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# OVERSEER® nutrient budgets – moving towards on-farm resource accounting

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## Abstract

Nutrient budgets are useful tools for assessing the sustainability of nutrient flows within a farm and for highlighting potential negative environmental impacts of nutrient use. The OVERSEER® nutrient budgets program is a decision support model to help users develop nutrient budgets. This paper outlines an upgrade to the OVERSEER® nutrient budgets program, with improvements in nitrogen (N), phosphorus (P), potassium (K) and sulphur (S), and addition of calcium (Ca), magnesium (Mg), sodium (Na) and hydrogen (potential acidity). Energy use and greenhouse gas emission profiles from farms have been included in the model. Using 'typical farm' and simulation studies, the paper then outlines how nutrient budget can be used to improve farm nutrient management.

**Keywords:** acidity, calcium, energy, green house gas, inventory, lime, magnesium, maintenance fertiliser, nitrogen, nutrient budgeting, phosphorus, potassium, resource accounting, sodium, sulphur

## Introduction

Nutrient budgets are useful tools for assessing the sustainability of nutrient flows within a farm and for highlighting potential negative environmental impacts of nutrient use. The OVERSEER® nutrient budgets program is a decision support model to help users develop nutrient budgets. The current version of the model covers the four main nutrients nitrogen (N), phosphorus (P), potassium (K) and sulphur (S). A new version of the model (nutrient budgets 2) was released in July 2003 and has been extended to cover three more nutrients (calcium: Ca, magnesium: Mg and sodium: Na), an acidity budget and inventories of greenhouse gas emissions and energy use.

Nutrient budgets are a form of resource accounting. In its simplest form, resource accounting is a measure of inputs and outputs of the item of interest across a defined boundary. In OVERSEER® nutrient budgets programs, the defined boundary is the farm, or blocks within the farm. Greenhouse gas and energy inventories have similar boundaries and can be derived from the same inputs required to develop nutrient budgets, which greatly facilitated their inclusion into OVERSEER® nutrient budgets program. In this paper we will outline how OVERSEER® nutrient budgets program has been used to improve farm nutrient management, and describe how greenhouse gas and energy emission profiles from farms have been included in the model.

## Methods

The upgraded OVERSEER® nutrient budget program was developed to improve the existing model using new information, to include new sub-models and greenhouse gas inventories, and to incorporate end-user feedback on potential model improvements. A series of end-user workshops and separate one-on-one meetings were held with consultants and farmers to identify limitations of the model and additional functionality users would like to see incorporated in the new model.

The new model for N, P, K and S is similar to that in the earlier version of the OVERSEER® nutrient budgets program although some modifications to the models have occurred to reflect more recent research results. Calculated pasture intake by grazing animals were modified based on a metabolic energy intake model developed as part of the national methane inventory for MAF (Clark 2001). Improved estimates of P runoff/leaching were also incorporated based on a new model developed from field trial results (McDowell pers. com.). In addition, the S leaching sub-model was also modified to include new data.

The Ca, Mg and Na nutrient budgeting frameworks were based on the model reported by Carey & Metherell (2002). The acidity model was based on that described by de Klein *et al.* (1997).

The greenhouse gas inventory is based on models and algorithms used for New Zealand's greenhouse gas national inventory, but with improvements to include on farm management practices. Methane emissions are based on a metabolic energy intake model developed by Clark (2001). Nitrous oxide ($N_2O$) emissions are based on the New Zealand

IPCC-based inventory, which includes the use of emission factors for direct $N_2O$ losses from excreta, fertiliser and effluent, and indirect losses from leached N and volatilised ammonia (de Klein *et al*. 2001). The amounts of effluent, leached N and volatilised ammonia are estimated from the associated N budget model. Carbon dioxide ($CO_2$) emissions from fuel and electricity, processing and some indirect contributions (e.g. fertiliser manufacturing) are largely based on the data of Wells (2001). In many settings, default values are presented, but can be overridden by the user if required.

To illustrate the new version of the model, a 'typical' Waikato dairy farm based on 2002 farm data for Livestock Improvement was used to illustrate how nutrient budgets can improve management decisions.

