The Mechanism of Flow Retardation and Erosion Control by Vegetated Buffer Strips on Sloping Lands

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Abstract

Buffer strips are commonly used to reduce runoff sediment transport on sloping lands and in the riparian zones of rivers and streams. One of the important aspects of buffer strip which is not well understood is the flow hydrology around the strips. The work reported here extends the current understanding of the physical processes involved in sediment and contaminant reduction by a vetiver grass buffer strip. Experiments were carried out in the Griffith University Tilting-Flume Simulated Rainfall facility using three different soils on three slopes. A dense vetiver strip was inserted in the path of surface runoff in the flume. The soils were made into slurry and introduced to the surface flow. The inflow and outflow of sediment were measured, together with the runoff rate. The rate of deposition in front of the buffer was measured at different distances and times in front of the buffer. Results indicated that the Vetiver grass strip caused a region of enhanced flow depth, upstream of the buffer. The region increased in depth and decreased in length with increasing slope. Buffering action resulted in the deposition of up to 95 % of the added sediment in the backwater region. Suspended sediment loads in the outflow increased with slope but remained primarily in the finer particle size range compared to the input sediment. With most fine particles remaining is suspension in the emerging water downstream of the strips, the value of Vetiver buffer strip in controlling pollutant transport on the slopes and into water bodies is not certain. Water depths, sediment concentrations and rate of deposition were simulated using both hydraulic and erosion/deposition models and predictions compared with data from the flume experiments.

Introduction

Vegetated buffer strips are widely employed to reduce fluxes of eroding soil and associated chemicals, from hillslopes into waterways. The flow hydrology and sediment reduction operating in buffers have been investigated by a number of researchers(Kemper *et al.*, 1992; Meyer *et al.*, 1995; Lakew & Morgan,1996; Raffaelle *et al*, 1997; Landry and Thurow, 1997). However, there are a number of inconsistencies in reported research and the associated recommendations for what type of buffer strip is most effective under what condition, and for which pollutant. Recent studies have shown that net deposition upslope of the buffer is the major contributor to sediment removal, rather than the supposed filtering action of the vegetation on runoff (Ghadiri et al., 2001; Rose et al., 2002; Rose et al., 2003). Because large particles settle more quickly than fine particles, the layer of deposited sediment has larger aggregates than the eroding sediment. Thus, fine sediments preferentially move through the buffer strips. This reduces the effectiveness of buffer strips as a method of preventing pollution since major pollutants are associated with such fine sediments.

The buffer strip efficiency is time dependent and changes as the sediment deposition builds up in the backwater, adding to the complexity of the situation None of the current erosion models handles deposition in the zone of sediment accumulation upstream of the buffer, except when this is at a sufficiently early stage of net deposition, for its effect on flow to be negligible. This current research is therefore aims to improve the predictive ability of physically-based erosion/deposition models. Recent work has shown a strong interaction between deposited sediment and hydraulics, length of hydraulic transition and reduced velocity being extended as net deposition progresses. The work reported here extends the current understanding of the physical processes involved in sediment reduction by a vetiver buffer strip.

Materials and Methods

Experiments were carried out in a 3.5 m by 0.3 m section of the Griffith University Tilting-Flume Simulated Rainfall facility. A dense vetiver strip, 0.3 m in length, (similar to a vetiver hedge base in the field at 1-2 years growth) was prepared by inserting 30 vetiver plants into a Plaster of Paris block. The block was inserted in the flume and a raised flume surface was constructed level with, and on either side of the buffer, using boards (Fig 2). The surfaces of the boards were covered with rough material (Manning coefficient of 0.03) to simulate a soil surface. Replicate experiments were conducted at 1, 3 and 5% slopes. At each slope, surface flow was introduced 1.8 m in front of the buffer and the water surface elevations in front of, and behind, the buffer were recorded using thin boards covered by water-soluble dye, inserted into the centre of the flume. A Vertosol from the Darling Downs area of Queensland was then introduced as a slurry into the surface flow (maintained at the same rate as previous) through a sediment dispenser and the inflow and outflow of sediment was measured, together with the runoff rate. The rate of deposition in front of the buffer was estimated using small tags introduced into the flow at different distances, and times, in front of the buffer. At the end of the sediment addition (~20 minutes), the elevation of the new water surface was again measured, using dyed boards. Flow was then cut off and as soon as the flow ceased, the surface elevation of the sediment both across and along the flume was recorded with dyed boards and with a surface relief device using aluminium pins spaced at intervals across the flume. Photographs of the sediment deposits were taken. The depth to the tags imbedded in the sediment were recorded, and then samples of the sediment were taken at different distances in front of the buffer. The collected outflow and deposited sediment samples were analysed for particle size distribution

Results and Discussions

Results indicated that the vetiver strip caused a region of enhanced flow depth, upstream of the buffer (Fig 1). The region increased in depth and decreased in length with increasing slope. As slope increased, therefore sediment was deposited nearer to the buffer with deposited soil moving into the buffer at 5% slope (Fig 3). Buffering action resulted in the deposition of 86 to 95 % of the added sediment, with the remaining 5 to 14 % lost in the runoff. Sediment loads in the outflow increased with slope but remained primarily in the 0.002 – 0.02 mm size range compared to the input sediment, which was primarily in the 0.02 –2.00 mm size range. Particle size range of the deposited sediment increased slightly in coarseness away from the buffer but overall, was similar in size range to the added sediment. Deposition started at the beginning of the enhanced water depth but subsequently moved

