Spotlight on OVERSEER: perspectives and approaches to addressing nutrient management challenges using an integrated farm systems model

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Abstract
OVERSEER® Nutrient Budgets (OVERSEER) is a whole-farm nutrient budgeting tool using a yearly time scale. It calculates a nutrient budget for the farm, taking into account inputs, outputs, and some of the internal recycling of nutrients around the farm. The model integrates multiple animal enterprises (dairy, sheep, beef, deer, dairy goats) and different land uses, including pastoral, cropping (arable, vegetable, fruit), and cut and carry areas. Nutrient budgets are calculated for the nutrients nitrogen (N), phosphorus (P), potassium (K), sulphur, calcium, magnesium, and sodium. With an increased emphasis on water quality, the model is being used to assess N leaching from pastoral farms. This paper discusses some perspectives and emerging practices that are occurring as a result of using an integrated farm systems model like OVERSEER, with a focus on urine patch, irrigation, effluent management and fodder crops.

Key Words
Nitrogen, leaching, farm systems, effluent, irrigation

Introduction
OVERSEER® Nutrient Budgets (OVERSEER) is a whole-farm nutrient budgeting tool that reports nutrient movements at a yearly time scale. It calculates a nutrient budget for the farm, taking into account inputs, outputs, and some of the internal recycling of nutrients around the farm. The model integrates multiple animal enterprises (dairy, sheep, beef, deer, dairy goats) and different land uses, including pastoral, cropping (arable, vegetable, fruit), and cut and carry areas. Nutrient budgets are calculated for the nutrients nitrogen (N), phosphorus (P), potassium (K), 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. Users range from farmers and their consultants through to policy makers and policy implementers (regional councils).

Water quality is an increasing issue within New Zealand, and regional councils are increasing considering the effect of N loss from pastoral lands on water quality as part of their regulatory plans. As the loss of N is a diffuse source, one method to assess the impact of farming systems on plans or policy, and to monitor farm discharges is to use a model. OVERSEER has been used in this capacity as it estimates N leaching from a wide range of farm systems within New Zealand.

This paper discusses some perspectives and emerging practices that are occurring as a result of using an integrated farm systems model to addressing nutrient management challenges, with a focus on urine patch, irrigation, effluent management and fodder crops, and a focus on dairy systems.

Method
Description of the model methodology is available on the website http://overseer.org.nz. Sub-models relevant to this paper include the drainage and irrigation sub-model (Wheeler 2015). N leaching is estimating using urine patch and background sub-models (Wheeler et al. 2011). The background N model integrates the effect of N applied in fertiliser, effluents, organic materials, and irrigation water, and estimates N leaching (Cichota et al. 2010). Typically, the amount of N leaching from the background is small in pastoral systems in New Zealand unless large amounts of fertiliser or effluent is applied (typically more than 200 kg N/year), or timing of application coincides with drainage.

OVERSEER estimates the amount of urine N deposited on a block each month (kg N/ha), which is a function of stock numbers, their diet and their location (whether they are on pasture). Urine patch N concentrations, size and shape are known to vary between animal species, sex of animal, time of day, etc. (Selbie et al. 2015). Thus N leaching from a urine patch has been modelled using a standard urine patch to estimate the proportion of that N in that patch that leaches each month (Wheeler et al. 2011). The proportion of the urine N that leaches is dependent on soil properties that define a break through curve (Cichota et al. 2012), drainage, and the rate at which N is removed from the urine patch, for example, by pasture uptake, volatilisation, and denitrification (Wheeler et al. 2011).

Leaching from urine patches
The proportion of N that is leached has been encapsulated in a unitless urine leaching risk indicator, which includes the effect of site factors (soil, climate, including the effect of soil moisture and temperature on N uptake) on the risk of N leaching from a standardised urine patch each month. Note that it is not necessarily an indicator of the month that N is actually leached, which can be several months or the following year after deposition (Shepherd et al. 2011). Figure 1 shows that the risk varies with rainfall (drainage) and profile available water, and that the period of highest risk is late autumn/early winter. The higher risk in this period is a result of drainage and lower pasture uptake after deposition. The role of uptake has been further emphasised by Buckthought et al. (2016) who showed that uptake extends beyond the urine patch wetted area. The ability to model lysimeter trials has been added, and one of the important differences between field and lysimeter trials was that extended uptake doesn't occur in lysimeter trials.

