FROM STOCK NUMBERS TO N LEACHING AND NITROUS OXIDE – THE PROGRESSION THROUGH *OVERSEER*

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Abstract

OVERSEER® Nutrient Budgets (*Overseer*) provides users with tools to examine the impact of nutrient use and flows within a farm, namely nutrient use efficiency, and off-farm losses of nutrients and greenhouse gases. The objective of this paper is to describe how Overseer uses internally calculated data to illustrate how *Overseer* progresses through the calculations from animal ME requirements to estimate N leaching and nitrous oxide emissions from urine patches.

Introduction

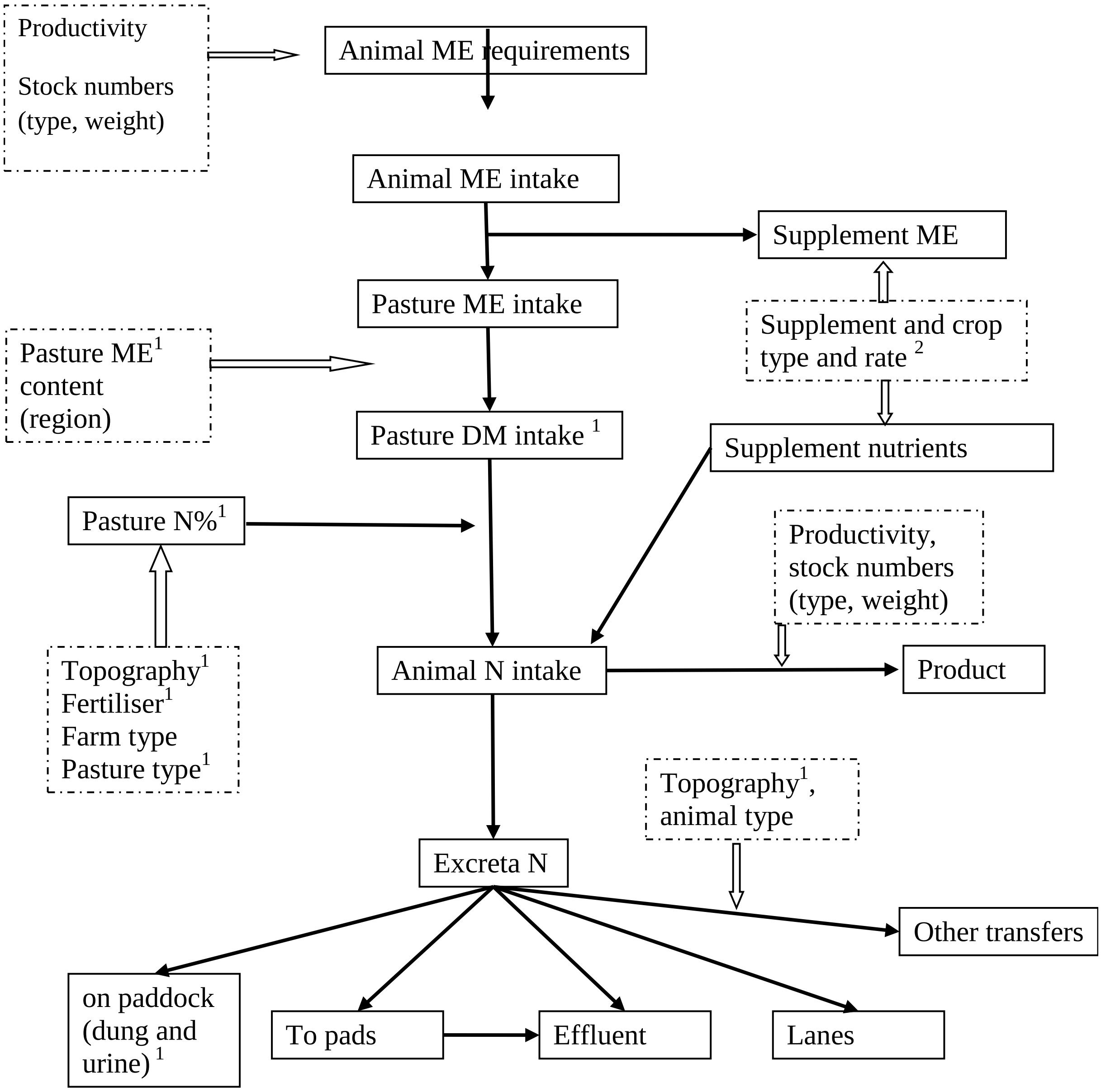
OVERSEER® Nutrient Budgets (*Overseer*) calculates a nutrient budget for the farm, taking into account inputs, outputs, and some of the internal recycling of nutrients around the farm. Nutrient budgets are calculated for the nutrients nitrogen (N), phosphorus, potassium, sulphur, calcium, magnesium, and sodium. Items in the nutrient budget can be extracted to examine the impact of nutrient use and flows within a farm, namely nutrient use efficiency, and off-farm losses of nutrients and greenhouse gases. *Overseer* can be used to model pastoral, horticultural, arable, and vegetable farm systems (Wheeler and Shepherd 2012). *Overseer* calculates a nutrient budget for the farm, taking into account inputs to, outputs from, and some of the internal cycling of nutrients within the farm. Users range from farmers and their consultants through to policy makers and policy implementers.

