Effects of stock type on soil physical properties and losses of phosphorus and suspended sediment in surface runoff

Fiona Curran-Cournane[A, B], Richard W. McDowell[A], Roger Littlejohn[A] and Leo M. Condron[B]

[A]AgResearch, Invermay Agricultural Centre, Private Bag 50034, Mosgiel, New Zealand, Email Fiona.curran-cournane@agresearch.co.nz
[B]Faculty of Agriculture and Life Sciences, Lincoln University, New Zealand

Abstract
By altering soil physical properties and dung deposition, livestock grazing can enhance the loss of phosphorus (P) and suspended sediment (SS) in surface runoff which can impair the quality of receiving water bodies. The impact of cattle, deer, and sheep on surface (0-5 cm) soil physical properties and P and SS losses in surface runoff was investigated. No significant difference was found between stock type and P and SS losses. However, significant differences were evident for the interaction of stock type with soil physical properties (bulk density, macroporosity, and saturated hydraulic conductivity-K_{sat}). Furthermore, a gamma log generalised linear model detected a significant relationship between macroporosity, K_{sat} or time (days) since grazing and certain concentrations and loads of P fractions and SS losses, whereby more pore space, a greater infiltration rate or time since the paddock was last grazed decreased losses. This suggests that soil physical measurements may have the potential to aid management to decrease P and SS losses in surface runoff.

Key Words
Treading, rainfall, dissolved phosphorus, particulate phosphorus, concentrations and loads.

Introduction
Livestock treading can have detrimental impacts on soil physical properties and promote the loss of non-point source pollutants such as phosphorus (P) and suspended sediment (SS) in surface runoff (McDowell *et al.* 2003a). Although cattle have been reported to have greater influence on soil surfaces than that of sheep from a soil physical condition and pasture production (Drewry 2006), little work has examined the impacts of livestock other than cattle on contaminant losses in surface runoff (McDowell *et al.* 2003a; McDowell *et al.* 2003b; Nguyen *et al.* 1998). McDowell and Wilcock (2008) reported that mean loads of P were similar from catchments grazed by deer or mixed stock (sheep and beef) to those grazed by dairy cattle, whereas loads of sediment were greatest for deer followed by mixed stock and dairy cattle. The current study looks at the impact beef cattle, sheep and deer grazing on soil physical properties and losses of P and SS in surface runoff from a soil known to be structurally vulnerable to treading damage, a Pallic silt loam.

Materials and methods
The trial was located at the AgResearch Invermay sheep, beef, and deer farm, near Mosgiel, New Zealand. The soil at the site was a Pallic silt loam (Fragic Pallic according to the NZ soil classification, or a Fragiochrept in US soil taxonomy; (Hewitt 1998). Two paddocks grazed by sheep and beef cattle and one adjacent paddock, grazed by deer, were chosen for study. Within each sheep and beef paddock areas 20 x 20 m were fenced off for one of the following three treatments: cattle, sheep, and control (nil grazing). Each treatment was replicated twice. Within each 20 x 20 m grazing zone a pair of sub plots were installed. Sub plots, 4 m long and 1 m wide, were bounded by wooden boards 150 mm wide by 25 mm thick. At the downslope end an open ended metal gutter was fitted which directed all surface runoff into a 50 L container placed below the height of the gutter and connected via an underground hose. Within the deer paddock, the control area was fenced off which contained a pair of subplots. However, due to the problem of containing deer within small enclosures, 2 sets of paired subplots were further installed in the remainder of the paddock and deer allowed to roam freely. Pasture was cut and carried off each control area when necessary.

Each stock class was rotationally grazed in accordance with feed supply and generally on the same day or within a few days of one another. After grazing, soil cores (3) were taken for macroporosity, bulk density and saturated hydraulic conductivity (K_{sat}) analysis. After each rainfall event, any surface runoff was collected, the volume noted, and analysed for dissolved reactive P (DRP), dissolved unreactive P (DURP), total dissolved P (TDP), particulate P (PP), total P (TP) and SS.

