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Effectiveness of tropical grass species as sediment filters in the riparian zone of Lake Victoria

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Abstract

The effectiveness of tropical grass species in strips of different length in trapping sediment from cropland was assessed, and the influence of filter length was determined. The assessment was made under natural rainfall which induced sheet and rill erosion in run-off plots and then using simulated run-off which caused concentrated erosion. The evaluated grasses were elephant grass, lemon grass, paspalum and sugarcane. Run-off plots were on a 10% slope in a randomized complete block design replicated three times. Filter lengths were 2.5, 5 and 10 m against a 10-m-long sediment source area planted with maize on a clay loam soil. The results show that sediment trapping effectiveness (TE) increases nonlinearly with increasing filter length for all grasses. Under natural rainfall, more than 70% of sediment was trapped in the first 5 m, and lengthening the strip to 10 m only resulted in a marginal increase in TE. With concentrated run-off, more than 70% of sediment was trapped in the first 5 m and lengthening the strip to 10 m resulted in a significant increase in TE. Paspalum and lemon grass performed significantly better than other grasses ($P < 0.05$), owing to their spreading growth pattern over the soil surface. Paspalum also has the highest root density in the upper 0.3-m layer of the soil followed by lemon grass, hence offering the greatest resistance to erosion from concentrated flow. The results demonstrate that tropical grass filter strips provide a viable means for reducing the sediment flux from cropland.

Keywords: Tropical grass species, sediment trapping, Lake Victoria basin.

Introduction

Soil erosion from cropland is an important sediment source for rivers and lakes in the Lake Victoria basin. Sediment lost from cropland is mainly from the topsoil which is rich in nutrients critical for crop production. Low agricultural productivity and fish catches which are attributable to soil erosion and sediment pollution of Lake Victoria as well as others threaten the fragile livelihoods of local people (Olago & Odada, 2007). The major run-off pathway from cropland is overland flow causing sheet and rill erosion followed by concentrated flow along gullies and footpaths.

Various studies have shown that sediment flux from cropland can be controlled in the riparian zones through the use of grass filter strips, for example, Dillaha *et al.* (1989); Van Dijk *et al.* (1996); Ghadiri *et al.* (2001); Hook (2003); Abu-Zreig *et al.* (2004); Blanco-Canqui *et al.* (2004); Mckergow *et al.* (2004); Ziegler *et al.* (2006); Mankin *et al.* (2007) and Owens *et al.* (2007). Grass filter strips are defined as strips of cropland adjacent to water bodies or drainage ditches that are planted with grass, with the aim of trapping sediment.

The factors determining the performance of a grass filter strip are its characteristics (length, slope, vegetation height, density, stiffness and type), water inflow (run-off velocity, discharge, volume and type), sediment inflow (grain-size distribution, aggregation and concentration) and rainfall (intensity and depth) (Verstraeten *et al.*, 2006). Various

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studies have shown that filter length is the most important factor (Dillaha *et al*., 1989; Van Dijk *et al*., 1996; Lee *et al*., 1999; Abu-Zreig, 2001; Abu-Zreig *et al*., 2004; Owens *et al*., 2007; Yuan *et al*., 2009). Most previous studies investigated grass filter strip performance for sheet and rill flow with a shallow flow depth where the grass was not submerged (Dillaha *et al*., 1986; Magette *et al*., 1989; Van Dijk *et al*., 1996; Valentin *et al*., 2008). The sediment trapping effectiveness (TE) of the filter is expected to decrease with concentrated flow owing to a decline in the overall hydraulic roughness of the filter following submersion (Verstraeten *et al*., 2006).

Furthermore, despite the wealth of information on performance of grass filter strips, especially in North America and Europe, there is a paucity of quantitative information for tropical regions (Valentin *et al*., 2008). There is no published research on grass filter strips for East Africa and on the best grass species that can be used. Also, there is no information on the effect of filter length on the performance of appropriate grass filter strips in this region. The effectiveness of grass filter strips depends on environmental conditions such as climate, soil type, topography and grass species (Syversen, 2005).

The National Environment Regulations in East Africa require a 60- to 200-m-long buffer zone for major rivers and lake shore (URT, 1999; GOU, 2000), and this has important socio-economic implications in regions of a high population density. Furthermore, the buffer zones are usually located on old lacustrine terraces which are the best agricultural soils. Under such circumstances, a win–win situation exists when buffers satisfy both ecological and socio-economic requirements. Also, owing to land pressure, it is important to determine the minimum grass filter length that should be used to reduce run-off and sediment fluxes.

The objectives of this research were to (i) assess on an economic basis selected tropical grass species for trapping sediment from cropland, (ii) determine the effectiveness of these grass species in reducing run-off discharge in the riparian zone of Lake Victoria under natural rainfall and simulated concentrated run-off, and (iii) determine the influence of filter length on run-off- and sediment TE values.