Overseer develops nutrient budgets by modelling nutrient transfers around the farm, and the fate of the nutrients at each transfer point. Examples of the latter include N leaching from urine patches, and gaseous N emissions from effluent systems. The model incorporates two scales, farm and block, to reflect the scale at which management decisions are made (Wheeler and Shepherd 2012). A block is a collection of paddocks with the same management and site characteristics.

Typically in pastoral based systems, nutrients are moved around the farm as feed (supplements, crops), as effluent or in the gut of animals. To be able to model the transfer of nutrients by animals, the amount of nutrient eaten (nutrient intake) is required. In pastoral based systems, there are two options: (1) estimate on-farm pasture production and utilisation to provide animal intake, or (2) estimate pasture intake based on the energy requirements of a defined group of animals. The estimation of on-farm pasture production and utilisation to provide animal intake is difficult, open to different interpretations, and difficult to validate.

An alternative approach is to estimate the animal metabolic energy (ME) intake requirements and calculate dry matter intake (DMI) using pasture diet ME content. Animal production data is usually more available and easier to validate, although pasture ME content is variable and not always easily obtained. On balance, it was decided that pasture nutrient intake would be estimated from animal productivity via the metabolic model. This was fortuitous as the Greenhouse Gas National Inventory methodology for methane and nitrous oxide uses animal production statistics to estimate ME requirements based on Feeding Standards for Australian Livestock (CSIRO, 2007) and average monthly pasture ME statistics to calculate DMI (Ministry for the Environment, 2010). intake via an animal ME intake model (Ministry for the Environment (2010). Hence, a similar method could be used to estimate greenhouse gas emissions in *Overseer*.

The objective of this study is to use internally calculated data to illustrate how *Overseer* progresses through the calculations from animal ME requirements to estimate N leaching and nitrous oxide emissions from urine patches. Figure 1 provides a simplified representation of the elements for determining excreta N calculations, although the same basic framework applies to all nutrients. Some of key elements are described in more detail in the following sections



ME = metabolisable energy [1] = block scale, [2] = block and farm scale

Figure 1. Schematic diagram of the elements that constitute the animal model framework.

Method and results

A typical Waikato pasture-based dairy farm (standard farm) running a seasonal milking herd only was set up using *Overseer* beta version. This model is equivalent to the recently released *Overseer* version 6. The farm had two blocks, main and effluent with effluent sprayed back onto the land.

A duplicate Waikato dairy farm was set up that had 50% of the diet was supplied by supplements (high supplement farm). It was assumed that supplements were fed evenly over the year, and that a small proportion of the supplement was fed in the milking shed from the start of lactation to February. This set up was to demonstrate some of the principles behind the calculations in *Overseer*.

The internal calculated values animal ME requirements, dry mater intake, N intake, an excreta N intake were extracted and are presented. For each section, there is a generic description of the how the model works, followed by the results for the two example farms.

ME requirements

Overseer estimates animal ME requirements using a monthly metabolic model sub-model (Wheeler 2012a). This sub-model estimates the amount of energy animals require for maintenance, to produce milk production, wool and velvet, live weight gain and for pregnancy. The total ME intake requirement for each month is determined for each class of animals that have attributes such as sex age, weight, and when they are in gestation or lactating. Thus the calculated ME requirements are dependent on stock class, stock numbers and animal production.

