents (%, or g/m$^3$) of N, P, K, S, Ca, Mg, and Na in the effluent are required.

## 2.2. Application month

All fertiliser entries within OVERSEER require the month of application. The month of application is relevant for the N and P sub-model and will be discussed in more detail in the N and P technical manuals (under development).

## 2.3. Method of application

The method of application is only required on crop blocks. Two methods are identified in OVERSEER; incorporated and surface applied. Only one method can be selected per fertiliser application. The method of N application has an effect on N volatilisation [3.1.4]. It is assumed that all fertiliser N applied to pastoral and cut and carry blocks is surface applied.

## 2.4. Unit conversion

Fertiliser products and lime can be entered using the units of total kg, total tonnes, or kg/ha. However, all block calculations use the units kg/ha. To convert the entered units to kg/ha, rates are multiplied by unitfactor, which is estimated as:

*Equation 1:* 

$$\text{unitfactor} = 1 / \text{area}_{block} \quad \text{if entered using units of total kg}$$
$$= 1 * 1000 / \text{area}_{block} \quad \text{if entered using units of total tonnes}$$
$$= 1 \quad \text{if entered using units of kg/ha}$$

units are user selected units of kg, tonnes or kg/ha.
area is block area (ha).
1000 is 1000 kg/Tonne.

# 3. Inorganic fertilisers

Inorganic or conventional fertilisers are defined as naturally occurring chemical salts such as potassium chloride and magnesium oxide, but excluding the liming materials (calcium and magnesium carbonates). It includes manufactured products made from mixing natural chemical salts or chemicals synthesised or manufactured from naturally occurring chemicals, for example, superphosphate. The synthesis process is typically done to increase solubility, increase the range of nutrients in the product, or to improve handling properties.

## 3.1. Application amounts

### 3.1.1. Amount of fertiliser product applied

When inorganic fertilisers are added as fertiliser products, the amount of fertiliser added (kg product/ha/ application) is estimated as:

*Equation 2:* $AmtFert = amount_{mon} * unitfactor$

$amount_{mon}$ is the entered amount of fertiliser product applied (kg, tonnes or kg/ha).

unitfactor is based on user selected units [Equation 1].

### 3.1.2. Amount of fertiliser nutrient applied

The amount of fertiliser nutrient applied each application for each form of the nutrient (rate, kg nutrient/ha/application) is estimated as:

*Equation 3:* $rate_{form,\ nut} = \sum((AmtFert * Fertconc_{nut} / 100)$

AmtFert is the amount of fertiliser added per month (kg/ha/month) [Equation 2].

Fertconc is the concentration of nutrients in inorganic fertiliser product (%) from either the fertiliser database (Appendix 1) or the user-defined database.

For inorganic fertiliser products, if the form of N is mixed, then the fertiliser N is equally split between nitrate and ammonia forms. That is:

*Equation 4:* $rate_{NO3,\ N} = \sum((AmtFert * Fertconc_{N} / 100 * 0.5)$

*Equation 5:* $rate_{NH4,\ N} = \sum((AmtFert * Fertconc_{N} / 100 * 0.5)$

For S, fertiliser rate is split between elemental and sulphate S as:

*Equation 6:* $rate_{sulphateS,\ S} = \sum((AmtFert * Fertconc_{S} / 100 * (1 – elementalcontent / 100))$

*Equation 7:* $rate_{elementalS,\ S} = \sum((AmtFert * Fertconc_{S} / 100 * elementalcontent / 100)$

elementalcontent is the % of S that is in the elemental form.

If soluble fertiliser or fertiliser forms is inputted then:

*Equation 8:* $rate_{form,\ nut,} = FertNutForm_{form,\ nut}$

FertNutForm is the user-entered amount of nutrient (kg nutrient/ha/month) as soluble fertiliser with pre-defined forms [section 2.1.2] or as fertiliser forms [section 2.1.3].

### 3.1.3. Weight of inorganic fertiliser

The total weight of product applied to a farm is used in the greenhouse gas sub-model to estimated embodied $CO_2$ emissions associated with transport and spreading of inorganic fertilisers. The total weight of product applied is split between urea (urea as a product, not urea as a form) and non-urea products as differences in transport distances and spreading methods for urea and non-urea products are included in the embodied $CO_2$ emissions. Total weights are estimated by summing up the weight of fertiliser applied per application.

For fertiliser products, urea was defined at each application as a product with an N form of urea, and where the sum of the other nutrients was zero. If this condition is met, the weight of urea transported to the farm is the amount of inorganic fertiliser product that is applied:

*Equation 9:* FertNweightApp = AmtFert

AmtFert is the amount of inorganic fertiliser product applied (kg/ha/application) [Equation 2].

Otherwise, the weight of non-urea fertiliser transported is the amount of inorganic fertiliser product:

*Equation 10:* FertweightApp = AmtFert

If fertiliser is entered as nutrients only (soluble fertiliser, fertiliser by form), then the weight of the product applied is based on nutrient contents of typical forms. Thus it is assumed that the weight of fertiliser is based on amount of N in urea, P in superphosphate, K in KCl, Na in NaCl, and Mg in serpentine (Table 3). Calcium is usually part of a fertiliser component (e.g. as superphosphate, or gypsum) and hence to avoid double accounting, is ignored. Similarly, S as sulphate may be part of superphosphate and hence the weight is covered by the P component. However, if no P is present, it is assumed to be present as calcium sulphate. Some of the fertiliser and P forms are assumed to be from compound fertilisers (Table 3), and these are assumed to contain 25% of the nutrient.

For products, the fertiliser weight transported is the amount of fertiliser applied excluding urea [Equation 11]. For non-urea fertilisers, weight is estimated across all forms and nutrients.

*Equation 11:* $\text{FertweightApp} = \sum((\text{rate}_{\text{form, nut}} / \text{KFert}_{\text{form, nut}})$

rate is the user inputed fertiliser nutrient rate (kg nutrient/ha/application) for each form, except urea.

KFert is a constant based on the fertiliser form [Table 3].

The weight of urea transported and applied is estimated separately (Equation *12*) as:

*Equation 12:* $\text{FertNweightApp} = \text{rate}_{\text{Nurea, N}} / \text{KFert}_{\text{Nurea}}$

rate is the user inputed urea nutrient rate (kg nutrient/ha/application)

KFert is a constant based on the fertiliser form [Table 3].

**Table 3: Fertiliser form and proportion of nutrient ('constant') used for estimating product weight.**

| Nutrient | Fertiliser form | Constant[1] | Condition |
|---|---|---|---|
| N | Urea | 0.46 | |
| | DAP | 0 | Covered by DAP under P |
| | Other $NH_4$ forms | 0.25 | Assume to be compound fertilisers |
| | $NO_3$ forms | 0.25 | Assume to be compound fertilisers |
| | Mixed | 0.25 | Assume to be compound fertilisers |
| P | Super | 0.093 | |
| | DAP | 0.201 | |
| | Rock | 0.127 | |
| | Other | 0.25 | Assume to be compound fertilisers |
| K | | 0.50 | |
| S | Sulphate | 0 | If fertiliser P is greater than zero |
| | | 0.18 | If no fertiliser P applied |
| | Elemental | 1 | |
| Ca | | 0 | Part of the fertiliser component |
| Mg | Serpentine | 0.20 | |
| | Magnesium oxide | 0.52 | |
| | Dolomite | 0.09 | |
| | Other | 0.15 | |
| Na | | 0.39 | |

[1]Constant is the proportion of the nutrient in that form.

### 3.1.4. Volatilisation of ammonia from inorganic N fertiliser

**Inputs**: Urea monthly amount or urea-N applied (kg N/ha).

DAP monthly amount or DAP-N applied (kg N/ha).

$NH_4$ monthly amount or ammonium-N applied (kg N/ha).

$NO_3$ monthly amount or nitrate-N applied (kg N/ha).

rain average daily rainfall for month fertiliser was applied (mm/day).

temp average monthly temperature for month fertiliser was applied (°C).

SM monthly soil moisture content (mm to 60cm).

FC field capacity (mm to 60 cm).

sand sand content of topsoil (%).

**Outputs**: monthly volatilisation rate (kg N/ha/month)

The derivation of the fertiliser volatilisation sub-model is outlined in Woodward (2008) and was derived from applying a regression approach to available experimental data. Monthly volatilisation of fertiliser N (kg N/ha/month) was estimated as:

*Equation 13:* Volat = baseloss * raineffect * tempeffect * SMeffect * covereffect * soileffect

baseloss is a base volatislisation rate (kg N/ha/month) [Equation 14].
raineffect is a factor driven by rainfall (0-1) [Equation 17].
tempeffect is a factor driven by temperature (0-1) [Equation 18].
SMeffect is a factor driven by soil moisture content (0-1) [Equation 19].
covvereffect is a factor accounting for crop cover (0-1) [Equation 20].
soileffect is a factor driven by soil sand content (0-1) [Equation 21].

Volat was restricted so that a maximum of 80% of the applied N could be volatilised. Baseloss is based on the average volatilisation rates for the different forms of N a dry month at 20 °C, the soil moisture content is at field capacity, and there is no plant cover. For surface applied N, baseloss was estimated as:

*Equation 14:* $\text{baseloss} = \text{baseN}^{1.548}$

where baseN is based on the average volatilisation rates for the different forms of N such that:

*Equation 15:* $\text{BaseN} = 0.1117*\text{Urea} + 0.0598*\text{DAP} + 0.0186*NH_4 + 0.0181*NO_3$

Urea, DAP, $NH_4$, $NO_3$ is the amount of N for each form (kg N/ha/month).
0.1117, 0.0598, 0.0186, and 0.0181 are release rates (kg N/kg N) [Woodward, 2008].

However, if the N is incorporated, base volatilisation losses are is assumed to be low.

