Soil conservation using palm-mat geotextiles on loamy sand soils in the United Kingdom

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1. Abstract

Geotextile-mats constructed from *Borassus aethiopum* (Borassus Palm) and *Mauritia flexuosa* (Buriti Palm) leaves have the potential to decrease soil erosion. In the U.K., field experiments are being conducted on the effectiveness of palm-mats to reduce soil erosion at Hilton, east Shropshire. Twelve plots (each plot measuring 1.0 x 1.0 m; 6 plots were completely covered with Borassus mats, and the other 6 plots were bare) were established to study the effects of geotextile-mats on splash erosion. Eight runoff plots (10 x 1 m on a 15^o slope) were used, with duplicate treatments: (i) bare soil; (ii) grassed, (iii) bare soil with 1 m Borassus-mat buffer zones and (iv) completely covered with Borassus mats. Runoff volume and sediment yield were measured after each substantial storm from 25/03/02-10/05/04 (total precipitation = 1320 mm). Results indicate that palm-mats on bare soil significantly reduced total soil splash erosion by ~50% compared with bare soil (34.2 g m^{-2}; during 10/06/02-09/02/04, total precipitation = 1038 mm). Total runoff from bare plots was 3.58 litres m^{-2} and total sediment yield was 8.58 g m^{-2}. Borassus mats as buffer strips reduced runoff by ~36% and soil erosion by ~57%. Total soil loss from the completely covered plots was only ~16% less than the buffer zone plots.

To confirm the results, another set of runoff experiments are in progress at Hilton, with one additional treatment (bare soil with 1 m Buriti-mat buffer zones) compared with the earlier experiment. Results (08/01/07-24/08/07; total precipitation = 702 mm) indicate that total runoff from bare plots was 21.2 litres m^{-2} and total sediment yield was 2302 g m^{-2}. Borassus and Buriti mats as 1 m buffer strips reduced runoff by ~86 and 61%, respectively, and soil erosion by ~93 and 98%, respectively. Buffer strips of Borassus mats are as effective as complete cover of the same mats and are more effective in reducing runoff water than the buffer strips of Buriti mats. Combined results from both sets of runoff experiments (total precipitation = 2022 mm) suggest that application of Borassus mats as 1 m protective buffer strips on bare soil reduced runoff by ~77% and soil erosion by ~93%. Thus, Borassus-mat (buffer strips) cover on vulnerable segments of the soilscape is highly effective for soil and water conservation on temperate loamy sand soils.

2. Introduction

Considerable effort has gone into studying and controlling water erosion (Pimentel et al., 1987; Renard et al., 1997; Fullen and Booth, 2006). On a problematic slope, geotextiles protect soil and seeds in the initial stages of vegetative growth. Geotextiles can provide instant rain splash and runoff control, creating a stable non-eroding environment (Mitchell et al., 2003). Geotextiles constructed from organic materials are highly effective in erosion control (due to their 100% biodegradability) and vegetation establishment, in spite of the fact that synthetic geotextiles dominate the market (Langford and Coleman, 1996). Palm-mat geotextiles have the potential to reduce soil erosion on temperate agricultural soils (Davies et al., 2006). Geotextile-mats constructed from the leaves of *Borassus aethiopum* (Black rhun pam of West Africa) and *Mauritia flexuosa* (Buriti pam of South America) are termed Borassus and Buriti mats, respectively. Available studies do not allow quantification of the effectiveness of palm-mat geotextiles in reducing water erosion (soil splash erosion and sediment yield). In this experiment, we investigated the effectiveness of employing palm-mat geotextiles as a potential soil conservation technique.

3. Materials and methods

Investigations were conducted at the Hilton Experimental Site, east Shropshire, U.K. (52.0^{o}33'5.7" N, 2.0^{o}19'18.3" W; NGR SO778952). The region experiences a temperate climate with a mean annual precipitation of 620.0 mm (SD = 104.9, n = 15 years). In most of the area the Permo-Triassic sandstones are overlain by a suite of glacial and proglacial sediments (Hollis and Reed, 1981).

The soil of the splash erosion site is loamy sand [typical Ap horizon texture: 79.8% sand (2000-60 µm), 14.8% silt (60-2 µm) and 5.4% clay (<2 µm)] (Fullen and Brandsma, 1995). The soil had 1.9% organic matter content (Brandsma et al., 1999). Twelve plots were established to study the effects of palm-mat geotextiles on splash erosion. Each individual plot was 1.0 m^2 (1.0 x 1.0 m). Using random selection, six plots were completely covered with palm-mats, and the other six plots were left bare.

