DESCRIPTION OF A CUT AND CARRY PASTURE MODEL WITHIN OVERSEER® NUTRIENT BUDGETS

David Wheeler[1], Tony van der Weerden[2] and Mark Shepherd[1]

[1]Agresearch Ltd, Ruakura Campus, East Street, Private Bag 3123, Hamilton 3240
[2]Agresearch Ltd, Invermay, Mosgiel, PO Box 50034, Mosgiel 9053
Email: david.wheeler@agresearch.co.nz

Abstract

A new 'cut and carry' model has been added to OVERSEER®[1] Nutrient Budgets (*Overseer*) to allow blocks to be set up that are used solely for growing supplement. It is based on the previously upgraded and validated crop model combined with a pasture growth module. This paper describes validation of the drainage and N leaching components of the model.

A review of the international literature and the few NZ measurements collated 15 data sets, comprising mainly ryegrass/clover swards, where sufficient information was provided to allow detailed data input into *Overseer*. These experiments were all independent of the data used to develop the model. Agreement between modelled (*Overseer* 5.5 beta version) and measured N leaching was good for 13 of the 15 sites. One site was sown to pure ryegrass with nil N fertiliser; *Overseer* assumes ryegrass/clover and would have overestimated N supply. In an experiment on the Central Plateau measured losses were much smaller (19 kg N/ha) than modelled (38 kg N/ha), even though the N fertiliser inputs were relatively large (230 kg N/ha) and reported yields small for the inputs (8 t DM/ha). Two other experiments in the same area gave good agreement (15 and 14 kg N/ha for measured and modelled, respectively, as a mean of the two sites).

A paired t-test for the dataset of 15 sites showed no significant difference (P=0.6) between measured (mean 13 kg N/ha) and modelled (mean 15 kg N/ha) N leaching. When modelled data were plotted against measured, excluding the two sites as described above, there was a highly significant linear regression (P<0.01), with 53% of the variance explained. Comparison of reported drainage data and *Overseer* modelled results was even better (slope 0.99, intercept not significantly different to zero and 98% variance explained).

We can conclude that the cut and carry model within *Overseer* adequately represents N leaching and drainage in situations where paddocks are used solely for growing pasture based supplements, especially for ryegrass/clover swards.

Background

Versions of the OVERSEER® Nutrient Budgets (*Overseer*) up to and including v. 5.4 had placed upon them a restriction regarding the amount of supplement that could be removed from a pasture block in any one year, i.e. <50% of the total annual pasture DM production or less than 8t/ha, whichever was the smaller. This was becoming an increasing obstacle to correctly represent farm systems in *Overseer* as an increasing number of farms either have blocks where they remove >50% of production as supplement (plus some grazing), or have

[1] OVERSEER is a registered trademark and is jointly owned by AgResearch, MAF and FertResearch

dedicated 'Cut and Carry' blocks. Therefore, in 2008/09 the *Overseer* Owners funded a project to address this.

Literature searches were undertaken to identify key pieces of information required for upgrading *Overseer* such as: practical aspects of supplement use (typical yields, utilisation, growth curves, N fixation); typical nutrient losses under cut and carry systems, particularly N and P losses; specific information on lucerne (production details and nutrient losses) as this crop had, to date, not been included in the *Overseer* software.

This information was then used to update databases and develop algorithms within *Overseer* to better handle greater levels of pasture removal as supplement. This resulted in two major changes to the *Overseer* model (version 5.5):

- Development of a specific cut and carry block where all production is removed from that block and either fed on farm or exported
- Adjustment of pasture blocks so that they can now accommodate supplement removal of >50% production plus some grazing

The aim of this paper is to describe: how a specific cut and carry block has been implemented in *Overseer* v 5.5; the input data required and the input options; and the comparison between experimental data and calculated values from *Overseer*.

