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Performance of Narrow Strips of Vetiver Grass (*Vetiveria zizanioides*) and Napier Grass (*Pennisetum purpureum*) as Barriers against Runoff and Soil Loss on a Clay Loam Soil in Kenya

Owino[a], James and Ralph Gretzmacher[b]

[a] Universität für Bodenkultur Wien (BOKU) / Egerton University, Department of Agricultural Engineering, PO Box 536, Njoro, Kenya. E-mail: joowin@yahoo.com

[b] Universität für Bodenkultur Wien (BOKU), Institute für Pflanzenbau und Pflanzenzüchtung, Gregor Mendel Str. 33, A-1180 Wien, Austria. E-mail: ralph.gretzmacher@boku.ac.at

Abstract

In this study runoff plots were used to investigate the performance of narrow strips of Vetiver and Napier grass as barriers against runoff and soil loss on a clay loam soil at Egerton University, Kenya, between January 2000 and August 2001. A total of nine runoff plots, each measuring 16 m long by 2 m wide were used. The study site had an average slope of 8% and the grass strips were located at the lower end of the plots. The experiment was a randomised complete block design having three blocks with Napier grass strip, Vetiver grass strip and no grass strip (control) as treatments. Compared with the control the runoff from the Napier and Vetiver grass strip plots averaged 46% and 88% (runoff reduction of 54% and 12%) respectively, while the soil loss from the plots averaged 8% and 52% (soil loss reduction of 92% and 48%) respectively. Compared with the control the deposition of soil sediment along Napier and Vetiver grass strips was significantly higher at the end of the study period. The growth rate in width and height of Napier grass strip was 78% and 36% respectively, higher than that of Vetiver grass. Napier grass was more effective in reducing runoff and soil loss under the conditions of the study due to its faster growth rate.

Introduction

Soil erosion is becoming severe in most agricultural regions of the world, and the problem is growing as more marginal land is brought into production. Soil loss rates in most parts of Kenya have been estimated to range from 15 to 40 t $ha^{-1}yr^{-1}$ depending on the cropping system in the area. (STOORVOGEL AND SMALING, 1990). On steep slopes very high losses of up to 247 t $ha^{-1}yr^{-1}$ have been reported (GACHENE, 1995; SCHNIEDER, 1993; THOMAS ET AL, 1981). Soil erosion causes reduction in soil depth and loss of nutrient leading to decline in soil productivity. Studies have shown that the nutrient losses from cropped land in Kenya and in other low-input agricultural regions depend on the total amount of runoff and eroded soil (ZÖBISCH ET AL, 1995; STOORVOGEL AND SMALING, 1990).

Soil conservation measures are broadly grouped as structural, vegetative, agronomic and management control measures (VAN LYNDEN ET AL, 2001). Structural measures have been used in Kenya for a long time and in most cases they have been effective. The main problem with them, which has been observed in other parts of the world, is that they are expensive, create unnatural systems of drainage and take a wide piece of land out of production (WORLD BANK, 1993; TRUONG ET AL, 1996; MANGO, 1999). In contrast the vegetative measures use nature to protect the soil. Only a small strip of land is disturbed. Whereas some of the structural measures have to be made with bulldozers or by hired labour, the vegetative measures require no special tool or labour beyond that which a farmer already has.

Various types of vegetative measures used in soil and water conservation include narrow grass strips or vegetative barriers, buffer strips, vegetated filter strips, and riparian filter strips. Narrow grass strips are strips of erect stiff perennial grass laid across a slope or along the contour at intervals to control soil erosion (DABNEY ET AL, 1993). Buffer strips are resident vegetation laid out across the slope. They are predominantly composed of grass species but also include other types of vegetation. The vegetated filter strips are bands of vegetation located at the base of a slope. Riparian filter strips are located along stream channels or bodies of water. They are designed to reduce the amount of sediment reaching offsite water bodies (RENARD ET AL, 1997).

