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Impact of cattle on soil physical properties and nutrient concentrations in overland flow from pasture in Ireland

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Abstract

The loss of nutrients from agricultural land to water bodies is a serious concern in many countries. To gain information on the contribution of grazing animals to diffuse nutrient losses from pasture areas to water, this study looked at the impact of cattle on nutrient concentrations in overland flow and on soil hydrology (bulk density, macroporosity and resistance to penetration). Rainfall simulations to produce overland flow were conducted and soil physical measurements were taken on experimental plots assigned to one of two treatments: (1) cattle had unrestricted access to the plot; (2) cattle could graze the plot but they could neither walk on the plot area nor deposit excrements on it. Areas to which the cattle had free access were characterised by 57–83% lower macroporosity, by 8–17% higher bulk density and by 27–50% higher resistance to penetration than areas from which the cattle were excluded. The nutrient losses from grassland that can specifically be attributed to the presence of grazing animals were found mainly in the particulate nitrogen, the organic phosphorus and in the potassium exports. Overall, the presence of cattle had a longer lasting effect on the soil hydrological parameters measured than on the nutrient concentrations in overland flow.

Keywords: Cattle grazing; Soil compaction; Nutrient concentration; Overland flow

1. Introduction

Grassland managed with the aim of supporting intensive animal husbandry can, under some circumstances, become a source of nutrients in water bodies (Kurz et al., 2005a; Sharpley and Syers, 1979). Stock can impact on stream water quality directly by entering and excreting into the streams (Sharpley and Syers, 1979), and by trampling and eroding the stream banks (Line et al., 2000). Grazing animals can alter the hydrology and the drainage pathways at a site by compacting the topsoil, which is indicated by increased bulk density (BD) and decreased macroporosity (MP) (Singleton et al., 2000). This can result in a decrease of the infiltration capacity of the soil (Pietola et al., 2005) and, consequently, in an increased occurrence of overland flow (Heathwaite et al., 1990), which is considered to be an important nutrient loss pathway (Kurz et al., 2005b). Grazing animals can also change the characteristics of grassland as a nutrient source. They may alter the type and amount of nutrients that can be mobilised and lost to water by effecting a spatial and chemical re-distribution of nutrients and, sometimes, by causing enough soil physical damage to reduce grass growth (Drewry and Paton, 2000).

The effects of grazing animals on nutrient losses to water are reported to range from not measurable (Owens et al., 1989) to considerable (Heathwaite and Johnes, 1996). This variation is probably due to the great number of variables involved in the nutrient loss process, and to the considerable effect the relative timing of management and weather factors can have on nutrient movement.

The aims of this project were (1) to measure the impact of rotationally grazing cattle on bulk density, macroporosity and resistance to penetration; (2) to investigate whether rotationally grazing cattle influence the nutrient concentra-

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tions in overland flow produced at pasture sites; (3) to assess the likely impact of rotationally grazing cattle on nutrient concentrations in overland flow.

2. Methods

2.1. Overview of study sites and measurements taken

Four fields of pasture were used as study sites for the soil physical investigations. Two of the sites (JC1 and JC2) were located at Johnstown Castle, Wexford, Ireland (302404/11fc UTM) and two (G1 and G2) at Grange, Co. Meath, Ireland (297959/254978 UTM). At each of the four field sites two treatments were applied to small (1.5 m × 15 m) delineated plots. Treatment 1 (UnAc) gave cattle unrestricted access to the five plots assigned to that treatment. Treatment 2 (NoTrEx) allowed cattle to eat the grass on the five plots assigned to that treatment but cattle could neither walk (trample) on the plot areas nor deposit excrement on them. At each site, the five plots per treatment were selected randomly. The plots of the NoTrEx treatment were fenced with electric wire. The corners of the plots of the UnAc treatment were marked with coloured stakes driven to ground level. The plots were set up in spring of 2002, before the start of the grazing season. Machinery was excluded from all plots. The UnAc treatment was representative of established grazed grassland, and the NoTrEx treatment of established grazed grassland from which cattle trampling and excrement deposition had been removed. A randomised replicated block design was used.

This study consisted of two experiments: an investigation into the effects of grazing animals on soil physical properties and a rainfall simulation experiment on the impact of grazing animals on nutrient concentrations in overland flow. Soil physical measurements (BD, MP and resistance to penetration (RP)) to assess the impact of cattle on soil hydrology were taken at the four study sites from November 2002 to February

Table 1
Resistance to penetration (RP)/soil moisture (SM) survey dates, macroporosity (MP)/bulk density (BD) sampling dates, and grazing dates for the soil physical investigations

Site	Date	RP/SM surveys	MP/BD sampling	Soil nutrient sampling	Grazing dates
JC1	30 April 2002–03 November 2002				Rotational grazing as detailed in Table 2
	November 2002		X		
	11 December 2002	X			
	02 April 2003	X			
	14 April 2003–12 November 2003				Rotational grazing as detailed in Table 2
	October 2003				
	10 November 2003	X			
	30 April 2002–03 November 2002				
JC2	19 April 2002–10 October 2002				Rotational grazing
	November 2002		X		
	31 March 2003	X			
	12 April 2003–17 September 2003				Rotational grazing
	October 2003		X		
	15 October 2003	X			
	March 2004			X	
G1	15 April 2002–24 October 2002				Rotational grazing
	November 2002		X		
	09 December 2002	X			
	23 January 2003	X			
	14 March 2003	X			
	15 April 2003–11 November 2003				Rotational grazing
	December 2003		X		
	03 December 2003	X			
	16 February 2004	X			
	March 2004			X	
G2	15 April 2002–24 October 2002				Rotational grazing
	11 December 2002–15 December 2002				Additional grazing
	January 2003		X		
	23 January 2003	X			
	14 March 2003	X			
	15 April 2003–11 November 2003				Rotational grazing
	25 November 2003–28 November 2003				Additional grazing
	12 February 2004–14 February 2004				Additional grazing
	February 2004		X		
	16 February 2004	X			
	March 2004			X	