Implementation

The cut and carry block model is an adaptation of the crop sub-model already used in *Overseer*. The crop sub-model estimates the water balance, crop growth and soil mineral N pool changes such as leaching, denitrification, plant uptake and residual decomposition using a monthly time-step (Cichota et al., 2009). The modifications were centred on estimation of N uptake, residual N and N fixation within the nitrogen sub-model. Assumptions made were that:

- Pasture or lucerne could be modelled as specific types of crop.
- Soil moisture and temperature are the primary determinates of monthly distribution of uptake. Hence, the timing of supplement removal could be avoided as an input requirement.
- There is an additional 10% growth that is not harvested due to senescence and lost during the harvest period.
- Total root weight is constant but there is continually turnover. Mineral N is removed from the soil pool and returned as more recalcitrant by root residual N.
- Both pasture and lucerne fix N.
- Soil N mineralisation rates equate to those in long-term pasture with no additional effect of recent soil disturbance from cultivation

Total annual N uptake was estimated as

$$\text{Nuptake} = \Sigma(\text{yield}_s * \text{Nconc}_s) * C$$

Where:

yield_s = the total amount of supplements removed over 12 months as specified by the user

Nconc = the nitrogen concentration in the supplement

C = constant to include uptake from roots and material not harvested (set at 1.4)

In pasture, Nconc is based on the pasture model within *Overseer*, which takes into account the effect of pasture type and fertiliser application on N concentration. Pasture N concentrations are then adjusted as supplements typically have lower concentrations due to more mature pasture being sampled. The size of the adjustment depends on the type of supplement. For Lucerne, a typical N concentration of 3.68% for silage and 2.88% for hay was used based on a survey of nutrient concentrations of lucerne for silage and hay submitted to a commercial testing laboratory.

Clover content was set at 15% for pasture (the *Overseer* default), and 100% for lucerne, it being a leguminous crop. Clearly there could be considerable discussion on the adequacy of these equations to estimate total yield, but they were considered adequate for estimating the *distribution* of growth. *Overseer* does not model yield but uses production data to estimate it. As described above, supplement production is a required input and is used to estimate yield from the Cut and Carry block.

Annual N fixation (Nfix) was estimated as:

$$\text{Pasture Nfix} = \Sigma(\text{yield}_s) * \%\text{clover} * 0.04 * 1.6 * 0.9$$

$$\text{Lucerne Nfix} = \Sigma(\text{yield}_s)/1000 * 25 * 1.6$$

Where:

0.04 = clover N content, 0.9 = proportion of clover N uptake that is fixed (e.g. Ledgard, Wheeler), and 1.6 takes account of N fixation in roots (Jorgenson and Ledgard). For Lucerne, N fixation was based on average from literature review of 25 kg N fixed per tonne DM grown (Moot).

The inputs were distributed in a monthly pattern as:

$$\text{Nuptake}_{mon} = \text{Nuptake} * \text{Pgrowth}_{mon}$$

$$\text{NStover}_{mon} = \text{Nuptake}_{mon} * 0.1$$

$$\text{NRoots}_{mon} = \text{Nuptake}_{mon} * 0.3$$

$$\text{Nfix}_{mon} = \text{Nfix} * \text{pNfix}_{mon}$$

Where:

Pgrowth_{mon} = the monthly proportion of total annual pasture growth and was based on growth patterns used in the crop model for seed crops (Brown, 2008)

pNfix_{mon} = the monthly proportion of total annual N fixation. For lucerne, in the absence of better data, pNfix was assumed to be the same as pgrowth_{mon}. pNfix for pasture was based on a survey of N fixation rates in New Zealand trials (Wheeler et al., 1997), Table 1.

Table 1: Estimated proportion of total annual N fixation that occurs each month (adapted from Wheeler et al., 1997)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
6%	5%	9%	9%	5%	4%	4%	10%	15%	13%	12%	8%

Apart from the above changes, the crop model was implemented with no reference to the literature review, i.e. it was developed independently so that data from the literature reviews could be legitimately used to validate the model.

The main limitation to the model is if there is a factor other than temperature and soil moisture that decreases both growth and soil N mineralisation rate. If so, this may lead to overestimation of the amount of soil available N, and hence overestimation of N leaching.

Data requirements and reports

The input data requirements (Table 2) and the reports generated (Table 3) are similar to the other block set-ups in *Overseer*.