The soil was prepared by removing the grass turfs and rotavating the surface. All plots were maintained in a bare condition by regular 'RoundUp' [(N-(phosphonomethyl) glycine] herbicide treatments. Soil splash was measured in each plot by collecting splashed particles in a centrally positioned trap. Each trap consisted of a 15.2 cm diameter circular tube inserted into the soil, containing a similar-sized funnel on top of a 1 L bottle. They were installed 1 cm above the soil surface, thus only allowing splashed soil particles to enter. Comparable splash traps have been used by Poesen and Torri (1988). The collecting bottles were emptied after each substantial storm and trapped fauna were removed using a 2.0-mm sieve in the laboratory, then splashed particles were oven-dried overnight at 40^oC and weighed.

Eight runoff plots (situated on a 15^o south-west facing slope, numbered D1-D8 and measuring 10 x 1m) were established to study the effectiveness of palm-mat geotextiles on runoff and soil loss. Using random selection, plots D2 and D8 were completely covered with palm-mats, D4 and D5 had 1 m buffer zones of palm-mats at the plot lower end, D1 and D6 were the bare soil (control) plots and D3 and D7 were grassed plots. The plots were bordered with black plastic lawn-trim, with 10 cm intruding into the soil and 10 cm protruding above the soil. Prior to observations, the bare (control) and treated plots were rotavated to ~20 cm depth and treated with 'RoundUp' herbicide to remove vegetation. Soil splash erosion, splash height, runoff volume and sediment yield were measured after each substantial storm from 25/03/02-10/05/04.

To further validate the results, another set of runoff experiments have been in progress at Hilton, with an additional treatment (bare soil with 1 m Buriti-mat buffer zones) compared with the earlier experiment. Runoff volume and sediment yield were measured after each substantial storm from 08/01/07-24/08/07.

4. Results

4.1. Soil splash erosion

The investigation consisted of 14 sets of observations of soil splash height and 18 sets of observations of soil erosion (10/06/02-09/02/04). The results showed that covered plots had 100% less total splash erosion than the bare plots (17.1 g m^{-2}) (Table 1). Comparatively, mean height of soil splashed from the geotextile-covered plots (14.1 cm) was significantly less than the bare plots, by ~45% (Table 1). During the first year of measurements (n = 12 sets of measurements), mean splash erosion of the covered plots (1.08 g m^{-2}) was 27% less than the bare plots. However, in the next year (n = 6), there was a mean decrease of 296%. The same was the case with splash height. The splash heights were 27 and 52% less in the first and second year of the study, respectively, on the covered plots compared with the bare. Thus, covering the bare plots with palm-mat geotextiles was very effective in reducing splash erosion, as splash height and amount of soil splashed from geotextiles-covered plots were less than those of bare plots with time.

Table 1 Effect of palm-mat geotextiles on soil splash erosion for the plots (area of each plot = 1 m^2) at the Hilton Experimental Site (10/06/02-09/02/04)

Parameters	Splash erosion (g m^{-2})		Splash height (cm)	
	Bare plots	Covered plots	Bare plots	Covered plots
*Total	34.2	17.1	-	-
Mean	1.90	0.95	20.5	14.1
Minimum	0.14	0.10	8.3	2.0
Maximum	9.60	4.11	37.0	33.7
Standard deviation	2.27	0.54	9.2	2.4
Standard error of mean	1.24	0.29	11.6	3.1
Number of observations	18	18	14	14

*Precipitation during the experiment = 1038 mm.

The correlation between splash height (cm) and amount of soil splashed (g m^{-2} area) for the bare plots was significant (R^2 = 0.76, n= 14, P <0.001). The soil splash erosion per unit area (here 1 m^2) increased significantly with increasing soil splash height (cm) at a rate of 0.13 g cm^{-1}. Covering bare plots with palm-mat geotextiles was effective in reducing splash height and splash erosion rate. Furthermore, there was no significant relationship between the reduced splash height and splash erosion (R^2 = 0.08, n = 14, P = 0.33).