Materials and methods

Study site

This study was at Mayuge, Uganda, located between 33°15′ and 33°25′E and between 0°25′ and 0°30′N in the subcatchment of Kafunda bay (ca. 1 km^2), along the Lake Victoria shoreline (Figure 1). The landscape is an undulating peneplain (1204–1371 m a.s.l), characterized by erosion-resistant quartzitic hills (De Meyer *et al*., 2011). The interfluves between the isolated hills and swamps are underlain by rocks with Lixi-Rhodic Ferralsols developed on the oldest landforms and Plinthic Acrisols and Petric Plinthosols on the lower ones. The soil texture at Mayuge is clay loam (clay, 35%; silt, 24%; and sand, 41%). The site has a bimodal rainfall pattern with a mean annual rainfall of 1050 mm. The rainy seasons are from

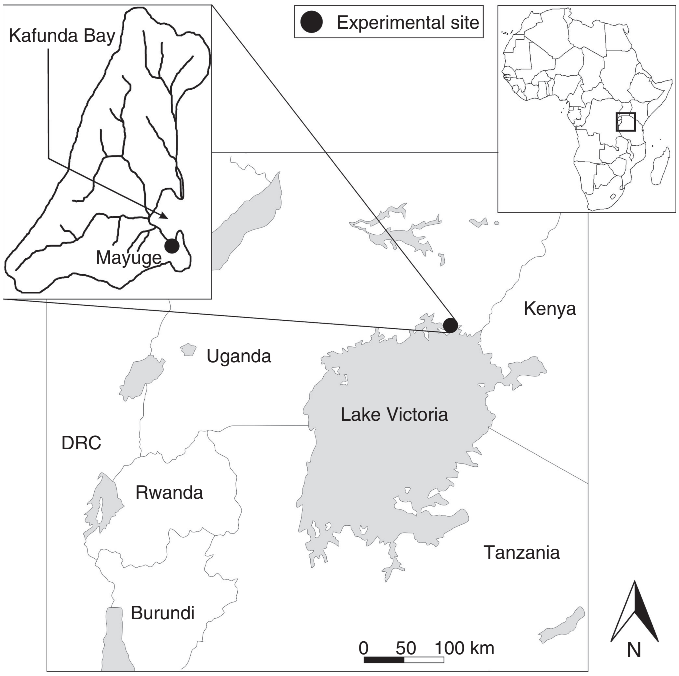

Figure 1 Location of experimental site for evaluating tropical grass species as sediment filters in Lake Victoria basin, Uganda.

March up to May and from September to December. The area is dominated by intensive agriculture based on a banana–coffee system with maize as the main annual crop. Fishing is also important.

Selection of grasses

Four tropical grasses compatible with local farming systems were selected as follows: lemon grass (*Cymbopogon citratus*), elephant grass (*Pennisetum purpureum*), paspalum (*Paspalum notatum*) and sugarcane (*Saccharum officinarum*). Lemon grass is a perennial that grows in dense clumps up to 1.8 m in height. Lemon grass is used as a non-toxic insect repellent and as an ingredient in citronella oil for pesticides, toothpaste, tea flavours and perfume. Lemon grass was planted at a spacing of 0.6 m × 0.6 m in the filter strips. Elephant grass is a perennial that grows in dense clumps up to 3 m tall and 0.03 m in thickness near the base and is drought tolerant. It is harvested for animal fodder. Elephant grass was planted at a spacing of 1 m × 1 m in the filter strips. Paspalum is a low creeping perennial with stolons and stout scaly rhizomes. It can grow up to 0.2–0.6 m in height, is adapted to a range of soil types and is drought tolerant. Paspalum is harvested for livestock feed or for mulch. It was planted at a spacing of 0.15 m × 0.25 m in the filter strips. Sugarcane grows in clumps with stems up to 3.5 m in height and 0.02–0.03 m in diameter. It is grown as a cash crop for sugar and is often chewed by people to extract the juice. Sugarcane was planted at a spacing of 0.3 m × 1 m in the filter strips.

Run-off plots

The experimental bounded run-off plots were 2 m in width and 10, 12.5, 15 and 20 m in length. Within these plots, filter lengths were 2.5, 5 and 10 m with a standard sediment source area of 2 m width and 10 m length planted with maize (*Zea mays*), which is a dominant food crop grown along the Lake Victoria shoreline. The filter lengths were selected based on farmers' plot sizes as obtained during a reconnaissance survey. The grass filter strips were planted 3 months before maize was planted on the standard plot to allow for establishment.

The treatments were arranged in a randomized complete block design replicated three times (Figure 2). The plots were bounded by 0.3-m-high corrugated iron sheets on the upper and lateral sides. At the bottom end of each bounded run-off plot, run-off collecting tanks of 200-L capacity were installed in a 1-m-deep trench to collect sediment delivered by sheet and rill run-off from the maize plots through the grass filter

