NUTRIENT MANAGEMENT ON THE LINCOLN UNIVERSITY DAIRY FARM: "NUTRIENT BUDGETING FOR EFFICIENT PRODUCTION"

Jim Moir, Keith Cameron and Hong Di
Centre for Soil and Environmental Quality, Lincoln University

Introduction

Nutrient management plays an important role in any dairy farming system. Soil fertility status and fertiliser inputs are key drivers of pasture and animal production, whilst fertiliser represents a significant annual cost to the farm. At the same time, intensive agricultural systems also face the challenge of minimising or reducing nutrient loss in order to maintain environmental quality. Therefore 'best practice' may involve nutrient management in terms of balancing production, economic, environmental and efficiency goals. With ever increasing regulation and compliance requirements for the New Zealand farmer, best practice nutrient management will play an increasingly important role in achieving long term sustainability of the farming system.

This paper gives an overview of the use of nutrient budgeting as a method of effective and efficient on-farm nutrient management. The paper will focus on nutrient management on the Lincoln University Dairy Farm (LUDF), including soil fertility monitoring and targets, the decision making process and the use of the nutrient budget output. Aspects of environmental research on the LUDF will also be discussed, including the quantification of nitrogen (N) losses, and results from research into nitrogen loss mitigation technology (*eco-n* nitrification inhibitor).

Nutrient Management on the LUDF

Capital fertiliser

The LUDF was converted from the old Lincoln University sheep breeding unit in 2000. Capital fertiliser (Single Superphosphate (SSP), or 20% sulphur SSP) was applied at rates between 250 and 750 kg ha^{-1} with higher rates applied to areas identified as having lower soil

Notes:

fertility. A total of 149 kg P ha^{-1} was applied in 2001, resulting in a mean increase of 10 Olsen P units, or 15 kg P for every 1 unit increase in Olsen P. Relatively speaking, this is a modest shift in Olsen P for such a high fertiliser P input, but is typical for a dairy conversion scenario, where a significant amount of the capital fertiliser P is 'immobilised' by soil microbial activity during the early soil fertility building phase. After soil fertility has developed, much less fertiliser is required to shift the Olsen P. Fertilisers applied in 2001 included SSP and sulphur SSP which were the most economic fertiliser options and gave rapid increases in soil fertility for sustaining high pasture growth. The farm management team followed advice that good economic modelling supports —increasing soil fertility levels quickly to the higher levels required for the farm to be operating at its biological optimum.

Monitoring soil fertility

Regular soil testing is an important activity on LUDF and the information collected is used to make better management decisions about fertiliser inputs. A total of 18 soil sampling 'transects' were established across the farm in 2001 and the exact location of each was recorded using survey-grade GPS. The annual soil sampling programme involves taking soil cores along all transects in June and analysing these samples for soil fertility levels. Exact GPS location of the transects allows staff to return to the same area for sampling every year, which gives improved accuracy for tracking changes in soil fertility status over time. The transects encompass all major soil types and different land use areas on the farm. Soil fertility data for the LUDF are presented in Table 1 (after Van Bysterveldt et al, 2006).

Table 1: LUDF Soil Fertility 2000 - 2005

Year	Block	pH	Olsen P µgP ml^{-1}	Sulphate S µgS g^{-1}	Exchangeable Cations (MAF) Ca	Mg	K	Mineralisable N (kg ha^{-1})
2000*	**Mean**	**6.0**	**21**	**4**	**8**	**25**	**14**	**N/A**
2001	North	5.7	31	36	8	20	12	108
	Efflnt	5.8	30	30	8	16	10	123
	South	5.7	33	47	10	34	11	193
	Mean	**5.7**	**31**	**37**	**8**	**23**	**11**	**141**
2002	North	5.8	31	39	8	16	16	164
	Efflnt	5.9	32	35	9	16	15	151
	South	5.8	34	38	11	31	12	219
	Mean	**5.8**	**32**	**37**	**9**	**22**	**14**	**178**
2003	North	6.1	32	6	7	17	11	162
	Efflnt	6.2	38	5	8	19	17	180
	South	6.2	41	7	10	29	10	234
	Mean	**6.2**	**37**	**6**	**8**	**22**	**13**	**192**
2004	North	6.5	39	11	9	20	10	N/A
	Efflnt	6.4	37	11	8	21	11	N/A
	South	6.3	38	9	11	32	8	N/A
	Mean	**6.4**	**38**	**10**	**9**	**24**	**10**	**N/A**
2005	North	6.1	29	8	8	17	11	198
	Efflnt	6.3	37	8	8	21	18	215
	South	6.2	40	7	10	27	10	253
	Mean	**6.2**	**36**	**7**	**9**	**21**	**13**	**222**
Target		**5.8-6.2**	**30-40**	**8+**		**20+**	**5-8**	**N/A**