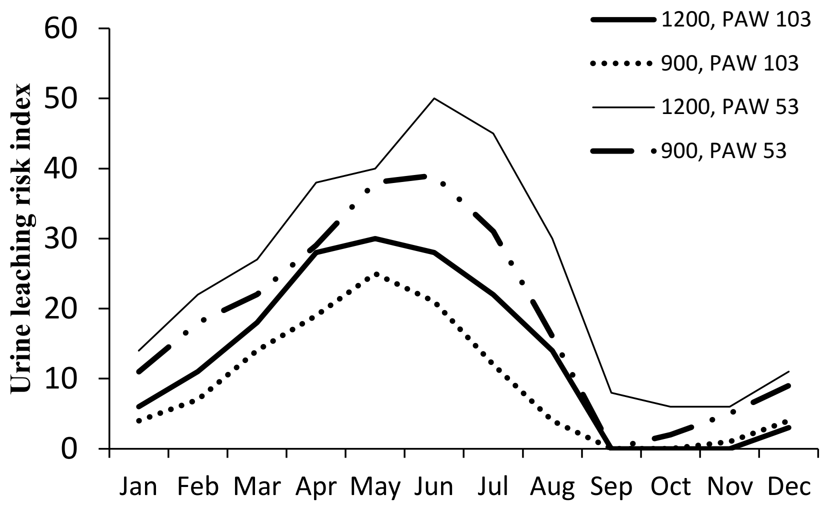

Figure 1. Effect of rainfall (mm/year) and profile available water (PAW, (the difference between field capacity and wilting point expressed as mm per 600 mm depth)) on urine leaching risk index (max =100).

Mitigation options to reduce deposition of excreta on pastures include removing animals from the pasture, for example through the use of animal shelters, although this is an expensive option. This option can reduce N leaching by 15-40%, depending on the farm. In practice, there is frequently an increase in the use of supplementary feeds brought onto the farm to increase production to pay for the capital costs associated with feeding infrastructures, and this results in decreased effectiveness. It also replaces the risk of leaching from urine patch with the risk of leaching from effluent application, although the latter can be managed. The model indicates that shortening lactation length, removing cull cows early, or changing the time animals regain weight can decrease N leaching, although the impact tends to be small (6-10%). Manipulating intake, such as substituting high N supplements (for example, pasture silage) for low N supplements (for example, maize silage) also reduces leaching. In sheep systems, the use of high fecundity ewes, reducing wintering ewe numbers and selling of lambs by autumn has achieved a similar effect.

The DCD sub-model (Shepherd et al. 2012) shows that DCD had the effect of DCD in decreasing N leaching was greatest in autumn, and for decreasing denitrification/nitrous oxide emissions, the greatest effect was in late winter when soils where wettest. This indicates that the mitigation options to reduce both nitrous oxide and N leaching may vary, or that the period mitigation options are applied may need to be longer than if mitigating a single pollutant.

Irrigation
The effect of irrigation on N leaching is driven by the effect of irrigation on drainage, and soil moisture levels. The model indicates that if irrigation is optimised so that there is little or no additional drainage, then irrigation can result in significant increases in N uptake, and N leaching can decrease. If N leaching is

reduced, then soil N levels could increases, resulting in higher potential for N leaching losses in the future, or denitrification and nitrous oxide emissions may increase.

The corollary is that if irrigation is not efficient, the critical periods for urine deposition on pasture shifts from autumn to spring (Figure 2). In this example, irrigation increases the risk of N leaching in spring and summer, partly due to extra drainage in October as a result of excess irrigation (not shown) resulting in urine N deposited in June to September to be susceptible to leaching losses. The susceptibility is enhanced by low temperatures reducing N removal, particularly via pasture N uptake, from the urine patch. Using an optimised management system in October decreases drainage and thus reduces this impact. In the January to April period, the increased drainage due to the March irrigation has been offset by higher N removal by the pasture as the soils are moist and temperatures encourage the removal of N. This suggests that the shoulder periods (spring and autumn) are an important time to manage irrigation systems. Similarly urine deposition in spring and autumn may be more important than the typical period of late autumn/winter. Ironically, a driver to improve water use efficiency may be the impact of irrigation on N leaching. Figure 2 also indicates that there are complex interactions between timing of drainage and urine deposition and N removal from the urine patch. Further work on N cycling in irrigated pasture systems is required to understand these interactions.