*Equation 16:* $\text{baseloss} = 0.005* (\text{Urea} + \text{DAP} + NH_4 + NO_3)$

The effect of temperature, rainfall, soil moisture, cover is estimated based on integrating experiment data up to a monthly estimate. Rainfall immediately after application is known to reduce volatilisation losses. The more rain that falls and the sooner after fertiliser application, the greater the reduction in volatilisation losses. The volatilisation sub-model applies an integrated approach that takes account of these factors and estimates the likely effect based on average daily rainfall for the month. This results in the term from Woodward (2008) of:

*Equation 17:* $\text{raineffect} = ( \text{EXP}( -0.432 * \text{rain} ) + 1.187 ) / ( 1 + 1.187 )$

Rain is the average daily rainfall for the month (mm/day).

where average daily rainfall for the month is typically the monthly rainfall divided by the number of days in the month. The resultant curve is shown in Figure 2.

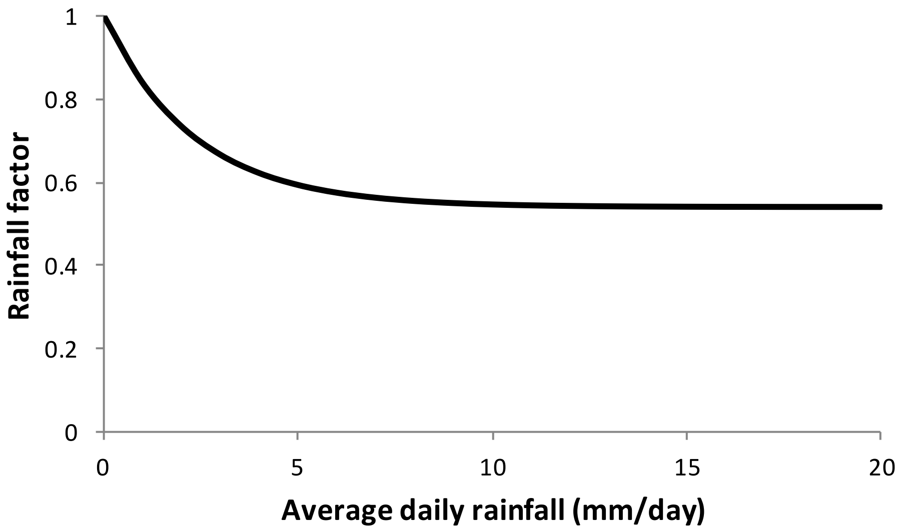


**Figure 2. The effect of average daily rainfall on the rainfall factor for estimating N volatilisation losses from inorganic fertiliser.**

Volatilisation rates tend to increase as temperature increases, or as the base rate is based on 20 °C, decrease when the temperature is below 20 °C. This results in the term from Woodward (2008) of:

*Equation 18:* tempeffect = 0.991 * (1 - exp( -0.282 * (Temp - 6.230)))
Temp is the average monthly temperature (°C).

and such that tempeffect is greater than zero. The resultant curve is also shown in Figure 3.

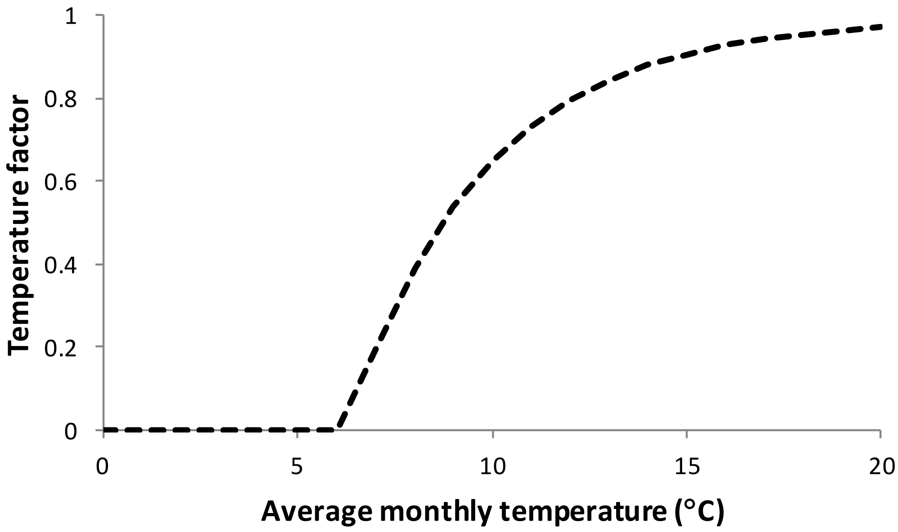


**Figure 3. The effect of average monthly temperature on temperature factor for estimating N volatilisation losses from inorganic fertiliser.**

Laboratory studies indicate that reduced soil moisture at the time of fertiliser application results in increased ammonia volatilisation (Woodward 2008). This results in the term from Woodward (2008) of:

*Equation 19:* SMeffect $= 1$ if $SM \geq SMfc$

$= (1 + 0.153 * (1 - SM/SMfc))$ otherwise

SM is the average monthly soil moisture content (mm to 60 cm).

SMfc is the field capacity (mm to 60 cm).

Thus, Equation 19 indicates that volatilisation rates were about 15% higher on very dry soils. The resultant curve is also shown Figure 4.

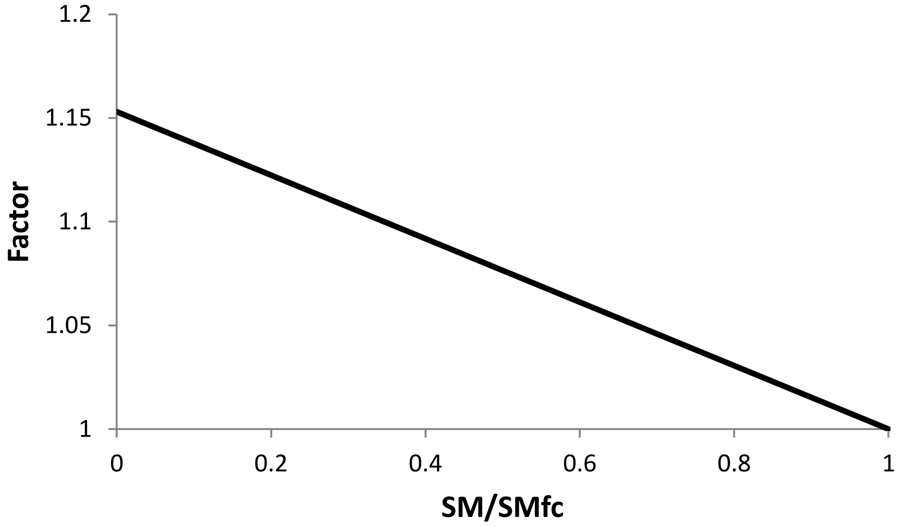


**Figure 4. The effect of the ratio of monthly average soil moisture (SM) content to SM at field capacity (SMfc) on the soil moisture factor for estimating N volatilisation losses from inorganic fertiliser.**

It was noted in Woodward (2008) that volatilisation from soils with full cover was typically about 60% of that on bare soil. Most experiments were done on bare soils, but the developed volatilisation sub-model requires adjustment for soils with plant cover. Therefore, cover effect was estimated as:

*Equation 20:* covereffect = 0.6 + 0.4 * (1 - cover)
cover is the estimated crop cover.

Thus on pasture, cover is 1 and covereffect is 0.6. On bare soils, cover is zero and hence covereffect is 1. On crops, the cover increases as the crop matures, and thus covereffect varies from 1 on sowing to 0.6 at maturity.

Woodward (2008) also indicated that volatilisation losses varied with the cation exchange capacity of the soil. Sand was used as a surrogate by Woodward (2008) such that as sand content increased, volatilisation rate increased (Figure 5). This results in the term from Woodward (2008) of:

*Equation 21:* soileffect = (1 + 0.993 * (sand/100 - 0.659))
sand is the sand content of the top soil (%) [see Soils Chapter of the Technical Manual].

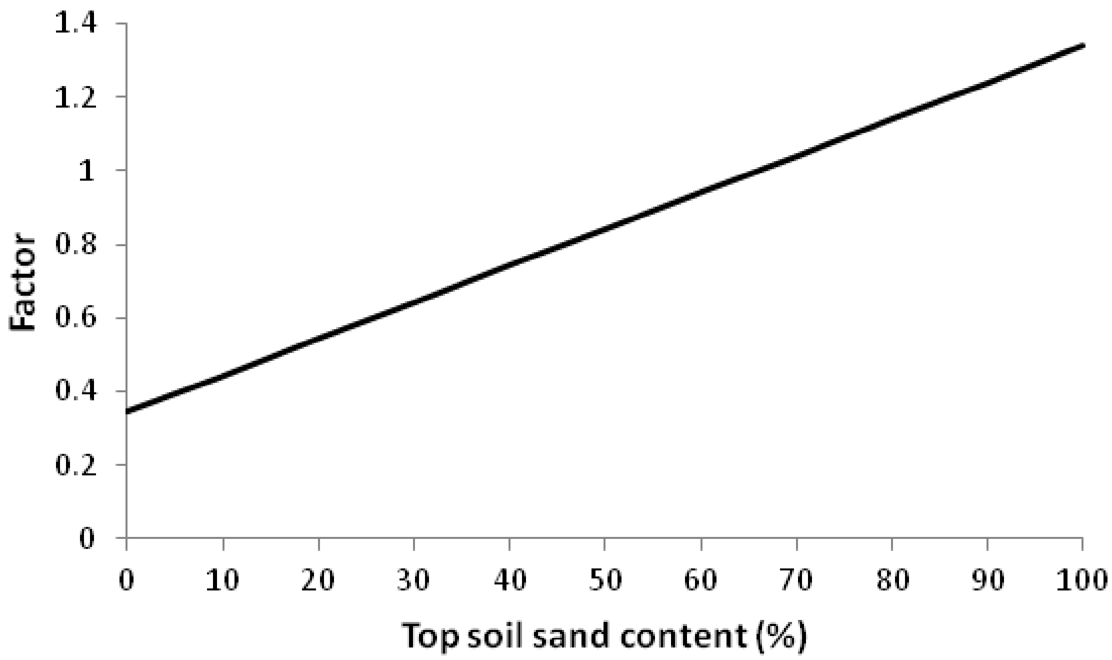


**Figure 5. Effect of sand content on the soil factor for estimating N volatilisation losses from inorganic fertiliser.**

## 3.2. DCD applications

DCD (linear formula $NH_2C(=NH)NHCN$ or condensed to $C_2H_4N_4$ ) contains about 66% N, and this N is relatively readily available given the half-life of DCD (Kim *et al*., 2012). The DCD sub-model only applies if the effective recommended rate of 10 kg DCD/ha/application is applied. Thus, the total amount of N added as DCD is estimated as:

*Equation 22:* DCDN = NoDCDApplications * 6

6 is the amount of N applied as DCD (kg N per effective application of 10 kg DCD).