4.2. Runoff and sediment yield

Results of runoff plots showed that during the experimental period total runoff from the buffer zone plots (22.92 litres) was ~56 and 23% less than those of the bare plots and permanent grass plots, respectively (Table 2). Total sediment yield from the buffer zone plots was ~131% less than that of bare plots (85.8 g). Although total soil loss from the geotextile completely covered plots was ~19% less than the buffer zone plots, the runoff volume from the buffer zone plots was ~94% less than that of the completely covered plots. Mean total soil loss equates to 0.09, 0.03, 0.04 and 0.01 t ha^{-1} from the bare plots, covered plots, buffer zone plots and grass plots, respectively (Table 2). Total runoff in the plots under buffer strips was ~50% less than that of geotextile-covered plots and soil erosion from buffer strip plots was similar to completely covered plots.

Results of the second set of experiments (08/01/07-24/08/07; total precipitation = 702 mm; n = 20 sets of measurements) indicate that total runoff from bare plots was 21.2 litres m^{-2} and total sediment yield was 2302 g m^{-2}. Borassus and Buriti mats as 1 m buffer strips reduced runoff by ~86 and 61%, respectively, and soil erosion by ~93 and 98%, respectively (Table 3). Buffer strips of Borassus mats were as effective as complete cover of the same mats. Thus, use of 1 m buffer zones (of palm-mat geotextiles in bare plots) appears very effective for soil and water conservation.

Table 2 Mean runoff and soil erosion rates for the plots at the Hilton Experimental Site (n = 30; 25/03/02-10/05/04).

Parameters	Bare	Grass	Borassus buffer	Borassus completely covered
Total runoff (litres)	35.8 (78)	28.2 (110)	22.9 (103)	44.5 (90)
Total runoff (mm depth)	3.58	2.82	2.29	4.45
Total runoff as a % of precipitation	0.27	0.21	0.17	0.34
Total sediment yield (g)	86 (116)	13 (69)	37 (135)	31 (93)
Soil loss equivalent (t ha^{-1})	0.09	0.01	0.04	0.03

*Precipitation during the experiment = 1320 mm. Data in parentheses indicate Coefficient of Variation (%).

Table 3 Mean runoff and soil erosion rates for the plots at the Hilton Experimental Site (n = 20; 08/01/07-24/08/07).

Parameters	Bare	Grass	Borassus completely covered	Borassus buffer	Buriti buffer
Total runoff (litres)	187.6 (277)	18.1 (222)	48.8 (129)	27.6 (121)	78.2 (279)
Total runoff (mm depth)	18.8	1.81	4.88	2.76	7.82
Total sediment yield (kg)	22.44 (408)	0.13 (137)	0.28 (153)	1.59 (407)	0.31 (237)
Soil loss equivalent (t ha^{-1})	22.44	0.13	0.28	1.59	0.31

*Precipitation during the experiment = 702 mm. Data in parentheses indicate Coefficient of Variation (%).

5. Discussion

Results suggest palm-mat geotextiles are effective in reducing splash erosion (both splash height and amount of soil splashed). The low amount of splashed soil and sediment yield of the covered plots is particularly noteworthy, and reiterates the importance of retaining protective covers on sloping land. This is because geotextiles serve as a protect barrier that dissipate raindrop kinetic energy impact. Following intense rainfall, fine sediment was visible, trapped by the palm-mats, resulting in decreased splash erosion. Furthermore, besides offering protection, geotextiles might have improved soil organic matter that bind soil particles and aid the retention of topsoil structure and aggregate stability, thereby reducing splash erosion by encouraging infiltration.

Apart from reducing the amount of splash erosion, the presence of geotextile netting on the slope controls surface erosion in several ways: (i) surface runoff is divided into a number of smaller paths, due to the numerous obstructions caused by the presence of netting, thus decreasing the overall damaging impact of flowing water. (ii) Soil and seeds are thereby preserved in place, providing increased chances of germination and vegetation growth (Pillai, 1994). As geotextiles become wet they expand to the soil surface, enhancing drapability (adherence to surface micro-topography) and hence runoff and erosion control. The low runoff and sediment yield of the grass plots confirms the importance of retaining protective vegetative covers on sloping land. This is because grass swards serve as a protective barrier that dissipates the impact of raindrop kinetic energy. The sward also offers a source of organic matter to bind soil particles and the dense network of grass roots aids the retention of topsoil structure and aggregate stability and promotes infiltration. The net of geotextiles increased infiltration with their saturation and reduced the flow of water by creating a network of small microdams, which further increased infiltration. All these factors may have contributed to the increased effectiveness of palm-mat geotextiles in decreasing soil splash erosion with time (as found in the splash erosion experiment), thereby reducing total runoff and erosion from the runoff plots. Other studies conducted on runoff and erosion control support these findings (Sutherland and Ziegler, 1996; Langford and Coleman, 1996). UK field experiments, comparing the effectiveness of different treatments in controlling sediment yield, revealed jute-net had only 1.4% of the sediment yield from bare plots, while jute-mat had 1.1% (Mitchell et al., 2003). Erosion rates of ~0.1-0.5 t ha^{-1} yr^{-1} were much less than the 1-2 t ha^{-1} yr^{-1} considered tolerable on British arable soils (Morgan, 1986). The low rates even on bare plots, were mainly due to low rainfall amounts during the study period.

