Strategies to reduce nitrate leaching losses from intensive crop production in northern Tasmania

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Abstract

A combination of high input management systems, high annual rainfall and deep, permeable soils in northern Tasmania create conditions that are conducive to high drainage and nitrogen losses below the root zone. Modelling of the fate of nitrogen and water across seven mixed vegetable-based farming enterprises in the Panatana catchment identified substantial drainage losses (>100mm average seasonal loss) across all phases of the crop rotation. Crop nitrogen demand was found to be close to crop nitrogen supply for all crop and pasture rotation elements with the exception of potato, which had an average surplus nitrogen supply of 89 kg N/ha. This resulted in potato having the highest nitrogen leaching loss of all crops. Practicable management options such as deficit-based irrigation and reduced N fertiliser rates were found to maintain current levels of productivity while reducing potential offsite N loss and generating significant financial savings via reduced input costs.

Keywords

Nitrate leaching, drainage, nitrogen, farm system modelling

Introduction

The Panatana catchment in central north Tasmania, Australia (~41?12'S, 146?26'E) is one of the most intensively cropped catchments in the state due to a favorable climate, productive soils and ready access to various agricultural processing and port facilities. A wide range of vegetable, pharmaceutical, industrial, fodder and cereal crops are typically grown in rotation with a longer-term pasture phase. The potential for high yields and the high value of some of the crops has encouraged farmers to invest in new irrigation infrastructure (e.g. dams, low pressure pivot irrigators) to overcome crop water deficits during the summer months, and to adopt a liberal approach to nitrogen fertiliser rates, especially for high value crops such as potato. While irrigation application rates are often high, the timing of irrigation is rarely based on technology measuring soil moisture deficits. Rainfall distribution is typically winter dominant, however substantial falls can occur at any time of the year. These attributes and the prevalence of Ferrosol soils that have high infiltration rates and rapid permeability (Drewry *et al.* 2006) create conditions that are conducive to high drainage rates and associated nutrient loss via leaching. Such losses have potential financial (i.e. inefficient use of inputs) and environmental (i.e. ground and surface water pollution) consequences (Drewry *et al.* 2006; Zang *et al.* 2006).

Farm system models which capture the key biophysical processes and the interactions between management, climate, soil and crop components provide a means to help understand how water and nitrogen move through the farming system over time at both the paddock and whole farm scale and the potential impact of different management practices. When integrated with long-term climate records the models can also be used to explore the effect of seasonal climate variability. This paper describes the results of a farm system modelling study to analyse the impact of current management practices on water and nitrogen loss below the root zone and to identify viable alternative management practices for reducing these losses.

Materials and method

The study is based on seven farms selected to represent the typical range of soil, crop and management practices prevailing across the Panatana catchment. A variety of farm management information was collected for each farm for the purposes of: a) understanding the farming systems in question; b) model calibration/validation and; c) developing performance baselines against which to compare alternative management practice. Interviews were conducted with each farmer to collect key management details relating to crop sequence, cultivar selection, crop establishment (e.g. sowing date, seeding rate), nutrient management, irrigation management, tillage practices and residue management. Farmers were also asked to provide estimates for crop yield to enable comparison with simulated values. Rotations for the seven farms are comprised of up to five annual crops including a range of vegetable crops (i.e. potato, broccoli, fresh pea, green bean), poppy and wheat. All rotations have a pasture phase of between 2-6 years in duration and fodder ryegrass is commonly grown in-between summer crops to reduce drainage and to provide valuable winter feed for stock (Figure 1).