## Results and discussion

### End-user surveys and comments

The results from end-user surveys and meetings identified the desire for different levels of complexity, information on interpretation and mitigation options, the ability to compare scenarios, associated estimates of maintenance fertiliser nutrient requirements, and access to data needed to parameterise the model. Therefore, the new OVERSEER® pastoral nutrient budgets model was designed with an express (basic farm user default settings, simple outputs) or detailed mode (non-basic farm with options for multiple blocks, more detailed reports). Within the detailed mode, the user can override some of the default settings, compare different scenarios and access more advanced reporting information.

One of the primary roles of nutrient budgeting is to review nutrient management policies. Within the nutrient budget, accumulation of nutrients in the inorganic soil pool indicates that excess nutrients (positive) are being added to the system. Anecdotal reports back to the program developers indicated that on some farms, significant cost savings have occurred after re-examining fertiliser policies. This is backed up by results from a survey of over 240,000 soil test results over a 14-year period were at least 20% of farms were above the biological and economic optimum values (unpublished data). A maintenance fertiliser and lime recommendation module has been included as part of the software.

### Typical dairy farm simulations

On our 'typical' dairy farm, 12% of the farm received farm dairy effluent, with effluent applied at the calculated rates shown in Table 1. Also shown in Table 1 are the calculated maintenance fertiliser requirements for the effluent block and the non-effluent blocks. These indicate that on the effluent block, N and K fertiliser can be omitted as the N application rate is already in the recommended maximum range of 150-200 kg N/ha/yr, and more than sufficient K was applied to meet pasture K requirements. Phosphorus maintenance fertiliser applications for the effluent block were about half that of the rest of the farm. Effluent supplied 29%, 71 % and 16% of the pasture requirements for Ca, Mg and Na respectively and reduced lime requirements.

Excessive K applications can result in Mg-related metabolic problems in cows (Towers 1983). On some farms where effluent blocks have been used for calving, we have had reports that the high K applications from effluent have resulted in such metabolic problems in spring. Nutrient budgeting highlights the large returns of K in effluent and demonstrates the need to adjust maintenance fertiliser K inputs to these blocks accordingly.

Maintenance lime rates are generally lower on effluent blocks due to the alkalinity brought in from the effluent. The rates shown in Table 1 will vary from farm to farm but the general trends still apply if the effluent block receives the equivalent of 150-180 kg N/ha/yr as effluent.

It has been well documented that hay and silage paddocks require higher fertiliser inputs due to the removal of nutrients as supplements. Similarly, supplements brought onto the farm can form a significant source of nutrients. Significant supplement inputs will also lead to increase in the amount of nutrients excreted in the effluent, and consequently the size of the effluent block needs to

**Table 1** Rates of nutrients applied in effluent to a 'typical' dairy farm effluent block, and the maintenance fertiliser requirements for this effluent area and rest of farm. Effluent block was assumed to constitute 12% of farm area.

| | N | P | K | S | Ca | Mg | Na | Lime |
|---|---|---|---|---|---|---|---|---|
| | | | | (kg /ha/yr) | | | | |
| Applied in effluent | 161 | 18 | 152 | 12 | 26 | 16 | 5 | |
| Maintenance effluent block | | 22 | 0 | 14 | 66 | 6 | 14 | 50 |
| Maintenance rest of farm | | 42 | 40 | 26 | 101 | 22 | 19 | 210 |

be increased to maintain the N application rate at 150 kg N/ha/yr (Table 2).

**Table 2** Effect of bringing maize silage onto a farm on the percentage of total farm area required for an effluent block to maintain effluent N application rates equivalent to 150 kg N/ha/yr for a 'typical' dairy farm. The simulation assumes that the supplements also resulted in an increase in milksolids production.

| Rate of supplement (t DM/ha/yr) | Percentage of area for effluent block |
|---|---|
| 0 | 12 |
| 2 | 14 |
| 5 | 18 |
| 10 | 21 |

### Model simulations

Simulation studies with the new version of OVERSEER® nutrient budgets software suggest that the nutrient balances for Ca, Mg and Na are negative in many intensive systems, indicating net soil depletion of these nutrients. For example, on our typical dairy farm net loss in soil Mg was about 20 kg Mg /ha/yr. This net loss is supported by the small but significant decline in soil test quick test (QT) Mg levels over a 14-year period in a survey of over 240,000 soil test results (unpublished data). On most dairy farms cows are supplemented with Mg as either a drench or dusting to overcome any animal deficiencies which reduces but may not stop soil Mg depletion.