NoDCDApplications is the number of DCD applications per year.

## 3.3. Outputs from inorganic fertiliser sub-model

Outputs from fertiliser sub-model required in the rest of OVERSEER are listed below. N and P are required on monthly basis as inputs into the N and P loss sub-models, whereas S, K, Ca, Mg, and Na are only required on an annual basis.

The sum of fertiliser nutrients of all forms applied in a year (Fert, kg nutrient/ha/year) is used throughout, for example, in estimating pasture nutrient concentrations, weathering and slow release of nutrients, and leaching of non-N nutrients. It is estimated as:

*Equation 23:* $Fert_{nut} = \Sigma_{form,\ application}(rate_{form,\ nut})$

rate is the rate of nutrient applied (kg nutrient/ha) per application [Equation 3, section 3.1.2].

The sum of fertiliser nutrients for each form applied in a year for N, P, S and Mg (FertForm, kg nutrient/ha/year) is estimated as:

*Equation 24:* $FertForm_{nut,\ form} = \Sigma_{application} (rate_{form,\ nut})$

The acidifying effect of fertiliser (nut = acidity) is calculated using the method of deKlein *et al*. (1997) to give:

*Equation 25:* $Fert_{nut} = \Sigma_{mon} (FertForm_{P,\ PDAP}) * -0.032 + \Sigma_{mon} (FertForm_{P,\ PRock}) * -0.064 + \Sigma_{mon} (FertForm_{S,\ SElemental}) * 0.063$

PDAP, PRock, and SElemental refer to the forms of P or S.

The constants -0.032, -0.64 and 0.63 are acidifcation rates (kmol H+/kg P) [deKlein *et al*., 1997].

The other fertiliser types; single superphosphate containing 14% $H_2PO_4$-P, mono-calcium phosphate and mono-ammonium phosphate listed by deKlein *et al*. (1997) were not included as a P form as they were not considered to be common enough. They can be entered as either superphosphate or 'other' as both have a minimal effect on acidity.

N and P are required on monthly basis as inputs into the N and P loss sub-models. Hence, the sum of fertiliser nutrients for each form applied in a month for N and P (FertFormMon, kg nutrient/ha/mon) is estimated as

*Equation 26:* $FertFormMon_{nut,form,\ mon} = \Sigma_{application}(rate_{form,\ nut})$

rate is the amount of nutrient added of each form per application (kg nutrient/ha) [section 3.1.2].

The total amount of N volatilised per month is estimated as:

*Equation 27:* $FertNVolat_{mon} = \Sigma_{application}(Volat)$

Volat is N volatilisation for a given application (kg N/ha) [section 3.1.4].

Finally, the total weight of urea and non-urea product applied per year (kg/ha/year) is estimated as:

*Equation 28:* $FertNweight_{block} = \Sigma_{application}(FertNweightApp)$

FertNweightApp is the weight of fertiliser urea that was applied (kg/application) [section 3.1.3].

*Equation 29:* $Fertweight_{block} = \Sigma_{application}(FertweightApp)$

FertweightApp is the weight of fertiliser excluding urea that was applied (kg/application) [section 3.1.3].

The number of months urea and non-urea was applied (application times) is required to estimated embodied $CO_2$ emissions associated with spreading of inorganic fertilisers. For urea fertilisers, the number of application times is estimated as the number of months that had at least one application of urea N. Multiple entries within a month was counted as one application time. A similar approach was used for non-urea fertilisers. For crop blocks, it was only calculated for the reporting year.

## 3.4. Importing fertiliser products from previous OVERSEER versions

In earlier versions, fertiliser applications were entered on an annual basis. The amount of N applied in winter or P applied in high-risk months could also be entered. When information has been entered as fertiliser products applied yearly into previous version of OVERSEER (prior to version 6.0), it is difficult to know how to allocate to monthly applications. Therefore, there is an option to keep data as is and a default allocation is used, or the applications can be allocated to months manually. Currently only N and P need to be known on a monthly basis for other sub-models.

In allocating N, it is assumed that winter N, defined as N applied in May, June and July, is applied in June, and that non-winter N is applied first in spring then in autumn at the same application rate, see equations below.

*Equation 30:* $FertNtype_{Nform, 9} = AppRate$ if $NoApplications > 0$

*Equation 31:* $FertNtype_{Nform, 10} = AppRate$ if $NoApplications > 1$

*Equation 32:* $FertNtype_{Nform, 11} = AppRate$ if $NoApplications > 2$

*Equation 33:* $FertNtype_{Nform, 4} = AppRate$ if $NoApplications > 3$

*Equation 34:* $FertNtype_{Nform, 8} = AppRate$ if $NoApplications > 4$

*Equation 35:* $FertNtype_{Nform, 3} = AppRate$ if $NoApplications > 5$

NoApplications is the number of applications [Equation 38].

AppRate is the application rate for a given form of N [Equation 36].

The number at the end of $FertNtype_{Nform}$ refers to the months of the year.

The application rate for each form of the nutrient is estimated as:

*Equation 36:* $AppRate_{Nform} = NonWinterN_{form} / NoApplications$

NonWinterN is the amount of N applied outside of winter (kg N/ha/year) [Equation 37].

NoApplications is the number of applications [Equation 38].

where is the amount of N applied outside of winter is estimated as:

*Equation 37:* $NonWinterN_{form} = rate_{form, N} * (1 - ratio)$

$rate_{form, N}$ is calculated as previously described [section 3.1.2].

$ratio = WinterN / Fert_N$

WinterN is the amount of N applied in winter (kg N/ha/year), an input from older versions of *Overseer*.

$Fert_N$ (kg N/ha/year) is calculated as for fertiliser products.

and the number of applications is estimated as:

*Equation 38:* $NoApplications = INTEGER(NonWinterN / 35)$

35 kg N/ha was assumed to be an average application rate of N.

The number of applications is restricted such that they are greater than one if non-winter N is greater than zero, and has a maximum value of 6.

P entered as applied in high-risk months is assumed to be applied in June, as that month is common to all monthly risk categories as described by McDowell *et al.* (2005) and the remainder in October as that avoids all high-risk periods, except the West Coast, which is high risk in all months.

*Equation 39:* $FertPtype_{Pform, 6} = (rate_{form, P}) * ratio$

*Equation 40:* $FertPtype_{Pform, 10} = (rate_{form,P}) * (1 - ratio)$

$rate_{form, P}$ is calculated as previously described [section 3.1.2].

ratio = HighRiskP / $Fert_P$

HighRiskP is the amount of P added in high risk months (kg P/ha/year) and is an input from older versions of OVERSEER.

$Fert_P$ (kg P/ha/year) calculated as for fertiliser products.

# 4. Lime

Lime (calcium and magnesium carbonates) can be added in the year it is applied, by entering the material, amount (tonnes, kg/ha, kg), and whether it dissolves within one year. Agriculture lime may take 18 months to 2 years to dissolve (Carey and Metherell, 2002). In addition, the effects of lime on pasture Mg concentrations can be seen for up to five years after application (see Characteristics of pasture chapter of the Technical Manual). Hence, lime can also be entered as having been applied in previous years using the same inputs as for the year of application, plus years since lime was applied.

The nutrients added when lime is applied in the reporting year can be estimated from rates and nutrient concentrations in the lime. The amount of lime that dissolves and remains undissolved in the year of application is also estimated. In the year following application, the amount of the undissolved lime from year 1 that becomes available (dissolves) is estimated. From this, the change in nutrients in the soil mineral pool from lime that dissolves, or lime that dissolves in years after application can be estimated. Nutrients from lime that dissolve are added to the plant available inorganic pool.

## 4.1. Applied rates

The amount of lime added (kg lime/ha/month) is estimated as:

*Equation 41:* LimerateApp = LimeAdded * unitfactor

LimeAdded is the entered lime rate (T, kg or kg/ha).

Unitfactor is a conversion factor based on selected units [Equation 1].

The amount of lime added to the fertiliser pool (LimerateAdd, kg lime/ha/application) is the amount of lime applied in the reporting year. Thus if the year of application is the reporting year, then:

*Equation 42:* LimeRateAdd = LimerateApp

otherwise LimerateAdd is zero.

### 4.1.1. Lime dissolution and recovery

Carey and Metherell (2002) summarised that dissolution of lime can take up to two years based on soil-exchangeable Ca concentrations in the topsoil, and that in large applications of lime, not all the Ca is recovered in the soil. Based on Carey and Metherell (2002) and an Excel spread sheet supplied by Carey (pers. comm.), two factors were modelled, namely:

- lime dissolution rate, which defines the amount of lime applied that dissolves each year (section 4.1.2). This results in dissolved and undissolved lime fractions.
- lime recovery factor (LRF), which is a measure of the amount of lime found in the soil profile after application (section 4.1.3). This results in recovered and unrecovered lime fractions.

The lime recovery factor and dissolution rates are based on limited data (Carey and Metherell, 2002).

Nutrients in lime that dissolves and is recovered is added to the soil inorganic plant available pool (Technical Note No 6, 2013). Nutrients in undissolved lime is added to the soil inorganic mineral pool in the year of application, and released to the plant available pool in the year after application. Similarly, unrecovered lime is added to the soil mineral pool in the year of application, but in contrast is not released to the plant available pool in subsequent years after application.

If lime dissolves in year of application (user selection) or the application rate is less than 500 kg/ha, then all lime is dissolved, but only some is recovered. Thus, the amount of lime that is added to the soil inorganic mineral pool (LimeRateUnDiss, kg lime/ha) is estimated as:

*Equation 43:* LimeRateUnDiss = LimerateApp * (1 – LRF)

LimerateApp is the applied lime rate (kg/ha) [Equation 41].

