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SHORT COMMUNICATION

Phosphorus losses in surface run-off from grazed permanent pastures on a volcanic soil from Chile

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Abstract

Reactive (RP) and organic phosphorus (OP) losses from grazed paddocks were determined on a volcanic soil during 2004 and 2005. Paddocks were grazed by Holstein Friesian steers (3.5 steers ha^{-1}) and received N (67.5 kg ha^{-1}) and P fertilizer (30 kg P ha^{-1}). Total losses ranged between 4 and 15 g P ha^{-1} $year^{-1}$ and were greatly affected by incidental P losses associated with spring P fertilizer application. Reactive P constituted 90% of the total losses on average. Due to the high water infiltration capacity of the soil, run-off was <1% of total drainage, therefore, phosphorus losses in run-off were small.

Keywords: Andisol, grazing, reactive P, organic P, run-off P

Introduction

The Mediterranean maritime temperate climate and the volcanic soils of the Lake Region in southern Chile (39–44 S and 71–74 W) is home to more than 45% of the national cattle herd grazing on natural and improved pastures.

Volcanic soils are widespread in southern Chile accounting for 60% of the total arable area. These soils have high organic matter (OM) contents, low pH and high phosphorus (P) fixation capacity (Escudey *et al*., 2001), which has created the perception that P transfer to water is minimal. Consequently there have been no studies on the transfer of P from grazing pastures to surface waters.

The aim of this study was to evaluate the quantity of P lost in surface run-off from field-based beef production systems on a volcanic soil.

Materials and methods

Experimental site

The experiment was carried out at the National Institute for Agricultural Research, Remehue Research Centre (40°35′S, 73°12′W), between March 2004 and December 2005. Soil at the site is an Andisol of the Osorno soil series (Typic Hapludands; CIREN, 2003), more than 1 m in depth with 18% OM and high Olsen P in the topsoil. The mean annual precipitation in the area (29 years) is 1284 mm.

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Phosphorus losses were measured from two fenced off areas (2 ha each) grazed by Holstein–Friesian steers (3.5 steers ha^{-1}) with an initial live weight of 212 ± 9.9 and 170 ± 23.0 kg in 2004 and 2005 respectively. The 20-year-old permanent pasture was rotationally grazed. The main grass species were *Lolium perenne*, *Dactylis glomerata* and *Holcus lanatus*. In autumn 2004 and 2005, 45 kg N ha^{-1} were applied as sodium nitrate, 16% N. In each spring, 22.5 kg N ha^{-1} and 30 kg P ha^{-1} were applied as sodium nitrate and triple superphosphate (TSP, 46% P_2O_5) respectively.

Three surface lysimeters (5 × 5 m, 0.5 m depth) were established in both closed areas, as described by Scholefield & Stone (1995). This lysimeter isolates a known area from the paddock, allowing the separate collection of surface run-off and subsurface run-off (0–50 cm) through drainage pipes. Leaching was estimated as the difference between rainfall and evapotranspiration, after discounting surface and subsurface run-off.

Methods

Rainfall. Daily rainfall was recorded with an automatic weather station within 1 km of the experimental site.

Soil. Soil samples (n = 16) were taken randomly from the paddocks in autumn each year (0–10 and 10–20 cm depth) and bulked for determination of Olsen P and pH using standard methods (Sadzawka, 1990). Each autumn, soil cores (0–5 cm depth, n = 15) were taken to determine the soil bulk density (Rowell, 1997).

Phosphorus losses in run-off. Surface run-off samples were collected three times per week from the surface lysimeters and the volume measured on each occasion. The samples were stored at 4 °C until analysis. Reactive P (RP) was determined by the ascorbic acid method (Clesceri *et al*., 1998), total P (TP) by digestion with acid persulphate (method 8190®; Hach, 2000). Organic P (OP) was estimated as the difference between TP and RP and values reported might also contain particulate P.

Phosphorus concentration in surface water. The RP concentration of a stream located in the area was determined in 2005. Samples were collected weekly and analysed for RP as described above.

