Soil nutrient concentrations and variations on dairy farms in Australia

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Abstract
Nutrients are essential for dairy productivity but excesses pose a potential environmental threat. We investigated soil nutrient levels on 44 commercial dairy farms that represented a broad range of dairying operations across Australia. Soil nutrient levels were found to be highly variable within and between dairy farms. Organic and conventional dairy farms had similar pH and available K and S in pasture soils but organic dairy farms had substantially lower available P. On conventional dairy farms, soil P levels were generally high, with 80% of grazed pastures above agronomic optimum soil P concentrations. In areas where there were high stock densities, available soil nutrients were extremely high. We also found a highly significant negative relationship between soil P, K and S levels and distance of a pasture from the dairy shed. A key driver of within-farm nutrient heterogeneity appears to be stocking density of land and the resultant nutrient deposition from urine and dung.

Key Words
Soil phosphorus, potassium, sulphur, nutrient management.

Introduction

Fertiliser inputs of nitrogen (N), phosphorus (P), potassium (K), and sulphur (S), are still commonly applied to dairy pastures, despite the fact that most dairy farms are in net positive balance for all of these nutrients (Reuter 2001). Nutrient losses from dairy farming regions and eutrophication of our waterways has gained strong public and political attention and our intensive pasture systems are no longer seen as 'clean and green' (Gourley and Ridley 2005). Soil-testing has been long recognised as an important nutrient management tool, and renewed efforts in both Australia (Gourley *et al.* 2007a) and New Zealand (Edmeades *et al.* 2006), have aimed to improve their interpretation in pasture systems. In Australia, data from more than 4000 experimental trial years has recently been collated and re-analysed to improve and standardise P, K and S soil-test pasture response calibration relationships (Gourley *et al.* 2007a).

The distribution of soil nutrient levels within a farm plays an integral role in overall production and potential environmental losses. Nutrients can be unevenly distributed due to the net removal of nutrients in harvesting and grazing in some areas, and in other areas a net surplus of nutrients can occur due to manure deposition from stock, effluent applications and over-enthusiastic fertiliser use. Areas with declining nutrient availability may have reduced pasture and crop production, while areas with surplus nutrients are unlikely to generate increased production, as soil nutrient levels are often well above agronomic requirements. Excessive nutrient accumulation can contribute disproportionately to nutrient losses (Sharpley 1995) and also lead to mineral imbalances that can result in herd health problems such as grass tetany and milk fever (VandeHaar and St-Pierre 2006).

The objective of this research was to assess the spatial distribution of agronomic P, K and S concentrations and the influence of management and land-use, on a diverse range of commercial dairy farms in Australia.

Methods

Forty-four commercial dairy farms representing a broad range of geographic locations, productivity (litre milk/grazed hectare), herd size, farm size, reliance on irrigation, and soil P sorption capacity, were selected for this study (Figure 1). Four of the selected 44 dairy farms were certified organic producers, and as such did not use conventional inorganic fertilisers or chemicals. Digital mapping of each farm used aerial photographs and schematics of farm layouts to determine paddock boundaries, fence lines, total milking areas, grazed paddock areas, and distances of each paddock to the dairy. Amongst the 44 dairy farms involved in the study, farm-area ranged from 47 to 496 ha, cow numbers per farm ranged from 59 to 1930 cows, and paddocks sampled per farm ranged from 14 to 141.

Figure 1. The location of the 44 dairy farms involved in the study.

Soil nutrient levels were determined in a detailed sampling of all paddocks used for pasture and crop production and areas where stock was confined (holding areas, feeding areas, sick paddocks, bull paddocks). Thirty 0-10 cm soil cores were collected along a diagonal transect across each area. Soil cores from each paddock were bulked, dried at 40ºC for 48 h and passed through a 2 mm sieve before being analysed for pH (0.01M CaCl2) (Rayment and Higginson 1992), Olsen extractable P (Olsen *et al.* 1954), Colwell P and K (Colwell 1963), KCl extractable S (Blair *et al.* 1991), and P buffering index (PBI) (Burkitt *et al*. 2008).

Results

The average soil pH, available P, K and S and PBI concentrations of different land areas from the 40 conventional and 4 organic dairy farms are presented in Table 1. While pH, Colwell K and PBI levels were similar from pastures on the conventional and organic dairy farms, Olsen and Colwell P levels were around twice as high on the conventional dairy pastures. Within the conventional dairy farms, areas with high animal densities (feeding areas, holding areas, sick paddocks, and bull paddocks) had considerably higher soil pH, P, K and S than grazed pasture soils. Nutrient loads from dung and urine are often extremely high in these confinement areas as a result of the high density of cows held for extensive time periods (Gourley *et al.* 2007b). Land used for non-dairy grazing animals had the lowest nutrient availability on conventional dairy farms and was comparable to the organic dairy pastures.

