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Effects of cattle manure on erosion rates and runoff water pollution by faecal coliforms

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Abstract

The large quantities of slurry and manure that are produced annually in many areas in which cattle are raised could be an important source of organic matter and nutrients for agriculture. However, the benefits of waste recycling may be partially offset by the risk of water pollution associated with runoff from the fields to which slurry or manure has been applied. In this paper, the effects of cattle manure application on soil erosion rates and runoff and on surface water pollution by faecal coliforms are analysed. Rainfall simulations at a rate of 70 mm h^{-1} were conducted in a sandy loam soil packed into soil flumes (2.5 m long $\times$ 1 m wide) at a bulk density of 1400 kg m^{-3}, with and without cattle slurry manure applied on the surface. For each simulation, sediment and runoff rates were analysed and in those simulations with applied slurry, presumptive faecal coliform (PFC) concentrations in the runoff were evaluated. The application of slurry on the soil surface appeared to have a protective effect on the soils, reducing soil detachment by up to 70% but increasing runoff volume by up to 30%. This practice implies an important source of pollution for surface waters especially if rainfall takes place within a short period after application. The concentrations of micro-organisms (presumptive faecal coliforms (PFCs)) found in water runoff ranged from 1.9×10^4 to 1.1×10^6 PFC 100 mL^{-1}, depending on the initial concentration in the slurry, and they were particularly high during the first phases of the rainfall event. The result indicates a strong relationship between the faecal coliforms transported by runoff and the organic matter in the sediment.

Keywords: Runoff rates; Sediment rates; Cattle manure; Faecal coliforms; Rainfall simulation

1. Introduction

The large quantities of slurry and manure that are produced annually in many areas in which cattle are raised could be an important resource of organic matter and nutrients. Recycling these wastes via land application could lead to improvements in physical properties of soil, such as soil porosity, structure, and water holding capacity (León-González et al., 2000; Ouédraogo et al., 2001; Nyamangara et al., 2001). For this reason, the application of faecal wastes could be beneficial for soil conservation (Pinamonti and Zorzi, 1996), especially in degraded soils and soils susceptible to erosion, although the response to soil amendment is soil-site specific. However, the benefits of waste recycling may be partially offset by the risk of water pollution associated with runoff from fields to which slurry or manure has been applied, especially if rainfall occurs shortly after application.

The contamination of surface waters with pathogenic micro-organisms transported from fields to which livestock slurries and manure have been applied is a serious environmental concern because it may lead to humans being exposed to such micro-organisms via several routes: drinking water (Ongerth and Stibbs, 1987; Hansen and Ongerth, 1991; Poulton et al., 1991; Skerrett and Holland, 2000); bathing waters (Geldreich, 1996; Wyer et al., 1996; Baudart et al., 2000); and water used for the irrigation of ready to eat foods (Tyrrel, 1999).

The aim of this work was to evaluate the effects of cattle manure application on soil erosion rates and runoff and on the detachment and transport of faecal coliforms.

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2. Material and methods

The study was performed in the laboratory. A sandy loam soil, classified as Lamellic Ustipsamment (Soil Survey Staff, 1999), sampled at Bedfordshire, (UK) was used throughout the experiments. The soil was passed through a 9.5 mm sieve and packed into soil flumes (2.5 m long × 1 m wide and 30 cm deep) at a bulk density of 1400 kg m^{-3}, set at a 5% slope. The flumes are designed to separate overland flow from water that has infiltrated the soil. Surface runoff generated along the slope flows into a collection chamber at the end of the flume and then through an outlet hose from which discharges could be measured and samples taken for analysis. Water percolating through the soil was able to drain freely from the flume thus avoiding the creation of saturated conditions (Fig. 1).

In order to increase soil surface moisture conditions, one day prior to each runoff experiment, the erosion plot was exposed to simulated rainfall whilst protected with fabric to avoid soil detachment. Simulated rainfall was applied to the plots at an intensity of 70 mm h^{-1} for 45 min using a pressure irrigation sprinkler. The sprinkler had a nozzle (LECHLER GMbh 56072830-CE) positioned 2 m above the soil surface. Raindrop size ranged between 0.7 and 2.8 mm, with a D_{50} value of 1.2 mm. The intensity used in the simulation was high enough to produce runoff, which became constant after 15 min. This intensity corresponds to the 15-min intensity for a 20-year return period storm.

For each simulation, runoff samples were taken every 5 min. Runoff volumes (including water and sediment) were determined using calibrated measuring cylinders. Sediment concentration in runoff was determined in 1-L aliquots of runoff, which were then decanted and dried at 105 °C, and then weighed. The organic matter content in the sediments collected in runoff was determined for each sample by weight after ignition in a furnace at 550 °C for 4 h of an aliquot (Nelson and Sommers, 1996). The results were expressed in grams of organic matter per runoff volume. Two simulations and three replications of each analysis were done.

In similar plots, cattle slurry was spread onto the soil surface at a rate of 30 Mg ha^{-1} (7.5 kg per plot) which is below the maximum recommended value (MAFF, 1998). Slurry application was done by hand but just left on the surface, simulating the way in which it could be applied by farmers with machinery. The dry solids content of the slurry ranged from 8 to 24%. In this case, simulated rainfall was applied to the plots within 24 h of the slurry application. Runoff samples were collected and managed in the way described above to determine sediment and organic matter concentration. In addition, aliquots of 300 mL were collected in sterile bottles to determine the number of PFCs in the runoff following serial dilution according to the membrane filter procedure (method no.: 9222D, APHA, 1998). The analysis was done within 2 h of the end of the rainfall simulation and each sample was analysed in triplicate.

Prior to application the number of PFCs present in the slurry was also enumerated. Ten grams of moist slurry was added to 200 mL of sterile water and placed on a mechanical shaker for 20 min. This solution was also serially diluted prior to the membrane filtration.

A statistical analysis (Duncan's mean test and one-way analysis of variance) of total runoff volume, average sediment concentration in runoff recorded during the 45 min rainfall, final constant runoff rates and final sediment

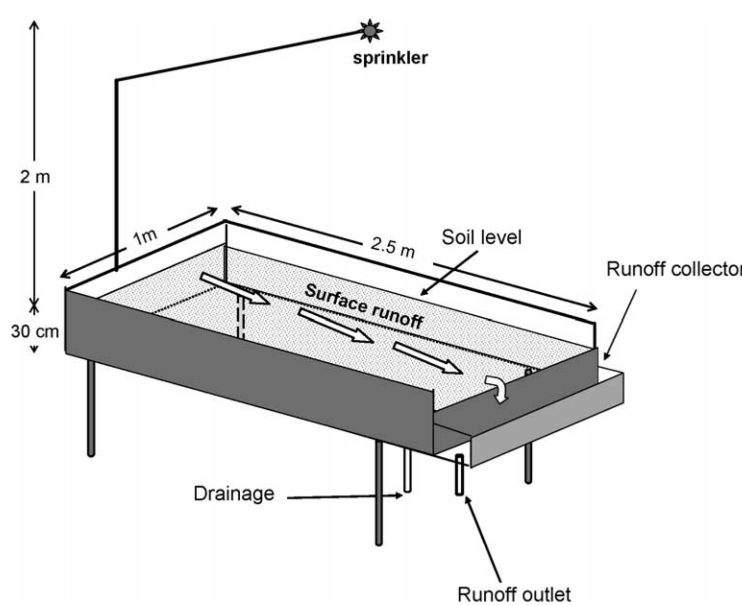

Fig. 1. Diagram representing the flume type used for the rainfall simulation.