* Pre-conversion.

Target soil fertility levels (Table 1) were decided by referring to the guidelines indicated in "Fertiliser use on New Zealand Dairy Farms" (Roberts *et al.*, 1994; Roberts & Morton, 1999) and from research which indicates that near maximum pasture production on sedimentary soils is obtained at Olsen P levels in the range of 30 – 40 ug P mL^{-1} (Moir *et al.*, 1997).

Nutrient budgets and nutrient management

Fertiliser policy and recommendations for annual fertiliser applications are constructed and implemented by a panel of South Island Dairying Development Centre (SIDDC) partners: (The Business Advisory Group) including staff from Dexcel; Ravensdown Fertiliser Co-op; Lincoln University; dairy farmers and the LUDF farm manager. The objective of the current fertiliser policy is to maintain soil fertility status at the agronomic and economic optimum while

Notes:

following best management practices. To meet this objective detailed nutrient budgets for the LUDF are calculated annually using the Overseer® nutrient budget model and the Overseer® 3 econometric model. Nutrient budgets are generated for the effluent and non-effluent areas within the North Block and for the South Block. These nutrient budgets provide nutrient inputs and outputs for the given farming system and indicate whether the farm is in 'balance' for key nutrients. This provides critical information on the long-term sustainability of the current farming system and practices and indicates areas where adjustments to current fertiliser policy are required.

The nutrient budget for the effluent area (28 ha) indicated that fertiliser inputs were able to be reduced due to the nutrient input from the effluent (185 kg N; 20 kg P; 201 kg K; 16 kg S ha^{-1} yr^{-1}). This represents a significant financial saving to the farm. No areas of the farm receive K fertiliser because of naturally high soil K reserves and current Quicktest K levels. Using values determined from the nutrient budgets, current annual fertiliser applications amount to a modest 50 and 73 kg ha^{-1} of P and S respectively over non-effluent areas and no or only small quantities of fertiliser are applied to the effluent area.

N fertiliser use is limited to 200 kg N ha^{-1} yr^{-1}. The decision to limit annual N fertiliser inputs to 200 kg N ha^{-1} yr^{-1} is aimed at limiting leaching of nitrate from the soil (Di & Cameron, 2000) and is in line with the Fertiliser Industry Code of Practice (FertResearch, 2002). The effluent area does not receive N fertiliser.

Nutrient inputs and farm production

Since the 2001/2002 season, milk production per ha has steadily increased to 1750 kg MS ha^{-1} on the LUDF, despite N fertiliser input and nutrient input from brought–in supplements having remained the same (Van Bysterveldt et al, 2006). This indicates that additional production was not derived from additional supplements fed to the cows or the additional nutrients imported in these supplements or from the use of additional N fertiliser. Over time the amount of supplements and nutrients from supplements has in fact been reducing. Despite this, the soil test levels have also been maintained or increased on the farm (Table 1; Figure 1), demonstrating that the current fertiliser policies and nutrient management system have been successful in achieving and maintaining a high production grazed pasture system with modest nutrient inputs from fertiliser.