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towards the buffer as the surface of the deposit approached the water surface and flow reached critical values (Fig 3). Surface relief measurements indicated non-uniform deposition with some rilling, usually formed towards the centre of the flume. Rilling increased with slope and caused variation in the hydraulic radius across the flume. Water depths, sediment concentrations and rate of deposition were simulated using both hydraulic and erosion/deposition models and predictions compared with data from the flume experiments. Modifications to such models are on-going using these data and further flume runs are underway using two additional soil types. Chemical analyses of the runoff and sediment samples are also on-going.

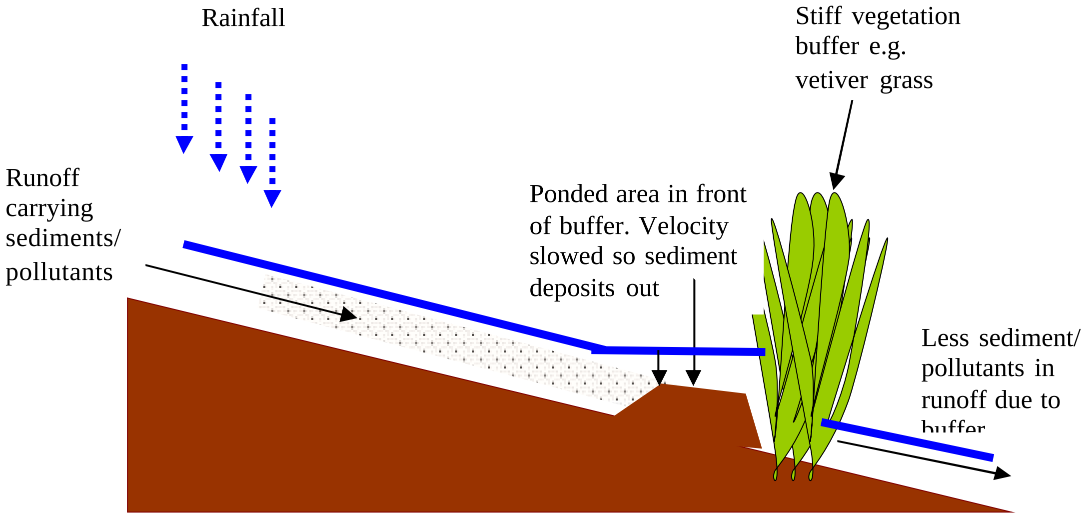

Fig 1. Schematic representation of sediment deposition in front of the Vetiver grass strip

Fig 2. Zone of backwater upstream of the Vetiver buffer strip

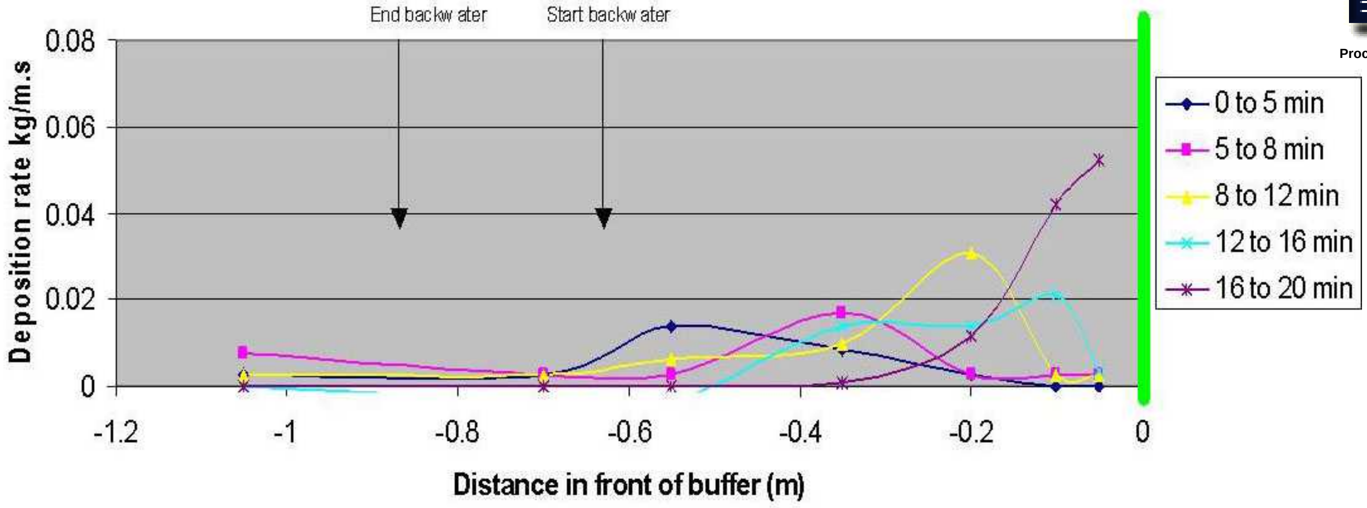

Fig 3. Changes in sediment deposition rate with time and distance in front of the buffer strip

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