OVERSEER® NUTRIENT BUDGETS – THE NEXT GENERATION

Mark Shepherd & David Wheeler

AgResearch Ltd., Ruakura Campus, Hamilton

Summary

OVERSEER® Nutrient Budgets (*Overseer*) was engineered as a decision support tool to illustrate nutrient flows around farm systems. It also includes maintenance fertiliser nutrient recommendations and is integrated with Fertiliser Company systems to provide fertiliser recommendations. Its strength is that the user is able to represent a farm system with a manageable amount of input data; the model then estimates nutrient flows around that farm system. Version 6, to be released in 2012 marks a step change in the model development; complete redesign of the software, the addition of new features and a review of the science underpinning key parts of the model. All of the changes have been made to keep the tool relevant and useful for end-users, particularly in response to evolving farm management systems (e.g. fodder crops, supplement management, mitigation of nutrient losses). This paper describes the changes in the model and the benefits to the user, and discusses the key tasks in maintaining decision support software.

Introduction

Loss of nitrate-N by leaching from farming systems is well known to have implications for water quality in many catchments. Actual quantification of nitrate leaching from soil is difficult; all measurement techniques have advantages and disadvantages (Lilburn et al., 2012). Whilst such methods are useful at the experimental scale to provide information on key factors that drive and affect leaching, it is impractical to deploy such techniques at a farm-level for routine monitoring. Yet, farmers need to know the consequences of their farm management decisions if nitrate leaching (and other emissions) is to be managed.

For this reason, farm-scale models or decision support systems/tools (DSS) are developed to model nutrient flows around farm systems. In New Zealand, a farm-scale nutrient budgeting model was developed in the 1990s: OVERSEER® Nutrient Budgets (‘*Overseer’*). It calculates a nutrient budget for a farm and for management blocks within the farm, taking into account inputs and outputs and internal cycling of nutrients around the farm (Wheeler et al. 2003, 2006; Cichota & Snow, 2009). It covers pastoral systems and a wide range of vegetable, arable crops and horticultural crops.

Development of this model has continued such that it now underpins New Zealand’s pastoral farm fertiliser recommendation systems. However, because the *Overseer* estimates nutrient flows around the farm, including nitrate (and phosphorus) losses in drainage and run-off, it is increasingly used by consultants and policy makers to estimate the likely effects of farm management practices on off-farm losses of nutrients. As one example, Overseer is used in a cap and trade policy for nitrogen leaching control around Lake Taupo (Shepherd et al., 2009).

The cropping component of the model was recently revised (Cichota et al., 2010), and the pastoral model has now been revised. Here, we identify the key tasks in maintaining decision support software and describe the key changes in this version of the model.

Maintaining decision support tools

A number of papers provide an overview of how *Overseer* works (Wheeler et al., 2003, 2006; Cichota & Snow, 2009; Shepherd & Wheeler, 2010). The vision for *Overseer* is a robust, science-based decision support tool and policy support tool that is widely used for improving farm profitability, optimising nutrient use and minimising impacts on air, soil and water quality.

There is a significant body of opinion that agricultural DSS have failed to deliver tangible benefits to date (Matthews et al., 2008), generally failing at the implementation phase (McCown, 2002). Thus, there is a sustained effort required afterwards to encourage and maintain use of the DSS. Various approaches can be adopted in this implementation phase, which then moves the project beyond scientific development into sustained use by stakeholders (Shepherd & Wheeler, 2010). However, there are also a number of key tasks that need to be regularly addressed if the DSS is to be maintained in the longer term (Table 1).

