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Sediment Trapping from Hyperconcentrated Flow as Affected by Grass Filter Strips*[1]

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ABSTRACT

To evaluate the effect of vegetative filter strips on sediment trapping, the spatial distribution of deposited sediment, and the size distribution of deposited particles from hyperconcentrated flows, a simulated grass filter strip experiment was conducted with plastic grass using an adjustable slope steel flume. The simulated vegetation cover was 36%, and the inflow sediment concentrations applied were 147, 238, 320, and 429 kg m^{-3}. The sediment concentration in the outflow, and the sediment particle size were determined. The results showed that the grass filter strips trapped most of the sediment from inflow at low sediment concentration. The deposition efficiency decreased with increasing sediment concentration, being 55.2% and 15.7% in the 147 and 429 kg m^{-3} sediment treatments, respectively. Most of the deposited sediments were distributed in the upper flume. In addition, the grass filter strips mainly trapped the coarse sediment (particle size > 10 μm).

Key Words: erosion, Loess Plateau, sediment particles, vegetation cover

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INTRODUCTION

In extensive farming or grazing areas, erosion of soil, which is often exacerbated by road and building construction, is a major problem since the eroded sediments, and pollutants that may be bound to them, can severely damage infrastructure and reduce stream water quality (Verstraeten and Poesen, 1999). To treat these problems, grassy buffer strips are commonly established to reduce sediment delivery to surface water. Numerous studies have examined the effects of grass or vegetative filter strips (VFS) located at the downstream end of fields or along the sides of surface water bodies (Ghadiri *et al*., 2000; Rose *et al*., 2003; Deletic, 2005; Fiener and Auerswald, 2005). Most of these studies have considered situations with low slopes or flows with low sediment concentrations (Tollner *et al*., 1976; Deletic, 2001, 2005; Jin and Römkens, 2001). Nevertheless, reported sediment loads varied widely, from 0.62 kg m^{-3} (Deletic, 2005) to 100 kg m^{-3} (Tollner *et al*., 1976; Jin and Römkens, 2001), and reported reductions of sediment delivery range from 15% (Chaubey *et al*., 1994) to 99% (Schmitt *et al*., 1999). From the highly variable results of these VFS studies, it has been concluded that the sediment trapping efficiency depends on inflow characteristics, sediment characteristics (concentration and grain size distribution), grass characteristics, slope gradients and other factors.

In the Loess Plateau of China, soil water erosion is a very serious problem, most slope gradients exceed 15°, and reported sediment concentrations can be very high, up to 1 000 kg m^{-3} (Qian, 1989). From existing studies, it is not possible to predict VFS efficiency in trapping sediment from hyperconcentrated flow. Therefore, the aim of the present study was to extend the available information by assessing the sediment deposition efficiency of a grass filter strips, and the size distribution of deposited particles, under hyperconcentrated flow conditions.

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MATERIALS AND METHODS

An experiment was carried out using an adjustable-slope steel flume (5.0 m long, 1.0 m wide, 0.35 m deep, slope 15°) and a simulated grass filter strip made of 7 cm tall plastic grass (substantially exceeding the depths of water flow employed) fixed to the flume bed at a density of 3 500–4 000 bunches m^{-2} and total simulated vegetation cover of 36%. A constant flow of water to the top of the flume of 60 L m^{-1} min^{-1} was supplied by a constant-head device through a flow buffer chamber (Fig. 1). Four treatments with inflow sediment concentrations of 147, 238, 320 and 429 kg m^{-3} were applied.