LRF is the lime recovery factor [Equation 47].

Otherwise, in the year of application, some lime remains undissolved, and some of the dissolved lime is not recovered. Thus:

*Equation 44:* LimeRateUnDiss = LimerateApp * (1 - LimeDissRate)
+ LimerateApp * LimeDissRate * (1 - LRF)

LimeDissRate is the lime dissolution rate [Equation 46].

LRF is the lime recovery factor [Equation 47].

For lime applied in the previous year, the undissolved lime becomes available although not all is recovered in the soil inorganic mineral pool. The change in soil inorganic mineral pool is negative as the pool is decreasing in size. Thus:

*Equation 45:* LimeRateUnDiss = - LimerateApp * LimeDissRate * LRF

LimerateApp is the applied lime rate in the previous year (kg/ha) [Equation 41].

LimeDissRate is the lime dissolution rate for the previous year [Equation 46].

LRF is the lime recovery factor [Equation 47].

#### 4.1.2. Lime dissolution rate

It is assumed that at low lime rates (500 kg/ha/application), all lime is dissolved. At higher rates, the user can indicate that all lime dissolves within one year. It is assumed that the lime dissolution rate is independent of rate, quality, and type (for example, dolomite vs. lime). The lime dissolution rate is thus estimated as:

*Equation 46:* LimeDissRate = 1 rate is less than 500 kg/ha
= 1 lime dissolves within year is selected
= 0.67 year of application is reporting year
= 0.33 applied previous year
= 0 otherwise

#### 4.1.3. Lime recovery factor

It is assumed that LRF is independent of quality and type of lime (for example, dolomite vs. lime) but varies with rate as indicated by Carey and Metherell (2002). Thus:

*Equation 47*: LRF = 1 if LimerateApp < 2500 kg/ha
= 0.5 if LimerateApp > 7500 kg/ha
= 1 – (LimerateApp – 2500) /10000 otherwise
LimerateApp is the amount of lime added (kg/ha/application) [*Equation 41*].
1000 conversion kg to tonnes.

#### 4.1.4. Nutrients applied

For each nutrient, the amount of nutrients applied when lime is applied is added to the fertiliser pool is estimated as:

*Equation 48:* $LimeAddApp_{nut} = LimeRateAdd * Clime_{nut} / 100$
LimeRateAdd is the amount of lime added (kg/ha) [Equation 42].
Clime is the concentration of nutrient (%).

and to the soil mineral pool is estimated as:

*Equation 49:* $LimeDissApp_{nut} = LimeRateUnDiss * Clime_{nut} / 100$
LimeRateunDiss is the amount of lime moving in or out of the undissolved pool (kg/ha) [Equation 43, Equation 44 or Equation 45].
Clime is the contentration of nutrient (%).

Concentrations of nutrients in lime ($Clime_{nut}$) are the concentrations stored in an internal (Appendix 2) or a user defined lime database, except for acidity.

For acidity, Clime is based on deKlein *et al*. (1997) given that:

- four tonnes of pure lime applies 20 cmol/ha (deKlein *et al*., 1997)
- thus, based on 1 tonne per ha, 400 kg/ha Ca can neutralise 20 cmol/ha acidity
- thus 1 kg Ca neutralises 20/400 cmol/ha acidity

A similar approach is applied to Mg, assuming all Mg in lime is presence as $MgCO_3$, and one tonne of $MgCO_3$ contains 285 kg Mg. As lime decreases acidity, $Clime_{acidity}$ is negative. Given that 1 mol of $H^+$ is equivalent to 1 kg $H^+$, the rate of change in acidity (kg $H^+$/ha/kg lime) is estimated as:

*Equation 50:* $Clime_{acidity} = -(Clime_{Ca} / 20 + Clime_{Mg} / 14.2857) / 100$

$Clime_{Ca}$ and $Clime_{Mg}$ are the concentrations (%) of Ca and Mg respectively in the lime.

20 is based on 1 kg Ca in lime neutralising 20/400 cmol/ha acidity

14.2857 is based on 1 kg Mg in lime neutralising 20/285 cmol/ha acidity

100 converts from % to kg/kg

### 4.2. Outputs from lime sub-model

The amount of nutrients added when lime is applied and displayed in the nutrient budget is the LimerateApp for lime applied in the reporting year, i.e. it includes previous years' lime applications

*Equation 51:* $LimeAdd_{nut} = \sum_{application} LimeAddApp_{nut}$

*Equation 52:* $LimeDiss_{nut} = \sum_{application} LimeDissApp_{nut}$

The total amount of applied lime is used in the greenhouse gas sub-model to estimated embodied $CO_2$ emissions associated with spreading and transport of lime to a block is also estimated as:

*Equation 53:* $TotalLime_{block} = \sum_{application} LimerateApp$

LimerateApp is the rate of lime applied (kg/ha/application) [Equation 41].

The number of months lime is applied (number of application times) is required for the greenhouse gas sub-model to estimated embodied $CO_2$ emissions associated with spreading of lime. This is estimated as the number of months that had at least one applications of lime in the reporting year. Multiple entries within one month were counted as one application time. Previous years lime applications are not included.

## 5. Organic fertiliser

Similar to inorganic fertilisers, organic fertiliser require an estimate of the amount of nutrient applied. The weight of material is used to estimate embodied $CO_2$ emissions associated with spreading and transport or organic fertiliser.

Within the N sub-model, organic N concentration is required for estimating the decomposition of the organic component of the organic fertiliser. The inorganic component is treated similarly as inorganic fertiliser N. The determination of the concentration of organic and inorganic N requires the following information (user inputted and calculated internally):

- Nutrient load applied (kg nutrient/ha/month).
- N concentration of the organic fraction.
- Amount of inorganic N added (kg N/ha/month).

## 5.1. Effluent fertilisers

The following effluents can be applied to a block as a fertiliser:

- Imported dairy effluent (effluent form farm dairy and associated pads), where the user can select the form as either slurry/liquid or a solid.
- Imported piggery effluent, where the user can select the form as untreated, liquid after separation, or solids from separation or from ponds.
- Dairy factory effluents. These are the by-products from milk processing factories and are typically liquids with a low nutrient content.

The forms of imported dairy and piggery effluents are primarily used to define the nitrogen characteristics of the effluents.

### 5.1.1. Imported dairy and piggery effluent

Imported dairy effluent and piggery effluents are entered as a total loading of nutrient applied to the block (kg/application). The form (slurry, liquid, untreated) is also specified. The amount of nutrient added is estimated as

*Equation 54:* $OtherFertApp_{nut} = Effload_{nut} / area_{block}$

$Effload_{Nut}$ is entered loading (kg nutrient/application).

area is the block area (ha).

For dairy and piggery effluent, the contribution to acidity is estimated as:

*Equation 55:* $OtherFertApp_{acidity} = OtherFertApp_{P} * facidity$

$OtherFertApp_{P}$ is the amount of P added (kg P/ha/application) [Equation 54 for P].

facidity is a factor for estimating acidity contribution [Table 4, acidity column].

The amount of inorganic N (kg N/ha/month) is estimated as:

*Equation 56*: $InorgN = OtherFertApp_{N} * propInorgN$

$OtherFertApp_{N}$ is the amount of N added (kg N/ha/month) [Equation 54 for N].

propInorgN is the proportion of N that is inorganic [Table 4].

The weight of material transported and spread was ignored as it is assumed that imported dairy and piggery effluent is close by or is pumped, and hence there are no emissions associated with transport or spreading.

**Table 4: For each effluent source, the organic N concentration, proportion of total N that is inorganic and the acidity.**

| Source | Type | Organic N concentration (% of DM) | Proportion of N that is inorganic | Acidity factor |
|---|---|---|---|---|
| Dairy | Slurry/liquid | 2.5 | 0.25 | -0.230 |
| | Solid | 2.5 | 0.10 | -0.105 |
| Piggery | Untreated | 2.5 | 0.68 | -0.690 |
| | Liquid after separation | 2.5 | 0.56 | -0.690 |
| | Solids (from separator or ponds) | 0.5 | 0.12 | -0.105 |
| Dairy factory | | 2.5[1] | 0.80 | 0 |

[1] see Equation 60 for derivation.

### 5.1.2. Dairy factory effluent

Dairy factory effluents are entered as either a rate of nutrient (loading, kg nutrient/application) or volume (litres/ha/ application) of lactic acid whey, sulphuric acid whey, cheese whey or a user defined product.

If a loading is entered, then

*Equation 57:* $OtherFertApp_{Nut} = \sum_{application} (loading_{nut} / area_{block})$

$loading_{nut}$ is the nutrient loading (kg nutrient/application)

sarea is the block area (ha).

If the volume is entered and source selected then:

*Equation 58:* $OtherFertApp_{Nut} = \sum_{application}(volume * Cnut)$

volume is the entered volume of effluent applied (litres/ha/ application).

Cnut is the nutrient content of the selected whey, adjusted for units which are %, ug/ml, g/m3 or ppm if user defined or default % values as shown in Table 5.

The contribution to acidity is estimated as:

*Equation 59:* $OtherNutApp_{acidity} = OtherNut_{P} * facidity$

$OtherNut_{P}$ refers to [Equation 57] for phosphorus.

facidity is factor for estimating acidity contribution [Table 4 acidity column].

The organic N concentration for dairy factory effluent was based on Parkin *et al*. (1985) who reported that 40,000 litres supplied 56 kg of N. Assuming a DM content of 5.6%, and that all organic N was in the solids, then the organic N content (%) was estimated as:

*Equation 60:* $orgN = 56 / (40000 * 0.056) * 100$

to give 2.5%, as shown in Table 4.

The weight of dairy effluent transported and spread at each application (OtherWeightApp, kg/ha/application) when nutrient loading data is entered is estimated as:

*Equation 61:* $\text{OtherWeightApp} = \text{loading}_N / 0.0014 / \text{area}_{block}$

$\text{Loading}_N$ is the N loading (kg N/application)

0.0014 is the average nutrient content of wheys (kg/kg effluent) [Table 5].

area is the block area (ha).

otherwise if the volume is entered and source selected then:

*Equation 62:* $\text{OtherWeightApp} = \text{loading}_{nut} * 5.6 / 100$

volume is the volume applied (litres/ha/ application).