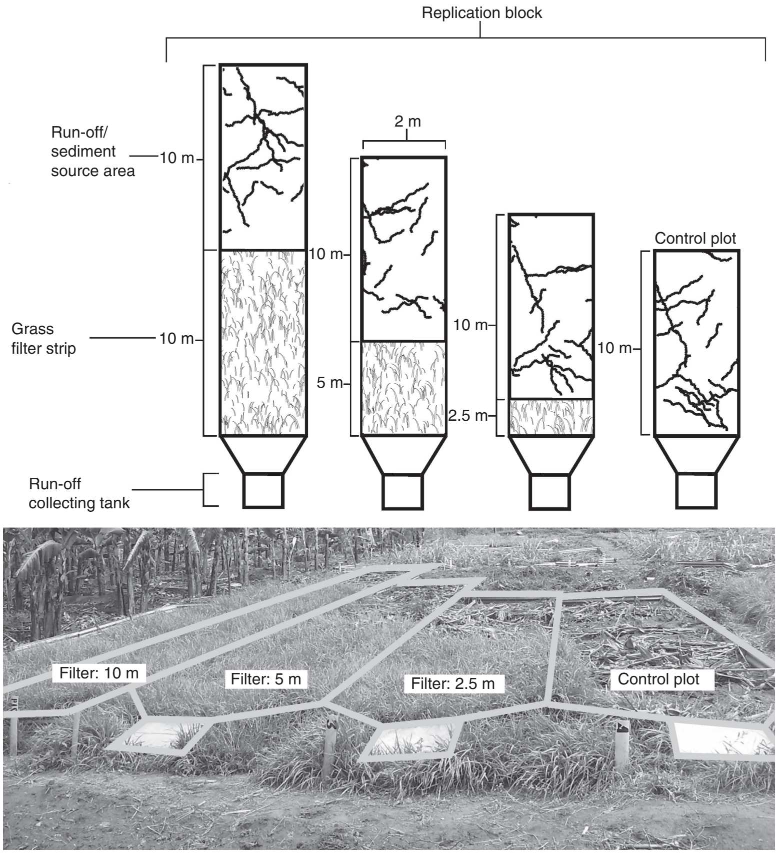

Figure 2 Schematic design of a run-off plot block (upper) and an application of the design of such a block for paspalum at Mayuge, Uganda (lower).

strips. Maize was planted at a row spacing of 0.3 and 0.6 m between rows. Land preparation such as planting and weeding was carried out according to local practice, and after harvesting maize, straw was left on the plot. In total 48 run-off plots were installed; in four grass species, three filter lengths replicated three times. The slope gradient at the experimental site was 10%.

Vegetation cover (VC, %) of the filter strips was determined following Sheila (1996), also taking any mulch into account. Vegetation cover was determined when the grasses were fully established. Root density (RD, kg/m^3) for each grass species was assessed using the dry excavation method (De Baets *et al*., 2007a). From each grass species, at least three representative plants were selected and excavated. The volume of soil column was considered as a cylinder with the vertical orthogonal projection of the above-ground biomass as a diameter. A soil column was dug along this circle as deep as local conditions permitted. The soil material was removed carefully from the excavated soil column from the top to the bottom. After excavation, digital photographs of the root systems were taken. Height and diameter of the orthogonal projection of the above-ground biomass were measured. Then, grasses with their root system were laid on a horizontal plastic sheet, and the root pattern during growth was reconstructed. The roots were then cut along soil depth intervals of ca. 0.1 m. The roots were collected per soil depth interval and placed in a labelled plastic bag. Next, the roots were sun-dried for 2 days and then weighed. By dividing the dry root mass (M_D, kg) with the volume (V, m^3) of the corresponding soil depth class, the root density for each soil depth class was calculated.

Run-off plot experiments under natural rainfall conditions

Data collected included rainfall, run-off and sediment delivery. Rainfall depth (P, mm) was measured after each rainfall event by means of a manual rain gauge installed at the site. Run-off depth (R, mm) was measured from the run-off in the tanks (Figure 2) after every rain event. The collected run-off was stirred thoroughly, and a depth-integrated sediment sample was taken by ensuring that the travel rate of the sampler was constant in upward or downward directions. This run-off sample was filtered through a pre-weighed standard filter with 0.45-μm pore openings and oven-dried at 105 °C for 24 h in the laboratory.

The corresponding sediment concentration (SC, g/L) was obtained using a mass balance method by the following equation:

$$\mathrm{SC} = \frac{G_1 - G_2}{V_{\mathrm{sample}}} \tag{1}$$

where G_1 is the dry mass of the filter paper and the sediment in grams, G_2 is the dry mass of the filter paper in grams determined by taking the average of 10 oven-dried filter papers, and V_{sample} is the volume of sample in litres determined using a graduated cylinder. Sediment delivered (SL, g) was determined by multiplying the sediment concentration with the run-off collected in the tanks. The experimental run-off plots were monitored under natural rainfall between February 2007 and June 2008, and data were collected from 67 events.

Run-off plot experiments under simulated concentrated run-off

The same run-off plots established to collect data under natural rainfall were used for simulated concentrated run-off with an average sediment concentration of 5500 mg/L. A 1000-L water reservoir with an adjustable opening of 0.07 m diameter was set up horizontally 0.3 m above the soil surface and 1 m before the top of the filter strip. Concentrated run-off was generated by emptying the reservoir onto the grass filter strip through a 1-m-long and 0.3-m-wide V-shaped iron gutter designed to represent a channel (Figures 3 and 4). At

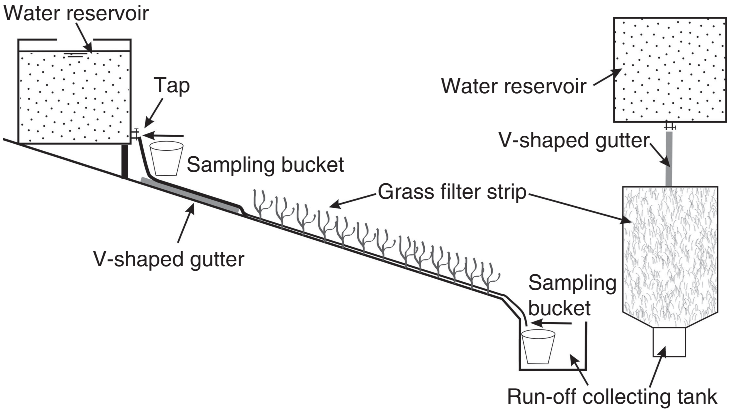

Figure 3 Schematic presentation of the experimental layout simulating concentrated flow: left, side view; right, front view (V-shaped gutter; 1 m long and 0.3 m wide).