The effect of terraces is to reduce the length of slope between structures and this in turn results in reduction in soil erosion (HAMMER, 1981; WENNER, 1981; FORSTER AND HIGHFILL, 1983). Terraces are made mechanically by excavating the slope to form the terrace structures. They can also be made by creating a barrier across the slope to intercept soil sediments from the up slope side of the barrier resulting in the formation of the terrace over a period of time (WENNER, 1981; RAO ET AL*,* 1992; KASSAM ET AL*,* 1992). The barrier can be in the form of soil dug and thrown upslope, as in the case of converse ("fanya juu") terrace, a vegetative barrier, a trash line or a stone line laid across a slope or along the contour. The barrier causes the runoff velocity to decrease thus resulting in deposition of sediments in the up slope area next to the barrier. Over a period of time the deposited sediments accumulate and eventually develop into a terrace.

A number of studies have shown that vegetative barriers can cause accumulation of soil sediments and eventually lead to development of terraces. In South Honduras live barriers of Vetiver grass and Napier grass caused accumulation of soil sediment ranging from 2.6 to 11.2 cm on the up slope of the hedge leading to formation of terraces after three years (WALLE AND SIMS, 1998). A study carried out in the highlands of northern Thailand, showed that the grass varieties *Seteria anceps* and *Brachiaria ruziziensis,* which were used as strips resulted in gradual terrace formation resulting from down slope hoeing and sedimentation of eroded soil (TURKELBOON ET AL, 1991). In the central Kenyan highlands studies have shown that Napier grass (*Pennisetum purpureum*), Donkey grass (*Panicum trichocladum),* creeping Signal grass (*Brachira humidicola*) and tall Guinea grass (*Panicum maximum*) are capable of causing the formation of terraces on slopes (ANGIMA ET AL, 2000; KINOTI ET AL, 1999)

Studies have also been carried out to evaluate various perennial grass species as means of reducing surface runoff and soil erosion. In their study RAO ET AL (1993) compared the performance of Vetiver grass, stone band and lemon grass as barriers in soil erosion control. The results they obtained indicated that Vetiver was a better barrier but then cautioned that the hedge establishment was a problem. RODRÍGUEZ (1997) evaluated the efficiency of 50 cm width hedgrows of Vetiver grass, Lily (*Agapanthus africanus*), Fern (*Nephrolepis sp*), Lemon grass (*Adropogon citratum)* and no hedgerow as a control. He found that Vetiver hedgerow was more efficient and concluded that this was due to its highly dense vegetative structure. YUDELMAN ET AL (1990) assessed Vetiver's performance and potential as a soil and water conservation measure, comparing it to a range of alternative species. They observed that only *Atripex spp* and

Cymbopogon nardus were close to but below Vetiver performance. MEYER ET AL (1995) in their study of sediment trapping effectiveness of stiff grass hedges, found that hedges of switch grass and Vetiver grass caused backwater depths of up to 400mm and trapped more than 90% of sediment coarser than 125 µm. Lesser percentages were trapped as sediment size decreased with only 20% of the material finer than 32 µm caught. They concluded that sediment trapping resulted mostly from up slope ponding by the hedges rather than the filtering action, and so the physical characteristics of different grasses were important primarily to the extent that they retarded flow

While Vetiver grass appears to have shown very good performance in a number of studies, some of these results may only be valid in the areas where these studies were done due to agro-ecological influence on the grass. There is therefore a need to study Vetiver under other ecological conditions to exhaustively establish its suitability (SIVAMOHAN, SCOTT AND WALTER, 1993). This is important because there have been cases of low adoption or even rejection of Vetiver by farmers in some areas (TRUONG AND GAWANDER, 1996). Such cases have been associated with factors such as rainfall temperature and maintenance of the hedge, which influence its establishment. In some regions these factors been reported to have negatively affected the performance of Vetiver grass (SIVAMOHAN, SCOTT AND WALTER, 1993; NATIONAL RESEARCH COUNCIL, 1993).