Results

Paddocks were grazed seven times between August 2008 and July 2009. Surface runoff was produced within a few days of these grazing events, and there were forty three runoff events in total, mostly in winter (Figure 1). No significant differences were found between mean concentrations and loads of P and SS lost according to stock type (data not shown). However, the effect of stock type was significant (P <0.001) for bulk density, K_{sat}, and macroporosity (Figure 2). Overall mean macroporosity was least for the cattle treatment and greatest for the cattle/sheep control. Saturated hydraulic conductivity followed a similar pattern with the slowest rates occurring in the cattle treatment and fastest rates in the cattle/sheep control (data not shown).

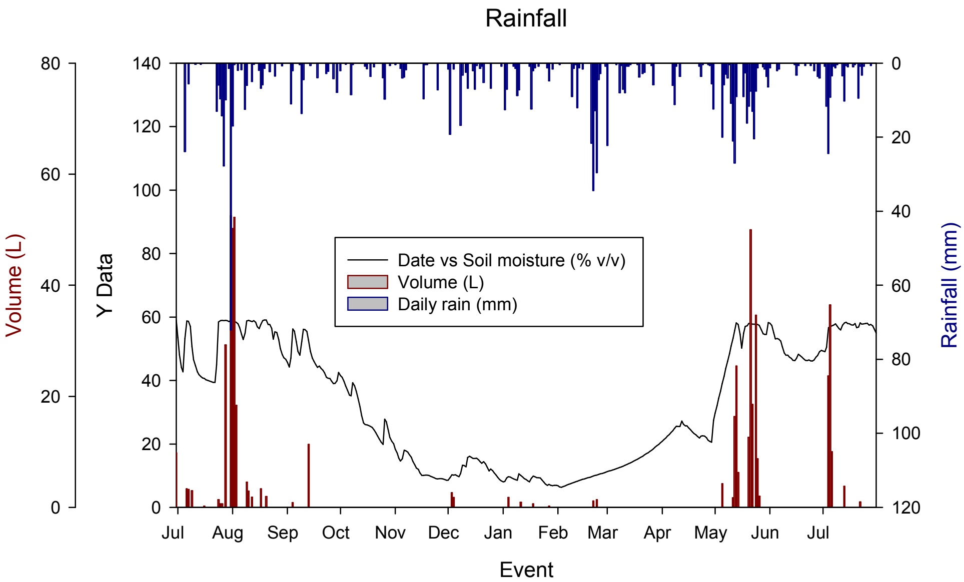

Figure 1. Interaction of rainfall and soil moisture on the mean volume (L) of surface runoff produced for all plots

