A REVIEW OF N LOSSES DUE TO LEACHING AND SURFACE RUNOFF UNDER INTENSIVE PASTURE MANAGEMENT IN AUSTRALIA

Lucy Burkitt

Fertilizer and Lime Research Centre, Massey University, Palmerston North
Email: L.Burkitt@massey.ac.nz

Abstract
Nitrogen leaching and surface runoff research is well advanced in New Zealand, whereas the recent focus of the Australian dairy industry has been on P and gaseous N loss. Although there have been some very informative studies examining N leaching and runoff under intensive dairy pasture systems in Australia to date, given the importance of N loss in terms of water quality, this review concluded that more research is required, particularly in the area of nitrate leaching and in specific areas of surface N runoff.

Nitrate leaching losses following N fertiliser treatments were higher in New Zealand studies (~40 kg N/ha following 0 kg fertiliser N/ha and ~80 kg N/ha following 200 kg fertiliser N/ha) compared to an Australian study (3.7-14.5 kg N/ha following 0 kg fertiliser N/ha and 6-22 kg N/ha following 200 kg fertiliser N/ha). Nitrate leaching rates following urine application are also generally higher in New Zealand compared to an Australian lysimeter study (26-33 kg N/ha/year under irrigation and 10-13 kg N/ha/year under rain fed conditions). It is often suggested that nitrate leaching losses are higher in New Zealand due to the prevalence of free draining soils. However, this review highlights that there are simply not enough Australian nitrate leaching data to undertake a rigorous comparison. A national nutrient budgeting study has recently reported that median N surpluses on Australian dairy farms are higher (198 kg N/ha) than those reported for an average dairy farm in New Zealand (135 kg N/ha). Given that many of the soils used for intensive pasture production in Australia are lightly textured or free draining clay loams and that water quality monitoring in dairy dominant catchments often indicate elevated N loads, it is possible that nitrate leaching could be a significant issue for the Australian dairy industry.

Australian data on surface runoff of N are more prevalent, however, the overall contribution to N losses are likely to be low. Despite this, more research is required to quantify N leaching and runoff following effluent applications and to quantify losses of dissolved organic forms of N.

Introduction

Recent nutrient loss research in the Australian dairy industry has been particularly focussed on phosphorus (P), with nitrogen (N) research tending to focus on improving the agronomic efficiency of N fertiliser use and greenhouse gas losses. The inputs of N fertiliser to Australian dairy pasture systems have increased rapidly over the last two decades in the form of increased N fertiliser application and increased N contained in brought in feed, with the aim of increasing pasture and milk production. Increased N inputs result in an increase in the amount of N cycling in the soil/plant/animal system and increased concentrations of N in intensively managed pasture systems have progressively resulted in an increase in the risk of N loss to the environment (Hatch *et al.* 2002).

Recent data from the national Accounting for Nutrients on Australian Dairy Farms project (Gourley *et al*. 2010) confirmed that whole farm N surpluses measured on 44 commercial farms ranged from 47-600 kg N/ha/year and were positively related to milk production. The median N surplus on these farms was 198 kg N/ha/year, which is higher than that previously reported for an average New Zealand dairy farm (135 kg N/ha/year; Ledgard *et al.* 2004). Of note, two thirds of the farms studied measured an annual N surplus above the current European Union compliance standard of 180 kg N/ha/year. Whole farm N use efficiency (which is determined by the proportion of nutrient exported, divided by that imported) in the Australian study, ranged from 14-50%. Median N use efficiency was lower in the Australian study (26%) compared to an average New Zealand farm (33%; Ledgard *et al.* 2004). The national data set highlights that there is a large surplus of N on Australian dairy farms and that it is likely that N loss to the environment could be an issue for the Australian dairy industry.

The increasing concern regarding environmental N loss from the Australian dairy industry has prompted a new Dairy Australia Ltd. initiative called the Dairy Nitrogen Use Efficiency and Loss Pathways project. The project, which began with a range of literature reviews, aims to identify where the greatest opportunities are to improve N use efficiency and reduce N losses on Australian dairy farms. This paper reviews the current state of knowledge in the area of N leaching and runoff losses under Australian dairy pasture systems, and compares findings with other pasture based industries, namely New Zealand.