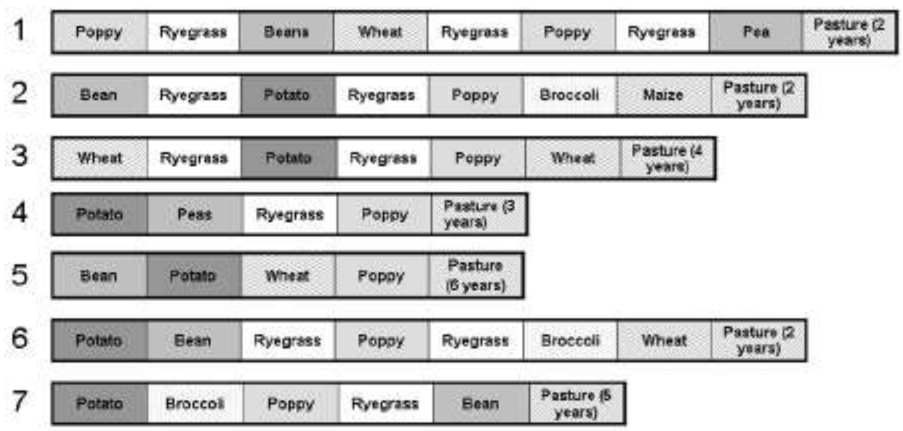

Figure 1. Simulated crop sequences for the case farms

For most crops and on most farms, nitrogen fertiliser is typically applied at sowing and as a top-dressing later in the season. While some farmers used standardized fertiliser application rates, most used pre-season soil testing of the upper part of the profile and in-season tissue nutrient results to modify their regimes. The highest N fertiliser application rates are for potato with up to 479 kg N/ha applied across basal and topdress applications. All farms use irrigation water sourced from on-farm dams and river resources to offset summer deficits. Most of the farmers have made (or are in the process of making) the transition from high pressure traveller delivery equipment to low pressure pivot technology. Just one of the seven farmers (Farm 1) uses soil moisture monitoring to schedule irrigation. The remaining farmers operate fixed schedules delayed only when water runs out or when there are significant rainfall events prior to the scheduled irrigation event. The highest application rates are for potato with up to 28 irrigation events of 15 mm each (Farm 7). Across all farms there is a focus on minimising tillage and, where possible, retaining crop residues in order to maintain soil health and nutritional status.

One soil on each farm was fully described and characterised to a depth of ~120cm and these results were used to parameterise model configurations for each farm. Each simulation used long-term daily temperature, radiation and rainfall data for the Devonport Airport (41.7?S, 147.1?E), sourced from the SILO database (www.bom.gov.au/silo). For each farm, a series of separate model runs offset by one year (the number of runs determined by the number of crop elements in the rotation) were conducted such that each element of the crop rotation was simulated in every year of the 25-year period from 1980 to 2005. The 25 year simulation period enables consideration of long-term system impacts (i.e. carry-over from year to year) and the effects of seasonal climate variability.

Soil, management and climate data/information collected from each case farm was used to calibrate and parameterise the farming system model, Agricultural Production Systems Simulator (APSIM, Keating *et al* 2003). Model output from the baseline (current management) runs was used to analyse system water and nitrogen balances and, more specifically, the extent of water and nitrogen ‘leakage’ from these systems and the mechanism and source of loss. The final step was to identify and analyse a number of practical, alternative management options that have the potential to reduce nutrient and water loss while maintaining productivity.

Results and discussion

Drainage

While the greatest drainage losses occurred from crops and pasture in the winter phase of the rotation, there was substantial leakage from summer crops that exceeded 100 mm per crop (Fig. 2). These leakages during summer were attributable to the large irrigation volumes that are applied and the absence of deficit based irrigation scheduling.

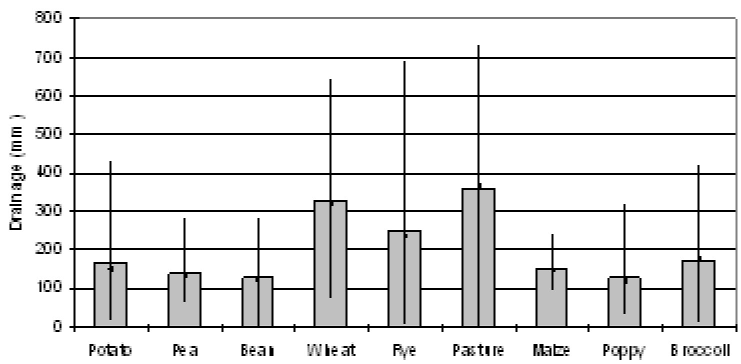

Figure 2. Seasonal crop (i.e. sowing to harvest) and annual pasture (i.e. calendar year) drainage between planting and harvest, calculated across all seven case farms and all years of the simulation period (1980-2005). The vertical line shows the full range of simulated values (minimum to maximum). The point corresponds to the 50th percentile (median).