5.6 is the estimated DM content (%) [Parkin *et al*., 1985].

### 5.1.3. Dairy factory effluent nutrient contents

Dairy factory effluents are added as fertiliser substitutes. There are three effluents defined in the internal database, and these are based on a manufacturing process (Table 5). These values were derived by dividing the amount of nutrient applied (kg nutrient/ha) by litres applied as given by Parkin *et al*. (1985), and assuming 1 litre of effluent weighs 1 kg.

However, most factories use a combination of processes and hence user-defined concentrations or using the loading option is often more reliable.

**Table 5: Nutrient contents (percentage of wet weight) of dairy factory effluents in the internal database.**

| Name | N | P | K | S | Ca | Mg | Na | Cl |
|---|---|---|---|---|---|---|---|---|
| Lactic acid whey | 0.14 | 0.065 | 0.15 | 0.015 | 0.125 | 0.01 | 0.043 | 0 |
| Sulphuric acid whey | 0.13 | 0.063 | 0.15 | 0.088 | 0.105 | 0.01 | 0.038 | 0 |
| Cheese whey | 0.15 | 0.04 | 0.15 | 0.015 | 0.048 | 0.01 | 0.055 | 0 |

### 5.1.4. Dairy factory irrigation

Dairy factory effluent can be added as irrigation or as organic fertiliser. To improve consistency between the sub-models, the amount of water added is included as input in the hydrology sub-model. Given that 1 litre/ha is equivalent to 0.0001 mm, or conversely, 1 mm is the same as 1 litre/$m^2$, then if the rate of application is entered then the amount of water applied (mm/application) is:

*Equation 63:* $\text{IrrApplied}_{mon} = \sum_{application}(\text{volume}_{application} / 10000$

volume is the entered rate (litres/ha/application).

Otherwise, the amount of water applied is based on K and N concentrations

*Equation 64:* $\text{IrrApplied}_{mon} = (\text{OtherFertN} / \text{area}_{block} / 0.0014 / 10000 + \text{OtherFertK} / \text{area}_{block} / 0.0015 / 10000) / 2$

OtherFertN and OtherFertK is the entered nutrient loading for N and K (kg nutrient).

0.0014 and 0.0015 is the average N and K contents of wheys (kg/kg effluent applied) [derived from Table 5].

## 5.2. Other organic fertilisers

Other organic fertilisers are split into two categories, composts/mulches and other organic fertilisers. The methodologies are similar for both. The main difference between the two is that the composts are assumed to be entirely organic material, whereas other organic fertilisers can be a mix of organic and inorganic components.

### 5.2.1. Amounts

The amount of material applied at each application is estimated for both wet weight and dry weight basis. Thus, the amount of wet weight (kg WW/ha/application) is estimated as:

*Equation 65:* $wetweight = rate * 1000/area$
rate is the entered wet weight of material applied (tonnes).
1000 converts tonnes to kgs.
area is the block aerea (ha).

and the amount of dry weight (kg DW/ha/application) as:

*Equation 66:* $weight = wetweight * DMcontent / 100$
DMcontent is the entered DM content (%).

### 5.2.2. Nutrients

For composts, and other organic fertilisers, the amount of nutrient added per application is estimated as:

*Equation 67:* $OtherFertAppn_{ut} = weight * C_{nut} / 100$
weight is the applied dry weight (kg DW/ha/application) [Equation 66].
Cnut is the entered concentration of nutrients on a dry weight basis (%).

For composts, it is assumed that all N is in the organic form. Hence, the concentration of N in the organic form is assumed to the same as the entered N concentration. Thus:

*Equation 68:* $OrgN = C_N$
$C_N$ is entered concentration of nitrogen (%).

Given that all N is in the organic form, the amount of inorganic N added with compost is zero.

For other organic material, the user enters the percentage of N in the inorganic form, and hence the amount of inorganic N (kg N/ha/application) can be estimated as:

*Equation 69:* $InorgN = OtherFertApp_N * CInorgnicN / 100$
$OtherFertApp_N$ is the amount of N applied (kg N/ha/application) [Equation 67].
CInorgnicN is the entered percentage of N in the inorganic form (%).
100 converts % to kg/kg.

## 5.3. Atmospheric N losses

The amount of N loss to the atmosphere as volatilisation during application of organic fertilisers is estimated for each application as:

*Equation 70:* $\text{Volat} = \text{OtherFertApp}_N * \text{kNlossvolat}$

$\text{OtherFertApp}_N$ is the amount of N applied as organic fertiliser (kg N/ha/application) [Equation 54, Equation 57, Equation 58, or Equation 67].

kNlossvolat [Table 6].

Dairy effluent in the slurry/liquid from is assumed to be sprayed onto paddocks and hence the volatilisation losses are based on the emission factor for volatilisation of farm dairy effluent during the spraying process (Effluent management chapter of Technical Manual, in preparation). Piggery effluent compared to dairy effluent has a higher proportion of N in $NH_4$ and less in the organic N form that dairy effluent, and the pH is higher (Laurenson *et al*., 2006; Smith 2001). Total volatilisation losses of piggery effluent were slightly higher than that from urea fertiliser (Wheeler 2007), and higher than that from dairy effluent (Laurenson *et al*., 2006). No information was found on losses during the spraying process. Hence, it was assumed that spray volatilisation losses were about twice that of dairy effluent for untreated pig effluent and the same as dairy effluent if separated liquids are sprayed on. It is assumed that solids are applied direct to the soil and hence there are no spray losses.

It is assumed that denitrification, and nitrous oxide losses emissions during application are negligible and hence are ignored. Atmospheric N losses after application to the soil are covered in the Nitrous Oxide chapter of the Technical Manual. OVERSEER assumes that organic materials are not stored on the farm prior to use. If this were occurring, then the amount of N that is added to the soil would be over-estimate.

**Table 6: Emission factors for volatilisation from organic fertilisers.**

| Source | Type | Volatilisation |
|---|---|---|
| Dairy | Slurry/liquid | 0.02 |
| | Solid | 0 |
| Piggery | Untreated | 0.04 |
| | Liquid after separation | 0.02 |
| | Solids (from separator or ponds) | 0 |
| Dairy factory | | 0 |
| Composts | | 0 |
| Other organic | | 0 |

## 5.4. Outputs from organic fertiliser sub-model

The total amount of nutrient applied per year from organic fertilisers is estimated as:

*Equation 71:* $\text{OtherFert}_{nut} = \sum_{application}(\text{OtherFertApp}_{nut})$

$\text{OtherFertApp}_{nut}$ is the amount of nutrient applied as organic fertiliser (kg nutrient/ha/application) [Equation 54, Equation 57, Equation 58, or Equation 67].

In addition, for imported dairy and pig effluent, the amount of nutrient in each effluent form

*Equation 72:* $ImportDairy_{block,\ effluentForm,\ nut} = OtherFert_{nut}$

*Equation 73:* $ImportPig_{block,\ effluentForm,\ nut} = OtherFert_{nut}$

$OtherFertApp_{nut}$ is the amount of nutrient applied as organic fertiliser (kg nutrient/ha/application) [Equation 54, Equation 57, Equation 58, or Equation 67] for the given effluent form.

The total losses of N as volatilisation, denitrification, and nitrous oxide from organic fertilisers are estimated for each block (kg N/ha/year) as:

*Equation 74:* $OtherVolatloss = \sum_{application} Volat$

*Equation 75:* $OtherDenitloss = \sum_{application} Denit$

*Equation 76:* $OthernitOx = \sum_{application} NitOx$

Volat, denit and NitOx are the losses of N to atmosphere as volatilsiation, denitrification and nitroux oxide [Equation 68, Equation 69, Equation 70 respectively].

The amount of inorganic and organic N added to the ground each month is required as part of the background N sub-model. First, it is assumed that atmospheric N loses first come from the inorganic pool. Thus for each application:

*Equation 77:* $Addinorg = InorgN - Volatloss - Denitloss – NitOx$

*Equation 78*: $Addorg = (Fert[Nitrogen] - InorgN)$

If Addinorg is less than zero, it is assumed that the N losses must have also come from the organic pool. Thus:

*Equation 79*: $Addorg = Addorg - Addinorg$

and Addinorg is set to zero. The organic and inorganic N from organic fertilisers is then accumulated for each block for each month (kg N/ha/month), that is:

*Equation 80:* $OtherInorgN_{mon} = \sum_{application} Addinorg$

*Equation 81*: $OtherOrgN_{mon} = \sum_{application} Addorg$

In the background N sub-model, the slow release component of organic fertiliser is based on the crop sub-model. The release rate is governed by the term ko (Cichota *et al*., 2010). Rather than track all the organic materials that may be applied, a weighted average release rate for each block is estimated for each month organic material is applied.

*Equation 82:* $ko\_other_{mon} = stoverko_{mon} / OtherOrgN_{mon}$

$OtherOrgN_{mon}$ is the amount of organic N added to the soil (kg N/ha/month) Equation 81].

where

*Equation 83:* $Stoverko_{mon} = \sum_{application} ((a\_Stover * NconcOrg / 100) * Addorg$

a_Stover is a constant from the crop sub-model [Cichota *et al*., 2010].

NconcOrg is the concentration of N in the organic fraction of the applied organic fertiliser (%).

100 converts % to kg/kg.

Addorg is the amount of organic N added to the soil (kg N/ha/application) [Equation 78 or Equation 79].

Finally, the total weight of organic fertiliser (kg/ha) is used to estimate the embodied $CO_2$ emissions for transporting and spreading organic fertiliser. The wet weight is required to give:

*Equation 84:* $OtherWeight_{block} = \sum_{application} wetweight$

Wetweight is the wet weight (kg/application) [Equation 65].

The number of times organic fertiliser is applied to each block is taken as the number of applications entered. Multiple entries within a month are counted as separate applications.