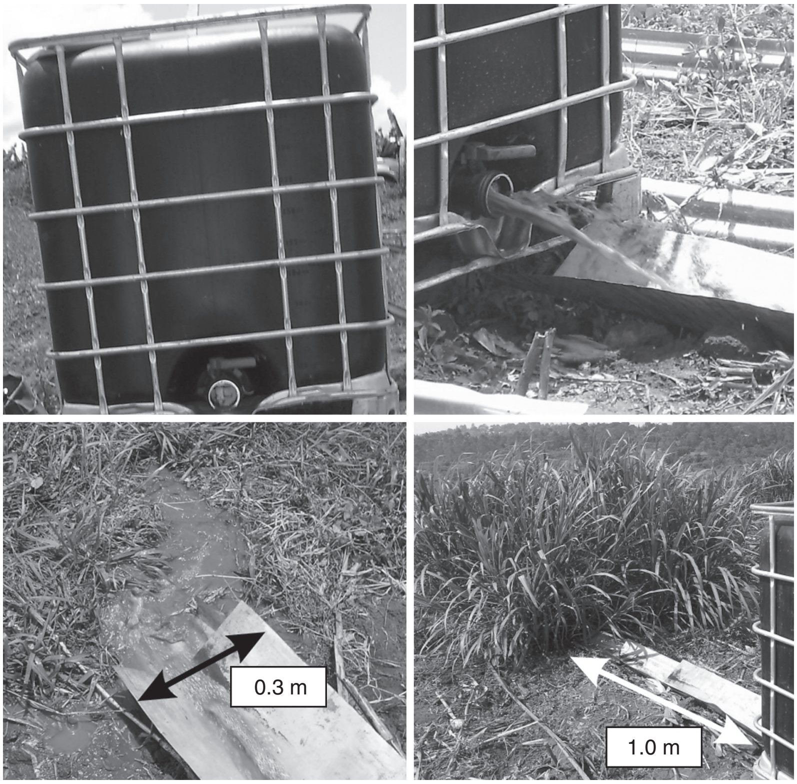

Figure 4 Set-up of simulated concentrated flow experiment: top left, water reservoir (1 m high, 1 m long and 1 m wide); top right, close-up from tap with adjustable aperture (0.07 m in diameter); and bottom left, mixture of sediment and water is conducted by a V-shaped gutter (1m long and 0.3 m wide; vegetation in photo is paspalum), and bottom right; experimental lay-out (grass in the photograph is elephant grass).

the start of each experimental run, 10 kg of topsoil from the experimental site was added into the reservoir and stirred continuously throughout the experiment. The experiment run-time started immediately the tap was opened. Run-off samples were taken intermittently at time intervals of ca. 2 min for 5 s during the experiment at the inlet and outlet of the filter strip. For each experimental run, 10 run-off samples were taken at the inlet and the outlet of the filter. Run-off discharges (Q, m^3/s) were obtained using the sample volume measured and the corresponding sampling duration. Run-off collected in the buckets was stirred thoroughly, and a sample was taken. This sample was filtered and oven-dried at 105 °C for 24 h in the laboratory, and the corresponding inlet and outlet sediment concentration determined (equation 1). A total of 72 simulated concentrated run-off experiments were carried out, that is, six experimental runs per filter length per grass species in October 2008.

Data analysis

To examine the performance of the grass filter strips in reducing run-off discharge and sediment, the TE was calculated:

$$\mathrm{TE} = \frac{X_{\mathrm{in}} - X_{\mathrm{out}}}{X_{\mathrm{in}}} \tag{2}$$

where X_{in} is the incoming amount and X_{out} is the outgoing amount of either sediment mass or run-off volume. Under natural rainfall, the measured sediment mass or run-off volume from the control plots was assumed to be the incoming value for the plots with a grass filter strip in each set of plots (Dillaha *et al*., 1986; Vigiak *et al*., 2008; Yuan *et al*., 2009). The TE was computed for each run-off-generating event in the control plots, and a mean TE value was calculated for the monitoring period. Under simulated concentrated run-off, the TE of all grasses and filter lengths was determined for each experimental run (equation 2), and a mean TE value was calculated for the experimental runs. Testing for significant differences between TE of different filter lengths and different grass species was carried out using the Mann–Whitney Wilcoxon *U*-test, a nonparametric two-sample probability test. This test was chosen because the compared data groups were not normally distributed. The correlation between sediment and run-off TE was analysed by means of Spearman's rank correlation coefficient (r_s).