N loss to surface runoff

There have been several studies examining N loss to surface runoff under Australian dairy pasture systems, mainly as an 'add on' to experimental designs that primarily focussed on surface P runoff. Studies have been undertaken at the re-packed tray, plot and sub-catchment scale and under both rain-fed and irrigated conditions, which were undertaken following N fertiliser application. Findings suggest that surface runoff losses range from 1-23 kg N/ha/year, with losses above 17 kg N/ha/year generally measured under border check flood irrigation (Nexhip and Austin 1998) or under hump and hollow surface drainage in the north west of Tasmania (Holz 2008). The review found that very few Australian studies have measured surface N runoff following effluent application, which is a concern given the rapid expansion of the dairy industry in some areas of Australia. Surface N runoff following effluent application or grazing can contain elevated dissolved organic N (DON) concentrations (Hatch *et al*. 2002), which can represent an important source of soluble N in freshwater. However, surface DON losses have rarely been measured in Australia. A recent study in New Zealand reported that DON concentrations in intensive dairy pasture soils were higher than other land uses such as extensive pasture, cropping, native vegetation and forestry and this is an important soil N pool that should be routinely measured (Ghani *et al*. 2007).

Similar to P, most Australian surface runoff N studies have reported that the timing of runoff in relation to N fertiliser application and the rate of N fertiliser applied, have a significant impact on N losses. In addition, more recent unpublished work has reported a strong, positive relationship between soil mineral N concentration and total N loss in surface runoff (W. Dougherty *pers. comm.*), suggesting that more efficient use of N fertiliser and reducing the amount of N cycling through the farm system, may reduce N runoff. As such, reasonable confidence surrounds the best management practices required to reduce N surface losses (excluding effluent) in most dairy regions of Australia and surface N losses are likely to be low compared to possible N losses via leaching.

N loss to leaching

Unlike losses of N via surface runoff, nitrate leaching in Australian dairy pasture systems has received little attention. Of the handful of studies undertaken, most used lysimeters or suction cup methodology (Prove *et al.* 1997; Mundy and Bethune 2001; McCaskill and Lamb 2001; Fillery 2011). Eckard *et al.* (2004) measured nitrate leaching under title drains in a Victorian study and reported nitrate leaching losses of 4-15 kg N/ha/year following applications of zero N fertiliser and 6-22 kg N/ha/year following applications of 200 kg N/ha applied as urea, with nitrate losses continuing to increase over the 3 year monitoring period. Menneer *et al.* (2004) reported the range of nitrate leaching rates measured from New Zealand dairy farms following various N fertiliser applications, was 5-115 kg N/ha/year, with average losses of 65 kg N/ha/year. However Menneer *et al.* (2004) highlighted that typically, nitrate losses are around 40 kg N/ha/year. Comparing typical nitrate leaching losses from New Zealand dairy farms to the values measured in the Eckard *et al*. (2004) study suggest that losses in the Australian study were more than 50% lower, with lower drainage rates one likely explanation for this difference. Higher drainage rates in New Zealand are commonly offered as an explanation for higher nitrate leaching rates compared to Australia. However, the Australian dairy industry is commonly located in high rainfall zones (800-1200 mm/year) and on well drained soils, therefore the potential for drainage is high and it has previously been established that the amount of N cycling in Australian dairy pasture systems is likely to enhance the risk of nitrate leaching.

Eckard *et al.* (2004) reported that nitrate losses increased over the 3 years of their study, possibly due to the experimental site having a low N fertiliser history (50 kg N/ha/year) prior to the start of the experiment which involved four annual applications of 50 kg N/ha. A more recent Western Australian study has reported higher nitrate concentrations in drainage water (~5-100 mg N/L) (Fillery 2011), compared to Eckard *et al.* (2004), and attributed this difference to the change in N fertiliser regime in the Victorian study and a greater accumulation of mineralised N over the dry summer/autumn period in the Western Australian study.

Even fewer Australian studies have examined nitrate leaching following cattle urine application. This is a serious concern given that urine which is highly concentrated in N, is considered to be the greatest source of N loss from intensively managed pasture systems. The literature suggests that only two Australian studies have examined this issue (Pakrou and Dillon 2004; Fillery 2011). Pakrou and Dillon (2004) reported nitrate leaching losses of 26-33 kg N/ha/year (13-17 mg N/L) under irrigation and 10-13 kg N/ha/year (9-11 mg N/L) under rain-fed pasture. Nitrate concentrations measured following irrigation exceeded the Australian Drinking Water Guidelines recommended maximum concentration of 10 mg nitrate-N/L. This issue warrants further investigation, as irrigation developments to support an expanding dairy industry are in full swing in states such as Tasmania, highlighting the need to quantify nitrate leaching under a greater range of soil, climatic and farm management scenarios.

Is there a problem?

The major concern this review highlighted was that there is simply not enough data on nitrate leaching, particularly following urine application, to know if nitrate loss is likely to be a problem for the Australian dairy industry. Like New Zealand, there is increasing evidence of the impact dairying is having on N in water ways. An example is the Montagu catchment in far north-west Tasmania, which has been identified as one of the most degraded in the state, with average annual N loads of 268 t N/year measured between 1999 and 2001 (Bobbi *et al.* 2004). A longditudanal study of water quality in the Montagu river identified that an intensive

grazing area called Togari/Brittons swamp was an important source of N to the river. Similar links have been made in western Victoria by A. Smith *pers comm.* and a recent modelling study of nutrient generation rates across Tasmanian catchments showed that the dairy industry was the major contibuter of N (Broad and Corkrey 2011). On this basis, it is possible that nitrate losses may be an issue for the Australian dairy industry in some catchments, particularly those with high rainfall or irrigation, and well drained soils.