While studies has shown that vegetative filter strips can effectively reduce sediment and chemical losses in surface water, research is limited concerning appropriate width that would be most effective. It has been reported that in the United States, which is one of the leading countries in soil conservation research, very little work has been done to evaluate the performance of narrow grass strips (GILLEY ET AL 2000; RAFFAELLE ET AL 1997). Such observations clearly indicated the need for more research on the use of narrow grass strips in soil erosion control. In this study the performance of narrow strips of Vetiver and Napier grass in controlling runoff and soil loss in the field was observed and evaluated. The objectives of this study were to (a) determine the efficiency of narrow strips of Napier and Vetiver grass as barriers against runoff and soil loss; (b) evaluate the effect of growth rate of Napier and Vetiver grass strips on their performance as barriers against runoff and soil loss; and (c) evaluate the potential of narrow strips of Napier and Vetiver grass to cause terrace formation on a slope.

Materials and Methods

Study site

This study was carried out at Egerton University, Njoro, Kenya. Egerton University is situated approximately 200 kilometers north west of Nairobi and lies $0^{o}22'$S and $35^{o}55'$E at an elevation of 2,240 m above seal level. The mean annual rainfall is 1,150 mm and is unimodal, starting from March to September. The study site had a uniform slope of 8% running in the northeast direction and the field had been under Rhodes grass for over three years.

The soils were well drained, very deep and the topsoil colour varied from very dark gray to very dark grayish brown. The texture of the topsoil was dominantly clay loam. The colour of the subsoil varied from dark brown to dark reddish brown. The texture of the subsoil was dominantly clay. The structure of both topsoil and the subsoil was weakly to moderately developed sub-angular blocky. Organic carbon varied from 2.4% in the topsoil to 0.4% in the subsoil. The CEC of the soil varied from 22.8 me/100g in the topsoil to 19.9 me/100g in the subsoil. The pH varied from 5.6 to 6.1 increasing with depth.

Equipment and procedures

In this study a randomised compete block design having three blocks and three treatments was used, with the treatments comprising of a control (no grass strip), Vetiver grass strip, and Napier grass strip. The field was initially ploughed and harrowed by a tractor. It was then partitioned into the three blocks. Three runoff plots each measuring 16 m long by 2 m wide were installed in each block. The spacing between the runoff plots was 1 m within the blocks and 2 m between the blocks. The borders of the plots were made by constructing embankments around the plots. The embankments were lined with plastic paper to prevent seepage. The collector troughs were fabricated using, plane galvanised iron sheets, and were installed at the lower end of the runoff plots. The design and the installation of the troughs were done based on the recommended specifications (ULSAKER, 1982; MUTCHLER, 1963; MUTCHLER ET AL, 1988; HUDSON, 1993).

Two sedimentation tanks with capacities of 800 litres and 70 litres were installed in a concentric arrangement inside a hole measuring 2 m wide, 2 m long and 2 m deep at the end on each plot. The larger tank was made of galvanised iron sheet while the small one was made of plastic. A cut-off drain was dug in the area adjacent to the up-slope end borders of the plots to intercept runoff from the upper catchment area.

The planting of the grass strips was done in March 2000. Splits were used as propagation material. The material was carefully uprooted from the nursery and then separated into splits consisting of single stems. The planting was done on a single row at spacing of 15 cm between plants at the lower end of the plots. This spacing was within the recommended range of 10 cm to 20cm for single row spacing of Vetiver grass (CHOMCHALOW, 2000; NATIONAL RESEARCH COUNCIL, 1993; WORLD BANK, 1990; SIVAMOHAN ET AL, 1993). The same spacing was applied to Napier grass since no recommendations were available regarding its propagation for soil conservation purposes. Furthermore the application of the same spacing to both grasses reduced the chances of a variation arising due to spacing difference. The spacing of the plants within the row has a significant influence on the development of grass strips into effective barriers. In order to ensure quicker establishment of the grass strips they were irrigated from the time they were planted up to the time the rains came in June 2000.