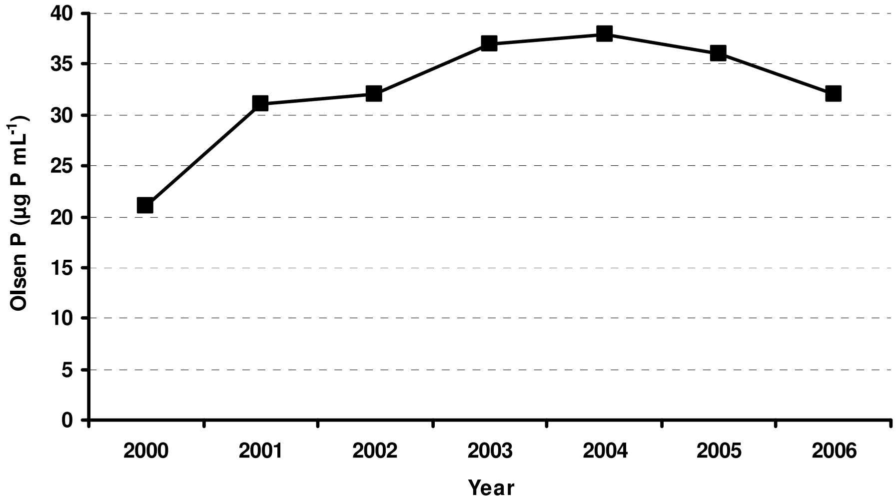

Figure 1: LUDF soil Olsen P levels over time

LUDF research – quantifying and mitigating N loss

On-farm monitoring of nitrate leaching on the LUDF using 60 lysimeters within the grazed paddocks indicates that to date the average nitrogen leaching losses for this farm are relatively low. The average nitrate leaching loss since conversion of the Lincoln University Dairy Farm is around 20 kg N ha^{-1} yr^{-1} (Figure 2). Over the first four years the loss was less than 20 kg N ha^{-1} yr^{-1} and over the last winter (2006) the leaching loss was higher at around 55 kg N ha^{-1} yr^{-1}. The variation in annual leaching losses emphasises the need to use a multi-year average value rather than using a single year value when trying to quantify N leaching losses from dairy farms.

Notes:

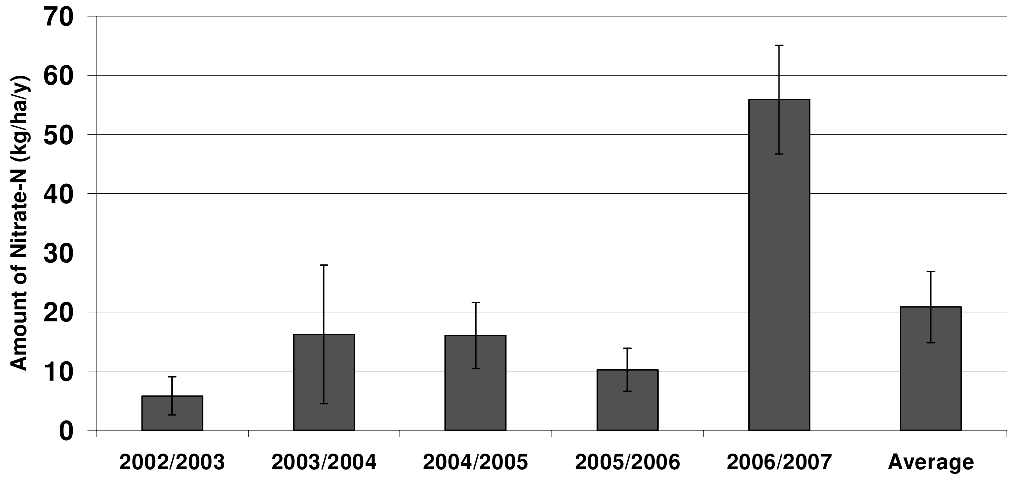

Figure 2: Average paddock losses of nitrate-N leached from Lincoln University Dairy Farm lysimeters

The larger amount of nitrate leached over the 2006/07 season is attributed to the larger than average amount of drainage (230 vs 135 mm; Figure 3) which was caused by the high winter rainfall in 2006. In contrast, the very dry winter of 2005/06 (34 mm of drainage) produced a relatively low leaching loss (10 kg N ha^{-1} yr^{-1}) (Figure 2).