6. Conclusions

The results after two years of investigation indicates the use of geotextiles constructed from palm leaves on bare soil significantly reduced soil splash height by ~45% and splash erosion by 100%. Combined results from two sets of runoff experiments (total precipitation = 2022 mm for nearly 33 months) suggest that application of Borassus mats as 1 m protective buffer strips on bare soil reduced runoff by ~77% and soil erosion by ~93%. Although total soil loss in the geotextile (Borassus-mat) completely covered plots was ~79% less than the buffer zone plots (1.63 kg), the runoff volume from the completely covered plots was ~59% more than that of the buffer zone plots (50.5 litres). Results of the current experiment showed that runoff volume in the plots with buffer strips of Buriti mats was ~65% higher than that with the buffer strips of Borassus mats. Thus, Borassus-mat (buffer strips) cover on vulnerable segments of the landscape (convex slopes and erodible soils) in bare plots is highly effective for soil and water conservation on these temperate loamy sand soils.

7. References

Brandsma, R.T., Fullen, M.A., Hocking, T.J., 1999. Soil conditioner effects on soil structure and erosion. J. Soil Water Conserv., 54: 485-489.

Davies, K., Fullen, M.A., Booth, C.A., 2006. A pilot project on the potential contribution of palm-mat geotextiles to soil conservation. Earth Surf. Process. and Landforms, 31: 561-569.

Fullen, M.A., Booth, C.A., 2006. Long-term grass ley set aside on sandy soils: A case study. J. Soil and Water Cons., 61: 236-241.

Fullen, M.A., Brandsma, R.T., 1995. Property changes by erosion of loamy sand soils in east Shropshire, U.K. Soil Tech., 8: 1-15.

Hollis, J.M, Reed A.H., 1981. The Pleistocene deposits of the southern Worfe Catchment. Proceedings of the Geologists Assoc., 92: 59-74.

Langford, R.L., Coleman, M.J., 1996. Biodegradable erosion control blankets prove effective on Iowa wildlife refuge. In: XXVII th Int. Erosion Control Assoc. Proceedings of Conf., Seattle, USA, pp. 13-20.

Mitchell, D.J., Barton, A.P., Fullen, M.A., Hocking, T.J., Zhi, Wu Bo, Zheng, Yi, 2003. Field studies of the effects of jute geotextiles on runoff and erosion in Shropshire, UK. Soil Use Manage., 19: 182-184.

Morgan, R.P.C., 1986. Soil degradation and soil erosion in the loamy belt of northern Europe. In: Chisci, G., Morgan, R.P.C. (Eds.), Soil Erosion in the European Community: Impact of Changing Agriculture. A.A. Balkema, Rotterdam, pp. 165-172.

Pillai, M.S., 1994. Protection of the side slopes of Kabini Canal. In: Vth Int. Conf. on Geotextiles, Geomembranes and Related Products, Singapore, 5-9 Sept., pp. 14-17.

Pimentel, D., Allen, J., Beers, A., Guinaud, L., Linder, R., McLaughlin, P., 1987. World agriculture and soil erosion: Erosion threatens world food production. Bio-Sci., 37: 277-283.

Poesen, J., Torri, D., 1988. The effect of cup size on splash detachment and transport measurements. Part 1: field measurements. Catena Supple., 12: 113-126.

Renard, K.G., Foster, G.A., Weesies, D.K., McCool, D.K., Yoder, D.C., 1997. A Guide to Conservation Planning with the Revised Universal Soil Loss Equation. Predicting Soil Erosion by Water, Agriculture Handbook 703, United States Department of Agriculture, Washington, DC.

Sutherland, R.A., Ziegler, A.D., 1996. Geotextile effectiveness in reducing interill runoff and sediment flux. In: XXVIth Int. Erosion Control Assoc. Proceedings of Conf., Atlanta, USA, pp. 359-370.