Phosphorus export in runoff from a dairy pasture, laneway and watering trough

Gina M. Lucci[A,B], Richard W. McDowell[A] and Leo M. Condron[B]

[A]AgResearch, Invermay Agricultural Centre, Private Bag 50034 Mosgiel, New Zealand, Email Gina.Lucci@agresearch.co.nz
[B]Agriculture and Life Sciences, Lincoln University, P.O. Box 84 Lincoln 7647, New Zealand.

Abstract
Laneways and the areas around watering troughs are areas which receive increased inputs of phosphorus (P) in the form of dung because of their frequency of use. The aims of this study were to measure runoff from these two sources with time and compare their P loading with that from the surrounding pasture. Samples were collected from May 29, 2008 until August 28, 2009 from 0.5m^2 runoff plots in a dairy farmed catchment. Results show that dissolved reactive phosphorus (DRP), the most immediately available form of P to periphyton, was greatest from the lane (311mg DRP/m^2/winter 1; 528mg DRP/m^2/winter 2) followed by the trough (146mg/m^2/winter 1; 22mg DRP/m^2/winter 2) and pasture (0.2mg DRP/m^2/winter 1; 0.6mg DRP/m^2/winter 2) during the two winter seasons measured. During the summer months there was no significant difference in the DRP export from all sites. In addition, the DRP concentrations in runoff were strongly correlated with runoff volumes in the laneway meaning that more runoff would carry greater concentrations of DRP and a higher risk of DRP loading. We found that DRP export was much greater from both the laneway and trough compared with the pasture and these sources need to be addressed in management decisions.

Key Words
Phosphorus, runoff, overland flow, pasture, source.

Introduction

Runoff from agricultural land use is known to be a source of phosphorus (P), which is a limiting nutrient in freshwater ecosystems. Since most point sources have been identified, there has been increasing focus on diffuse sources ((Haygarth *et al.* 1998; McDowell and Wilcock 2004). However there exist smaller areas within the paddock at the plot scale that may act as point sources that are not well understood or represented in P export calculations, or nutrient modelling simulations. These are areas which receive disproportionately high inputs of P in the form of dung, and risk losing more P by frequent treading by livestock that can promote runoff. Treading also increases soil bulk density (Mulholland and Fullen 1991)prevents pasture growth that may filter-out P loses and leaves the soil surface susceptible to erosion. Runoff from two of these potential sources: around a watering trough and a laneway used for moving stock, have been measured in situ on a dairy catchment in the south island of New Zealand. It is expected that a better understanding of the magnitude of these potential P sources and also the mechanisms involved in P export will be gained.

Methods

The site used for the experiment was a dairy catchment on Pallic soil (New Zealand Soil Classification: Waitahuna silt loam (Hewitt 1998), USDA Taxonomy: Fragiochrept) on the rolling hills of Hillend, Otago, New Zealand (46° 08'S, 169° 45'E). The median annual rainfall for the area is 1000 mm and the slope ranges from 5-15°. Pastures have received annual maintenance fertilizer inputs (50 kg super P/ha and 250 kg lime/ha) for the past 15 years. Stocking density is 3 cows/ha and grazing rotations range from 3-5 weeks depending on pasture mass and climate.

Runoff (or overland flow) was measured at three different areas in the same catchment: pasture, laneway and close to a watering trough. The runoff plots measured from an area 1m x 0.5m and the runoff was collected into covered buckets via garden hose. The plots were replicated three times on the lane, just downslope of a watering trough and in three areas at different hillslope positions. Runoff was collected from the 29 of May 2008 until the 28 of August 2009. The volume of runoff was measured for each plot and then analysed colorimetrically (Watanabe and Olsen 1965) for dissolved (filtered <0.45 µm) reactive P (DRP) and total P (TP) after persulphate digestion. Data analysis was done with GenStat® eleventh edition.

Results and discussion

DRP loading

During the first winter season, season 1 (22/5/2008-30/9/2008, Table 1) the average DRP loss was greatest from the lane (7 mg/m^2) followed by the trough (4 mg/m^2), with little contribution from the pasture sites (Figure 6). The cumulative loads also show that the lane was a much greater contributor to DRP in runoff than the trough even though runoff volume form the trough area was greater (Table 1, Figure 7). During the summer months, September 2008 to March 2009, little runoff occurred although rainfall occurred throughout the year (Table 1), and there was little difference in DRP load between sites.

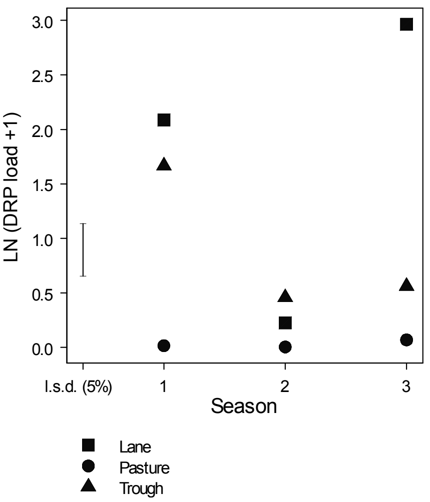

Figure 6. Average natural logarithm (mg /m2 + 1) loading values of DRP per event from the pasture, lane and trough for three seasons 1: 22/5/2008-30/9/2008; 2: 1/10/2008-31/3/2009; 3: 1/4/2009-28/8/2009.