Can modelling fill the gaps?

Given that countries like New Zealand are well advanced in terms of the quantification and understanding of N losses from intensive pasture systems, it makes sense to use this existing knowledge in computer models to avoid "re-inventing the wheel". However, at some stage, computer models will need to be validated for Australian soils, climate and farming systems and currently, there are not enough data available, particularly with respect to nitrate leaching, to be able to do this with any confidence.

Conclusions

This review has highlighted that there have been some very informative studies examining N leaching and runoff under intensive dairy pasture systems in Australia to date. However, it has also made very clear that given the importance of N loss from these systems and its potential impact on water quality, not enough research has been conducted in this area, particularly in the area of N leaching and some aspects of surface N runoff.

Acknowledgements

The author would like to acknowledge the funding provided by Dairy Australia Ltd and other support provided by the Tasmanian Institute of Agriculture, the University of Tasmania and Massey University.

References

Bobbi C, Bluhdorn, Andrews D, Bantich M (2004) Water quality of rivers in the Montagu river catchment. Department of Primary Industries Water and Environment, Hobart.

Broad ST, Corkrey R (2011) Estimating annual generation rates of total P and total N for different land uses in Tasmania, Australia. *Journal of Environmental Management* **92**, 1609-1617.

Eckard RJ, White RE, Edis R, Smith A, Chapman DF (2004) Nitrate leaching from temperate perennial pastures grazed by dairy cows in south-eastern Australia. *Australian Journal of Agricultural Research* **55**(9), 911-920. [In English]

Fillery IRP (2011) Observations on key nitrogen transformations that affect N use efficeincy in Western Australia dairy pastures. CSIRO Perth.

Ghani A, Dexter M, Carran RA, Theobald PW (2007) Dissolved organic nitrogen and carbon in pastoral soils:the New Zealand experience. *European Journal of Soil Science* **58**, 832-843.

Gourley CJP, Dougherty WJ, Aarons SR, Hannah M (2010) Accounting for Nutrients on Australian Dairy Farms. Department of Primary Industries, Ellinbank, Victoria. pp. 50-52. Final Report.

Hatch D, Goulding K, Murphy D (2002) Nitrogen. In 'Agriculture, Hydrology and Water Quality.' (Eds PM Haygarth and SC Jarvis). (CABI Publishing: Wallingford, UK)

Holz G (2008) Montagu River catchment, intensive grazing systems and water quality. Tasmanian Institute of Agricultural Research.

Ledgard SF, Journeaux PR, Furness H, Petch RA, Wheeler DM (2004) Use of nutrient budgeting and management oprions for increasing nutrient use efficiency and reducing environmental emissions from New Zealand farms. OECD, Palmerston North, NZ. OECD expert meeting on farm management indicators and the environment.

McCaskill M, Lamb J (2001) Nitrate Leaching in Western Victoria Nitrogen fertilisers on dairy pastures Terang leaching study. In 'Best management practices for nitrogen in intensive pasture production systems.' Ed. RJ Eckard) pp. 126-131. (Natural Resources and Environment: Ellinbank, Victoria)

Menneer JC, Ledgard SF, Gillingham AG (2004) Land Use Impacts on Nitrogen and Phosphorus Loss and Management Options for Intervention. AgResearch. Client Report Prepared for Environment Bay of Plenty.

Mundy GN, Bethune M (2001) Lysimeter study. Movement of surface applied nitrogen and phosphorus down red-brown soil cores - A preliminary evaluation. University of Melbourne and Natural Resources and Environment Ellinbank, Melbourne. pp. 105-113. Best management practices for nitrogen in intensive pasture production systems. Final Report.

Nexhip KJ, Austin NR (1998) Defining key nutrient reduction practices for irrigated dairy pastures. In 'Water is Gold-Irrigation Association of Australia National Conference and Exhibition', 1-21 May 1998, Brisbane, Australia,

Pakrou N, Dillon PJ (2004) Leaching losses of N under grazed irrigated and non-irrigated pastures. *Journal of Agricultural Science* **142**, 503-516.

Prove B, Moody PW, Reghenzani J (1997) Nutrient balances and transport from agricultural and rainforest lands: a case study in the Johnstone River Catchment. Queensland Department of Natural Resources South Johnstone, Queesnsland. pp. 1-21. Final Report DAQ3S.