Statistical analysis

ANOVA was used to compare P concentrations and P losses between years. Genstat 7.1 was used as statistical package.

Results

Rainfall

Total annual rainfall was 1232 mm in 2004 and 1723 mm in 2005. Between April and October 2005, there was 1.4 times more rainfall than in the same period of 2004.

Soil

The soil had adequate nutrient levels for grassland production. Average concentrations for the experimental period were 28 mg kg^{-1} Olsen P, pH 5.6 (water) and 18% OM (0–20 cm). Soil bulk density (0–5 cm) increased by 35% from 2004 to 2005 (0.51 ± 0.006 and 0.69 ± 0.002 g cm^{-3} respectively; $P \leq 0.05$).

Drainage

Total drainage was 634 mm in 2004 and 941 mm in 2005. Surface run-off was 1% or less of total drainage; subsurface run-off was negligible (Table 1).

P concentrations and losses

Reactive P concentration in run-off was 68% greater in 2005 than in 2004 (Table 1), and average OP concentration was 75% lower in 2005. Greater RP concentrations in run-off were found after P fertilizer application (Figure 1). Grazing did not affect RP concentrations in run-off.

Total P losses in run-off were small, ranging from 4 to 15 g ha^{-1} of which 90% on average was RP. In 2005, total P losses were nearly four times greater than in 2004 ($P \leq 0.05$; Table 1). Losses as OP were negligible and did not vary between years ($P > 0.05$; Table 1).

Table 1 Drainage (mm), average P concentration in run-off (mg L^{-1}) and total P losses (g ha^{-1}) from two paddocks grazed by Holstein–Friesian steers during 2004 (12 April 2004 to 31 October 2004) and 2005 (1 April 2005 to 15 December 2005), ±standard error of the mean

	2004	2005
Drainage (mm)		
Surface run-off	0.4	6
Subsurface run-off (0–50 cm)	0.1	1
Leaching (> 60 cm)	634	934
Total	635	941
Average reactive and 'organic' P concentrations in run-off (mg L^{-1})		
Reactive P	2.2 ± 0.46 b (0–11)	3.7 ± 1.32 a (0–252)
Organic P	0.8 ± 0.02 a (0–10)	0.2 ± 0.01 a (0–4)
Total P losses in run-off (g ha^{-1})		
Reactive P	3.1 ± 0.05 b	14 ± 0.9 a
Organic P	0.6 ± 0.05 a	0.8 ± 0.1 a
Total	3.7 ± 0.1 b	14.8 ± 0.9 a

Different letters in columns indicate significant differences between years ($P \leq 0.05$).

Surface water

Average RP concentration in the stream water was 0.2 ± 0.01 mg lg^{-1} for the period January–August 2005 increasing to 0.6 ± 0.09 mg lg^{-1} for the period September–December 2005.

Discussion

Results in both seasons showed that run-off represented only 1% of the total drainage, with leaching being the main pathway for water movement, in agreement with Alfaro *et al.* (2005). The low bulk density of the surface layer maintained a high rate of infiltration with surface run-off occurring only during the heaviest rainfall events.

Peaks of TP and RP concentrations in run-off were associated with spring P fertilizer application during both years and were greater than those reported by McColl *et al*. (1977) for grasslands on volcanic soils. These high RP concentration peaks may have been due to the direct transport of fertilizer granules in run-off after application (Heathwaite *et al*., 1998). The peak P losses resulted in greater RP concentrations in the stream during spring. Peaks of OP concentration in run-off samples were also measured during spring and were probably related to the flush of OM mineralization produced at that time of the year (Turner & Haygarth, 2000).