## 6. References

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# Appendices

## Appendix 1: Fertiliser database

The fertiliser database contains fertiliser products for which chemical composition and form was supplied by the supplier.  The lists are divided into categories based on the manufacturer/supplier, and general type (superphosphate based, cropping and other or general). The forms are defined in Table 7.

**Table 7: Nutrient forms available within OVERSEER and the form reference number for Table 8.**

| Nutrient | Form | Form reference number |
|---|---|---|
| N | Urea | 1 |
| | DAP | 2 |
| | Other $NH_4$ forms | 3 |
| | $NO_3$ forms | 4 |
| | Mixed forms | 5 |
| P | Super | 1 |
| | DAP / DCP | 2 |
| | Rock | 3 |
| | Other | 4 |
| Mg | Serpentine | 1 |
| | Magnesium oxide | 2 |
| | Dolomite | 3 |
| | Other | 4 |
| S | Elemental | Enter as % of S that is in the elemental form |

**Table 8: Fertiliser products listed in the OVERSEER internal database and their nutrient contents and form. The numbers for form are shown in Table 7.**

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental sulphur (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | |
| **Ravensdown super** | | | | | | | | | | | | |
| Superphosphate | 0 | 9 | 0 | 11 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Copper super 25 kg | 0 | 8.8 | 0 | 11 | 19.5 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Cobalt super 1 kg | 0 | 9 | 0 | 11 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Moly super 250g | 0 | 9 | 0 | 11 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Moly super 500g | 0 | 9 | 0 | 11 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Moly Sulphur super 30 250g | 0 | 7 | 0 | 30.1 | 16 | 0 | 0 | 0 | 0 | 1 | 0 | 70 |
| Moly Sulphur super 30 500g | 0 | 7 | 0 | 30.1 | 16 | 0 | 0 | 0 | 0 | 1 | 0 | 70 |
| Selenium Super 2kg | 0 | 9 | 0 | 11 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Magnesium super | 0 | 8.3 | 0 | 10.1 | 18.4 | 4.2 | 0 | 0 | 0 | 1 | 2 | 0 |
| Serpentine super | 0 | 6.7 | 0 | 8.6 | 15 | 5.5 | 0 | 0 | 0 | 1 | 1 | 0 |
| Nitrogen super | 6.2 | 6.3 | 0 | 14.9 | 14 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| Sulphur super 15 | 0 | 8.6 | 0 | 14.8 | 19.2 | 0 | 0 | 0 | 0 | 1 | 0 | 28 |
| Sulphur super 20 | 0 | 8 | 0 | 20.6 | 18 | 0 | 0 | 0 | 0 | 1 | 0 | 51 |
| Sulphur super 30 | 0 | 7 | 0 | 30.1 | 16 | 0 | 0 | 0 | 0 | 1 | 0 | 70 |
| Maxi sulphur super | 0 | 5.1 | 0 | 47 | 11 | 0 | 0 | 0 | 0 | 1 | 0 | 87 |
| Sulphur 90 | 0 | 0 | 0 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 10% potash super | 0 | 8.1 | 5 | 9.9 | 18 | 0 | 0.1 | 4.8 | 0 | 1 | 0 | 0 |
| 15% potash super | 0 | 7.7 | 7.5 | 9.4 | 17 | 0 | 0.2 | 7.2 | 0 | 1 | 0 | 0 |
| 15% potash serpentine super | 0 | 5.7 | 7.5 | 7.3 | 12.8 | 4.7 | 0.2 | 7.2 | 0 | 1 | 1 | 0 |
| 15% potash sulphur super | 0 | 6.8 | 7.5 | 17.5 | 15.3 | 0 | 0.2 | 7.2 | 0 | 1 | 0 | 51 |
| 20% potash super | 0 | 7.2 | 10 | 8.8 | 16 | 0 | 0.2 | 9.6 | 0 | 1 | 0 | 0 |
| 20% potash serpentine super | 0 | 5.4 | 10 | 6.9 | 12 | 4.4 | 0.2 | 9.6 | 0 | 1 | 1 | 0 |
| 20% potash sulphur super | 0 | 6.4 | 10 | 16.4 | 14.4 | 0 | 0.2 | 9.6 | 0 | 1 | 0 | 51 |
| 30% potash super | 0 | 6.3 | 15 | 7.7 | 14 | 0 | 0.4 | 14.4 | 0 | 1 | 0 | 0 |
| 30% potash serpentine super | 0 | 4.7 | 15 | 6 | 10.5 | 3.9 | 0.4 | 14.4 | 0 | 1 | 1 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental sulphur (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | |
| 30% potash sulphur super | 0 | 5.6 | 15 | 14.4 | 12.6 | 0 | 0.4 | 14.4 | 0 | 1 | 0 | 51 |
| 50% potash super | 0 | 4.5 | 25 | 5.5 | 10 | 0 | 0.6 | 24 | 0 | 1 | 0 | 0 |
| Lucerne mix + TE | 0 | 5.5 | 14.7 | 13.2 | 12.4 | 0 | 0.4 | 14.1 | 0 | 1 | 0 | 48 |
| Super boost | 5.1 | 6.8 | 0 | 14.3 | 15 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| Hi-Gro | 6.4 | 5 | 6.5 | 13.6 | 11.2 | 0 | 0.2 | 6.2 | 3 | 1 | 0 | 0 |
| Multicrop | 5.5 | 5.7 | 5 | 13.4 | 12.6 | 0 | 0.1 | 4.8 | 3 | 1 | 0 | 0 |
| Dairy pasture boost 4 | 4.1 | 6.5 | 4 | 12.7 | 14.4 | 0 | 0.1 | 3.8 | 3 | 1 | 0 | 0 |
| Dairy pasture boost 6 | 4.1 | 6.1 | 6 | 12.3 | 13.6 | 0 | 0.1 | 5.8 | 3 | 1 | 0 | 0 |
| Dairy pasture boost 10 | 4.1 | 5.4 | 10 | 11.4 | 12 | 0 | 0.2 | 9.6 | 3 | 1 | 0 | 0 |
| Dairy pasture boost 12 | 4.1 | 5 | 12 | 11 | 11.2 | 0 | 0.3 | 11.5 | 3 | 1 | 0 | 0 |
| Ravensdown pasture 6 | 5.6 | 5.5 | 6 | 13.2 | 12.1 | 0 | 0.1 | 5.8 | 3 | 1 | 0 | 0 |
| Super mag N | 6.9 | 5.7 | 0 | 7.3 | 12.8 | 4.7 | 0 | 0 | 1 | 1 | 1 | 0 |
| 15% potash super mag N | 5.9 | 4.8 | 7.5 | 6.2 | 10.8 | 4 | 0.2 | 7.2 | 1 | 1 | 1 | 0 |
| 20% potash super mag N | 5.5 | 4.6 | 10 | 5.8 | 10.2 | 3.7 | 0.2 | 9.6 | 1 | 1 | 1 | 0 |
| 35% potash Gold super 0-6-15 | 0 | 5.9 | 14.5 | 13.5 | 13 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Hautuma dicalcic super | 0 | 4.1 | 0 | 5.1 | 28.6 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Dicalcic High S | 0 | 4.2 | 0 | 9.3 | 26.9 | 0 | 0 | 0 | 0 | 2 | 0 | 44 |
| Lime revertd super | 0 | 6.8 | 0 | 8.3 | 24 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| **Ravensdown cropping** | | | | | | | | | | | | |
| Ravensdown 12-10-10 | 12 | 8.8 | 10 | 0.4 | 4.6 | 1.2 | 0 | 0 | 5 | 4 | 4 | 0 |
| Nitrophoska blue T.E. 12-5-14 | 12 | 5.2 | 14.1 | 9 | 5 | 1.2 | 0 | 0 | 5 | 4 | 4 | 0 |
| Nitrophoska blue extra 12-5-14 | 12 | 5.2 | 14 | 8 | 5 | 1.2 | 0 | 0 | 5 | 4 | 4 | 0 |
| Nitrophoska perfekt | 15 | 2.2 | 16.6 | 8 | 1.8 | 1.2 | 0 | 0 | 5 | 4 | 4 | 0 |
| Nitrophoska blue T.E. + B + Mg | 10.5 | 4.6 | 12.3 | 9 | 4.4 | 2.6 | 0 | 0 | 5 | 4 | 4 | 0 |
| Nitrophoska blue T.E. + kieserite | 9.2 | 4 | 10.9 | 10.8 | 3.9 | 4.4 | 0 | 0 | 5 | 4 | 4 | 0 |
| Premium 18 | 18 | 10 | 0 | 12 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Entec special | 12 | 5.2 | 14 | 6 | 5 | 1.2 | 0 | 0 | 5 | 4 | 4 | 0 |
| Entec 26 | 26 | 0 | 0 | 13 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Cuttings avocado regular | 9.7 | 3.6 | 13.6 | 9.2 | 3.5 | 3.5 | 0 | 0 | 5 | 4 | 4 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | sulphur (%) |
| Cuttings avocado young | 14 | 3.7 | 11.9 | 4.5 | 5.4 | 1.6 | 0 | 0 | 5 | 4 | 4 | 0 |
| Citrus 12-5-5 | 12.2 | 4.5 | 4.5 | 6.2 | 4.1 | 5 | 0 | 0 | 5 | 4 | 4 | 0 |
| Citrus 19-2-0 | 18.9 | 2 | 0 | 4.1 | 7.2 | 3 | 0 | 0 | 5 | 1 | 4 | 0 |
| Olive tree mix | 10 | 4.3 | 14.2 | 8.8 | 3.4 | 2.3 | 0 | 0 | 5 | 4 | 4 | 0 |
| Cropmaster DAP | 17.6 | 20 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Cropmaster 11 | 10.6 | 12 | 20 | 0.6 | 0 | 0 | 0.5 | 19.2 | 2 | 2 | 0 | 0 |
| Cropmaster 13 | 12.3 | 14 | 15 | 0.7 | 0 | 0 | 0.4 | 14.4 | 2 | 2 | 0 | 0 |
| Cropmaster 15 | 15 | 10 | 10 | 7.7 | 0 | 0 | 0.2 | 9.6 | 2 | 2 | 0 | 0 |
| Cropmaster 16 high K | 15.4 | 7 | 22.5 | 0.4 | 0 | 0 | 0.5 | 21.6 | 1 | 2 | 0 | 0 |
| Cropmaster 20 | 19.1 | 10 | 0 | 12.5 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Cropmaster DAP Boron plus | 16.4 | 18.6 | 0 | 0.9 | 0 | 0.5 | 0 | 0 | 2 | 2 | 2 | 0 |
| Cropmaster brassica | 14.1 | 16 | 10 | 0.8 | 0 | 0 | 0.2 | 9.6 | 2 | 2 | 0 | 0 |
| Cropmaster brassica + boron | 13.6 | 15.4 | 9.5 | 0.8 | 0 | 0 | 0.2 | 9.1 | 2 | 2 | 0 | 0 |
| Ammo-Phos MAP | 11 | 22 | 0 | 1 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 |
| Ammo-Phos/hycrop 8-15-15 | 7.7 | 15.4 | 15 | 0.7 | 0 | 0 | 0.4 | 14.4 | 3 | 2 | 0 | 0 |
| Ammo-Phos/hycrop 9-19-7 | 9.4 | 18.7 | 7.5 | 0.9 | 0 | 0 | 0.2 | 7.2 | 3 | 2 | 0 | 0 |
| Ammo-Phos Pea Fertiliser | 7.7 | 15.4 | 15 | 0.7 | 0 | 0 | 0.4 | 14.4 | 3 | 2 | 0 | 0 |
| Ammo 31 | 30.7 | 0 | 0 | 14.4 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Ammo 36 | 35.8 | 0 | 0 | 9.6 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 0 |
| Brassica base 1/2 SOP | 10.7 | 5.9 | 7.5 | 13.7 | 4.3 | 0.9 | 0.1 | 3.8 | 3 | 2 | 4 | 0 |
| Early potato base | 11.4 | 7.9 | 6.7 | 10.8 | 3.7 | 1.2 | 0.2 | 6.4 | 2 | 2 | 4 | 0 |
| Lawn fertiliser | 14.9 | 2.3 | 0 | 20.4 | 5 | 0 | 0 | 0 | 3 | 1 | 0 | 0 |
| **Ravensdown other** | | | | | | | | | | | | |
| Urea | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Ammonium sulphate | 20.5 | 0 | 0 | 24 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| Calcium ammonium nitrate (CAN) | 27 | 0 | 0 | 0 | 8 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| Calcium nitrate | 15.5 | 0 | 0 | 0 | 19 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| Low Biuret urea | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental sulphur (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | |
| Calcium sulphate (gypsum) | 0 | 0 | 0 | 18 | 23.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Potassium chloride | 0 | 0 | 50 | 0 | 0 | 0 | 1.2 | 48 | 0 | 0 | 0 | 0 |
| Potassium nitrate | 13 | 0 | 38 | 0 | 0 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| Potassium sulphate | 0 | 0 | 42 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Potash gold 8-15-13 | 7.7 | 15.4 | 12.5 | 6.1 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 |