The soil used in the experiment was a silty clay loam soil, with sand, silt and clay contents of 27.5%, 33.8% and 38.7%, respectively, according to mechanical analysis. The air-dried soil was passed through a 4.75-mm sieve prior to use in the experiment. The particle size distribution of the inflow sediment was analyzed by a Malvern-Mastersizer 2000 particle size analyzer (Malvern Instruments Ltd., Worcestershire, UK)

Before the scouring experiment, the grass filter strips were totally wetted using spring water. Infiltration was not considered in this experiment, as the flume was made of steel. Each flow scouring trial continued for 20 min. All outflows from the end of the flume, including sediment, were collected in a plastic bucket at 2-min intervals. Sediment from each 2 min sample was deposited, separated from the water, dried in an air-forced oven to constant weight at 105 °C, weighed, and its size distribution was measured with the Malvern-Mastersizer 2000 particle size analyzer. The sediment concentration in each sample was determined as the ratio of dry sediment mass to runoff volume.

After each erosion trial, the sediment deposited in the flume was scoured out and collected with water from each 1 m section, starting from the bottom end of the slope to the top. This sediment was also allowed to settle, separated from the water, dried in an air-forced oven to constant weight at 105 °C, and weighed.

RESULTS AND DISCUSSION

Effects of runoff time and sediment concentration on deposition

The mass of deposited sediment decreased with increase in the runoff time (Fig. 2a). For instance, the mass of deposition was 2.56, 3.91, 5.69 and 6.86 kg m^{-2} in the sediment concentration treatments of 147, 238, 320 and 429 kg m^{-3}, respectively, during the first 2 min after runoff initiation. However, in the same treatments, the mass of deposition decreased to 0.79, 0.84, −0.86 and −1.63 kg m^{-2}, respectively, in the last 2 min of runoff (Fig. 2a). In addition, the deposition efficiency followed the same trends as the mass of deposition in all treatments during the runoff time (Fig. 2).

The sediment concentration also impacted the mass and efficiency of sediment deposition (Fig. 2). The

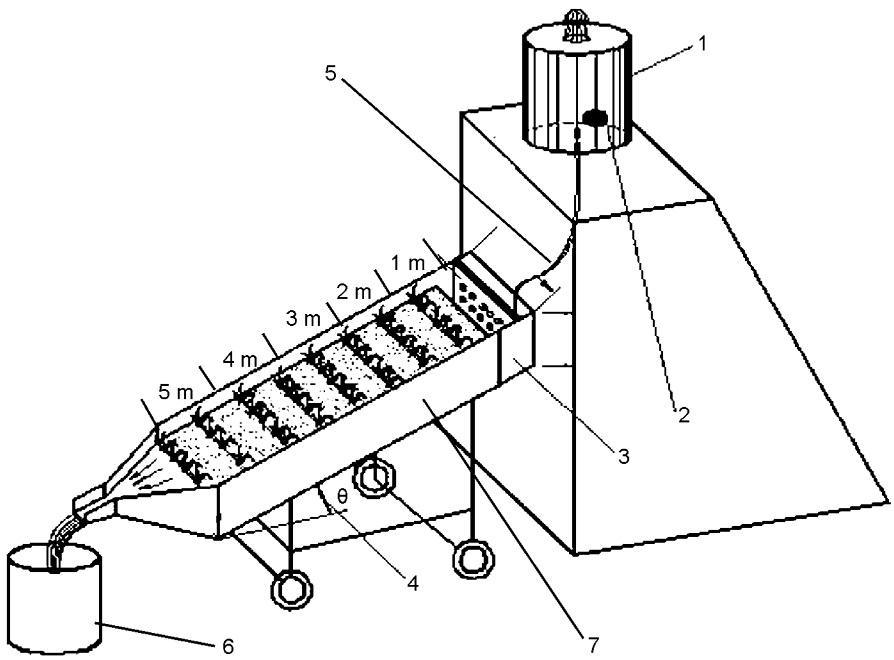

Fig. 1 Schematic illustration of the silt-laden flow supply system. 1 = silt-laden flow supply bucket; 2 = beater; 3 = flow buffer chamber; 4 = gradient-controllable shelves; 5 = water pipe; 6 = plastic bucket; 7 = flume.