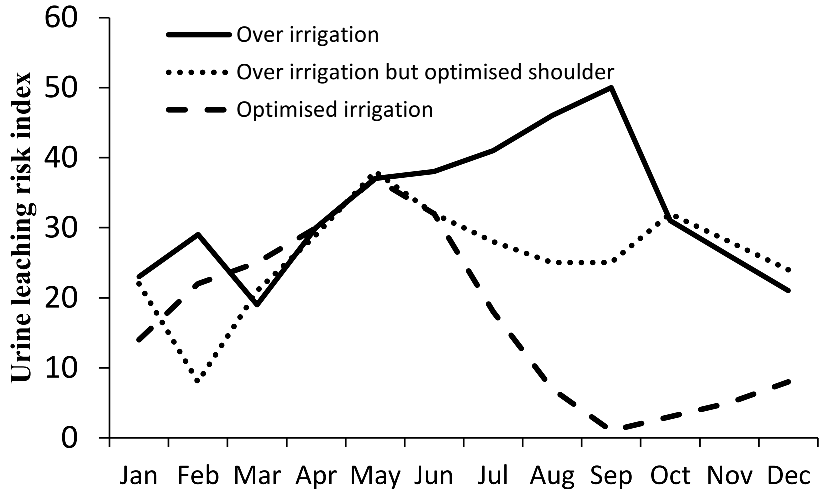

Figure 2. Urine leaching risk indicator for unirrigated and over-irrigated areas, and an over-irrigated area using an optimised system in October and March (100 = max).

Effluent management

On most New Zealand dairy farms, effluent is reapplied back onto pastures either directly from a sump, or after a period of storage. One of the early uses of the model was to illustrate the impact of effluent areas on animal health. Effluent areas were small and were also used for calving as they were close to the farm dairies. In one year there were a large number of cows with hypomagnesaemia, which is exacerbated by high dietary K levels. The model was used to illustrate the high K rates added as effluent contributed to this situations, and remedial action was taken.

Many regional councils in New Zealand have set a maximum application rate of 150 kg N/ha/year as effluent. The model is being used to provide an indication of effluent block sizes to achieve this rate. With increasing use of supplement feeds and feed pads, the proportion of the farm required to meet this target now varies from 25-30% of the farm for all pasture systems, up to over 100% of the farm for high supplement systems.

When fresh effluent is applied at the rate of 150 kg N/ha/year, the effluent accounts for 30-60% of P requirements required to maintain pasture production on effluent blocks. Differential application of fertilisers to effluent and non-effluent blocks represents a saving in fertiliser costs, the second largest cost on many farms, and through the fertiliser companies, differential applications is now widely practiced. When the effluent is stored in ponds, there tends to be a loss of N through volatilisation and denitrification. Hence, for a given amount of N, there is high rate of other nutrients, particularly K, being applied. On some farms, it may be more economical to focus on other nutrients than N in defining effluent block areas.

The model also showed that application of solid effluent (or any organic material) does not always result in reduction in N leaching when compared to conventional fertiliser. The timing of application, rate of N release (a function of inorganic N and N content of the organic fraction), rate of N uptake and amount of drainage are important. Hence if N release from summer/autumn applied organic material occurs as plant growth and uptake is starting to slow down, and this coincides with drainage, then higher leaching than using conventional fertiliser can occur.

Fodder crops

The crop model in OVERSEER is also based on Cichota et al. (2010). The important drivers of N leaching from crops are the time of cultivation, amount of soil organic N mineralised, contribution of residues from previous crops, time of crop uptake, and time of animal grazing.

On many New Zealand pastoral farms, fodder crops are grown for animal feed. These are typically cultivated direct out of pasture, and animals grazed the crop in situ. Either summer (for example, turnips), or winter crops (for example swedes, kale) are grown. In these systems, the decomposition of residue roots and stover from cultivated pasture is a significant source of N. Soil organic N mineralisation rates are also higher than in continuous cropping regimes. Urine deposited is modelled as for pasture blocks, but account is taken that fodder crops have frequently reached maturity at grazing time, and hence there is little N uptake during grazing. Post-grazing, there is no pasture uptake as the crop is consumed. Thus the model shows increased risk of N leaching from the background N model if crops are cultivated in late autumn/early winter, or left fallow over winter, and increased leaching from the urine patch if they are grazed in late autumn/early winter. Research work and farm management options are being investigated on how to manage cover crops to maximise plant N uptake over critical periods of N loss risk.

Conclusion

OVERSEER® Nutrient Budgets (OVERSEER) is an integrated farm system model. The development and use of OVERSEER as a tool for on-farm assessment of N leaching, particularly in a regulatory environment, is challenging and improving our understanding of farm nutrient dynamics.

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