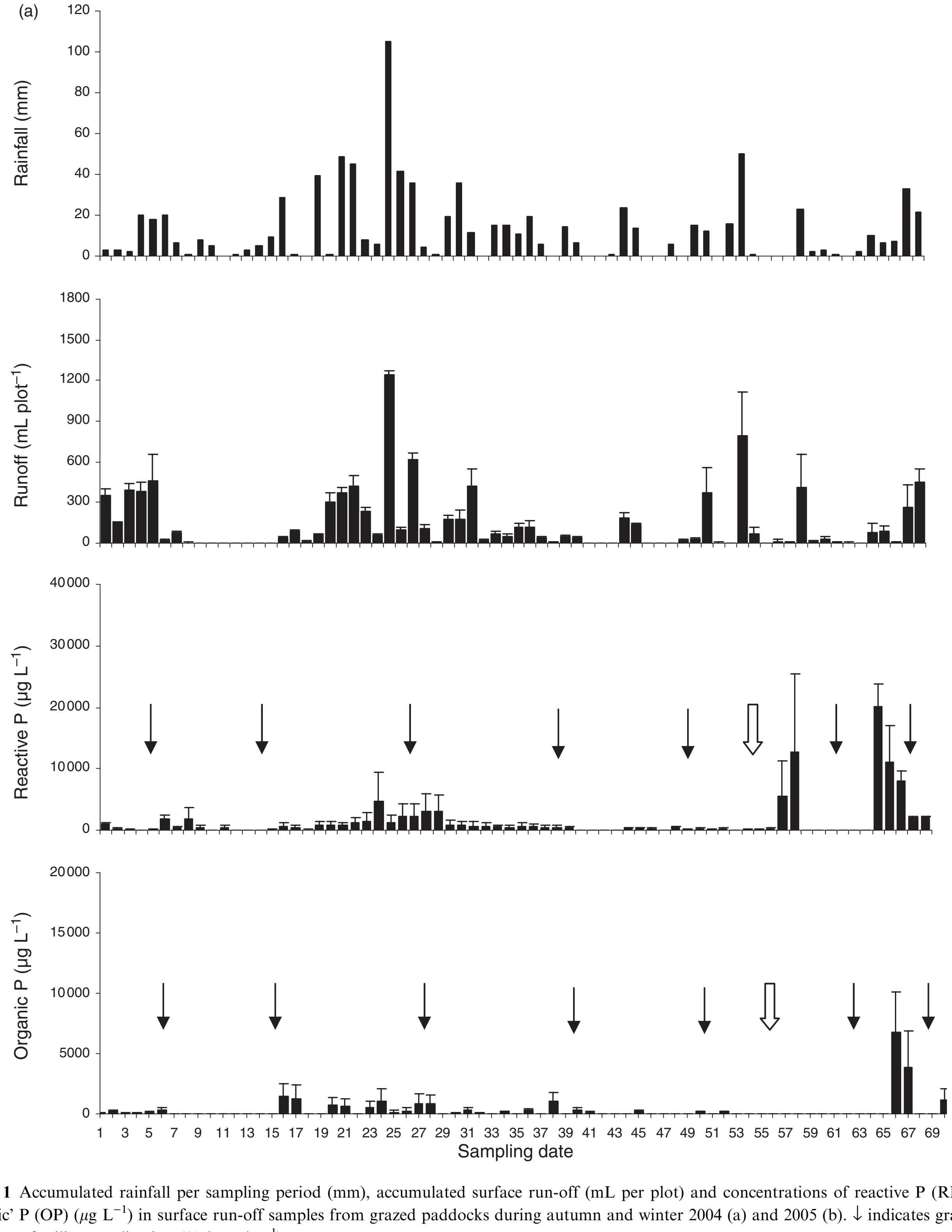

Figure 1 Accumulated rainfall per sampling period (mm), accumulated surface run-off (mL per plot) and concentrations of reactive P (RP) and 'organic' P (OP) (μg L^{-1}) in surface run-off samples from grazed paddocks during autumn and winter 2004 (a) and 2005 (b). ↓ indicates grazings, ⇩ indicates fertilizer application (30 kg P ha^{-1}).

Overall P losses were small compared with results of P transfer from grazed land in Europe (Haygarth & Jarvis, 1997) and New Zealand (McColl *et al.*, 1977). This is probably due to the small amount of surface run-off generated. Total losses were mainly as RP as found by Sharpley & Rekolainen (1997).