Table 1. Mean soil pH, available P, K and S and PBI levels of different land uses from 40 conventional and 4 organic dairy farms. Standard deviations are in parentheses.

Management/Use	Distance to dairy (m)	pH (CaCl2)	Olsen P (mg/kg)	Colwell P (mg/kg)	Colwell K (mg/kg)	KCl S (mg/kg)	PBI (mg/kg)
			Organic				
Pasture n=141*	625.5	5.4 (0.6)	16.7 (13.8)	65 (62)	271 (199)	18.4 (20)	302 (166)
			Conventional				
Pasture n=1773	881.4	5.3 (0.7)	35.6 (20)	127 (76)	296 (224)	23.4 (33)	263 (230)
Bull paddock n=6	444.0	5.3 (0.9)	48.8 (26)	169 (82)	703 (602)	45.3 (29)	262 (24)
Feeding areas n=12	53.1	6.8 (1.2)	319.9 (285)	1151 (1286)	4471 (3945)	263.5 (263)	321 (277)
Holding area n=13	400.4	5.8 (0.9)	143.5 (171)	510 (685)	1515 (1271)	73.8 (71)	251 (252)
Sick paddock n=16	46.9	5.6 (0.9)	71.4 (61)	280 (282)	771 (711)	27.5 (19)	178 (180)
Other animal n=104	na	5.1 (0.6)	27.4 (15)	100 (58)	269 (180)	14.6 (12)	301 (281)

* n= number of areas sampled

The soil P levels from grazed pasture paddocks on conventional dairy farms ranged between 3 and 189 mg/kg for Olsen P and 13 and 730 mg/kg for Colwell P. Only 20% of the paddocks sampled were below the recommended agronomic optimum (20 mg/kg for Olsen P; between 15 – 75 for Colwell P, depending on P buffering; Gourley *et al.* 2007a), while 50% of paddocks were two or more times the recommended agronomic optimum (Figure 2).

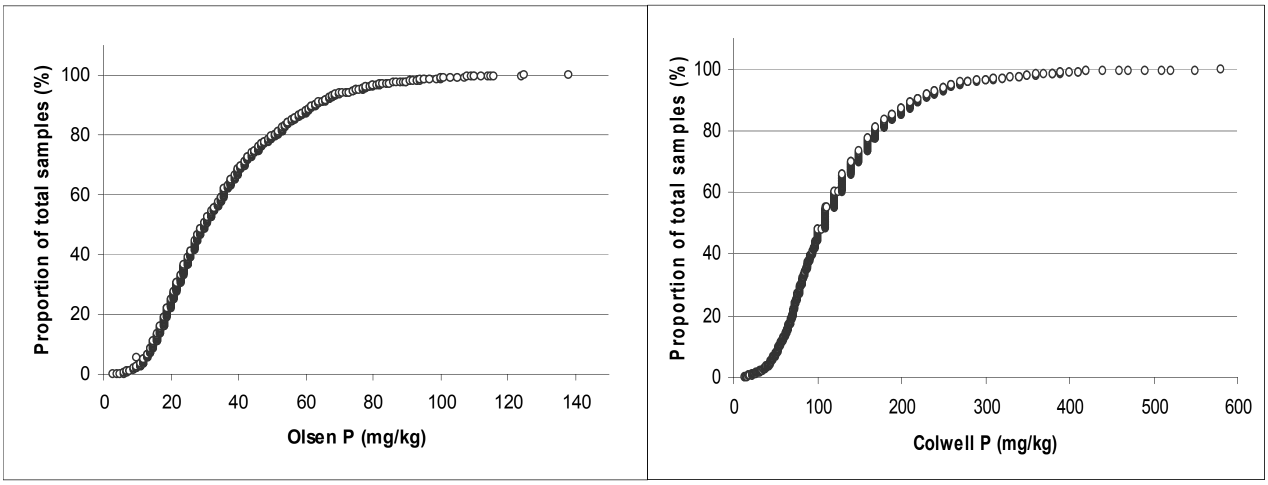

Figure 2. The proportional distribution of soil P levels determined from dairy pastures (n= 1768) from 40 conventional dairy farms across Australia.

The effect of distance-to-dairy was estimated using a fitted random coefficients model including PBI, grazing intensity, effluent application, land use, irrigation, and organic/conventional system, farm and residual error.

While individual pasture soil nutrient concentrations varied markedly between farms, there was a highly significant ($P<0.01$) relationship between distance-to-dairy and soil P, K and S concentration. For example, there was an overall 4-fold difference in Olsen P, between paddocks close to, and those furthest from, the dairy (Figure 3).