***Table 1**. A summary of the key tasks in maintaining and developing decision support software.*

What	Why	How
Maintain relevance to farming systems	It is important that the user is able to correctly represent their farm in the model. Farming systems continually evolve in response to a range of factors.	User feedback and industry intelligence on new farm managements. Try to add in to the model before their absence is deemed a significant barrier to use.
Capturing new science	Models are never perfect; scientific understanding is never perfect!	Best endeavours; document and explain assumptions; periodically review as new science becomes available.
Adding new features	Increases the usefulness for users or a group of users.	Whilst the emphasis always has to be on ensuring the model is fulfilling its core purpose well, there is scope for adding extra functionality if (a) it has synergy with the model's core purpose and (b) it can be based on much of the same input data.
Maintaining the software	Reliability, usability. Maintenance is often underestimated as a model moves from a research project to a publically available decision support system.	Allocate sufficient resources. Use specialist support.
User interaction	Ensure that the model is being used correctly, for its correct purpose, and within its limitations.	Training, documentary evidence, regular interaction with users.

Changes to *Overseer* version 6
Table 2 summarises the main changes in the upgrade of *Overseer* from version 5 to version 6. All of the changes fall into one or more of the categories described in Table 1.

***Table 2**. A summary of the main changes included in Overseer version 6.*

Feature	Benefit
Integration of pasture, crop and horticultural models into a single model.	• All block types now available on an individual farm • More consistency in modelling approaches across the block types resulting in fairer comparisons
Monthly time step for some inputs.	• Allows better modelling of time dependent outputs from the nutrient budget, particularly for N losses.
N and DCD models reviewed and upgraded.	• Better recognition of the timing of farm operations on N losses
Life cycle assessment added to the GHG model.	• Estimation of GHG emissions upgraded • Allows emissions to be expressed on a product basis
Dairy goats added to animal enterprises.	• Model now covers another important enterprise
Better handling of supplements: • Cut & carry block added • More supplement can be removed from a grazed block • Supplement can be fed on forage crop blocks	• The model can now better represent what is actually happening on farms
Improved drainage model	• Improved estimation of drainage from stony/sandy soils and under irrigation
Improved effluent management	• Ability to add effluent to increased range of blocks

Maintaining relevance to farming systems
Supplementary feeds are used to overcome quantitative and nutritional limitations of pasture (Penno et al., 1996). Whereas *Overseer* had previously been able to deal with imported supplementary feeds, handling of home grown pasture supplements was more limited. Whereas in practice pasture blocks are managed through a mix of grazing and harvesting for conservation in periods of excess pasture production, a model restriction was that no more than 50% of the block (or 8 t DM/ha) could be harvested as supplement. However, user feedback reported that this limitation was not practical. The model has now been adapted so that here is no such restriction; taken to the extreme, it is also possible to set up blocks that are solely used for cut and carry (cut and carry model described by Wheeler et al., 2010).

Capturing new science
Overseer is a useful conduit to make research findings available to the end-user. Models are a best representation of the science available at the time. However, science is a continual process of discovery and this leads to model improvement. The new version of the model reviewed two key components in particular: N leaching and N process inhibitors.

Nitrogen process inhibitors
Nitrogen process inhibitors are seen as possible mitigation methods for using N more efficiently on the farm. The nitrification inhibitor Dicyandiamide (DCD) has been shown to decrease nitrate leaching (and nitrous oxide emissions) in lysimeter experiments and in farmlet experiments (Gillingham et al., 2012). The use of DCD was included in the previous version of *Overseer*. The main drivers controlling the effectiveness of DCD are temperature and rainfall (Vogeler et al., 2011) and these were captured in the model that was implemented. As a part of the upgrade, the DCD sub-model was reviewed. The conclusion was that to date most of the published research was still highly empirical and there was insufficient information to substantially modify the model (Shepherd et al. 2012). Thus, the DCD sub-model is still driven primarily by temperature and rainfall/drainage (Shepherd et al. 2012). However, there is more flexibility in timing of applications of DCD and also, DCD can be applied at the management block or farm level (originally farm-level only). This flexibility has been enabled by the revision of the N model (described below).

Other N process inhibitors are available but are not yet captured in *Overseer*. For example, N-[n-butyl] thiophosphoric triamide, (NBPT) is a urease inhibitor that can decrease ammonia volatilisation losses. Reductions in losses are well documented (Watson, 2000), but will vary with environment. It would be feasible to include this in *Overseer* and it is being considered for a future release.