Crop nitrogen demand and supply

Leakage of N was greatest for potatoes, with relatively small differences among the other crops (Fig. 3). This was because the N supply exceeded crop demand in potatoes, whereas in the other crops the N supply was consistent with demand. Where supply exceeds demand, the surplus is either leached from the profile and/or carried over in the soil to the following season. Total N supply to potatoes averaged across the 7 farms was 397 kg N/ha. Simulated potato crop N uptake (i.e. total biomass N) across the six case farms growing potato, ranged from 4.20 kg N/t FW tuber to 5.52 kg N/t FW tuber (average 1980-2005). These values compare with previously published N uptake figures for potato crops grown under similar conditions in NW Tasmania i.e. 5.13 and 4.59 kg N/t FW tuber (ServeAg 2007). When averaged across all farms and years, modelled seasonal N uptake is 302 kg N/ha and total N supplied as fertiliser is 397 kg N/ha. This gives an average surplus N supply for potato crops of 95 kg N/ha. Mineralisation of N that occurs within the soil over the course of the season will add further to this surplus.

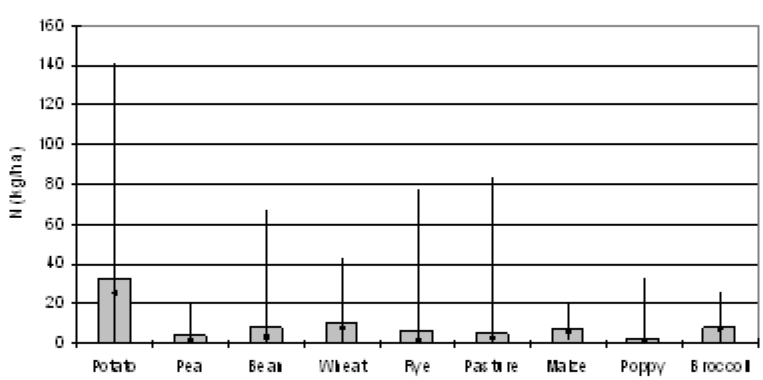

Figure 3. Seasonal N loss via leaching below the root zone calculated across all seven case farms and all years of the simulation period (1980-2005). The vertical line shows the full range of simulated values (minimum to maximum). The point corresponds to the 50^{th} percentile (median).

Nitrogen leached from the root zone

Potato had the highest average N leaching loss of 32 kg N/ha, compared with <10 kg N/ha for all other crops. The broad range of N loss figures shown in Figure 3 illustrate the extent of spatial and temporal variability in seasonal N leaching loss, and the potential for substantial seasonal N leaching losses from all phases of the rotation in some years. For example, heavy rainfall following fertiliser application may lead to high losses in some years with consequent enrichment of off-site surface and ground waters.

Options for reducing water and nitrogen loss below the root zone

The above results indicate that of all the crops grown, the highest average rate of N loss occurs under potato. Similarly, of the seven crop-based farms, Farm 3 exhibits the highest rate of average N loss. With this in mind, some exploratory modelling was conducted to analyse the potential impacts of various management options for reducing N loss from potato production on Farm 3. Shifting from the current management of applying 26 mm (effective irrigation) at fixed 11 day intervals to a schedule where irrigation (13 mm effective irrigation) is applied once the soil water deficit reaches 13 mm (at no less than 5 day intervals) reduced the average seasonal drainage from 135 mm to 52 mm and N loss below the root zone from 53 kg N/ha to 6 kg N/ha, while maintaining crop yield at 56 t FW/ha. Decreasing the basal rate from 215 kg N/ha to 100kg N/ha and the topdress rate from 115 kg urea/ha to 80 kg urea/ha resulted in a saving in fertiliser cost of $625/ha, a small reduction in N loss down to a negligible 3 kg N/ha, but importantly did not result in any reduction in yield.

Conclusions

Substantial drainage (> 100mm) was simulated from both the summer and winter phases of the rotation. Crop N demand was close to crop N supply for all rotation elements with the exception of potato which had an average surplus of 89 kg N/ha. The potential exists for substantial seasonal N leaching losses from all elements of the crop rotations but potato was the ‘leakiest’ of all crops with an average loss of 29 kg N/ha. Practicable management options, such as deficit-based irrigation and reduced N fertiliser rates, have the potential to generate significant financial savings via reduced input costs as well as reducing potential offsite N loss, while maintaining current levels of productivity.

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