Phosphorus and Carbon Losses off Dairy Catchments Located on Duplex Soils

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Abstract

To predict seasonal changes in the pathways, loads and forms of phosphorus and carbon off two grazed dairy pastures at Flaxley, South Australia, instrumentation was installed to automatically measure and sample runoff (overland flow and A/B horizon interflow). Runofff accounted for less than 15% of April to October rainfall in 1996, which was 28% above average. Between 88 and 96% of runoff was overland flow. As much as 2.3 kg/ha of phosphorus (P) and 19 kg/ha of total dissolved carbon (TDC) was lost from the catchments. Over 92% of P and 76% of TDC were lost in overland flow. Between 50 and 60% of P was in the dissolved form. Between 64 and 96% of TDC was dissolved organic carbon (DOC). Nutrient losses were predicted from simple empirical regression equations.

Key words: Catchment, pasture, runoff, phosphorus, carbon, dissolved, particulate, nutrient load, dairy.

Dairying is an intensive grazing industry often located on duplex soils in southern Australia. To increase pasture and milk production, managers are increasing fertiliser use, especially P fertiliser. This trend raises some concerns regarding environmental impacts of fertiliser use. This project has examined nutrient loads from pastures of a commercially grazed dairy property. Previous work has indicated that P loads from pastures are generally less than 1 kg ha/yr (5). This P was assumed to be mostly particulate (1), although Nash and Murdoch (12) found P in runoff from a highly fertile dairy pasture in Victoria was primarily dissolved. Particulate P is typically associated with erosion and therefore amenable to reduction by controlling erosion (6). We measured forms of C and P in runoff from grazed dairy pasture with a view to identifying processes relevant to P movement from dairy farms located on duplex soils (sandy loams over clays).

Methods and materials

Nutrient concentrations and loads are reported from two catchments at Flaxley Agricultural Centre, Mount Lofty Ranges, South Australia in 1996. The soils of the Flaxley catchments were dominantly Chromosols (9). The soils had a neutral to slightly acid pH and were characterised by a very strong texture contrast between the A and B horizons. The A horizon thicknesses were 11-15 cm and were of a sandy loam texture (*i.e.* 10 to 15% clay). All soils in the mid and upper slopes had a pale coloured leached horizon (the E horizon) immediately above the clay B horizon which inferred interflow was occurring. The E horizons usually contained a significant amount of ironstone gravel. The B horizons of all soils were medium to heavy clays but had a strong angular blocky structure. This open structure may have allowed water to penetrate relatively freely through the B horizon to the weathering bedrock (the C or R horizons). For further detail of the soils see Fleming *et al.* (7).

The catchments covered areas of 2.2 ha (East) and 2.6 ha (West), and were on adjacent sides of a small ridge. Catchments were defined by exclusion drains cut into the subsoil clay around the upper and perimeter areas, and by a stainless steel surface water barrier installed completely across the bottom edge of each catchment. Flumes were instrumented with an ISCO Model 4230 Flowmeter and Model 2700 Sampler. Surface water barriers were inserted 5 cm into the soil. Subsurface water in the A horizon flowed under the steel barrier and was trapped by plastic sheeting which was 1 m behind the barrier, inserted into the clay B horizon. The water then ran into slotted plastic drainage pipe installed on the plastic sheeting, and into a 75 mm RBC flume installed at the lowest point. Further detail of the catchments and infrastructure are provided by Fleming *et al.* (8).

Each catchment covered two paddocks of a commer-cially grazed dairy property. Single superphosphate was broadcast onto both catchments in April at a rate of 165 kg/ha (15 kg P/ha).

Sampling programme and chemical analyses

Water samples were collected throughout storm events. P was analysed as total, dissolved, and particulate (by difference). Samples were also analysed for TDC, DOC and dissolved inorganic carbon (DIC). Samples were passed through a 0.45 mm Millipore filter to measure the dissolved fractions. All samples were analysed by ICP. Nutrient loads were calculated by summing the volume of flow x concentration, over the season.

Estimation of overland nutrient loads

Nutrient loads from unsampled events were estimated by multiple regression equations of nutrient load, developed from the data of sampled events. Nutrient load (dependent variable) was regressed on the following independent variables: slope - 7% West, 13% East; volume - per event ('000 L); volume^2 - quadratic effect of volume; event - the median event was set to zero, event number reducing by one for each earlier event and increasing by one for each following event; event^2 - this variable was high at the beginning and end of the season and zero in the middle; peak - peak flow rate during the event in litres/second; ratio - peak flow rate divided by volume per event (a measure of event intensity); date - calendar days from the start of the runoff season, beginning at 1 on the first day of the first runoff event (25 June, 1996). A maximum of two outliers was discarded from each regression.

Estimation of interflow nutrient loads

There were insufficient interflow samples to confidently extrapolate to unsampled events. To calculate nutrient load, all interflow samples were averaged with respect to concentration. These concentrations were multiplied by interflow volume to estimate total inter-flow loads.

Results and discussion

Runoff events

The winter of 1996 was unusually wet, with 631 mm of rain from April to October, compared to the long term average of 494 mm. Runoff was recorded from 46 overland flow events in 1996. Thirty seven of these events were greater than one sample volume (4000 L). Samples were taken from 17 of these (10 East, 7 West), and 20 events were unsampled. Surface runoff com-prised 12% (East) and 5% (West) of the 730 mm of rain which fell in 1996.

