EFFECTIVENESS OF PALM AND BAMBOO GEOTEXTILES IN REDUCING CONCENTRATED FLOW EROSION

Smets, T.*, Langhans, C., Poesen, J., Knapen, A.

Physical and Regional Geography Research Group, K.U.Leuven, Geo-Institute, Celestijnenlaan 200E, B-3001 Heverlee, Belgium. *toon.smets@geo.kuleuven.be

1. Introduction

Rills and gullies, caused by concentrated flow erosion, represent an important sediment source in many environments (Poesen et al., 2003). Studies indicate that vegetation can be very effective in controlling gully development. However, the establishment of a vegetation cover can be delayed or obstructed by the development of rills and gullies due to concentrated flow erosion. Before the vegetation has reached a critical cover and root density to significantly reduce concentrated flow erosion, a period of high erosion risk occurs. Hann and Morgan (2006) indicate that applying geotextiles on the soil surface is the most efficient method to control erosion until a critical vegetation cover has been established. Preliminary investigations suggest palm-mat geotextiles could be an effective and cheap soil conservation method, with enormous global potential. However, very little is known about the effectiveness of (palm) geotextiles in reducing concentrated flow erosion. Almost no data are available on the impacts of palm geotextiles on the hydraulic, hydrologic and erosion characteristics of concentrated flow for a range of environmental conditions. Therefore, the objectives of this study are (i) to assess the effectiveness of two palm-mat and one bamboo geotextile in increasing the hydraulic roughness of the soil surface under concentrated overland flow and in reducing soil erosion rates by concentrated flow on an erodible soil type and for a range of flow shear stresses; and (ii) to investigate which is the most appropriate hydraulic variable (e.g. shear stress, unit length shear force or stream power) to predict the net soil detachment by concentrated flow.

2. Materials and methods

2.1. Experimental conditions

All experiments are conducted in the laboratory using a concentrated flow erosion flume (length: 2.0 m, width: 0.35 m, depth: 0.05 m, Fig. 1). Water can be stored in a small reservoir at the top of the flume and can be evenly applied to the top of the flume. Flow discharge can be regulated using the tap and pressure regulator connected to the reservoir. At the bottom of the flume runoff and sediment samples can be collected using a gutter. The slope of the erosion flume can be adjusted from 0-45%.

The soil used in this study is a Tertiary sandy loam (i.e. an erodible subsoil), quarried in central Belgium (Bierbeek). The sandy loam is often found in road cuttings and on construction sites; it has 13% clay (<0.002 mm), 24% silt (0.002-0.063 mm) and 63% sand (0.063-2 mm) and 0.2% organic matter.

Three natural geotextiles are used in this study: Borassus geotextile, constructed from the leafs of Borassus Aethiopum Palm in The Gambia (Davies et al., 2006); Buriti geotextile, constructed from the leafs of Brazilian Buriti Palm in Brazil; and Bamboo geotextile, constructed from Bamboo stems in Thailand. These three types of geotextile have dimensions of 0.50 x 0.50 m, a surface cover of 43, 42 and 40% and a mean thickness of 0.03, 0.02 and 0.01 m, respectively.

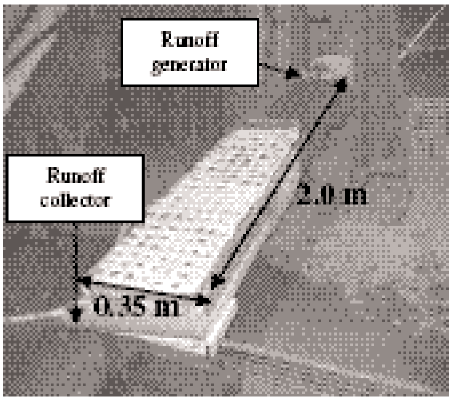

Fig. 1. Concentrated flow erosion flume.

2.2. Experimental treatments and measurements

Soil was air dried during 4 days and passed through a 2.7 cm sieve in order to minimize differences in soil structure among treatments. The upstream part of the flume (1.0m long) was covered with a wooden shelf over which the water was led to the entrance of the 1.0 m long test section without causing any erosion. The 5.0 cm deep test section was filled with sieved soil in two 2.5 cm layers to achieve a constant dry bulk density (1.2 g cm^{-3}). Before each experiment gravimetric moisture content and bulk density of the soil were determined using Kopecki cylinders (diameter=5cm; n=3). The treatments included: one soil type (sandy loam); three geotextiles (Borassus, Buriti and bamboo) and one bare soil surface (control); three slope gradients (15, 30 and 45%); and three flow discharges. All treatments had two replicates, so in total 72 experiments were conducted.