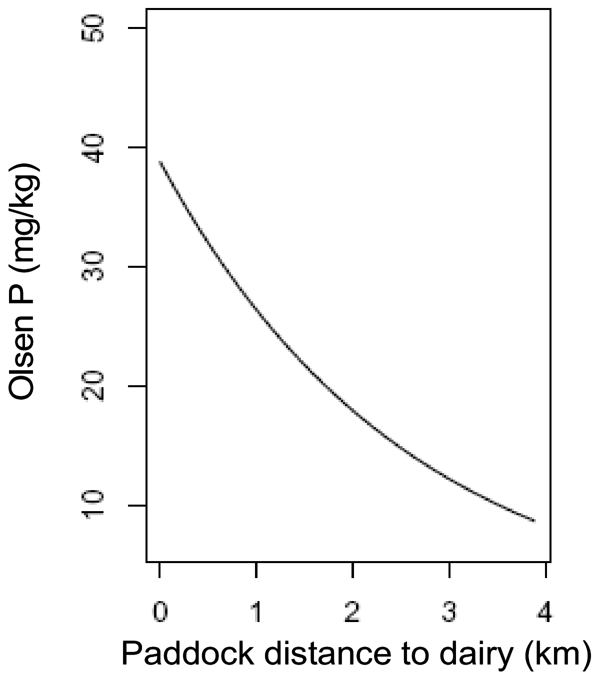

Figure 3. Partial effect of distance to dairy and Olsen P for pasture paddocks on 44 dairy farms.

Conclusion

Based on the results of this study, we conclude that there are large excesses of P, K and S on a broad range of dairy operations across Australia. The concentration and distribution of nutrients was related to farming type (organic v conventional), land use (e.g. feeding areas v grazed pastures), and distance of grazed pastures from the dairy. A key driver of within-farm nutrient heterogeneity appears to be the stock density and resultant nutrient deposition from urine and dung.

The current imbalance between nutrient inputs, primarily as feed and fertiliser, and nutrient outputs, in milk and livestock, and the uneven nutrient distribution within dairy farms, provides both an opportunity and a challenge to the Australian dairy industry. There are significant savings and productivity gains to be had from adopting a more spatially targeted approach to nutrient applications and more effectively using nutrients recycled in animal excreta. Conversely, continuing with current grazed dairy systems and nutrient management practices is likely to result in the significant accumulation of nutrients, particularly in high animal density areas, increased losses of nutrients to the broader environment, and stricter environmental standards which may limit inputs and dairy farm productivity.

References

Blair GJ, Chinoim N, Lefroy RDB, Anderson GC, Crocker GJ (1991) A soil sulphur test for pastures and crops. *Australian Journal of Soil Research* **29**, 619-626.

Burkitt LL, Moody PW, Gourley CJP, Hannah MC (2002) A simple phosphorus buffering index for Australian soils. *Australian Journal of Soil Research* **40**, 1-18.

Colwell J (1963) The estimation of the phosphorus fertiliser requirements of wheat in southern New South Wales by soil analysis. *Australian Journal of Experimental Agriculture and Animal Husbandry* **6**, 105-120.

Edmeades DC; Metherall AK; Waller JE; Roberts AHC; Morton JD (2006) Defining the relationships between pasture production and soil p and the development of a dynamic P model for New Zealand pastures; a review of recent developments. *New Zealand Journal of Agricultural Research* **49***,* 207-222.

Gourley CJP, Melland AR, Waller RA, Awty IM, Smith AP, Peverill KI, Hannah MC (2007a) Better fertiliser decisions for grazed pastures in Australia. [on-line] http://www.asris.csiro.au/themes/nutrient.html#Nutrient_BFD.

Gourley CJP, Powell JM, Dougherty WD, Weaver DM (2007b) Nutrient budgeting as an approach to improving nutrient management on Australian dairy farms. *Australian Journal of Experimental Agriculture* **47**, 1064-1074.

Gourley CJP, Ridley A (2005) Controlling non-point pollution in Australian agricultural systems. *Pedosphere* **15**(6), 763-777.

Olsen S, Cole C, Watanbe F, Dean L (1954) 'Estimation of available phosphorus in soils by extraction with sodium bicarbonate.' (U.S. Government Printing Office: Washington, DC)

Rayment GE, Higginson FR (1992) 'Australian laboratory handbook of soil and water chemical methods.' (Inkata Press: Melbourne)

Reuter DJ (2001) Nutrients – farm gate nutrient balances. Australian National Land and Water Audit 2001. [On-line] Available at http://audit.ea.gov.au/ANRA/land/farmgate/Nutrient_Balance.pdf.

Sharpley AN (1995). Dependency of runoff phosphorus on extractable soil phosphorus. *Journal Environmental Quality* **24**, 920-926.

VandeHaar MJ, St-Pierre N (2006). Major advances in nutrition: relevance to the sustainability of the dairy industry. *Journal Dairy Science* **89**, 1280-1291.