Reduction of N losses by the use of process inhibitors can result in increases in pasture production, although the size of reported benefits has been variable (Gillingham et al., 2012; Carey et al., 2012). Because *Overseer* is not a pasture growth model but back calculates pasture production based on milk/meat/wool production and the use of imported supplements (Wheeler et al. 2003), the size of the benefits is captured in the productivity data.

Nitrogen leaching model
Overseer's approach to modelling N leaching can be split into 2 parts: calculation of the amount of N (as urine/dung, effluent and fertiliser) that hits the soil and when; and then calculation of the proportion of the deposited N that is leached. Fundamentally, the modelling approach for calculating the amounts of deposited N have not changed between versions, although these are now all calculated for each month. The main change is in how leaching of deposited N is calculated.

Previously, N leaching was based on an empirical relationship between rainfall and soil-type. The relationship was calibrated against a series of farmlet trials. The revised model aims to better represent the main drivers of N leaching. Leaching is considered to fall into 'background', or between urine patches, and the urine patches themselves, which are seen as the main driver for N leaching.

The background N model is based on the cut and carry model described by Wheeler et al. (2010), with the assumption that in the absence of urine, pasture is very effective at retaining N applied as fertiliser or effluent (although this efficiency declines in winter). This model allows integration of the effect of rate and timing of non-urine N applications such as from fertiliser, effluent, organic material and irrigation. This has been linked to an upgrade of the effluent management calculations (Wheeler et al., 2012).

For urine, *Overseer* calculates the monthly deposition to the management block (example shown in Figure 1). The fate of the N in the urine patch is then modelled to take account of the key processes of immobilisation, volatilisation, denitrification and pasture N uptake. Any surplus present when drainage starts is potentially available for leaching. The amount leached is calculated from a transfer coefficient based on pore volumes of drainage, as described by Wheeler et al. (2011a). This is a major change to the model in that N leaching is now driven by the soil available water capacity and drainage, with drainage calculated using *Overseer*'s daily water balance model. An advantage is that this should better capture the effects of soil AWC on leaching risk, e.g. better representation of shallow soils.

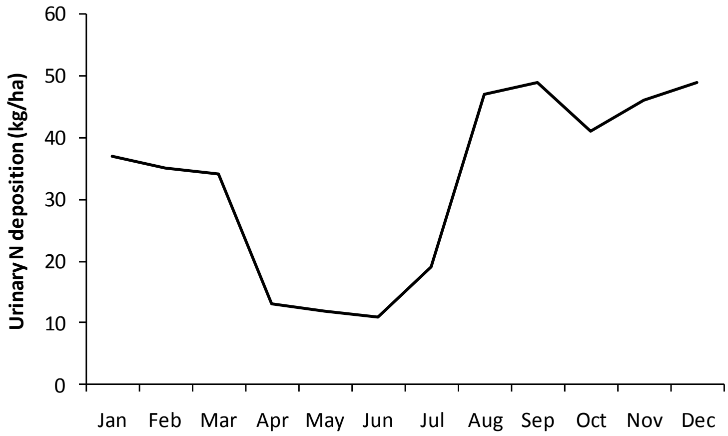

Figure 1. *An example of the calculated monthly distribution of urine-N deposited on a management block: 3 cows/ha, all year grazing.*