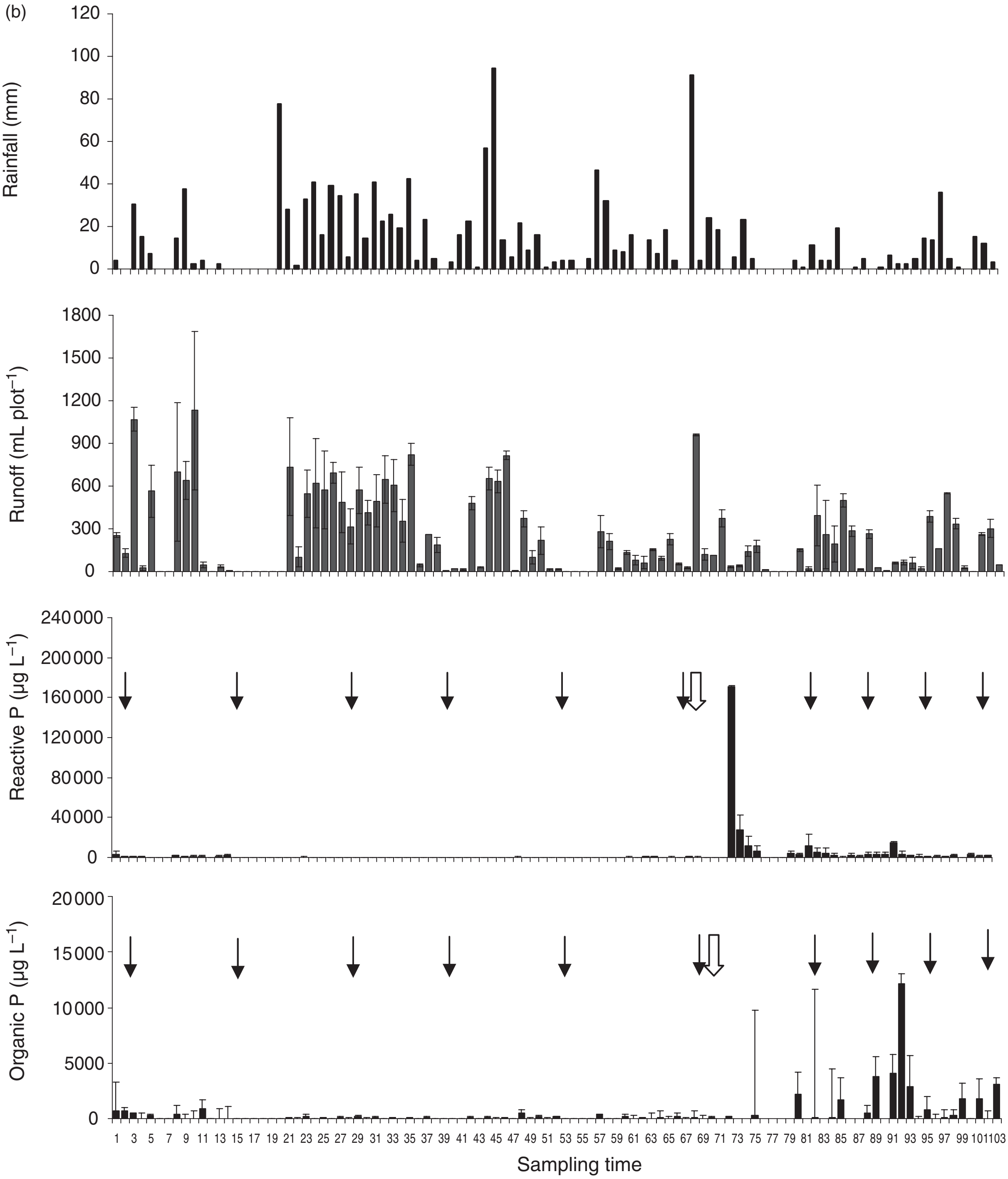

Figure 1 Continued.

Our results indicate that RP losses in run-off could be minimized if P fertilizer applications were confined to periods of low risk of run-off independently of the season. This might be of particular relevance in years of greater rainfall such as those of the 'El Niño' phenomenon.

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