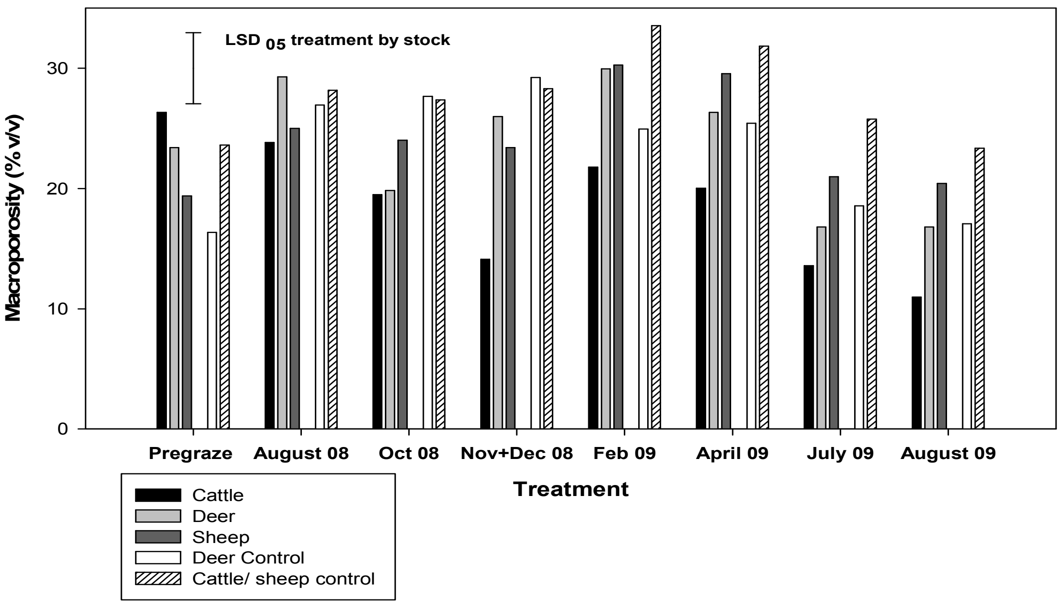

Figure 2. Effect of stock type on soil macroporosity % (v/v) after each grazing event (month given). The least significant difference (LSD) (P < 0.05) is given for the interaction of stock type with treatment.

A gamma log generalised linear model was used to analyse factors affecting concentrations and loads of DRP, TDP, and TP lost and showed, after adjusting for grazing treatment, stock, and time since grazing, that a decrease in macroporosity was associated (P<0.05) with an increase in losses (Figure 3a),. Likewise, concentrations and loads of DRP, DUP, TDP, TP, and SS showed significant decreases in losses with time since grazing (Figure 3b).

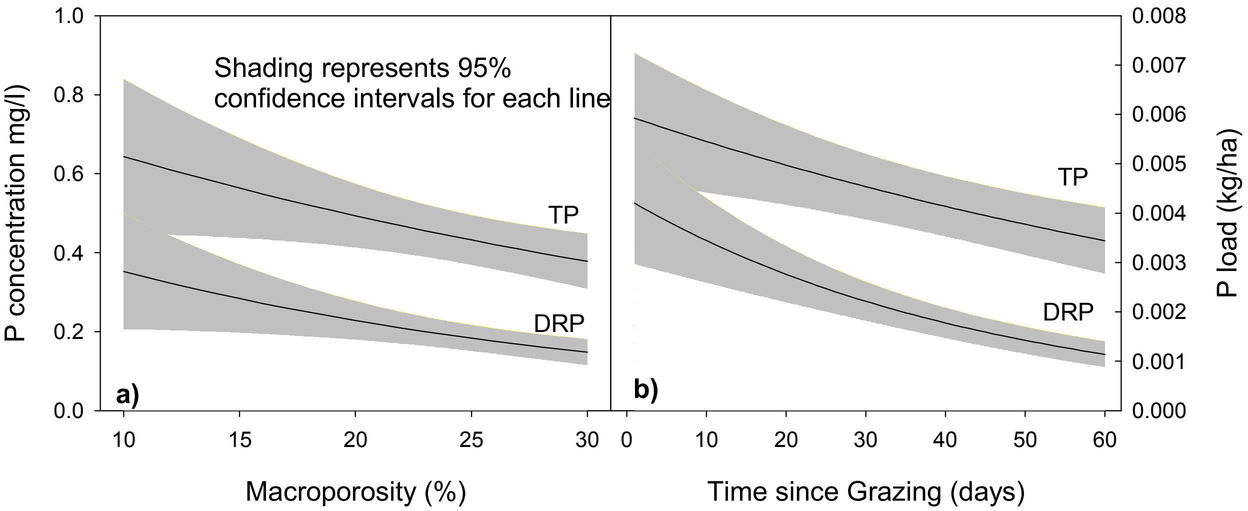

Figure 3. Regression of concentrations of DRP and TP in surface runoff against macroporosity (0-5 cm depth) (a) and days since grazing (b).

An association (P<0.05) was also observed between K_{sat} and the concentrations and loads of PP and SS losses, whereby losses decreased with an increase in infiltration rates (Figure 4).