Results

Run-off- and sediment TE values of grass filter strips for natural rainfall

Plot run-off depth (mm) and mass of sediment delivery (kg/ha) decreased nonlinearly with increasing filter length for all grasses (Table 1). Also, the run-off TE increased nonlinearly with increasing filter length for all grasses

Table 1 Mean run-off depth (mm) and mass of sediment delivery (kg/ha) for different grass filter lengths under natural rainfall (values between brackets are standard deviations, $n = 67$)

	Mean run-off depth (mm)			Mean sediment delivery (kg/ha)		
Grass species	2.5 m	5 m	10 m	2.5 m	5 m	10 m
Lemon grass	1.3 (0.11)	0.8 (0.10)	0.3 (0.09)	3.1 (2.2)	2.6 (1.9)	2.3 (1.5)
Paspalum	1.51 (0.20)	0.88 (0.15)	0.31 (0.10)	3.6 (3.0)	2.8 (2.1)	2.4 (1.7)
Elephant grass	1.62 (0.22)	0.89 (0.18)	0.31 (0.11)	3.9 (3.4)	3.2 (2.8)	2.6 (1.5)
Sugarcane	2.03 (0.70)	1.01 (0.30)	0.34 (0.24)	4.8 (4.0)	3.8 (3.3)	2.9 (1.8)
Control			2.3 (1.1)			11.8 (4.8)

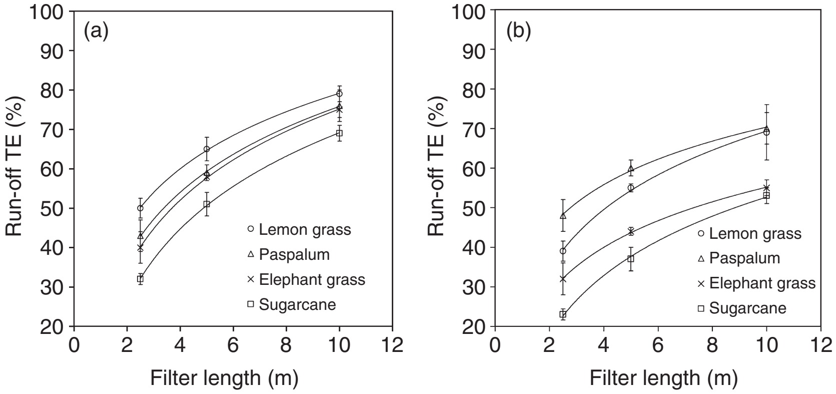

Figure 5 Mean run-off trapping effectiveness (TE) value for different filter lengths with tropical grass filter strips: (a); under sheet and rill flow (±standard error of mean, $n = 67$) and (b); under concentrated run-off flow (±standard error of mean, $n = 6$).

Table 2 Mean run-off- and sediment trapping effectiveness (TE) values (%) for different grass filter lengths under natural rainfall (values followed by a different letter within the same row are significantly different ($\alpha = 0.05$, $n = 67$)

	Mean run-off TE (%)			Mean sediment TE (%)		
Grass species	2.5 m	5 m	10 m	2.5 m	5 m	10 m
Lemon grass	50^{c}	65^{b}	79^{a}	72^{c}	84^{ab}	92^{a}
Paspalum	43^{c}	59^{b}	76^{a}	65^{c}	78^{ab}	88^{a}
Elephant grass	40^{c}	58^{b}	75^{a}	62^{c}	73^{b}	84^{a}
Sugarcane	32^{c}	51^{b}	69^{a}	56^{c}	70^{b}	82^{a}

(Figure 5). An increase in filter length from 2.5 to 5 m and from 5 to 10 m resulted in a significant increase in run-off TE for all the grasses ($P < 0.05$) (Table 2). At all filter lengths, run-off TE for sugarcane was significantly lower than that for lemon grass, elephant grass and paspalum ($P < 0.05$).

Sediment TE also increased nonlinearly with increasing filter length for all grasses (Figure 6). An increase in filter length from 2.5 to 5 m resulted in a significant increase in sediment TE for all the grasses ($P < 0.05$) (Table 2). The results show that over 70% of sediment was trapped in the first 5 m of the filters, and there was a marginal increase in sediment TE for a filter length more than 5 m. The percentage increase in sediment TE ranged 4.4–5.6% per metre of grass filter by increasing the filter length from 2.5 to 5 m. By doubling the filter length again from 5 to 10 m, the sediment TE increased by 1.6–2.4% per metre of grass filter strip. Results from elephant grass and sugarcane were the only ones to a show a significant increase in sediment TE when the filter length was increased from 5 to 10 m ($P < 0.05$). At all filter lengths, sediment TE for lemon grass and paspalum was significantly greater than that for elephant grass and sugarcane ($P < 0.05$).

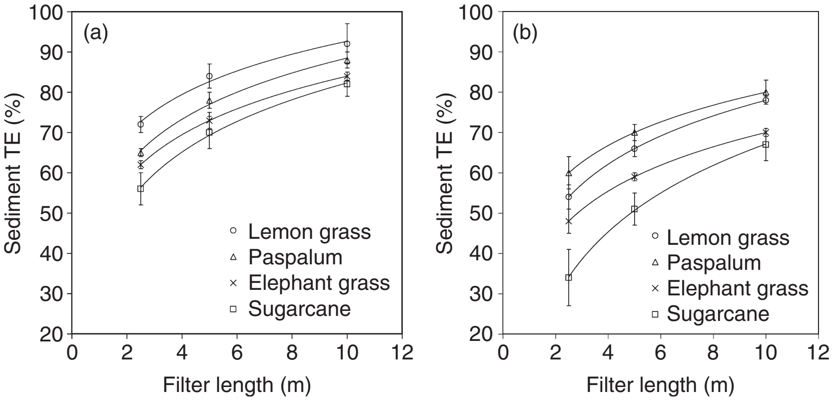

Figure 6 Mean sediment trapping effectiveness (TE) value for different filter lengths with tropical grass filter strips: (a); under sheet and rill erosion (±standard error of mean, $n = 67$) and (b); under concentrated run-off erosion (±standard error of mean, $n = 6$).