Animal ME requirement for the herd of the example dairy farms is shown in Figure 2. The curves are the same as animal numbers and milk production where the same in both files. The pattern over the year is typical of a seasonal supply dairy herd in that ME requirements are lower in winter when animals are not lactating, and culls are frequently sold.

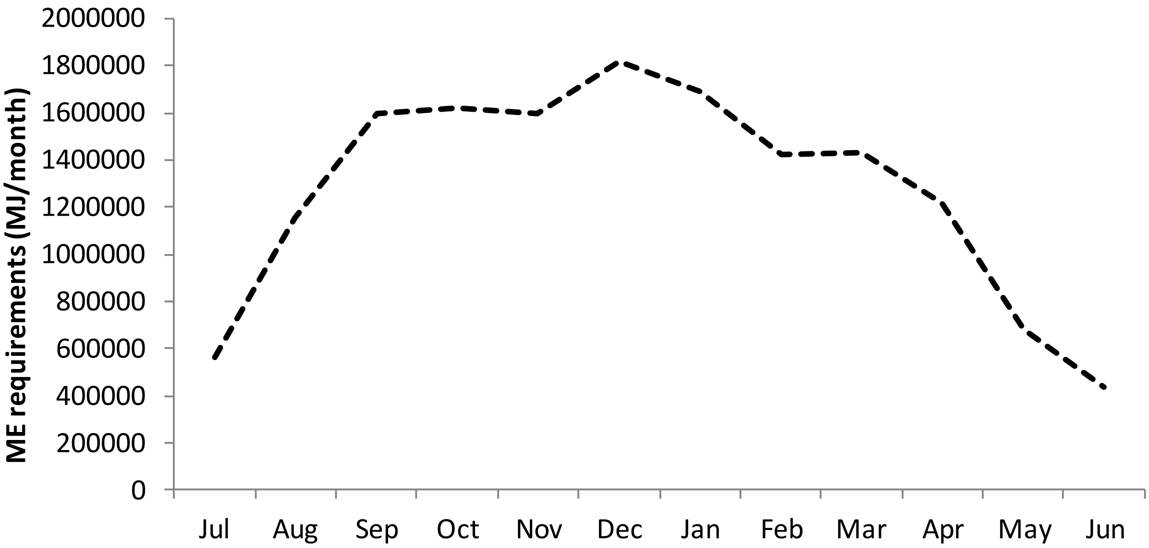


Figure 2. ME requirements per month for the dairy herd for the standard and high supplement farm.

Pasture ME intake
The animal ME requirement is assumed to be supplied by pasture, supplements, and/or crops. The amount of supplement and crop brought in (external source) or fed out (internal source) is supplied by the user. The amount fed out or brought in is adjusted for storage loss utilisation, which has a default value or can be modified by the user, to give ME intake from crops and supplements. The user can supply feed attributes such as ME, DM content, and nutrient composition for each supplement, or default values based on an analysis of a laboratory database are used. Each crop has default values for ME, DM content, and nutrient composition. By default, supplements are distributed on a pro-rata basis over months. The model assumes that pasture ME intake is the difference between animal ME intake, and the ME intake supplied by supplement and crops.

On the standard farm, all ME is assumed to be supplied by pasture as no supplements or crops are entered. On the high supplement farm, pasture ME is the difference between animal ME requirements and ME supplied by supplements, as illustrated in Figure 3 for the high supplement farm.