Nutrient loads

Over 90% of all C from the East catchment was overland flow. Slightly less (60-80%) was present as overland flow on the West catchment. Most C in overland flow (65% East, 81% West) and in interflow (83% East, 67% West) was present as DOC (Table 1).

P load from the East catchment was much higher than from the West. This was due to a combination of greater runoff volume (Table 1) and higher P concentrations (data not shown) on the East catchment. Most P from the West catchment, and almost all P from the East catchment was present in overland flow. Around half of the P in overland flow and interflow was present as dissolved P (DP).

P loads from the Flaxley East catchment were much higher than generally reported for grazed pastures (Table 2). This is of concern with respect to the amounts of P entering waterways. However, this was in a very wet year, and in the much drier year of 1997, less than 100 110 g/ha of P left the Flaxley East catchment (data not shown).

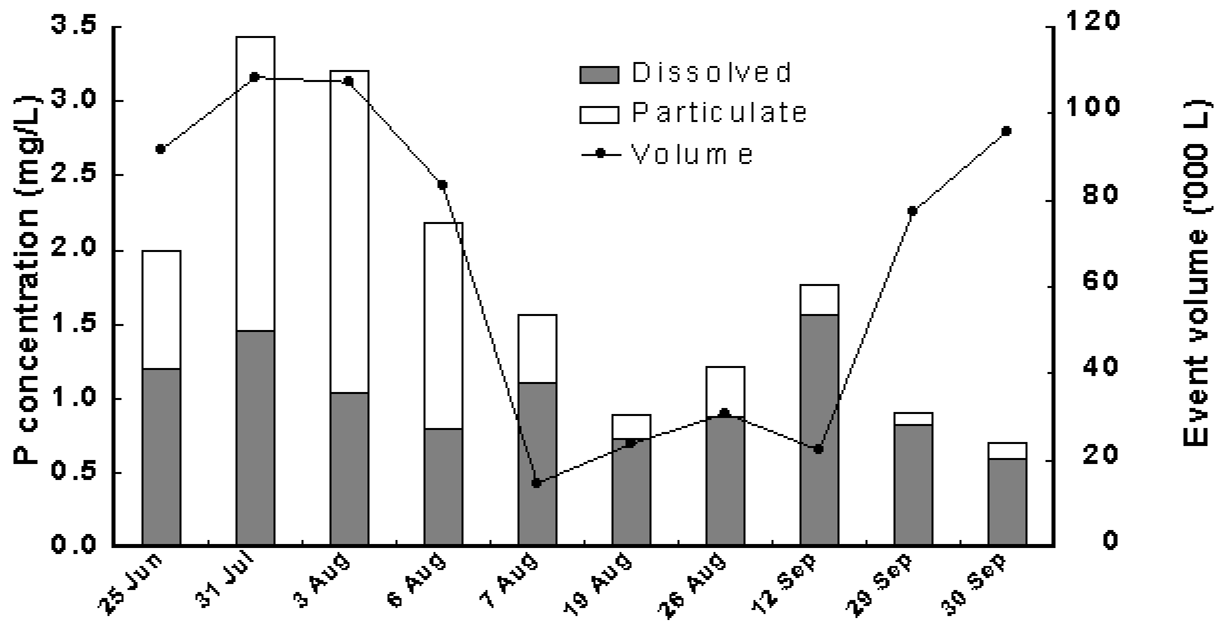

Figure 1

Changes during the season

Particulate P (PP) made up a large proportion of total P early in the season (Fig. 1), but declined to a very low proportion by late in the season. This proportion was not directly related to event volume. DP remained relatively constant over the season. The reduction in PP may be due to a combination of the loss of easily erodible materal over the runoff season, and increased plant cover during winter and spring, as this is known to reduce movement of particulate material (6). These findings differ from some published catchment work, where DP concentrations declined over a runoff season, consistent with exhaustion of a limited source solute (3). PP, on the other hand, is considered to be have an unlimited supply due to the quantity of soil available for erosion. However, the The relatively constant DP concentrations reported here, however,? agree with findings of Nash and Murdoch (12) on Victorian dairy pasture.

Estimation of nutrient loads

The relationships between measured and fitted C loads are described below.
DOC = (0.32*volume - 0.0015*volume$^{2?}$ + 0.090*date)^2 ; (R^2 = 0.98)
DIC = -103.1 + 14.8 slope + 0.95 volume - 1.08 event - 0.11 event^2 ; (R^2 = 0.91)
Statistically significant relationships were found between measured and fitted DOC and DIC loads.
The relationships between measured and fitted P loads are shown below.
DP = -47.3 + 3.43*slope + 0.56*volume - 0.70*event + 79.8*ratio - 1.28*peak;? (R^2 = 0.91)
PP = -58.9 + 8.28*slope + 0.0033*volume^2 - 1.2*event - 0.14*event^2 ; (R^2 = 0.96)
Statistically significant relationships were found between measured and fitted DP and PP loads.

Conclusions

We have found that nutrient losses from dairy pasture were far greater than generally reported in the literature (4, 14). Most nutrient was lost in overland flow. Around half of the P lost was in the dissolved fraction. This is higher than previously considered from agricultural land, but is consistent with recent findings on dairy pasture (12). Nutrient loads were predicted from simple empirical regression equations based on storm volume, event number, *etc*.

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