Table 3 Mean run-off- and sediment trapping effectiveness (TE) values (%) for different grass filter lengths under simulated concentrated run-off (values followed by a different letter within the same row are significantly different ($\alpha = 0.05$, $n = 6$))

	Mean run-off TE (%)			Mean sediment TE (%)		
Grass species	2.5 m	5 m	10 m	2.5 m	5 m	10 m
Lemon grass	39^{c}	55^{b}	69^{a}	54^{c}	66^{b}	78^{a}
Paspalum	48^{c}	60^{b}	70^{a}	60^{c}	70^{b}	80^{a}
Elephant grass	32^{c}	44^{b}	55^{a}	48^{c}	59^{b}	70^{a}
Sugarcane	23^{c}	37^{b}	53^{a}	34^{c}	51^{b}	67^{a}

Table 4 Mean vegetation cover (%) and root density (kg/m^3) for different grass species in the filter strips (values between brackets are standard deviations, $n = 6$)

		Mean root density (kg/m^3) at different soil depths (m)			
Grass species	Mean vegetation cover (%)	0–0.1 m	0.1–0.2 m	0.2–0.3 m	0.3–0.4 m
Paspalum	100 (0)	70.1 (0.2)	11.1 (0.8)	1.2 (0.1)	0.0
Lemon grass	92 (5)	20.0 (1.0)	7.8 (0.6)	1.6 (0.3)	0.8 (0.1)
Elephant grass	73 (7)	10.3 (1.3)	3.9 (1.2)	0.7 (0.1)	0.4 (0.2)
Sugarcane	65 (11)	11.4 (1.1)	7.1 (1.7)	1.4 (0.7)	0.6 (0.3)

Run-off and sediment TE values of grass filter strips for simulated concentrated run-off

Trends in run-off TE with increasing filter length for all grasses under concentrated run-off were similar to that from natural rainfall (Figure 5). At filter lengths of 2.5, 5 and 10 m, run-off TE for paspalum and lemon grass was significantly higher than that for elephant grass and sugarcane ($P < 0.05$).

Paspalum had the highest sediment TE for all filter lengths followed by lemon grass, elephant grass and sugarcane (Figure 6). An increase in filter length from 2.5 to 5 m and from 5 to 10 m resulted in a significant increase in sediment TE for all the grasses ($P < 0.05$) (Table 3). Sediment TE for paspalum and lemon grass at filter length of 2.5, 5 and 10 m was significantly higher than that of elephant grass and sugarcane ($P < 0 .05$).

Discussion

Paspalum and lemon grass perform better than elephant grass and sugarcane owing to their spreading growth pattern over the soil surface (Table 4) and to the dense network of fine roots. In addition, paspalum has the highest root density in the upper 0.3-m layer of the soil followed by lemon grass (Figure 7 and Table 4), hence offering the greatest resistance to concentrated flow erosion (De Baets *et al.*, 2007b; De Baets & Poesen, 2010). The below-ground biomass is thus an

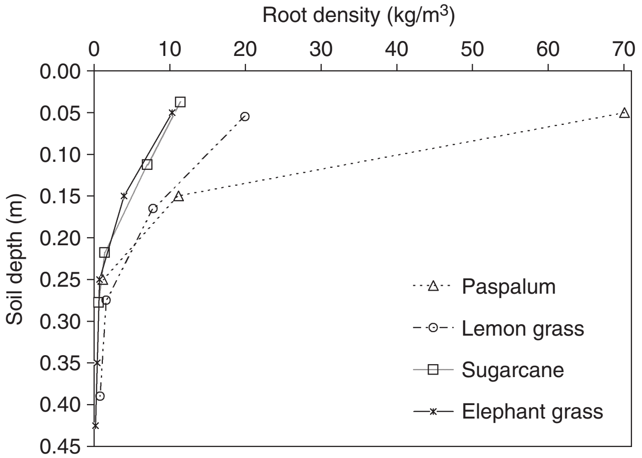

Figure 7 Root density at different soil depth for different tropical grass species in the filter strips.

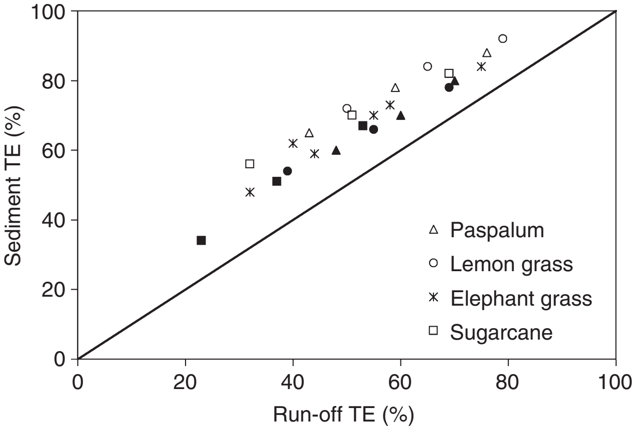

Figure 8 Sediment trapping effectiveness (TE) versus run-off TE values for tropical grass filter strips for all filter lengths under sheet and rill erosion (open) and concentrated flow erosion (black).

important aspect of the grass filter when the above-ground biomass is harvested, destroyed by fire or a storm event.