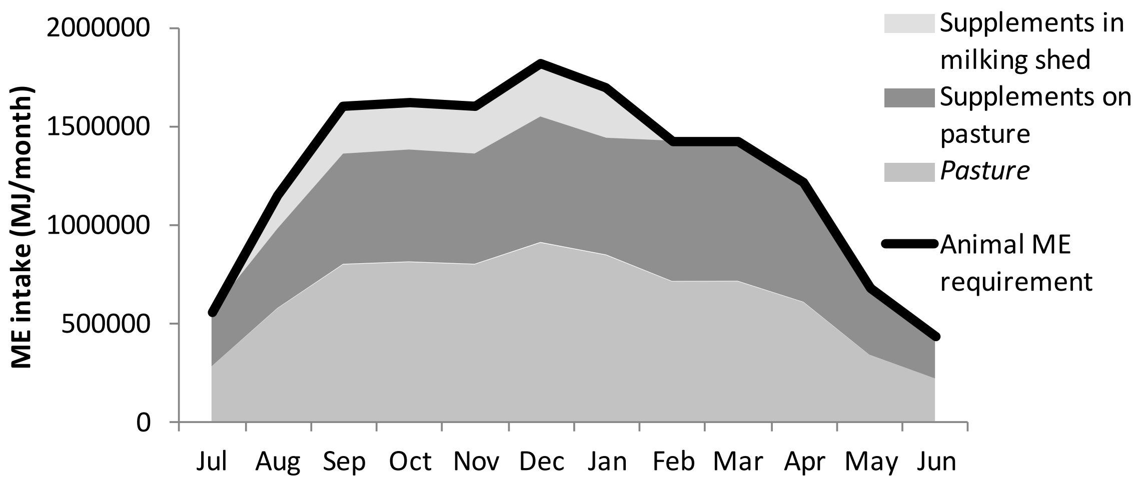


Figure 3. Distribution of ME intake for the herd between supplements and pasture for the high supplement farm. Animal ME requirements for the herd is also shown.

Dry matter intake
Pasture DMI is calculated as ME intake required from pasture divided by ME content of the pasture component of the diet. Pasture ME content is a block scale property and is a user input or default values can be used (Wheeler 2012b). Thus, the ME content of the pasture component of the diet is the average block ME, weighted by the amount of pasture intake from each block. Supplement and crop DMI is estimated from user inputs as for ME. Pasture DMI, along with supplement and crop DMI, can then be added to give total animal DMI. Animal DMI is used in the methane emissions model (Wheeler 2012c).

The ME content of the pasture component of the diet was the same for both farms, and is shown in Figure 4. The high supplement diet herd has lower DMI for the herd as the ME content of the supplement is higher than the ME content of the pasture (Figure 5). Over a 12-month period, total intake was 10% lower on the high supplement diet (Figure 5).

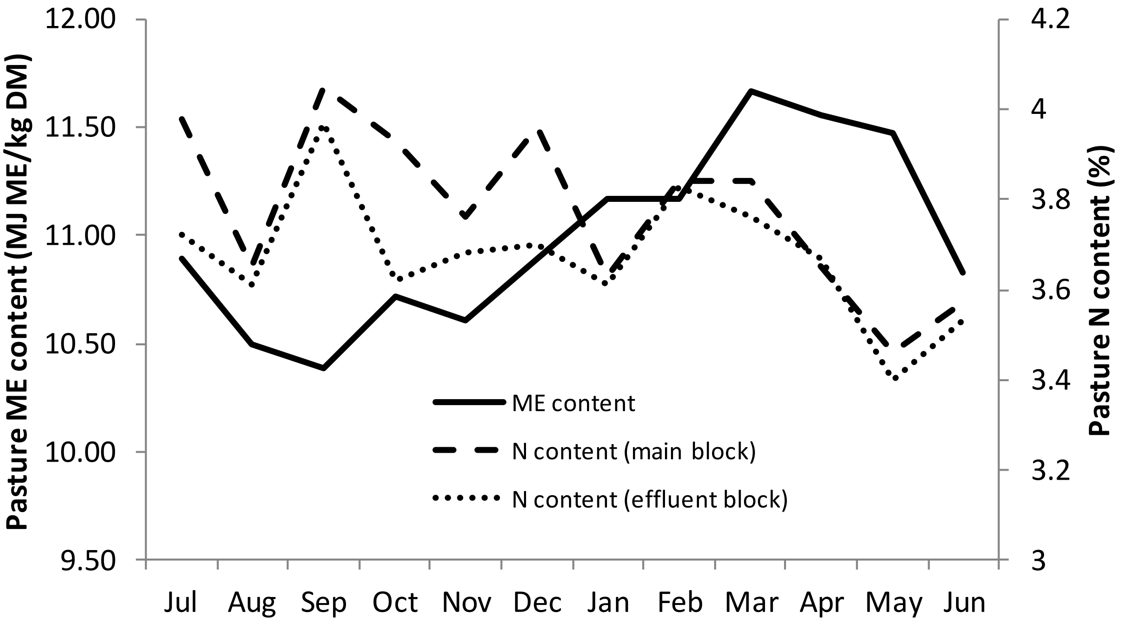


Figure 4. ME content of the pasture component of the diet, and estimated pasture N content from the main and effluent block for both farms.