During each experiment flow discharge, mean flow velocity, flow width and slope gradient were measured. Sediment loaded runoff samples were taken during 5 s every

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30 s in order to determine sediment concentration and net soil detachment rate. Flow depth, Manning's n, Darcy-Weisbach f, shear stress, unit length shear force, stream power and runoff rate were calculated. Experiments were continued until steady state flow and detachment conditions were reached, i.e. flow velocities and detachment rates no longer changed significantly over time. Therefore, experiments lasted between 5 and 15 min. Flow discharge was measured before and after each experiment at the top of the flume. Surface flow velocity was measured using the dye tracing technique (Giménez and Govers, 2002). A small amount of the dye (Brilliant Blue) was injected 0.3-0.4m upslope of the test section in the flume. Flow velocities were then measured by recording the travel time of the leading edge of the dye over a distance of 0.7m in the test section.

2.3. Data processing

2.3.1. Hydraulics

Flow depth (d, m) was calculated by dividing flow discharge (Q, $m^3\ s^{-1}$) by the product of mean flow velocity (V, $m\ s^{-1}$) and flow width (a). Using the calculated data of flow width and mean flow velocity, the following hydraulic parameters were calculated:

Darcy Weisbach f: $$f = \frac{8gRS}{V^2} \quad (1)$$

Hydraulic shear stress (τ, Pa): $$\tau = \rho g R S \quad (2)$$

Stream power (ω, $kg\ s^{-3}$): $$\omega = \tau V \quad (3)$$

Where, g is the acceleration due to gravity ($m\ s^{-2}$), S is the sinus of the soil surface slope angle in degrees, ρ is the water density ($kg\ m^{-3}$), and R is the hydraulic radius (m).

2.3.2. Soil detachment

The sediment loaded runoff samples were weighed and oven dried (105 °C) during 24 h. The oven-dried sediment was weighed and runoff discharge ($m^3\ s^{-1}$) was calculated by subtracting the mass of the oven-dried sediment from the mass of the loaded runoff samples. Sediment concentration (SC, $kg\ m^{-3}$) was determined as the ratio of dry sediment mass to runoff volume. Net soil detachment rate (net DR, $kg\ m^{-2}\ s^{-1}$) was calculated as the ratio of the product of sediment concentration and flow discharge to the area of the test section. Relative soil detachment rate ($DRrel$) was calculated as the ratio between net DR for a geotextile covered soil surface and net DR for a bare soil surface under the same experimental conditions.

3. Results

Preliminary results indicate that Borassus, Buriti and Bamboo geotextiles significantly reduce mean flow velocities compared to bare soil surfaces (Fig. 2); mean flow velocities were reduced relatively by 35-44% compared to a bare soil.

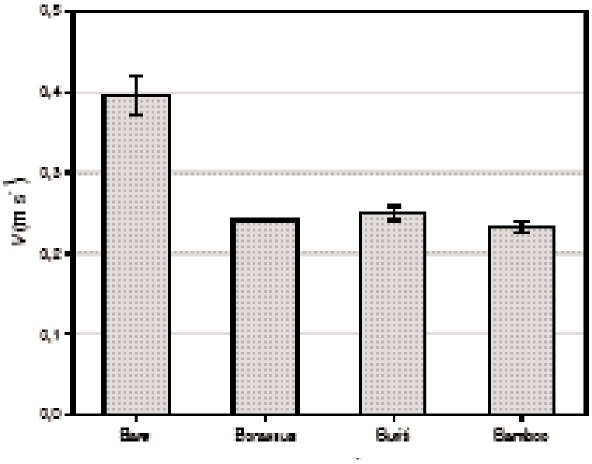

Fig. 2. Mean flow velocity (V, $m\ s^{-1}$) on a bare soil surface and soil surfaces covered with Palm and Bamboo geotextiles; slope: 15%, runoff discharge: 0.002 $m^3\ s^{-1}$, Reynolds number: 370.

Darcy-Weisbach friction coefficients, ranging from 0.06-1.75, significantly increased for all geotextile treatments compared to a bare soil treatment. Net DR ranges from 0.003-0.02 $kgm^{-2}s^{-1}$ and decreases significantly on geotextile covered soil surfaces. Final results on the effectiveness of Borassus, Buriti and Bamboo geotextile in increasing the hydraulic roughness of the soil surface and in reducing soil erosion by concentrated flow will be presented during the International Symposium on Gully Erosion.

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