At all filter lengths, run-off- and sediment TE values decrease under concentrated run-off erosion in comparison with sheet and rill erosion for all grasses (Figures 5 and 6). The grass filter strips are thus more effective when the run-off passes through the grasses in the form of shallow uniform overland flow than when the flow is concentrated in rills or gullies (Loch *et al.*, 1999; Verstraeten *et al.*, 2006). This implies that for trapping sediment and for reducing run-off in concentrated flow, a filter strip longer than 5 m is required, while under sheet and rill erosion, a filter length of 5 m is sufficient. Sediment TE exceeding 50% for grass filter strips with a minimum length of 5 m has been reported by Dillaha *et al.* (1989), Magette *et al.* (1989) and Daniels & Gilliam (1996) for sheet and rill erosion, and lengthening the filter strips does not always result in a significant increase in TE (Schmitt *et al.*, 1999; Abu-Zreig *et al.*, 2004).

Sediment TE is highly and positively correlated with the run-off TE ($r_s = 0.99$, $P < 0.01$). Hence, sediment trapping and run-off reduction are closely linked (Abu-Zreig *et al.*, 2004; Weihang *et al.*, 2011). Comparison of sediment- with run-off TE values shows that the former tends to be higher than the latter for all filter lengths and grasses (Figure 8). Hence, the tested tropical grass filter strips have a higher effectiveness in trapping sediment than in reducing run-off from cropland for the same filter length. To improve the sediment TE of grass filter strips, best management practices in soil and water conservation such as mulching and reducing run-off are needed upslope of the filter strip.

This study demonstrates that tropical grass species that have an economic value can be used as filter strips for trapping sediment from cropland. Thus, the portion of agricultural land set aside for the grass filter strip is not lost from an economic point of view. This is a win–win situation for farmers and for the environment. The four studied grass species can provide an additional source of income to the community besides their biophysical functioning for sediment filtration. The results suggest that there is a need to reassess the suitability of the 60- to 100-m buffer zone as required by legislation in the riparian zone of Lake Victoria basin. Filter strips with a smaller filter length, repeated at regular intervals, could be more effective than one large riparian filter strip as sediment is caught closer to its source and costs associated with filter strips are equitably distributed among land owners. This will boost the adoption of sediment filter strips in local farming systems and help to alleviate the problem of sediment pollution of Lake Victoria.

Although the initial run-off discharge in the experiments (mean 2.2 ± 0.3 L/s) was sufficient to simulate a realistic concentrated flow, future studies need to consider the application of an additional simulated rainfall on the grass filter strips to better mimic the natural situation. The experimental run-time in the simulated concentrated run-off was on average 25 min. However, the duration of some rainfall events may be several hours which could have an effect on the performance of the grass filter strips. This study is the first to test the effectiveness of tropical grass species in reducing run-off and sediment delivery in the Lake Victoria basin. However, it is recommended that further experiments are conducted in more varied ecological settings to determine the effect of soil texture, topography, area of the field draining towards the filter, type of grass species and different grass combinations on the performance of these tropical grass filter strips.

Conclusion

This study shows that tropical grass filter strips provide a viable means to reduce the sediment flux from cropland. Run-off- and sediment TE values increase nonlinearly with increasing filter length for all grasses. With a filter length of 5 m, lemon grass and paspalum have the highest run-off- and sediment TE values against a sediment source area with a length of 10 m planted with maize on a slope of 10%. Given the decrease in run-off and sediment flux associated with longer grass filter strips and the economic value of elephant grass and sugarcane, these grasses could also be used in filter strips at least 10 m in length.

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References

Abu-Zreig, M. 2001. Factors affecting sediment trapping in vegetated filter strips: simulation study using VFSMOD. *Hydrological Processes*, **15,** 1477–1488.

Abu-Zreig, M., Rudra, R.P., Lalonde, M.N., Whiteley, H.R. & Kaushik, N.K. 2004. Experimental investigation of runoff reduction and sediment removal by vegetated filter strips. *Hydrological Processes*, **18,** 2029–2037.

Blanco-Canqui, H., Gantzer, C.J., Anderson, S.H., Alberts, E.E. & Thompson, A.L. 2004. Grass barrier and vegetative filter strip effectiveness in reducing runoff, sediment, nitrogen, and phosphorus loss. *Soil Science Society of America Journal*, **68,** 1670–1678.

Daniels, R.B. & Gilliam, J.W. 1996. Sediment and chemical load reduction by grass & riparian filters. *Soil Science Society of America Journal*, **60,** 246–251.

De Baets, S. & Poesen, J. 2010. Empirical models for predicting the erosion-reducing effects of plant roots during concentrated flow erosion. *Geomorphology*, **118,** 425–432.

De Baets, S., Poesen, J., Knapen, A., Barbera, G.G. & Navarro, J.A. 2007a. Root characteristics of representative Mediterranean plant species and their erosion-reducing potential during concentrated runoff. *Plant and Soil*, **294,** 169–183.

De Baets, S., Poesen, J., Knapen, A. & Galindo, P. 2007b. Impact of root architecture on the erosion-reducing potential of roots during concentrated flow. *Earth Surface Processes and Landforms*, **32,** 1323–1345.

De Meyer, A., Poesen, J., Isabirye, M., Deckers, J. & Raes, D. 2011. Soil erosion rates in tropical villages: a case study from Lake Victoria basin, Uganda. *Catena*, **84,** 89–98.

Dillaha, T.A., Sherrard, J.H., Lee, D., Shanholtz, V.O., Mostaghimi, S. & Magette, W.L. 1986. *Use of vegetative filter strips to minimize sediment and phosphorous losses from feedlots: phase 1: experimental plot studies*. Virginia Poltytechnic and State University and Virginia Water Resource Research Centre, Blacksburg, Bulletin, 151. 73 pp.