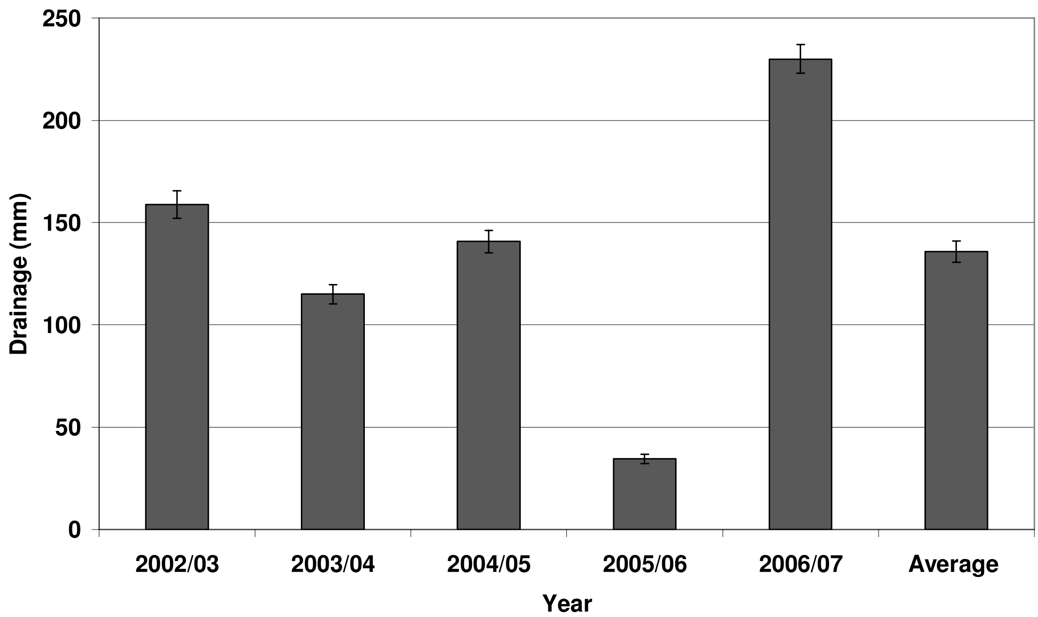

Figure 3: Lincoln University Dairy Farm drainage from lysimeters on North Block

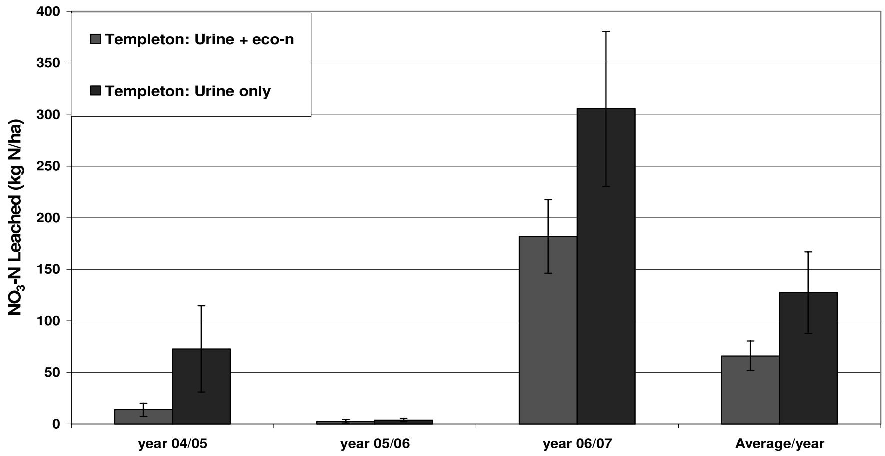

Figure 4: Mean NO_3^- leaching loss from urine affected lysimeters on the LUDF

The impact of dairy farming on the environment is currently an important issue (MFE, 2003). Use of the nitrification inhibitor technology '*eco-n*' has been shown to significantly reduce N leaching losses from grazed pasture soils, improving the efficiency of N use in the farming system (Christie, 2004; Di & Cameron, 2005). A large body of science has demonstrated the effectiveness of *eco-n* in reducing NO_3^- leaching (Figure 4; (Di & Cameron, 2002, 2004, 2005) and N_2O emissions (Figure 5; Di & Cameron, 2002, 2003, 2006; Di *et al.*, 2007) from the dairy cow urine patch, and has also demonstrated significant pasture growth responses (Figure 6; Moir et al, 2007). On average, *eco-n* reduced NO_3^- N leaching by 50% from urine patch areas (Figure 4) and N_2O emission by 73% (Figure 5) on the Templeton soil. On a whole paddock basis, the mean increase in annual pasture yield on the LUDF *eco-n* trial was 21% (Figure 6).