The main drivers of the acidification model are N leaching, excess cations removed from the system in product or excreta, or applied as effluent, and changes in soil C (Sinclair 1995). Maintenance lime requirements are derived from the acidity model, and are the amount of lime required to neutralise any accumulation in soil acidity. In the simulation studies, maintenance lime requirements typically varied from 40 to about 260 kg pure lime/ha/year depending on the size of the drivers of soil acidification.

Methane from animals is the largest contributor to total greenhouse gas emissions from New Zealand farms (Clark *et al.* 2001). Total $CO_2$ equivalent emissions tend to be higher under irrigation (high electricity cost), when supplements are brought on to the farm, under high fertiliser use, or when lime is applied. The main management practices to reduce greenhouse gas emissions have been reported previously (Clark *et al.* 2001; de Klein & Clark 2002). In summary, these options include decreasing animal numbers whilst increasing the production per animal (to reduce methane emissions), moderating fertiliser, lime and direct energy use (fuel and electricity), and reducing N losses (and hence nitrous oxide emissions). All these factors can be examined within the model.

Although an energy report has been added, there has been little experience in equating energy to farm practices within New Zealand. However, Wells (2001) reported that, in a survey of 150 dairy farms throughout New Zealand, overall energy ratio (OER) or energy use per unit energy produced in milk averaged 0.65 (range from 0.3 to 1.8). A lower value indicates a more energy efficient production system. Generally, OER values are higher for farming systems where farm inputs such as irrigation or supplements are increased. Based on the report of Wells (2001), the OER for New Zealand dairy farms is lower than that observed for many of our trading partners. These nations often use farming systems that house animals, which contributes to OER values greater than 2.

Combining nutrient budgets and greenhouse gas and energy inventories into a single model allows the user to assess some of the interactions that may occur. For example, results from user group meetings showed that the optimum use of fertiliser can result in cost savings, which also result in reduced $CO_2$ emissions and in some instances reduced environmental risk. They also showed that reducing N leaching is not only beneficial for water quality, but can also result in decreased Ca loss, reduce maintenance lime requirements and reduce $CO_2$-equivalent emissions (Table 3). In contrast, bringing high-energy low-N supplements onto the farm can result in improved efficiency per kg milksolids or per SU, lowered N leaching and methane emissions, but little change in total $CO_2$ equivalent emissions due to energy costs in producing the supplements (Ledgard *et al.* 2003). Constructing winter feed pads can result in reduced N leaching providing the pads are well

**Table 3** Effect of N fertiliser policy (total N applied and amount applied in winter on non-effluent block only) on annual N leached, greenhouse gas emissions and maintenance lime requirements for the farm.

| | 200 N 50 winter | 200 N nil winter | 150 N nil winter |
|---|---|---|---|
| N leached (kg N/ha/yr) | 55 | 52 | 46 |
| Maintenance lime (kg lime/ha/yr) | 260 | 240 | 220 |
| Greenhouse gas emissions ($CO_2$-equivalents/ha/yr) | | | |
| $N_2O$ emissions | 3590 | 3280 | 2900 |
| $CO_2$ from N fertiliser + lime dissolution | 630 | 620 | 470 |

constructed and effluent from the pad is collected and re-applied to the land using best management practices. Some of these interactions can be automatically set within the scenario testing part of the model.

## Conclusions

The OVERSEER® nutrient budgets model is a valuable farm-specific tool for examining nutrient flows and losses, and greenhouse gas emissions and energy inventories of individual farms. It is also enables the user to examine the impact of a range of specific on-farm management scenarios to increase the efficiency of resource use and decrease environmental impacts. It links to maintenance nutrient requirement models to define fertiliser and lime needs, and the implications of changes in farm management on fertiliser and lime needs.

## ACKNOWLEDGEMENTS

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