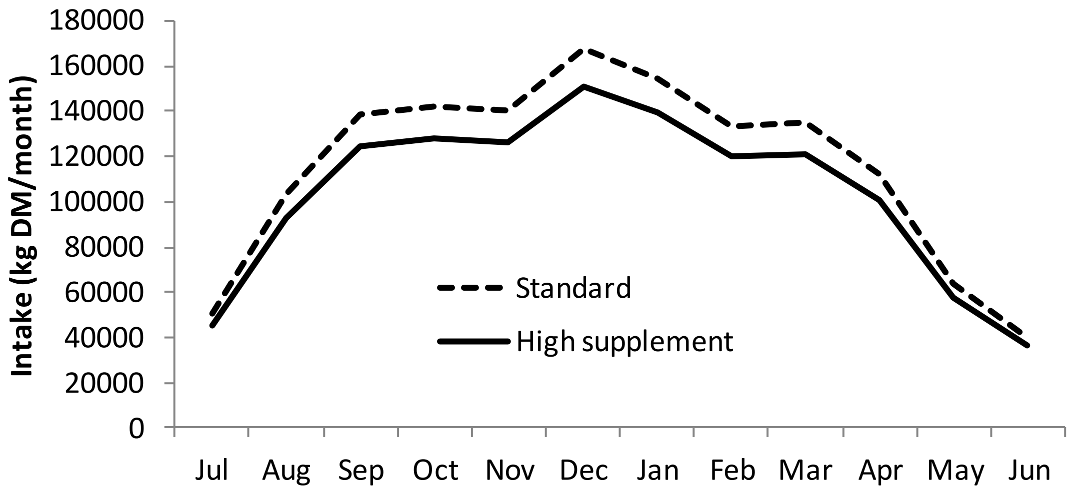


Figure 5. Predicted dry matter intake for the dairy herd for the standard and high supplement farms.

Pasture N intake

N intake is calculated as the sum of the product of DM intake and N concentration of each feed component. The pasture N content may be entered by the user or default values are used, as reported by Wheeler (2012c). N content of pasture is a block scale property, and varies with N inputs such as fertiliser, effluent, as well as pasture type, topography and soil moisture status. Thus to estimate pasture N intake, pasture DMI is distributed to a block, multiplied by the block N content and then aggregated up to the farm level to give animal N intake for the herd..

Pasture N content of the effluent and main blocks is shown in Figure 4. Over a 12-month period, N intake for the herd was 20% lower on the high supplement farm (Figure 6) due to higher ME in the supplement reducing DMI as above, and the supplement had a lower N content compared to pasture.

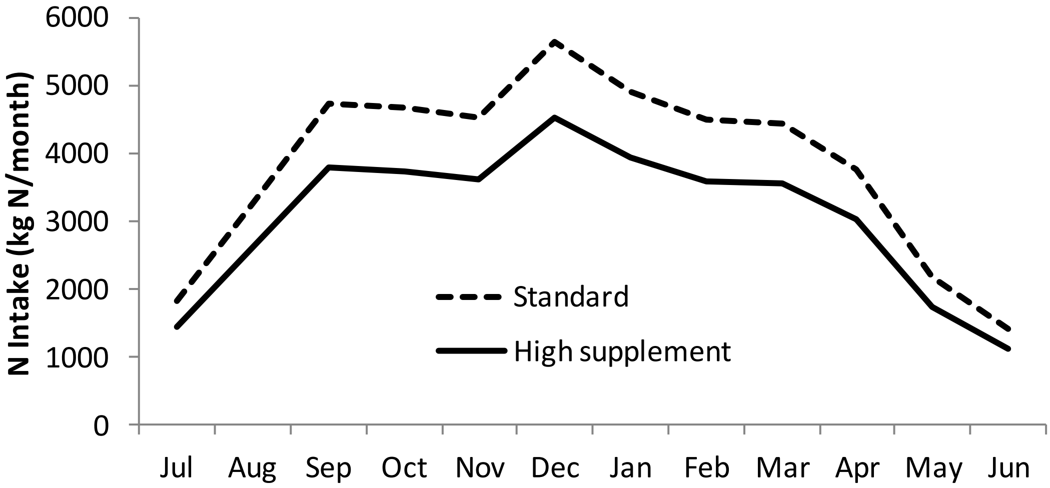


Figure 6. Predicted nitrogen intake for the dairy herd for the standard and high supplement farms