Results and Discussion

The data reported here were collected between March 2000 and August 2001. The duration was divided into two study periods, namely the year 2000-study period and the year 2001-study period. During the year 2000-study period a total of 670.8 mm of rainfall was received, which was lower than 1,150 mm, the 56-year mean annual rainfall for this area. During the year 2001-study period the total rainfall from January to August 2001, was 737.1 mm. This was very close to 727.1 mm, the 56- year mean for the same duration (January to August). The total amounts of rainfall (runoff producing storms) that resulted in the runoff measured from the treatments during the year 2000 and 2001-study periods were 350 mm and 400.5 mm respectively.

The analysis of variance (ANOVA) showed that the amount of runoff from the treatments was significantly different. The difference was significant during the year 2000-study period ($P = 0.017$), the year 2001-study period ($P = 0.019$) and for the average of the two periods ($P = 0.019$). A comparison of the means of the treatments using the least significant difference test (LSD) at $P < 0.05$ level of significance showed that the mean runoff amount from the Napier grass treatment was significantly lower than that from both the Vetiver grass and the control treatments. There was no significant difference between the mean runoff amount from the Vetiver grass and the control treatment. Compared with the control Napier grass reduced the amount of runoff by 40% and 70% during the year 2000 and 2001-study periods respectively and by an average of 54% for the two study periods. Compared with the control Vetiver grass reduced the depth by -1% and 28% during the year 2000 and year 2001-study periods respectively and by an average of 12% for the two study periods (Figure 1and 2.). The -1 % (negative one percent) reduction of runoff depth by the Vetiver grass strip implies that runoff through the Vetiver strip was 1% more than that through the control.

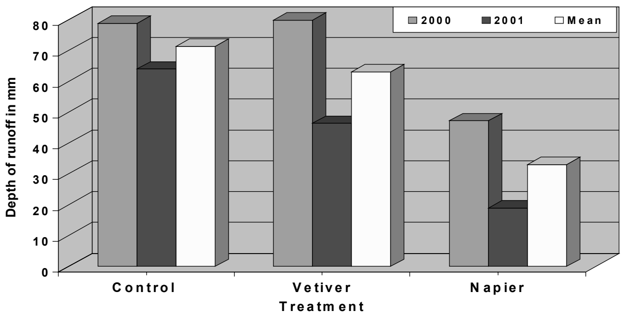

Figure 1. Amount of runoff from the treatments during the study periods

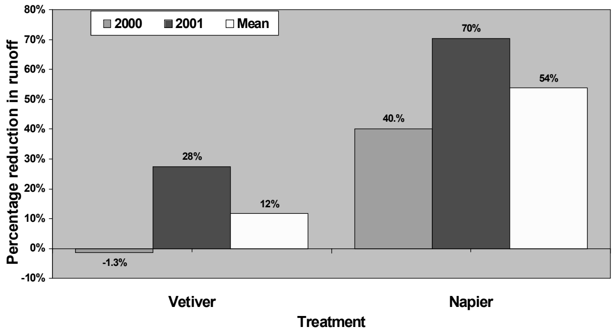

Figure 2. Percentage reduction in runoff from treatments during the study periods (Negative value indicates an increase)

While we can not rule out the possibility of imperfect field conditions playing a role in causing the negative reduction of runoff by Vetiver grass during the year 2000-study period, a number of studies have shown that the condition of the grass strip can also lead to such and outcome. In a study by LIGDI AND MORGAN (1995) on the role of simulated contour grass strips on soil erosion control, they observed that on steeper slope gradient and at high runoff discharge, the rate of erosion from the simulated contour grass strip doubled compared with bare soil. These results support the view by DE PLOEY ET AL (1976) that a plant cover can accelerate erosion on the steep slopes through concentration of runoff between the individual plant elements and the findings of DILLAHA ET AL. (1986) that grass strips are not effective under concentrated flow conditions. Even though Vetiver grass has shown high runoff reduction capacities in some studies (RAO ET AL, 1993; TRUONG ET AL, 1996; CHOMCHALOW, 2000), under the conditions of this study it was less effective compared to Napier grass. This is likely to have been due to the high growth rate of Napier grass, a view that is supported by the fact that there was a strong negative correlation between runoff from the grass strip treatments and the growth rate of the strip width ($r = -0.73$, $P = 0.024$) and height ($r = -0.67$, $P = 0.041$).