Notes:

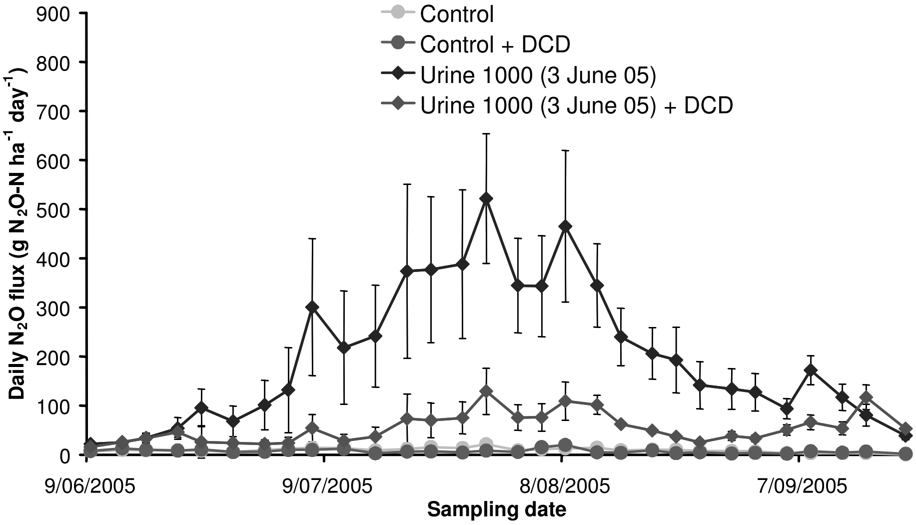

Figure 5: Daily N_2O emissions from the Canterbury Templeton soil (Di et al, 2007)

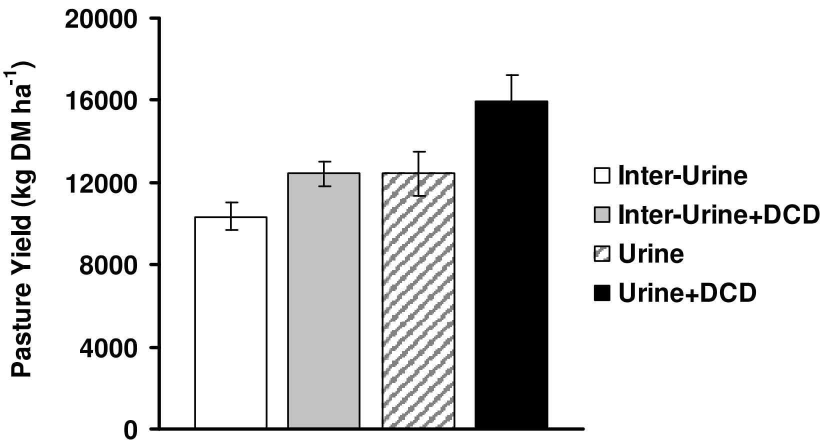

Figure 6: Mean annual pasture yield 2002/03 – 2005/06 in inter-urine patch and urine patch areas of the sward (Moir et al, 2007).

Summary

1. The recommended targets for soil fertility levels are sufficient for high pasture DM production, which if well managed can result in very high levels of MS production.
2. High production (over 1750 kg MS ha^{-1}) has been achieved with limited use of N fertiliser (200 kg N ha^{-1} yr^{-1}) and limited supplements.
3. This production level has been achieved as a result of effective and efficient nutrient and pasture management, not increased fertiliser use.
4. Nitrogen leaching losses are relatively small and are further reduced through the use of '*eco-n*' nitrification inhibitor.

5. Despite the low nitrate leaching losses from the LUDF, the use of *eco-n* has improved N use efficiency and has increased pasture growth.
6. Nutrient budgeting is a useful and powerful tool that can aid in the management of the fertiliser programme to optimise production and improve the efficiency and long-term sustainability of the farming system.