Excreta urine N

The amount of N excreted as urine is estimated as N intake, less N removed in product, multiplied by the proportion of excreta N that occurs as urine. The proportion of excreta N that is excreted as urine is dependent on the diet N concentration, and is typically between 65 and 80% of total N excreted (Ledgard et al. 2003). The proportion reduces as N content in the diet is reduced. Excreta N as urine and dung is then distributed around the farm, allowing for excreta deposited on blocks, farm dairy, pads, and lanes (Figure 1). Excreta deposited on the farm dairy and pads end up in the effluent management system. Thus, the model calculates the average amount of N deposited as urine (kg N/ha/yr) on a paddock for each animal class for each month.

The amount of N excreted as urine for the two farms is shown in Figure 7. Over a 12-month period, the amount of N excreted as urine was 24% lower on the high supplement diet farm due to the 20% lower N intake as above, and lower N content of the diet resulting in less N excreted in the urine. As there were no pads, more than 90% of the excreta were deposited on the blocks.

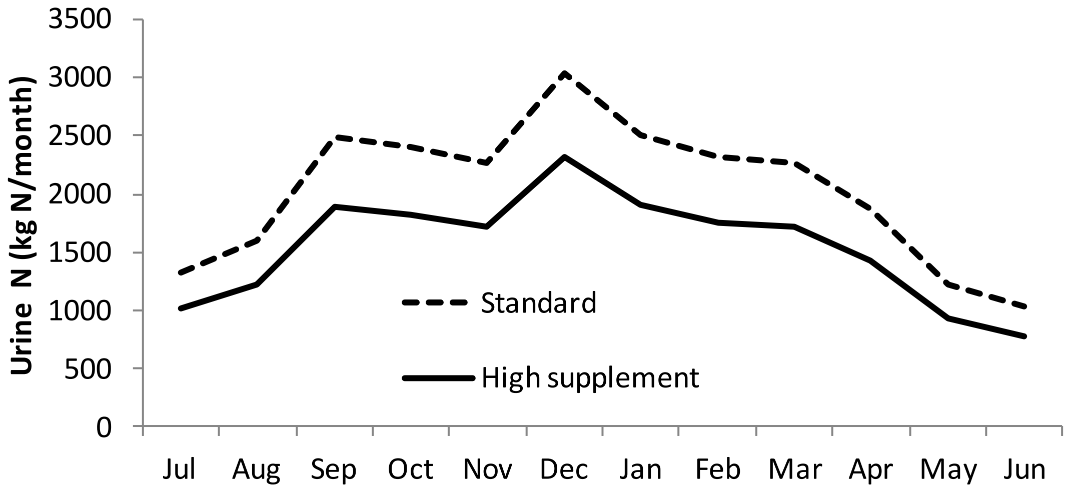


Figure 7. Predicted urinary nitrogen excreted by the dairy herd for the standard and high supplement farms.

N leached

In grazed pastures, the largest source of N leaching is from N deposited in urine patches. This is due to inefficiencies in capturing N from the high concentrations that occur in urine patches. There is also background N leaching loss sub-model (Wheeler et al. 2011) that accounts for leaching losses associated with the use of fertiliser and effluent.

The amount of N leaching from these urine patches is estimated as:

Urine N leached = Urine N * fleach

where Urine N is the total amount of N deposited by an animal type each month, and fleach is the proportion of N added as urine that is leached each month. Fleach varies with rainfall, rainfall pattern, soil properties, drainage system, and animal type. Thus, fleach for sheep is typically about half that for dairy cows. The derivation of fleach is reported in Technical Note 5 (2012).

The proportion of N added as urine that is leached each month for the example farms is shown in Figure 8. This resulted in 23.5 and 17.9 kg N/ha/yr leached for the standard and high supplement farms respectively, which corresponded to a 24% reduction. This is a reflection of the difference in the amount of urine N deposited on pasture. On a different site with exactly the same stock numbers and feed management, and with default supplement distribution, the absolute values would be different, but the relative difference would be similar to those in this example.