The analysis of variance (ANOVA) detected significant differences in the mean soil loss from the treatments during the year 2000-study period ($P = 0.037$), 2001-study period ($P = 0.009$) and in the average of the two periods ($P = 0.017$). A comparison of the means of the treatments using the LSD test at the $P<0.05$ level of significance showed that the soil sediment loss from the Napier grass treatment was significantly lower than that from the control during both study periods. Compared with the control the soil loss from the Vetiver grass treatment was lower during both study periods but the difference was only significant in the year 2000-study period. The soil loss from Napier grass treatment was lower than that from the Vetiver grass treatments. However this difference was only significant during the year 2000-study period. During the entire study period the mean soil loss rate from the Napier grass, Vetiver grass and the control was 1.07 tons $ha^{-1}y^{-1}$, 7.23 tons $ha^{-1}y^{-1}$ and 13.8 tons $ha^{-1}y^{-1}$ respectively (Figure 3.).

Compared with the control Napier grass treatment reduced soil sediment loss by 88% and 96% during the year 2000 and 2001-study periods respectively and by an average of 92% during the two study periods. Compared with the control Vetiver grass treatment reduced soil sediment loss by 17% and 78% during the year 2000 and 2001-study periods respectively, and by an average of 48% during the two study periods. Vetiver grass thus showed a tremendous improvement in its performance as a barrier during the year 2001. Its efficiency increased by 61% while that of Napier grass increased by only 8% (Fig 4.).

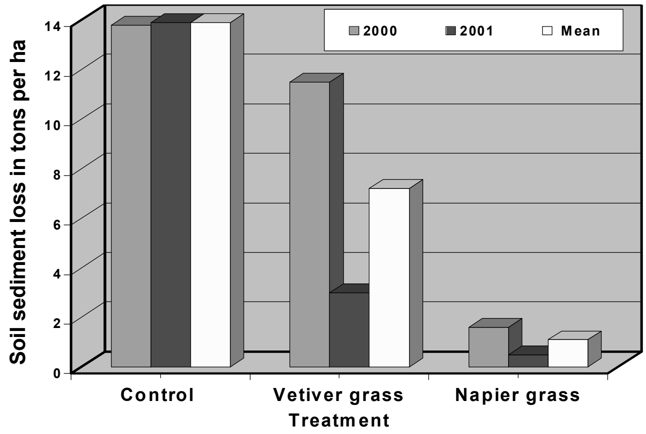

Figure 3. Soil loss from the treatments during the study periods

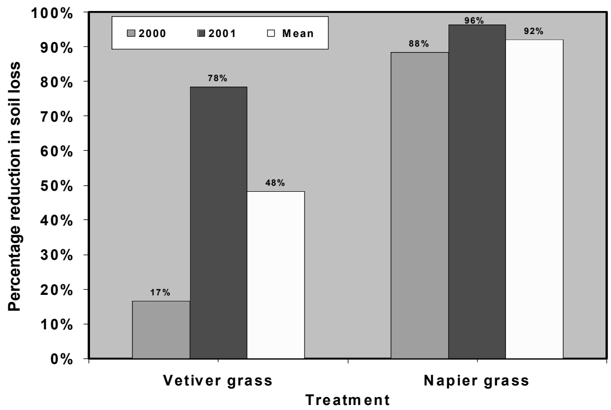

Figure 4. Percentage reduction in soil loss from treatments during the study periods

There was a strong negative correlation between the soil loss from the strips and the growth rate of the width ($r = -0.82$, $P = 0.01$) and the height ($r = -0.82$, $P = 0.01$) of the strips. This indicated that the efficiency of the grass strips was strongly related to the growth rate of the strips.