Table 2: Summary of the main input screens for the cut and carry block

Screen	Description/comment
Current farm - general	Select the **farm region**. Select the **type of blocks** that will be set up on the farm, e.g. dairy only, full range of blocks, etc.
Current farm – block set up	Enables the user to set up the farm in a number of **blocks** and defines their areas. One of these options is for a cut and carry block.
Block	Describes **distance from coast**. Selects the **type of crop** grown. There are 6 options: Ryegrass/white clover; Browntop; Unimproved/tussock; Summer C4 (paspalum) pastures; C4 (kikuyu) pastures; Lucerne.
Block - climate	Requires input of average annual **rainfall** and average annual **temperature** with **advanced options** for seasonal variation.
Block – soil description	Requires a soil description and is used to determine the water holding capacity of the soil. If the **soil order** is known, this will over-ride other input data. If the **soil group** is entered, this defines the subsoil texture and leaching characteristics, unless the 'sandy subsoil' option is selected. **Topsoil texture** is required and is used in some of the sub-models. **Soil depth** is also selected.
Block – soil tests	**Soil test** information required (default data available)
Block – soil settings	Allows **K leaching potential** to be set on a sliding scale. A default value is set for each soil group.
Block – supplement removal	Requires information of the **amount** of supplement grown, the **type** of supplement and its **destination**. The destination can be off-farm, paddocks, wintering pad, feed pad or storage. If the destination is paddock, then specific blocks may be identified.
Supplement removal – supplement calculator	Data can be entered either in amounts (t per block: NOT t/ha), or the amounts can be calculated from estimates of (in order of precedence): Number and types of bales; Volume of material; Number of cuts.
Storage loss and utilisation (advanced screen)	This is optional, but can provide further information on **storage conditions** for the material (poor, average, excellent) and **utilisation** either when feeding in a paddock or from bins.
Block – fertiliser and lime	Allows inputs of all **fertilisers, lime and organic materials on a monthly basis**. Various input options available, for example, either as rate of nutrient or rate of product.
Block - irrigation	Monthly input of irrigation **amount** and application **method**

All of the data inputs are those that allow a nutrient balance to be constructed, with soil and climatic factors used to model nutrient losses through leaching or gaseous emissions.

Table 3: Summary of the reporting screens for the cut and carry block

Report	Description/comment
Nutrient budget	Reports the inputs, outputs and transformations within the soil pools for each nutrient.
Default values	Lists the default values used in the calculations.
Comments	Provides information and warnings, e.g. if *Overseer* calculates that insufficient fertiliser has been applied to meet the stated level of production, or where *Overseer* identified scope for reducing other fertiliser inputs.
Block N	Summarises N leached, flow-weighted N concentration from the bottom of the root zone and N surplus for the block.
Block P	Estimates a P loss index from P sources.
Other outputs	Shows calculated values not shown in other reports, for example drainage volume from the block.

Model validation

Approach

The approach was to identify a number of key experiments from the literature where sufficient data was available in the reports to allow an accurate representation in *Overseer* of the experimental set up. These experiments are summarised in Table 4. The aim was to validate the nitrate leaching component of the model.

Table 5 summarises how data inputs were managed for the validation procedure. Generally, the experiment data could be well represented in *Overseer*. However, there were occasionally some input variables (mainly average annual temperature) that were not reported in the paper/report and then default values had to be used. Although *Overseer* is cited as a long-term average model, we used actual climate data and other inputs where these were available. Where more than one year of data was available, the mean of the available years was used (provided that the management/treatment throughout the years was similar). Comparisons were restricted to lucerne or ryegrass/clover; there were no available experiments for other pasture types. Other than the input issues covered in Table 3, *Overseer* default values were used for all other inputs unless there was a justifiable reason for changing these.

Once data were input, measured values were compared with modelled values. The main variates available for comparison were N leaching loss and drainage. We selected only experiments that measured nitrogen leaching as this was the main aim of the validation. Methodology varied between experiments, either using lysimeters/drained plots or using porous cups. If the latter, then the calculation relies on a modelled drainage value to convert concentrations to loads. Drainage was not always measured directly (only in lysimeter experiments). Even so, the alternative modelled data reported in the experiments reports was a useful check against the *Overseer* modelled data.

Table 4: A summary of the experiments used to validate the cut and carry block model