Dillaha, T.A., Reneau, R.B., Mostaghimi, S. & Lee, D. 1989. Vegetative filter strips for agricultural non-point source pollution control. *Transactions of the American Society of Agricultural Engineers*, **32,** 491–496.

Ghadiri, H., Rose, C.W. & Hogarth, W.L. 2001. The influence of grass and porous barrier strips on runoff hydrology and sediment transport. *Transactions of the American Society of Agricultural Engineers*, **32,** 259–267.

GOU. 2000. *The national environment (wetlands, river banks and lake shores management) regulations, 2000*. Statutory Instruments Supplement to the Uganda Gazette No. 5 Volume XCIII. Government of Uganda (GOU), Kampala.

Hook, B.P. 2003. Sediment retention in rangeland riparian buffers. *Journal of Environmental Quality*, **32,** 1130–1137.

Lee, K., Isenhart, T., Schultz, R. & Mickelson, S. 1999. Nutrient and sediment removal by switch grass and cool-season grass filter strips in Central Iowa, USA. *Agroforestry Systems*, **44,** 121–132.

Loch, R., Spigares, T., Costantin, A., Garthe, R. & Bubb, K. 1999. Vegetative filter strips to control sediment movement in forest plantations: validation of a simple model using field data. *Australian Journal of Soil Research*, **37,** 926–946.

Magette, W.L., Brinsfield, R.B., Palmer, R.E. & Wood, J.D. 1989. Nutrient and Sediment Removal by Vegetated Filter Strips. *Transactions of the American Society of Agricultural Engineers*, **32,** 663–667.

Mankin, K.R., Ngandu, D.M., Barden, C.J., Hutchinson, S.L. & Geyer, W.A. 2007. Grass-shrub riparian buffer removal of sediment, phosphorus, and nitrogen from simulated runoff. *Journal of the American Water Resources Association*, **43,** 1108–1116.

Mckergow, L.A., Prosser, I.P., Grayson, B.R. & Heiner, D. 2004. Performance of grass and rainforest riparian buffers in the wet tropics, Far North Queensland. 2. Water quality. *Australian Journal of Soil Research*, **42,** 485–498.

Olago, D.O. & Odada, E. 2007. Sediment impacts in Africa′s transboundary lake/river basins: case study of the East African Great Lakes. *Aquatic Ecosystems Health and Management*, **10,** 23–32.

Owens, P.N., Duzant, J.H., Deeks, L.K., Wood, G.A., Morgan, R.P.C. & Collins, A.J. 2007. Evaluation of contrasting buffer features within an agricultural landscape for reducing sediment and sediment-associated phosphorus delivery to surface waters. *Soil Use and Management*, **23,** 165–175.

Schmitt, T.J., Dosskey, M.G. & Hoagland, K.D. 1999. Filter strip performance and processes for different vegetation, widths, and contaminants. *Journal of Environmental Quality*, **28,** 1479–1489.

Sheila, B. 1996. Monitoring vegetation cover. Available at: http://animalscience.ucdavis.edu/extension/Factsheets/RangelandResources/pdfs/Veg_Cover_Monitoring2.PDF, accessed 13/10/2006.

Syversen, N. 2005. Cold-climate vegetative buffer zones as pesticide-filters for surface runoff. *Water Science and Technology*, **51,** 63–71.

URT. 1999. *The National Land Act*. The United Republic of Tanzania (URT), Dar es Salaam.

Valentin, C., Agus, F., Alamban, R., Boosaner, A., Bricquet, J.P., Chaplot, V., *et al*. 2008. Runoff and sediment losses from 27 catchments in Southeast Asia: impact of rapid land use changes and conservation practices. *Agriculture, Ecosystems and Environment*, **128,** 225–238.

Van Dijk, P.M., Kwaad, F.J.P.M. & Klapwijk, M. 1996. Retention of water and sediment by grass strips. *Hydrological Processes*, **10,** 1069–1080.

Verstraeten, G., Poesen, J., Gillijns, K. & Govers, G. 2006. The use of riparian vegetated filter strips to reduce river sediment loads: an overestimated control measure? *Hydrological Processes*, **20,** 4259–4267.

Vigiak, O., Ribolzi, O., Pierret, A., Sengtaheuanghoung, O. & Valentin, C. 2008. Trapping efficiencies of riparian vegetation in Northern Laos. *Journal of Environmental Quality*, **37,** 889–897.

Weihang, D., Xingyuan, H. & Wei, C. 2011. Runoff and sediment reduction by riparian buffer filters on steep slopes. International conference on computer distributed control and intelligent environmental monitoring (CDCIEM), pp. 998–1001. doi: 10.1109/CDCIEM.2011.147.

Yuan, Y., Bingner, L.R. & Locker, A.M. 2009. A Review of effectiveness of vegetative buffers on sediment trapping in agricultural area. *Ecohydrology*, **2,** 321–336.

Ziegler, A.D., Negishi, J., Sidle, R.C., Preechapanya, P., Sutherland, R.A., Giambelluca, T.W. & Jaiaree, S. 2006. Reduction of stream sediment concentration by a Riparian buffer: filtering of road runoff in disturbed headwater basins of Montane mainland Southeast Asia. *Journal of Environmental Quality*, **35,** 151–162.