| Potash gold 14-7-14 | 14.3 | 7 | 14.5 | 6.7 | 2.4 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Potash gold 15-10-10 | 14.3 | 10 | 9.5 | 11.1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Solupotasse (potassium sulphate soluble) | 0 | 0 | 42 | 18 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Magnesium oxide | 0 | 0 | 0 | 0 | 0 | 40 | 0 | 0 | 0 | 0 | 2 | 0 |
| Magnesium nitrate | 10.5 | 0 | 0 | 0 | 0 | 9.4 | 0 | 0 | 4 | 0 | 4 | 0 |
| Magnesium sulphate (Bittersalz, epsom salt) | 0 | 0 | 0 | 13 | 0 | 9.9 | 0 | 0 | 0 | 0 | 4 | 0 |
| Kieserite | 0 | 0 | 0 | 20 | 0 | 15 | 0 | 0 | 0 | 0 | 4 | 0 |
| Dolomite | 0 | 0 | 0 | 0 | 23 | 11 | 0 | 0 | 0 | 0 | 0 | 0 |
| Ferrous sulphate | 0 | 0 | 0 | 11.5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Gypsum | 0 | 0 | 0 | 18 | 23.3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Salt (sodium chloride) | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 60.3 | 0 | 0 | 0 | 0 |
| Triple super (TSP) | 0 | 20.5 | 0 | 1 | 16 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Ben Guerir reactive phosphate rock (RPR) | 0 | 14.1 | 0 | 0 | 36.2 | 0 | 0 | 0 | 0 | 3 | 0 | 0 |
| RPR 15 S | 0 | 10.6 | 0 | 15.1 | 26.1 | 0 | 0 | 0 | 0 | 3 | 0 | 70 |
| RPR/sulphur super | 0 | 11.3 | 0 | 12 | 28.1 | 0 | 0 | 0 | 0 | 3 | 0 | 70 |
| Mono potassium phosphate | 0 | 22.6 | 28.7 | 0 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Mono ammonium phosphate | 13 | 26 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 2 | 0 | 0 |
| DAP 13 S | 10.6 | 14.8 | 0 | 12.6 | 6.4 | 0 | 0 | 0 | 2 | 2 | 0 | 67 |
| Flexi-N | 41.4 | 0 | 0 | 0 | 0 | 5.2 | 0 | 0 | 1 | 0 | 2 | 0 |
| Flexi-N lift | 6.2 | 7.7 | 0 | 9.4 | 17 | 0.8 | 0 | 0 | 1 | 1 | 2 | 0 |
| Flexi-N Komplete | 6.6 | 6.4 | 6.5 | 7.8 | 14.2 | 0.8 | 0.2 | 6.2 | 1 | 1 | 2 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | sulphur (%) |
| Flexi-N high SDrought buster | 6.6 | 7.2 | 0 | 12.4 | 16.1 | 0.8 | 0 | 0 | 1 | 1 | 2 | 28 |
| **Ballance super** | | | | | | | | | | | | |
| Superten | 0 | 9 | 0 | 10.5 | 22 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superten 5K (10% potash superten) | 0 | 8.1 | 5 | 9.4 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superten 7K (15% potash superten) | 0 | 7.6 | 7.5 | 8.9 | 19 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superten 10K (20% potash superten) | 0 | 7.2 | 10 | 8.4 | 18 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superten 15K (30% potash superten) | 0 | 6.3 | 15 | 7.3 | 15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superten 25K (50% potash superten) | 0 | 4.5 | 25 | 5.2 | 11 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Sulphur gain 15S | 0 | 8.5 | 0 | 14.7 | 21 | 0 | 0 | 0 | 0 | 1 | 0 | 25 |
| Sulphur gain 20S | 0 | 8.1 | 0 | 20 | 20 | 0 | 0 | 0 | 0 | 1 | 0 | 45 |
| Sulphur gain 30S | 0 | 7 | 0 | 29.5 | 17 | 0 | 0 | 0 | 0 | 1 | 0 | 60 |
| Sulphur gain pure | 0 | 0 | 0 | 90 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| 15% potash sulphur super | 0 | 6.8 | 7.5 | 17 | 17 | 0 | 0 | 0 | 0 | 1 | 0 | 25 |
| 20% potash sulphur super | 0 | 6.4 | 10 | 16 | 16 | 0 | 0 | 0 | 0 | 1 | 0 | 35 |
| 30% potash sulphur super | 0 | 5.6 | 15 | 14 | 14 | 0 | 0 | 0 | 0 | 1 | 0 | 45 |
| 50% potash sulphur super | 0 | 4 | 25 | 10 | 10 | 0 | 0 | 0 | 0 | 1 | 0 | 60 |
| Pasturezeal G2 5K | 9.4 | 5.9 | 5 | 6.9 | 15 | 1.2 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 10K | 7.5 | 5.4 | 10 | 6.3 | 14 | 0.9 | 0 | 0 | 1 | 1 | 2 | 0 |
| Pasturezeal G2 15K | 7.5 | 4.5 | 15 | 5.3 | 12 | 0.9 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 pumice | 5.6 | 5 | 12 | 11.2 | 13 | 0.7 | 0 | 0 | 1 | 1 | 1 | 50 |
| Pasturezeal G2 peat | 5.6 | 5 | 12 | 11.2 | 13 | 0.7 | 0 | 0 | 1 | 1 | 1 | 50 |
| Pasturezeal G2 impact | 12.1 | 6.2 | 0 | 7.2 | 16 | 1.5 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 equaliser | 7.5 | 7.2 | 0 | 8.4 | 18 | 0.9 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 boost | 9 | 6.9 | 0 | 8 | 18 | 1.1 | 0 | 0 | 1 | 1 | 1 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | sulphur (%) |
| Pasturezeal G2 balancer | 6.6 | 6.2 | 7 | 7.3 | 16 | 0.8 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 high S | 7.5 | 5.2 | 7.5 | 13.5 | 13 | 0.9 | 0 | 0 | 1 | 1 | 1 | 57 |
| Pasturezeal G2 hay & silage | 11.3 | 2.7 | 20 | 3.2 | 8 | 1.4 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 9S | 5.7 | 7.6 | 0 | 8.9 | 19 | 0.7 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturezeal G2 15S | 9.4 | 6.1 | 0 | 15 | 16 | 1.2 | 0 | 0 | 1 | 1 | 1 | 50 |
| Pasturemag | 6.9 | 5.7 | 0 | 7 | 14 | 4.2 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag 5K | 6.2 | 5.2 | 5 | 6.4 | 13 | 3.8 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag 7K | 5.8 | 4.9 | 7.5 | 6 | 12 | 3.6 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag 10K | 5.5 | 4.6 | 10 | 5.7 | 11 | 3.4 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag 15K | 4.8 | 4 | 15 | 4.9 | 10 | 2.9 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag 12N | 11.5 | 5.1 | 0 | 6.3 | 12 | 3.8 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag 16S | 6.2 | 5.2 | 0 | 15.9 | 13 | 3.8 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag peat | 6 | 5.2 | 6 | 10.9 | 13 | 2.7 | 0 | 0 | 1 | 1 | 1 | 0 |
| Pasturemag pumice | 6 | 5.2 | 6 | 10.9 | 13 | 2.7 | 0 | 0 | 1 | 1 | 1 | 0 |
| Serpentine super | 0 | 6.8 | 0 | 8.4 | 17 | 5 | 0 | 0 | 0 | 1 | 1 | 0 |
| Serpentine super 5K | 0 | 6.1 | 5 | 7.5 | 15 | 4.5 | 0 | 0 | 0 | 1 | 1 | 0 |
| Serpentine super 7K | 0 | 5.7 | 7.5 | 7.1 | 14 | 4.2 | 0 | 0 | 0 | 1 | 1 | 0 |
| Serpentine super 10K | 0 | 5.4 | 10 | 6.7 | 13 | 4 | 0 | 0 | 0 | 1 | 1 | 0 |
| Serpentine super 15K | 0 | 4.7 | 15 | 5.8 | 12 | 3.5 | 0 | 0 | 0 | 1 | 1 | 0 |
| Serpentine super 25K | 0 | 3.4 | 25 | 4.2 | 8 | 2.5 | 0 | 0 | 0 | 1 | 1 | 0 |
| **Ballance cropping** | | | | | | | | | | | | |
| Cropzeal 15P | 13.5 | 15 | 12.5 | 0.7 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Cropzeal 16N | 15.4 | 8 | 10 | 9.6 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Cropzeal 20N | 19.2 | 10 | 0 | 12 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Cropzeal 25K | 9 | 10 | 25 | 0.5 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Cropzeal brassica base | 5.7 | 4.7 | 7.2 | 5.9 | 12 | 3.5 | 0 | 0 | 1 | 1 | 1 | 0 |
| Cropzeal boron boost | 16.5 | 19.5 | 0 | 0.9 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| YaraBela can | 27 | 0 | 0 | 0 | 4 | 2 | 0 | 0 | 5 | 0 | 4 | 0 |
| YaraMila complex | 12.4 | 5.2 | 15 | 8 | 2.5 | 1.6 | 0 | 0 | 5 | 1 | 4 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental sulphur (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | |
| YaraLiva nitrabor | 15.5 | 0 | 0 | 0 | 19.2 | 0 | 0 | 0 | 4 | 0 | 0 | 0 |
| YaraMila 12-10-10 | 12.2 | 10.3 | 10.5 | 5 | 1 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| YaraMila 8-11-20 | 8 | 11 | 20 | 5 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| Crop fertiliser | 5.1 | 4.4 | 5 | 11.2 | 11 | 3.3 | 0 | 0 | 1 | 1 | 1 | 0 |
| **Ballance other** | | | | | | | | | | | | |
| N-rich urea | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| N-rich 15K | 32.2 | 0 | 15 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| N-rich 20K | 27.6 | 0 | 20 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| N-rich 25K | 23 | 0 | 25 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| N-rich ammo 30N | 30.4 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| N-rich ammo 36N | 36.2 | 0 | 0 | 9.6 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| N-rich ammo 40N | 39.6 | 0 | 0 | 5.8 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Coated urea | 38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| Triple superphosphate | 0 | 20.5 | 0 | 0 | 14 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superextra | 0 | 14.7 | 0 | 5.3 | 18 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Superextra 15S | 0 | 13.8 | 0 | 14.7 | 18 | 0 | 0 | 0 | 0 | 1 | 0 | 67 |
| Durasul | 0 | 0 | 0 | 95 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 100 |
| Muriate of potash | 0 | 0 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sulphate of Potash | 0 | 0 | 42 | 17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Sulphate of ammonia | 20.5 | 0 | 0 | 23 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 0 |
| DAP | 17.6 | 20 | 0 | 1 | 0 | 0 | 0 | 0 | 2 | 2 | 0 | 0 |
| DAP sulphur super | 10.8 | 14.9 | 0 | 12.4 | 7 | 0 | 0 | 0 | 2 | 2 | 0 | 20 |
| 20% potash DAP sulphur super | 8.6 | 11.9 | 10 | 9.9 | 6 | 0 | 0 | 0 | 2 | 1 | 0 | 20 |
| Lucerne starter | 0 | 5.2 | 11.5 | 14 | 13 | 1.9 | 0 | 0 | 0 | 1 | 1 | 0 |
| Lucerne maintenance | 0 | 6 | 11.8 | 14.7 | 15 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| Kieserite | 0 | 0 | 0 | 16 | 0 | 16 | 0 | 0 | 0 | 0 | 4 | 0 |
| Magphos | 0 | 8.1 | 0 | 9.5 | 20 | 5 | 0 | 0 | 0 | 1 | 4 | 0 |
| Calmag | 0 | 0 | 0 | 0 | 2 | 42 | 0 | 0 | 0 | 0 | 2 | 0 |
| Serpentine gold | 0 | 7 | 0 | 19 | 17 | 2.5 | 0 | 0 | 0 | 1 | 1 | 0 |