Acknowledgements

We would like to thank Dairy InSight, MAF Sustainable Farming Fund (SFF), Ravensdown Fertiliser Co-operative Ltd, the Pastoral Greenhouse Gas Research Consortium (PGGRC) and Lincoln University for funding this research. We also wish to thank Kelly Morris, Ravensdown Fertiliser Co-operative Ltd, for nutrient budget information and comment on the manuscript.

References

Christie R. 2004. Using the Nitrification Inhibitor eco-n on New Zealand Dairy Farms. Primary Industry Management 7:38-41.

Di H J and Cameron K C. 2000. Calculating Nitrogen Leaching Losses and Critical Nitrogen Application Rates in Dairy Pasture Systems Using a Semi-empirical Model. New Zealand Journal of Agricultural Research 43:139-147.

Di H J and Cameron K C. 2002. The Use of a Nitrification Inhibitor, Dicyandiamide (DCD), to Decrease Nitrate Leaching and Nitrous Oxide Emissions in a Simulated Grazed and Irrigated Grassland. Soil Use and Management 18:395-403.

Di H J and Cameron K C. 2003. Mitigation of Nitrous Oxide Emissions in Spray-irrigated Grazed Grassland by Treating the Soil with Dicyandiamide, a Nitrification Inhibitor. Soil Use and Management 19:284-290.

Di H J and Cameron K C. 2004. Treating Grazed Pasture Soil with a Nitrification Inhibitor, eco-nTM, to Decrease Nitrate Leaching in a Deep Sandy Soil Under Spray Irrigation - a Lysimeter Study. New Zealand Journal of Agricultural Research 47:351-361.

Notes:

Di H J and Cameron K C. 2005. Reducing Environmental Impacts of Agriculture by Using a Fine Particle Suspension Nitrification Inhibitor to Decrease Nitrate Leaching from Grazed Pastures. Agriculture, Ecosystems and Environment 109:202-212.

Di H J and Cameron K C. 2006. Mitigating Environmental Impacts and Improving the Sustainability of Grazed Pasture Systems by the Use of a Nitrification Inhibitor. In: 18th World Congress of Soil Science, Philadelphia, USA.

Di H J, Cameron K C and Sherlock R R. 2007. Comparison of the Effectiveness of a Nitrification Inhibitor, Dicyandiamide, in Reducing Nitrous Oxide Emissions in Four Different Soils Under Different Climatic and Management Conditions. Soil Use and Management 23:1-9.

FertResearch 2002. Code of Practice for Fertiliser Use. NZ Fertiliser Manufacturers' Research Association. Auckland, N.Z.

MFE 2003. Dairying and Clean Streams Accord. An Accord Between Fonterra Co-operative Group Ltd., Ministry for the Environment and Ministry for Agriculture and Forestry, Ministry for the environment. Wellington, NZ:5.

Moir J L, Hedley M J, Mackay A D and Tillman R W. 1997. The Effect of Fertiliser History on Nutrient Accumulation and Plant-available Nutrient Supply in Legume-based Pasture Soils. In: XVIII International Grassland Congress, eds J G Buchanan-Smith L D Bailey and P McCaughey, International Grassland Association Winnipeg, Canada 10:68-69.

Moir J L., Cameron K C and Di H J. 2007. Effects of the Nitrification Inhibitor Dicyandiamide on Soil Mineral N, Pasture Yield, Nutrient Uptake and Pasture Quality in a Grazed Pasture System. Soil Use and Management (In Press).

Roberts A H C, Morton J and Edmeades D C. 1994. Fertiliser Use on Dairy Farms: The Principles and Practice of Soil Fertility and Fertiliser Use on Dairy Farms in the Lower North Island and South Island. NZ Dairying Research Corporation Ltd. Hamilton, N.Z: 36.

Roberts A H C and Morton J. 1999. Fertiliser Use on Dairy Farms: The Principles and Practice of Soil Fertility and Fertiliser Use on New Zealand Dairy Farms. New Zealand Fertiliser Manufacturers' Association. Auckland, NZ:36.

Van Bysterveldt A, Moir J L and Metherell A. 2006. Nutrient Management on the Lincoln University Dairy Farm. Primary Industry Management 9:17-22.