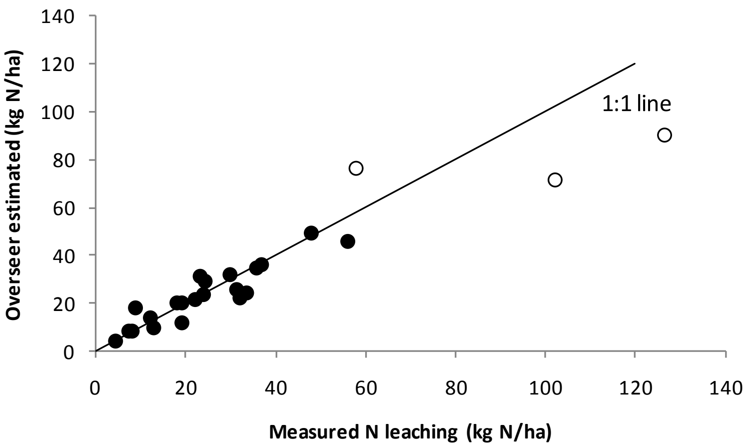

Figure 2. *Comparison of dairy farmlet experiments where N leaching was measured with Overseer estimates. This comparison uses a development version of the model, so may differ from the final release.*

Applying this model to the available NZ farmlet trials gives good agreement (Figure 2), especially for experiments that operated with annual N application rates of 0-200 kg N/ha, where most of the NZ farms operate (Shepherd, 2009).

Monthly time step

A key application of *Overseer* is to be able to estimate the effects of management practices on nutrient flows, including what could be considered methods for mitigating losses of nutrients to the wider environment (de Klein et al., 2010). Previous versions of *Overseer* have used an annual time step for key inputs such as fertiliser, effluent and irrigation. However, the inputs of these are now entered or calculated on a monthly time step. This allows a better representation of the nutrient flows, such as the effects of N fertiliser timing on direct losses by leaching.

The monthly calculation of N flows also improves estimation of mitigation options already included in the model such as use of pads, grazing off and DCD on N losses such as leaching, nitrous oxide, and denitrification; all have a temporal component to their losses.

Adding new features

Dairy goats have been added to the model, following a literature review and a survey of management practices within the industry (Carlson et al., 2011). Dairy goats generally remain housed with feed brought to them; this type of system was easy to reproduce within the model. However, one major difference with this animal type compared with cattle and sheep is their high feed rejection rate (i.e. low utilisation) (Carlson et al., 2011). It was therefore necessary to account for the wasted feed in the nutrient transfers around the farm; it has been assumed that the feed enters the effluent management system by default, or the waste feed can be fed to other animal types such as beef animals as is practiced on some farms (Carlson et al., 2011).

Overseer previously calculated greenhouse gas emissions (Wheeler et al., 2008). This included embodied CO_2 emissions. However, the GHG model has now been extended to include a wider range of embodied emissions in line with the PAS 2050 standard. In addition, on-farm allocation rules were developed so that emissions on a product basis (e.g. kg CO_2 equivalents per kg milk solids) can be reported (Wheeler et al., 2011b).

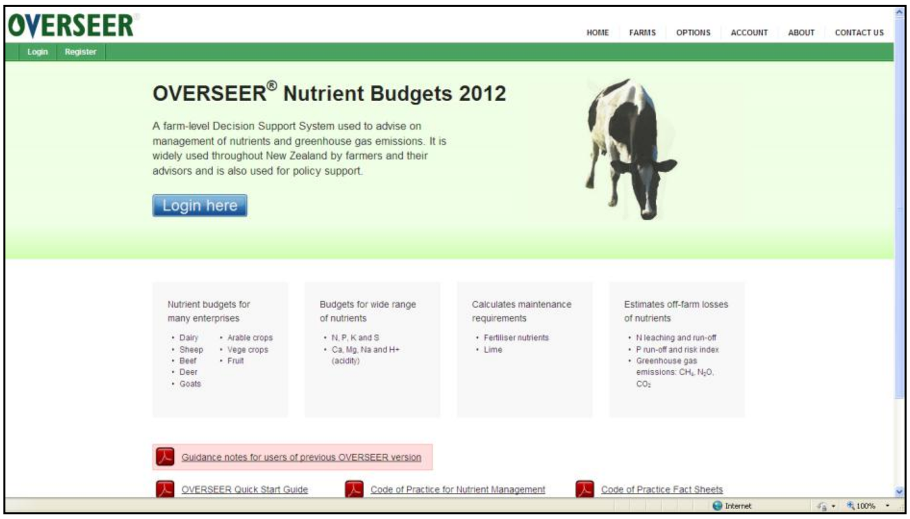

Figure 3. *Screenshot of Overseer version 6.*

Maintaining the software
The software for version 6 has been completely rewritten, so the model has a new look (Figure 3) and a new feel. There should be several benefits for users, including greater reliability of the software.

