Effectiveness of Grass Strips as Barrier Against Runoff and Soil Loss in Jijiga Area, Northern Part of Somali Region, Ethiopia

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ABSTRACT

In this study, sixteen standard runoff plots with a dimension of 22.13 × 1.8 m each were constructed in a contour on a cultivated land with slope gradient of 9 % in Jijiga area of the northern part of Somali region of Ethiopia at the end of the year 2003. To evaluate the effectiveness of grass strips as barrier against the runoff and soil loss, an experiment was laid out in randomized complete block design with four treatments by four replicates on the constructed sixteen runoff plots. The treatments were one control-without grass strip and three different grass strips of 1 m wide each. The grass strips, namely desho, setaria and vetiver were established at a spacing of 15 cm within a row on the lower end runoff plots. All the runoff and soil loss from the treatments were measured during 38 storm events in the years 2004 and 2005. The depth of sediment deposition along the strips and the growth rate of strips were also measured. In both 2004 and 2005 study years, the three grass treatments showed significantly lower annual runoff and soil loss results compared to the control treatment. However, the lowest runoff and soil loss were recorded from the vetiver grass. This was because of its faster growth rate than both the desho and setaria grass strips. The depositions of sediment along the three grass strip treatments were significantly higher than that of the control section, suggesting that three grass strips had the potential to cause terracing. However, the preference should be for the vetiver grass because it formed terraces much quicker than both the desho and setaria grass strips.

In general, even though the three grasses could be used as barrier against runoff and soil loss, and had potential to cause terrace formation on gentle slope, it was however recommended that they should be rated as: vetiver>desho>setaria in accordance with their relative effectiveness.

Key words: Ethiopia, grass strips, vetiver, desho, setaria, soil loss

INTRODUCTION

Mechanical soil and water conservation measures such as bunding, furrowing terracing, *etc*. have been reasonably effective in developed countries but totally inappropriate in developing countries. After almost two decades of implementation, many of the evaluations of the programs executed by different institutions and researchers came to the conclusion that the introduced mechanical soil land water conservation measures in Ethiopia have failure

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stories. Because these high cost structures were temporary and did not conform to the natural environment (Yohannes, 1994). Farmers do not feel involved with such measures and these are essentially governmental sponsored programs.

The current day focus of soil and water conservation programs is how farmers can manage their lands and maintain or restore the productivity of their soils. For this, they need cheap and easily implementable measures such as grass strips (Dano and Siapno, 1992). Several organizations are promoting grass strips as soil and water conservation measures because they demand less labour than the mechanical measures, do not bury the fertile topsoil and they can effectively reduce erosion on gentle slopes (ASAE, 1981; Hudson, 1981; Mulugeta, 1988; Turkelboom *et al*., 1994). However, the mechanical measures are too expensive and are difficult to maintain in the long run (Rodriguez, 1997) and are time consuming (Tripathi and Singh, 1993). An additional feature in favour of the grass strip lies in its maintenance (Grunder, 1988). After establishment and stabilization the grass strip needs no more attention to form a terrace while mechanical measures need annual maintenance to keep their effectiveness.

With a growing interest in the protection of environment and development emerging, there is a revival in the use of grass strips for soil and water conservation in the developing countries. However, the idea of establishing the grass strips on pre-determined key lines for soil and water conservation is relatively new innovation in Ethiopia in general, and northern part of Somali region in particular. Hence, there is a need to evaluate suitable grasses from the locally existing exotic and/or indigenous floral elements to form effective barriers against runoff and soil loss on gentle slope in northern part of Somali region. The locally existing grass types in the region are desho, setaria (*Setaria anceps*) and vetiver (*Vetiveria zizanioides*). The setaria and vetiver grasses had been known to be exotic while desho grass was discovered in 1991 in the Chenecha district of the southern region of Ethiopia. It is believed that desho grass belongs to Pyppogamusae family and Genius Penispum, however its species is not identified yet. The objectives of this paper were, therefore, to determine the effectiveness of desho, setaria and vetiver grass strips as barrier against runoff and soil loss on a gentle slope, to evaluate the effect of growth rate of desho, setaria and vetiver grass strips on their performance as barrier against runoff and soil loss on a gentle slope and to evaluate the potential of the desho, setaria and vetiver grass strips to cause terrace formation on a gentle slope.