Source	Crop	Location	Comments
Monaghan (unpublished)	Pasture	NZ (Southland)	Data from Southland on a poorly drained experiment using hydrologically isolated plots. Three years of data but the first year was treated separately because there was a significant amount of N applied in autumn, compared with the other two years.
Thorrold & Betteridge (2006)	pasture	NZ (Taupo)	There were two experiments, 'cropping' and 'grazing'. However, both included a cut and carry pasture option and the cropping trial also included a cut and carry lucerne. Although a three year experiment, the first year's data were excluded as the entire season was not measured, plus it was a set up year (including cultivation) for the cropping experiment.
Cameron et al. (2002)	pasture	NZ (Canterbury)	Lysimeter experiment, Templeton silt loam. Included two 'control' treatments that did not receive FDE (as did other treatments within the experiment. These controls received 2 rates of irrigation. Three year means calculated.
Decau et al. (2004)	pasture	France	Pasture trials using repacked lysimeters investigating the interaction of urine and mineral fertiliser. Single lysimeters received no urine. Two years of data 1996/97 and 1997/98.
Eriksen et al. (2004)	pasture	Denmark	Danish data from a 5 year experiment (1997-2001). The site had previously been in grass for the 3 years before this. Two treatments were of value; ryegrass plus 300 kg N/ha as fertiliser annually and ryegrass white clover with no N fertiliser, both under a cutting regime. The average of the 5 years was used.
Basso & Ritchie (2005)	lucerne	USA (Minnesota)	Maize/lucerne rotation, 3 years in each crop. Two rotations. Used only years 2 and 3 of each rotation to avoid establishment effects in year 1. Duplicate lysimeters received nil N fertiliser.
Randall et al. (1997)	lucerne	USA (Michegan)	Drained plots growing continuous lucerne 1988-93. Dry weather meant that drainage was only obtained 1991-1993 (i.e. 3 years). Mean calculated.
Thorrold & Betteridge (2006)	lucerne	NZ (Taupo)	See details of cropping trial, above; lucerne treatment included.

Table 5: Main input variables required and issues around their use

Input variable	**Issue**
Reporting year	This varied between experiments but was rarely a calendar year; more likely to be a cropping year. This was especially the case for N. hemisphere trials where the winter drainage period spans two years.
Soil-type	A soil description was generally published; no problem in accurately defining the soil within *Overseer* if a NZ experiment. For overseas experiments, it was necessary to select an appropriate NZ equivalent. As Soil Order/Soil Group can influence leaching dynamics within *Overseer*, this was critical information to get right.
Annual Rainfall	Usually reported, as was drainage (measured or modelled).
Temperature	Not usually reported. As this greatly influences the model, it is important to have as good an estimate as possible.
Region	For NZ studies, the actual region was used; for non-NZ studies, a region which was thought to best represent the experiment site was selected.
Sward type	Usually reported. *Overseer* gives 5 options including ryegrass/white clover and the (new feature) lucerne. There is no scope to decrease clover amount within the sward but fixation generally declined with N fertiliser input so swards with small clover levels that required N fertiliser were well represented. The 'pasture' was generally set to ryegrass/white clover unless there was good reason to change.
Fertiliser inputs	Amounts of NPK usually reported, but not always with sufficient detail on timings of N. For model input, arbitrary amounts of PK were applied simply to balance off-take. N applications were input using the best available information from the report and some interpretation of that. Unless stated otherwise in the report, N applications were not scheduled for late autumn/winter.
Yield	Always reported. N off-take also sometimes reported. As *Overseer* only requires the total annual yield, information of timing and frequency of cuts was not required.
Supplement type	Silage was always assumed.

Results

Fifteen measurements covering NZ and non NZ experiments were assembled. Agreement between modelled (*Overseer* 5.5 beta version) and measured N leaching was good for 13 of the 15 sites. One site was sown to pure ryegrass with nil N fertiliser (Decau et al., 2004); *Overseer* assumes ryegrass/white clover and would therefore have overestimated N supply compared with the ryegrass sward that was grown. In an experiment on the Central Plateau measured losses were much smaller (19 kg N/ha) than modelled (38 kg N/ha), even though the N fertiliser inputs were relatively large (230 kg N/ha) and reported yields small for the inputs (8 t DM/ha). Two other experiments in the same area gave good agreement (15 and 14 kg N/ha for measured and modelled, respectively, as a mean of the two sites).

A paired t-test for the dataset of all 15 sites showed no significant difference (P=0.6) between measured (mean 13 kg N/ha) and modelled (mean 15 kg N/ha) N leaching. When modelled data were plotted against measured, excluding the two sites as described above, there was a highly significant linear regression (P<0.01), with 53% of the variance explained (Figure 1).