The second winter season, season 3 (1/4/2009-28/8/2009), was drier than the preceding. There were 10 rainfall events compared with 13 the year before and the average event size was smaller (Table 1). The average soil water deficit for the period was also much greater, decreasing the probability of saturation excess runoff. As a consequence, runoff from around the trough area was less than half of the previous winters, and the average DRP loss from the trough was 2 mg/m^2. During the first winter season the trough exported 146 mg DRP/m^2/season, while during the second winter season the trough exported only 22 mg DRP/m^2/season. In contrast to the trough, the lane exported more DRP (311 to 528 mg/m^2 in season 3) despite less runoff. The pasture sites showed little DRP loss (0.84 mg/m^2) or variation with season compared with the trough and laneway. It is interesting to note that although the magnitude of DRP lost in runoff differs by three orders magnitude, the export response of the pasture and laneway is very similar while the trough has a different response altogether (Figure 7).

Table 1. The rainfall, runoff and events measured during three seasons from May 2008 until August 2009 at Hillend. The standard error of the mean (S.E.M.) is given in parenthesis below the mean event size and soil moisture deficit.

	Runoff Lane	Runoff Trough	Runoff Pasture	Rain	Average event size	Average deficit	Days	Events
	sum (mm)				(mm)		(n)	
Season 1 22/5/2008-30/9/2008	136	286	10	367	25 (3.3)	12 (0.6)	132	13
Season 2 1/10/2008-31/3/2009	3	29	1	365	15 (2.9)	87 (2.3)	182	9
Season 3 1/4/2009-28/8/2009	104	102	12	275	15 (2.5)	28 (3.2)	153	10

The laneway is in use almost daily and receiving regular P inputs in the form of dung from dairy cattle being taken to the milking shed or moved to different pastures. Meanwhile the pasture and trough only receive such inputs every 3-5 weeks depending on rotation, and as dung dries the potential for P loss decreases (McDowell and Stewart 2005). What this means is that more rainfall and consequently more runoff on the laneway will yield high concentrations of P, because the source is not readily diminished with each event, or is renewed between events. While in the paddock, more runoff will not necessarily lead to more P because the sources of P are variable and inputs from dung decrease with time until stock is relocated back into the paddock or fertiliser spread. By contrast the TP concentrations had a stronger correlation with runoff volumes at all sites. This is likely due to the contribution of particulate P which is not as transient as DRP in runoff.

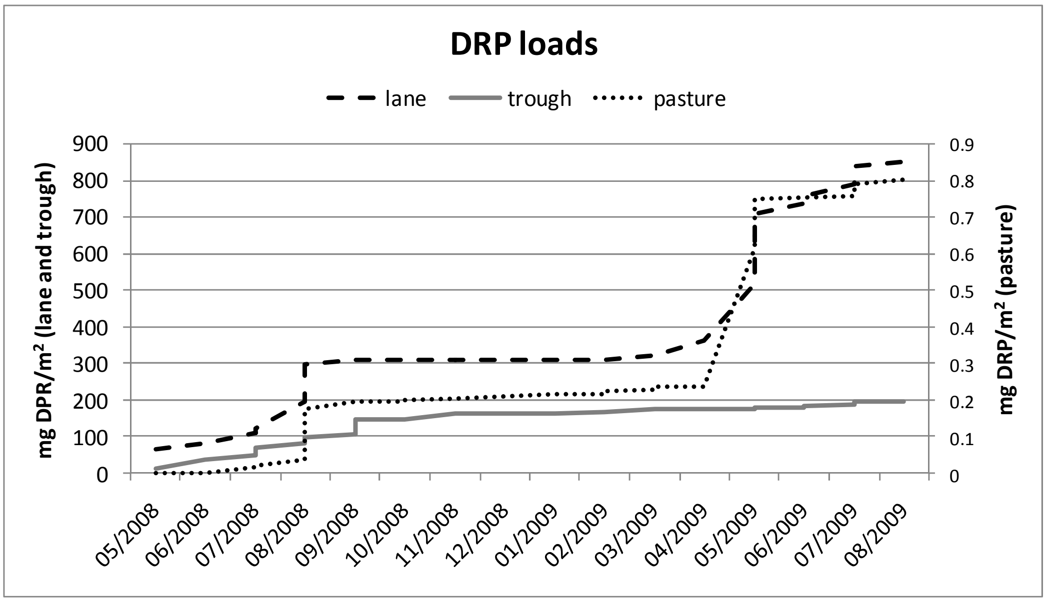

Figure 7. Cumulative DRP loads (mg/m^2) from the lane, trough and pasture during the whole measurement period. Please note the different scales on the y-axis.

Conclusions

Runoff from the laneway has great potential for P loading during the winter months, and even during drier winter conditions, the laneway exported high concentrations of P. The loading from the trough area was much more variable and subject to weather conditions and consequently exported much less DRP during a drier winter. Nonetheless both these point sources exported much greater loads of DRP than the pasture. More research needs to be done to see how great an effect these loads have on adjacent waterways.

References

Haygarth PM, Hepworth L, Jarvis SC (1998) Forms of phosphorus transfer in hydrological pathways from soil under grazed grassland. *European Journal of Soil Science* **49**, 65-72.

Hewitt AE (1998) 'New Zealand soil classification.' (Manaaki Whenua, Landcare Research: Lincoln).

McDowell RW, Stewart I (2005) Phosphorus in fresh and dry dung of grazing dairy cattle, deer, and sheep: sequential fraction and phosphorus-31 nuclear magnetic resonance analyses. *J Environ Qual* **34**, 598-607.

McDowell RW, Wilcock RJ (2004) Particulate phosphorus transport within stream flow of an agricultural catchment. *Journal of Environmental Quality* **33**, 2111-2121.

Mulholland B, Fullen MA (1991) Cattle trampling and soil compaction on loamy sands. *Soil Use and Management* **7,** 189-193.

Watanabe FS, Olsen SR (1965) Test of an ascorbic acid method for determining phosphorus in water and NaHCO3 extracts from soil. *Soil Soc. Am. Proc.* **29**, 677-678.