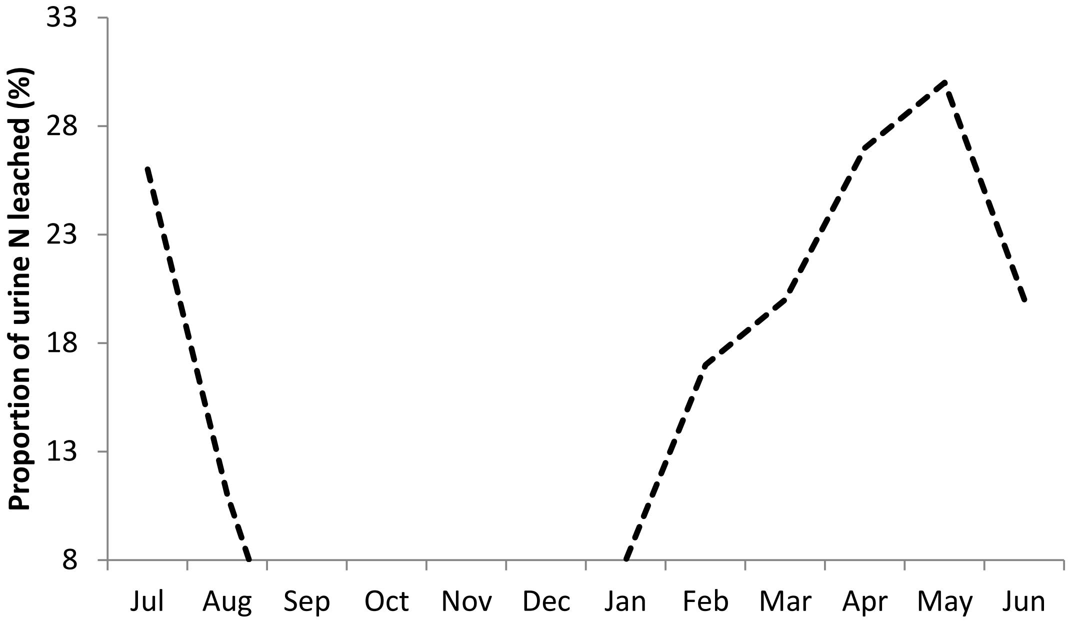


Figure 8. Proportion of urine N leached each month for the standard and high supplement farms.

Nitrous oxide emissions

Nitrous oxide emissions from urine are estimated each month as:

$$N_2O \text{ urine} = \text{Urine N} * \text{EFurine}$$

where EFurine is the monthly emission factor that varies with soil moisture content, soil properties, climate data (rainfall, PET) and drainage systems (Wheeler 2012d). The effect of varying soil group on a site receiving 1200 mm rainfall is shown in Figure 9.