The analysis of variance (ANOVA) revealed that the mean deposition of sediments on the erosion pins during the study periods was significantly different amongst the treatment except for the rear pins in the year 2000-study period ($P= 0.16$). A Comparison of the treatment means using LSD test at $P<0.05$ significance level, revealed that during the year 2000-study period the deposition of sediment on the front pins in the Napier grass treatment was significantly higher than in the Vetiver grass and control treatment. In the year 2001-study period the mean deposition of sediment on the front and the rear pins in the Napier and Vetiver grass treatments was significantly different from that of the control treatment. However the difference between Napier grass and Vetiver grass treatments was not significant (Table 1 and Figure 5). Apart from the rear pins during the year 2000-study period, there was a strong positive correlation between sediment deposition and the growth rate of the grass strips.

The analysis of variance (ANOVA) revealed that for the width and height growth rate, the difference between Napier grass and Vetiver grass treatments was highly significant ($P = 0.01$ for both width and height). The comparison of the means of the treatments using the LSD test at $P < 0.05$ level of significance showed that growth rate of Napier grass in width and height was significantly higher than Vetiver grass by 78% and 36% respectively

Table 1.. Comparison of the treatment means for sediment deposition using LSD test at P<0.05 level of significance

Treatment	Mean sediment deposition depth in cm*			
	Front00	Rear00	Front01	Rear01
Control	-0.5b	Ns	-1.33b	-0.70b
Vetiver grass	0.38b	Ns	5.83a	2.63a
Napier grass	2.03a	Ns	6.03a	3.80a

*Means with the same letter are not significantly different; Front 00, Rear00, Front 01, Rear01 = front and rear erosion pins during the year 2000 and year 2001-study periods respectively; Ns = F-value not significant

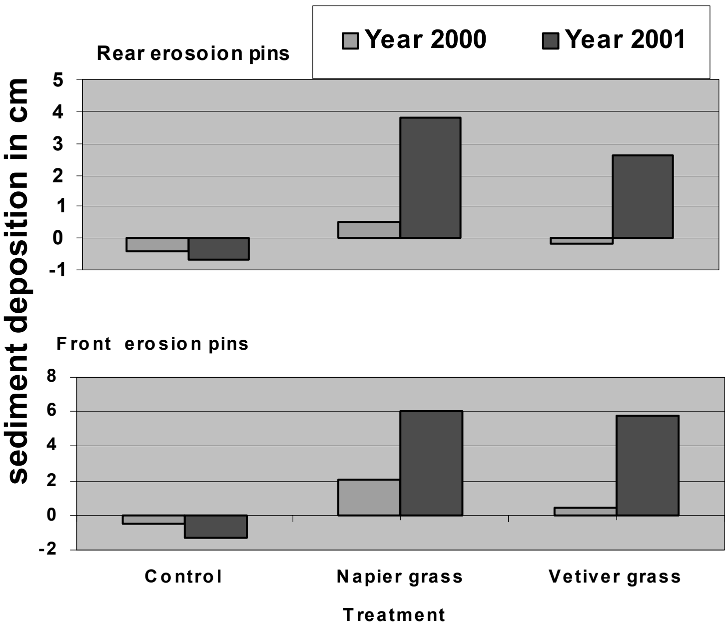

Figure 5. Soil deposition during the study periods (Negative values indicate reduction in soil surface depth

Conclusion

The results showed that under the conditions of this study, Napier grass was more effective than Vetiver grass in reducing runoff and soil loss. Because of the higher growth rate, Napier grass was able to develop a more effective barrier faster than Vetiver grass. The presence of gaps in the Vetiver grass strips encouraged concentrated surface flows through the strips thus increasing the rate of soil erosion. However the Vetiver grass barrier showed an improved performance during the second study period (2001). While some studies have indicated that Vetiver grass is capable of developing and effective barrier in less than two year, in this study the results indicated that it needed a longer period. The study showed that both grass species were capable of accumulating sediments and could thus be used to develop terraces on slopes.

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