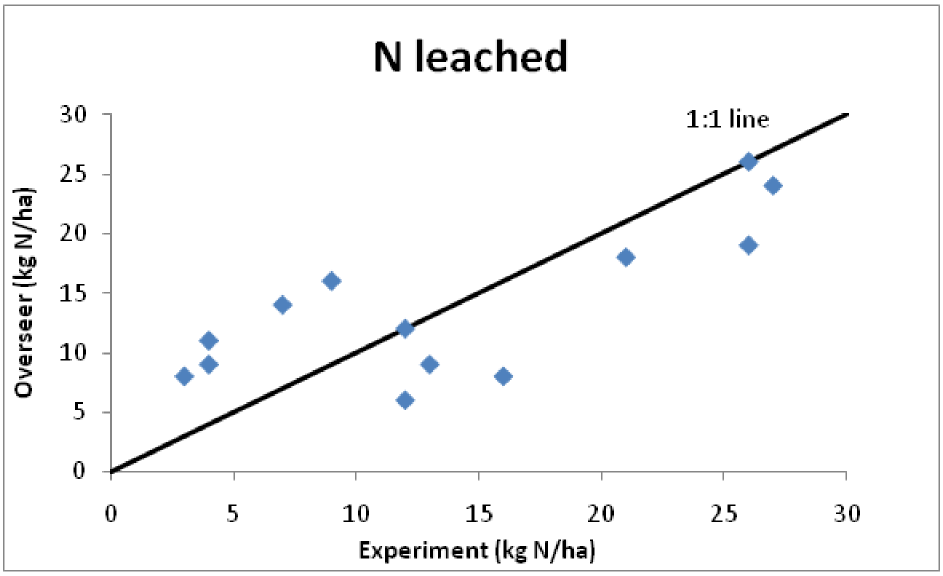

Figure 1: Comparison of experimental data and Overseer modelled results for 13 of the 15 sites

Figure 1 suggests that at the lower level of nitrate leaching reported in the experiment dataset, *Overseer* tends to overestimate leaching. There was a group of 5 points which included both pasture and lucerne, so the issue is not crop specific. There are a number of potential reasons for this, not least experimental error (not just the model). It may also be that *Overseer* is overestimating soil N supply, either through fixation or mineralisation of organic matter.

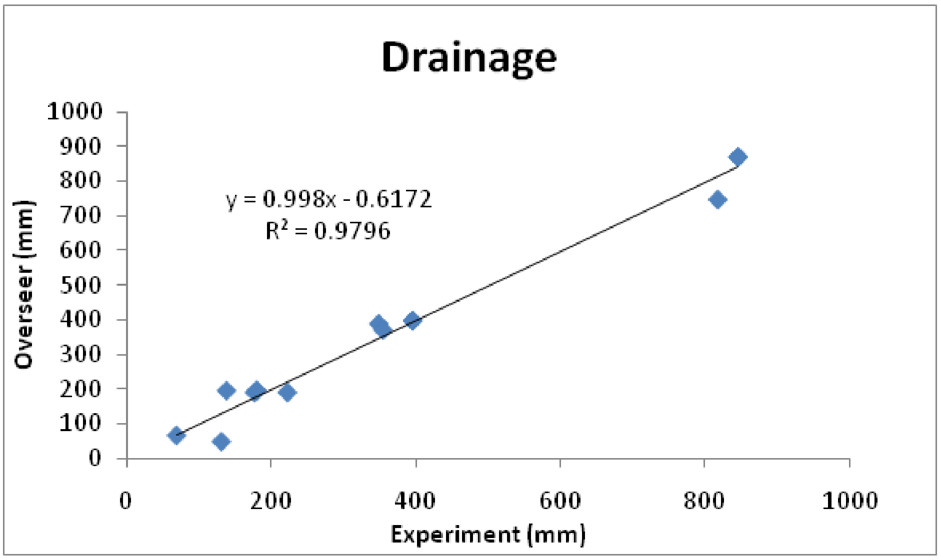

Figure 2: Comparison of drainage volume calculated by Overseer and reported in the experiments (not all experiments within the dataset provided this information)

Nevertheless, although this area may warrant further scientific investigation, the *Overseer* cut and carry block model worked well on average. There was not a wide range of values to test the model, but this is a system where large N losses are not expected (e.g. Scholefield et al., 1991), unless over-fertilised or with inappropriately timed N fertiliser. The model worked satisfactorily for pasture and a limited amount of lucerne data, but we were unable to test for other sward types due to lack of data.

The experiment dataset also allowed validation of the water balance model component of *Overseer*. Many of the experiments reported a drainage volume, either measured (in lysimeters) or a modelled value using a crop water balance model of the authors' choice. Figure 2 compares *Overseer* estimates with experiment estimates, either measured or modelled. The linear regression had a slope of 0.99 and an intercept not significantly different to zero.

Conclusion

From the comparisons that were made between experiment reports and *Overseer*, it can be can concluded that the cut and carry model within *Overseer* adequately represents N leaching and drainage in situations where paddocks are used solely for growing pasture based supplements, especially for ryegrass/clover swards.

Acknowledgements

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