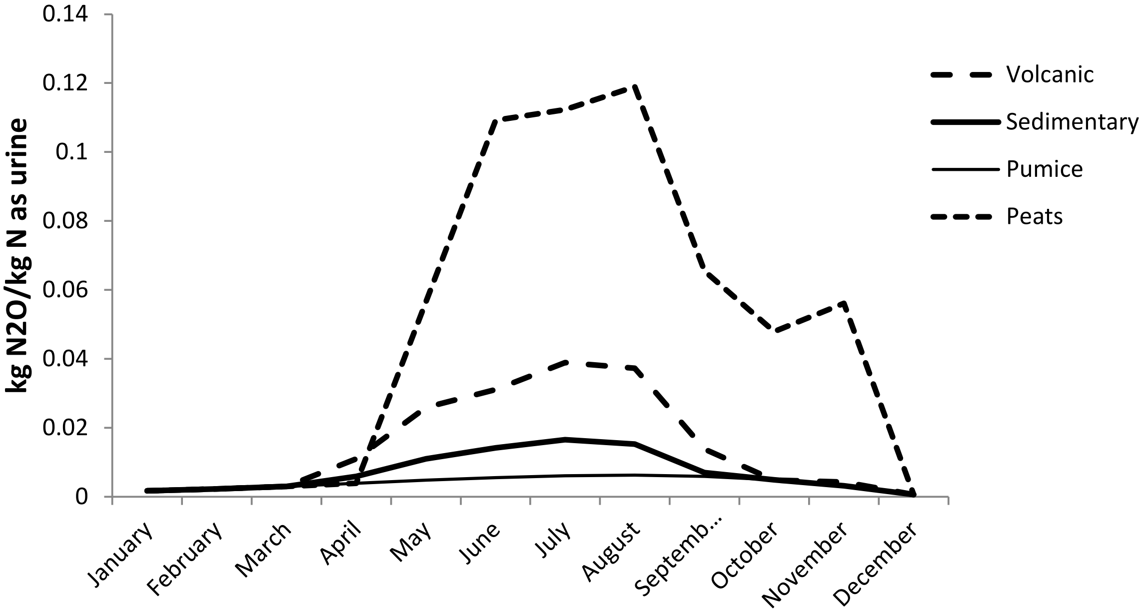


Figure 9. Proportion of urine nitrogen emitted as nitrous oxide from four *Overseer* soil groups.

Discussion

Overseer is constructed as a reporting tool, relying on the user to input actual farm data to describe the management system on the farm, along with site characteristics such as soil and climate data. The estimated N leaching is sensitive to animal production and numbers, and to dietary inputs such as supplements and crops. The long-term average and quasi-equilibrium assumptions used in the model (Wheeler and Shepherd 2012) means that the calculated N leaching value is the value if the farm maintains the entered animal numbers and production over time based on the entered rainfall and climate patterns.

The model constructed in this way means that any management activity that results in any increase in pasture production or quality on the farm is captured through animal numbers and production. For example, any pasture production increase from the use of nitrogen inhibitor is captured through changes in animal production. If the management activity results in significant changes in pasture N concentrations or pasture ME content, then these changes need to be modelled in addition to the change in stock production. This approach also means that

If animal numbers and production are entered correctly, then any errors in amount of supplements or crops entered will offset pasture intake because it is substituted for the supplements or crops. Thus if supplement use is under-reported, ME intake from pasture is over-estimated. This may have an effect on N intake, but providing the errors in rates and/or the difference in N concentrations between pasture and the supplement are not too large, then the effect on N intake on a per ha basis may be small.

There is also some self-balancing if the activity is not recorded. For example, moderate errors in fertiliser N inputs are not likely to have a large effect on N intake because the increase in pasture N concentration is small, and the primary impact of adding N fertiliser is to increase pasture production and hence stock production (unpublished results).

The downside of this approach is that for scenario or 'what if' analysis, any changes in animal numbers or production due to management changes must be entered. Thus, for example, if new irrigation is been considered, both irrigation and the resultant increase in stock numbers or production must be entered. Entering increased stock numbers or production results in modelled pasture production increasing, which is the purpose of irrigating. A toolbox to allow a limited range of scenario analysis is being prepared.

The amount of N leached or nitrous oxide emissions from urine patches is partially dependent on the amount of urine N added to a paddock. This, in turn, is derived from N intake, which is determined from supplements and crops fed to animals, and animal numbers and production. Thus, dietary N can vary due to the type of and amount of supplement feed, or increasing fed quality results in lower intake. Hence, substituting pasture silage with maize silage, which has lower N and higher ME, results in lower DMI, N intake, N in excreta, and N leaching.

On the high supplement farm, if the supplement was predominately fed from January to June, N leaching was estimated to be 10 kg N/ha/yr whereas if it was fed from July to December, N leaching was be estimated to be 25 kg N/ha/yr. The difference caused by supplement timing is due to the interaction of the supplement's effect on N intake and hence the amount of urine N deposited on the paddock, and the different proportions of N leached each month. In this case, on a different site with exactly the same stock numbers and feed management, the absolute values and relative differences between N leaching from the standard and high supplement farms would be different from the examples presented as the proportion of urine N leached each month is site-specific.

If a feed pad were used, leaching from urine patches would be lower as less urine is deposited on the paddock. However, leaching from the background N leaching loss sub-model, which accounts for the effects of fertiliser and effluent inputs, may be higher depending on the effluent management. However, placing animals on a feed pad and feeding homegrown supplements but keeping pasture intake constant may require a small reduction in animal numbers due to the lower quality (ME) of silage compared to pasture, and the losses associated with production, storage, and utilisation of the supplement.

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