| Product | Nutrient Content (%) | | | | | | | | Form | | | Elemental sulphur (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | N | P | K | S | Ca | Mg | Na | Cl | N | P | Mg | |
| Salt (sodium chloride) | 0 | 0 | 0 | 0 | 0 | 0 | 39 | 0 | 0 | 0 | 0 | 0 |
| Hatuma dicalcic phosphate | 0 | 4.5 | 0 | 5.5 | 28 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| HDP #7 S | 0 | 4.3 | 0 | 10 | 27 | 0 | 0 | 0 | 0 | 2 | 0 | 50 |
| HDP #8 | 0 | 3.6 | 0 | 4.4 | 30 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| HDP #8 S | 0 | 3.6 | 0 | 8 | 30 | 0 | 0 | 0 | 0 | 2 | 0 | 50 |
| HDP #9 | 0 | 2.7 | 0 | 3.3 | 31 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| HDP #9 S | 0 | 2.7 | 0 | 6 | 31 | 0 | 0 | 0 | 0 | 2 | 0 | 50 |
| HDP #14 | 0 | 1.8 | 0 | 2.2 | 32 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| HDP #14 S | 0 | 1.8 | 0 | 4 | 32 | 0 | 0 | 0 | 0 | 2 | 0 | 50 |
| HDP #4 10 Salt | 0 | 2.7 | 0 | 3.3 | 27 | 3 | 3.9 | 0 | 0 | 2 | 0 | 0 |
| HDP #7 15 K | 0 | 4 | 7 | 5 | 24 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| HDP #7 30 K | 0 | 3 | 15 | 4 | 20 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Hatuma dairy/hayblend | 0 | 2.2 | 12.5 | 2.7 | 19 | 1.6 | 0 | 0 | 0 | 2 | 0 | 0 |
| Hatuma lucerne | 0 | 2 | 12.5 | 7 | 18 | 1.6 | 0 | 0 | 0 | 2 | 0 | 65 |
| Ballance DCP | 0 | 6 | 0 | 6.5 | 29 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Ballance Dicalcic pastoral | 0 | 4.5 | 0 | 4.7 | 30 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| SustaiN Green | 46 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| SustaiN S Boost | 39.8 | 0 | 0 | 8.6 | 1.7 | 0 | 0 | 0 | 1 | 0 | 100 | 0 |
| SustaiN ammo 30N | 29.8 | 0 | 0 | 13.7 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| SustaiN ammo 36N | 35.4 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 5 | 0 | 0 | 0 |
| PhaSed N | 25.3 | 0 | 0 | 28.5 | 5.7 | 0 | 0 | 0 | 1 | 0 | 100 | 0 |
| PhaSed N QS | 31.5 | 0 | 0 | 17.1 | 2.3 | 0 | 0 | 0 | 1 | 0 | 66 | 0 |
| Clover King | 0 | 12.5 | 0 | 1.3 | 35 | 0.6 | 0 | 0 | 0 | 3 | 0 | 1 |
| Clover King + S | 0 | 11.4 | 0 | 9.7 | 31.9 | 0.5 | 0 | 0 | 0 | 3 | 87 | 1 |

## Appendix 2: Lime database

The lime database contains limes for which chemical composition was supplied by the supplier. "Good quality lime" is based on analysis of Te Kuiti lime used for experimental purposes (Wheeler 1998).

**Table 9: Nutrient concentrations (%) of limes in the *Overseer* internal database**

| Name | N | P | K | S | Ca | Mg |
|---|---|---|---|---|---|---|
| Lime (good quality)[1] | 0 | 0 | 0 | 0 | 35 | 0.36 |
| Dolomite | 0 | 0 | 0 | 0 | 23 | 11.0 |
| Balfour | 0 | 0 | 0 | 0 | 32 | 0.56 |
| Browns | 0 | 0 | 0 | 0 | 35.6 | 0.36 |
| Dipton | 0 | 0 | 0 | 0 | 32.8 | 0.4 |
| Geraldine | 0 | 0 | 0 | 0 | 32.4 | 0.36 |
| Greenleaf | 0 | 0 | 0 | 0 | 27.2 | 0.36 |
| McDonalds Lime | 0 | 0 | 0 | 0 | 37.5 | 0.46 |
| Ngarua | 0 | 0 | 0 | 0 | 39.2 | 0.24 |
| Supreme | 0 | 0 | 0 | 0 | 37.2 | 0.36 |
| Waitomo | 0 | 0 | 0 | 0 | 36 | 0.3 |
| Websters | 0 | 0 | 0 | 0 | 35.6 | 0.37 |
| White rock | 0 | 0 | 0 | 0 | 36 | 0.36 |
| Victory lime | 0 | 0.06 | 0.19 | 0 | 36.9 | 0.37 |
| Super AgLime | 0 | 0.9 | 0 | 1.1 | 32 | 0 |
| Mag AgLime | 0 | 0.0 | 0 | 0 | 33 | 2.6 |
| Sulphur AgLime | 0 | 0.25 | 0 | 2.5 | 33 | 0 |
| MagSulphur AgLime | 0 | 0.25 | 0 | 2.5 | 33 | 1.0 |
| Pot Super AgLime | 0 | 1.9 | 1.9 | 2.3 | 31 | 0 |

[1] Generic high purity limestone.