One potentially major benefit is for scope to link the *Overseer* calculation engine with other models. This means that double data entry, for example, could be avoided if the nutrient budget component of the model was linked to an economic model. This facility for linking models is facilitated through a licensing agreement with the Owners of *Overseer*.

User interactions
Overseer aims to use only inputs that are relatively easily obtainable by the user (Wheeler et al., 2003). Nevertheless, farming systems are complex, and an understanding of farming systems and the interactions within the systems is required to make best use of the model. Few farmers directly use the model; quite rightly so, since it has always been considered as an ‘expert system’. To this end, there is an initiative to produce a registry of accredited users (P. Mladenov, NZFRMA, Pers. Comm.).

One criticism has been the ‘black box’ nature of the model, with the argument that users cannot have confidence in the model because information about how it works is lacking and/or has not undergone per review. There are c. 30 conference and journal papers about *Overseer* (see website www.overseer.org.nz). Whist the aim is to continue to increase the publication record, papers cannot always give the level of detail that some users require. Therefore, detailed descriptions of the model components in the form of a technical manual are also being placed on the website.

Conclusions
Overseer version 6 aims to improve the model for end–users through:

- Improved software
- New features that make the model more applicable to a wider range of farming systems
- Better information exchange around the model
- Continued programme of reviewing and improving the science.

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References

Carlson, B., Wheeler, D. & Ledgard, S. (2011). *Integration of dairy goat farming systems into OVERSEER® Nutrient Budgets*. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 4 pages.

Carey, P., Jiang, S. & Roberts, A.H.C. (2012). *Pasture dry matter responses to the use of a nitrification inhibitor: a summary of a national series of New Zealand farm trials.* In: Advanced nutrient management: gains from the past - goals for the future. (Eds L.D.

Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 25. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Cichota, R. & Snow, V.O. (2009). Estimating nutrient loss to waterways - An overview of models of relevance to New Zealand pastoral farms. *New Zealand Journal of Agricultural Research* **52**, 239-260.

Cichota, R., Brown, H., Snow, V.O., Wheeler, D.M., Hedderley, D., Zyskowski, R. & Thomas, S. (2010). A nitrogen balance model for environmental accountability in cropping systems. *New Zealand Journal of Crop and Horticultural Science* **38**, 189-207.

De Klein, C.A.M., Monaghan, R.M., Ledgard, S. & Shepherd, M. (2010). *A system's perspective on the effectiveness of measures to mitigate the environmental impacts of nitrogen losses from pastoral dairy farming*. In: Australasian Dairy Science Symposium. eds G. R. Edwards & R. H. Bryant, Lincoln University, Lincoln University, pp. 14-28.

Gillingham, A.G., Ledgard, S.F., Saggar, S., Cameron, K.C., Di, H.J., De Klein, C. & Aspin, M.D. (2012). *Initial evaluation of the effects of dyciandiamide (DCD) on nitrous oxide emissions, nitrate leaching and dry matter production from dairy pastures in a range of locations within New Zealand*. In: Advanced nutrient management: gains from the past - goals for the future. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 25. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Lilburne, L., Carrick, S., Webb, T. & Moir, J. (2012). Computer-based evaluation of methods to sample nitrate leached from grazed pasture. *Soil Use and Management* **28**, 19-26.

Matthews, K.B. et al. (2008). Wither agricultural DSS? *Computers and Electronics in Agriculture* **61**, 149-159.

McCown, R.L. (2002). Changing systems for supporting farmers' decisions: problems, paradigms, and prospects. *Agricultural Systems* **74**, 179–220.