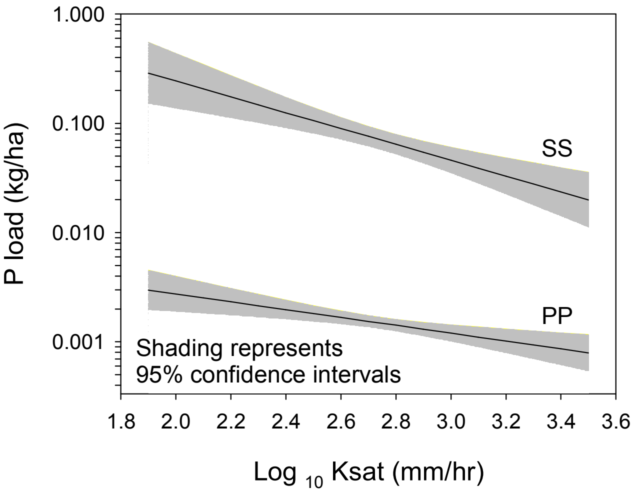

Figure 4. Regression relationship between saturated hydraulic conductivity (K_{sat}, mm/hr; 0-5 cm depth; log-transformed data) and the load of PP and SS lost during surface runoff.

Discussion

Results showed that macroporosity and K_{sat} may have an important role on SS and certain fractions of P losses in surface runoff. Macroporosity has been reported to be a useful tool to predict impacts on pasture production and P losses in surface runoff (Drewry *et al.* 2008; Mc Dowell *et al.* 2003b). Drewry *et al.* (2008) recommended a macroporosity range between 6 to 17% (v/v) for optimal pasture yield and McDowell *et al.* (2003b) reported a significant negative relationship between macroporosity and the time to ponding. Although soil physical properties never reached critical values whereby pasture was sacrificed or visual destruction was evident the relationships between soil physical values and P and SS losses confirms that environmental impacts may pose a threat well before agronomic effects are noticed.

The decrease in concentrations and loads of DRP, DUP, TDP, TP, and SS with time since grazing could be due to the recovery of soil physical properties (i.e. K_{sat} or macroporosity increased) or pasture after stock were removed (Drewry 2006; Nash and Haliwell 1999) or a decrease in P from dung with time as the threat posed by dung is greatest in the first few days of deposition (Mc Dowell 2006). However, dung counts on the plots were low throughout the study and the return of dung in runoff samples collected was unlikely and so was attributed to the former effect.

Conclusion

No differences in the concentrations and loads of P and SS losses in surface runoff from plots grazed by different stock types were detectable, but the effects of stock type were evident for soil physical properties with cattle being most detrimental. An significant relationship was found between macroporosity and K_{sat} on loads and concentrations of certain P fractions and SS losses, and was also evident with days since grazing. Therefore, soil physical measurements may have the potential to be used as a tool for environmental assessment which should be considered in future studies.

References

Drewry JJ (2006) Natural recovery of soil physical properties from treading damage of pastoral soils in New Zealand and Australia: A review. *Agriculture, Ecosystems & Environment* **114**, 159-169.

Drewry JJ, Cameron KC, Buchan GD (2008) Pasture yield and soil physical property responses to soil compaction from treading and grazing-a review. *Australian Journal of Soil Research* **46**, 237-256.

Hewitt AE (1998) 'New Zealand Soil Classification.' (Manaaki Whenua Press: Lincoln, New Zealand).

McDowell RW (2006) Contaminant losses in overland flow from cattle, deer and sheep dung. *Water Air and Soil Pollution* **174**, 211-222.

McDowell RW, Drewry JJ, Muirhead RW, Paton RJ (2003a) Cattle treading and phosphorus and sediment loss in overland flow from grazed cropland. *Australian Journal of Soil Research* **41**, 1521-1532.

McDowell RW, Drewry JJ, Paton RJ, Carey PL, Monaghan RM, Condron LM (2003b) Influence of soil treading on sediment and phosphorus losses in overland flow. *Australian Journal of Soil Research* **41**, 949-961.

McDowell RW (2006) Contaminant losses in overland flow from cattle, deer and sheep dung. *Water Air and Soil Pollution* **174**, 211-222.

McDowell RW, Wilcock RJ (2008) Water quality and the effects of different pastoral animals. *New Zealand Veterinary Journal* **56**, 289-296.

Nash DM, Halliwell DJ (1999) Fertilizers and phosphorus loss from productive grazing systems. *Australian Journal of Soil Research* **37**, 403-429.

Nguyen ML, Sheath GW, Smith CM, Cooper AB (1998) Impact of cattle treading on hill land 2. Soil physical properties and contaminant runoff. *New Zealand Journal of Agricultural Research* **41**, 279-290.