Penno, J.W., Bryant, A.M., MacDonald, K.A. & Carter, W.A. (1996). Enhamcing pasture-based dairying with supplementary feeds. *Proceedings of the New Zealand Grassland Association* **58**, 113-118.

Shepherd, M., Wheeler, D. & Power, I. (2009). *The scientific and operational challenges of using an OVERSEER® nutrient budget model within a regulatory framework to improve water quality in New Zealand*. Proceedings of the 16th Nitrogen Workshop, Turin, Italy, July 2009. pp. 601-602.

Shepherd, M. (2009). *Identifying the decision making processes for application of N fertiliser to an individual paddock*. Nutrient Management in a Rapidly Changing World. (Eds. L D Currie and C L Lindsay), Occasional Report No. 22, pp. 352-362.

Shepherd, M.A. & Wheeler, D. (2010). *OVERSEER® Nutrient Budgets – Thoughts on developing a decision support tool*. In: Currie, L.D. & Lindsay, C.L. eds. Farming's future – minimising footprints and maximising margins. Occasional Report No. 23. Palmerston North, New Zealand, Fertiliser and Lime Research Centre, Massey University pp. 192-202.

Shepherd, M., Wheeler, D., Chrystal, J. & Lucci, G. (2012). *Reviewing and revising the DCD model within OVERSEER® Nutrient Budgets*. In: Advanced nutrient management: gains from the past - goals for the future. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 25. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Vogeler, I., Cichota, R., Snow, V. & Monaghan, R. (2011). *The impact of climate on the efficiency of DCD in reducing N leaching*. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand.

Watson, C.J. (2000). Urease activity and inhibition - principles and practice, Proceedings - International Fertiliser Society. *International Fertiliser Society* **454**, pp 1-40. York UK.

Wheeler, D.M., Ledgard, S.F., de Klein, C.A.M., Monaghan, R.M., Carey, P.L., McDowell, R.W. & Johns, K.L. (2003). OVERSEER® Nutrient Budgets - moving towards on-farm resource accounting. *Proceedings of the New Zealand Grassland Association* **65**, 191–194.

Wheeler, D.M., Ledgard, S.F., Monaghan, R.M., McDowell, R.W., de Klein, C.A.M. (2006). *OVERSEER nutrient budget model - what it is, what it does*. In: Currie, L.D. & Hanly, J.A. eds. Implementing sustainable nutrient management strategies in agriculture. Occasional Report No. 19. Fertiliser and Lime Research Centre, Massey University. Palmerston North, New Zealand, pp. 231–236.

Wheeler, D.M., Ledgard, S.F. & DeKlein, C.A.M. (2008). Using the OVERSEER nutrient budget model to estimate on-farm greenhouse gas emissions. *Australian Journal of Experimental Agriculture* **48**, 99-103.

Wheeler, D., van der Weerden, T. & Shepherd, M.A. (2010). *Description of a cut and carry model within OVERSEER® Nutrient Budgets*. In: Currie, L.D. & Lindsay, C.L. eds. Farming's future – minimising footprints and maximising margins. Occasional Report No. 23. Palmerston North, New Zealand, Fertiliser and Lime Research Centre, Massey University 203-211.

Wheeler, D., Cichota, R., Snow, V. & Shepherd, M. (2011a). *A revised leaching model for OVERSEER® Nutrient Budgets*. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 6 pages.

Wheeler, D., Ledgard, S. & Boyes, M. (2011b). *Greenhouse gas footprinting using OVERSEER® - 'The whole picture'*. In: Adding to the knowledge base for the nutrient manager. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 24. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 9 pages.

Wheeler, D., Shepherd, M. &Power, I. (2012). *Effluent management in OVERSEER® Nutrient Budgets*. In: Advanced nutrient management: gains from the past - goals for the future. (Eds L.D. Currie and C L. Christensen). http://flrc.massey.ac.nz/publications.html. Occasional Report No. 25. Fertilizer and Lime Research Centre, Massey University, Palmerston North, New Zealand. 9 pages.