MATERIALS AND METHODS

Description of the study site

The study site was located in Jijiga town, a capital city of the Somali region of Ethiopia. Jijiga is situated in the Eastern part of Ethiopia and in the northern part of Somali region (Figure 1). The town is located at an altitude of 1650 m above sea level and geographically positioned at latitude of 9°34ʹ North and longitude of 42°78ʹ East. The initial soil analysis results of selected physical and chemical properties of soil of the study site are given in Table 1. Records from 1952 to 2004 indicated that the site received overall average rainfall of 661mm per annum. Jijiga area

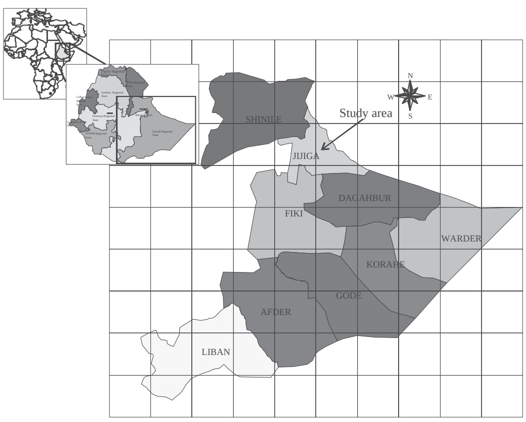

Figure 1 Location map of Ethiopia, Somali region, Jijiga and the study site.

is found to have bimodal rainfall pattern which mainly occurred during March to May (locally called belg season) and July to October (locally called kermt season). The mean annual temperature of Jijiga town is 13°c. The land slope of the study site is 9 %. Runoff plots were designed and constructed along the contour at the end of August 2003. Prior to the study, the site was under weeded.

Before the construction of the runoff plots, the site was cleared of weeds and the upper 30 cm of the soil was chiseled using a tractor to alleviate surface sealing and compaction. The site was fenced by barbed wire to protect against the interference of human and animals.

Construction and layout of runoff plots

In this study, sixteen standard runoff plots with a dimension of 22.13 m × 1.8 m each were constructed in a contour on a cultivated land with slope gradient of 9 % at the end of August 2003. To hydrologically isolate the plots from the adjacent area and collect all the runoff from the controlled sixteen plots, thin iron sheet boundaries were installed around each plot. The edges of the sheet were extended 20 mm above the soil surface. An experimental setup of the runoff plots is shown in Figure 2.

Table 1 Selected physical and chemical properties of soil at the study site.

Parameter		Physical and chemical properties
Texture		
	Sand	89.21 %
	Silt	9.31 %
	Clay	1.48 %
pH		7
Organic matter		0.71 %
Available P		11.23 ppm
Total nitrogen		0.8710 %

Figure 2 Experimental setup of the runoff plots.

The runoff and sediment loss were collected in a plastic can placed inside a barrel that was buried in the ground at a distance of about one meter from the lower end of each runoff plot. Each runoff plot was connected to the can inside a barrel by triangular shaped gutter made of iron sheet (Figure 2). The gutter was covered with a plastic sheet and the barrel was closed securely to prevent direct entrances of rainfall while the runoff collecting can was covered by a wire mesh screen to trap floating debris.

Measurement of runoff and soil loss

After each rainfall event, the depth of the water in the runoff collection cans was measured (in 2004 and 2005 study years). The plot runoff in millimeters was calculated. After thoroughly stirring the content of the runoff collectors, the settled sediment was weighted wet. 50 gm of wet samples (in some cases less than this) collected after each rainfall event was sun dried in the experimental site and taken to Alemaya University for oven dry weights and for calculating the total dry soil loss. The runoff collecting cans were emptied and cleaned after each measurement to make them ready for the next rainfall event.

Experimental design and treatments

An experiment was laid out in Randomized Complete Block Design (RCBD) on the constructed sixteen runoff plots with four treatments by four replicates. The treatments were one control without grass strip and three different grass strips of 1 m wide each. The grass strips, namely desho, setaria and vetiver were established at a spacing of 15 cm within four rows (forty-eight strip of each grass treatment) on the lower end of the 22.13 m long by 1.8 m wide runoff plots. The grass strips were established at end of September 2003.

Land preparation

After the experiment was laid out in RCBD on the constructed sixteen runoff plots, the plots were ploughed manually to depth of approximately 15 cm with inverted hoes locally called ‘Akafa’ and then seeded along the contour on March 21, 2004 with Jijiga-local-maize variety.

Measurement of growth rate of grass strips

The growth in height and width of all the forty-eight strips of each grass treatment were measured every two months in cm and then the strip trimmed down to 15 cm.

Measurement of sediment deposition depth

Four erosion pins were fixed into the ground at the four edges (ends) of the grass strip treatments and the control treatment, forming a grid on the down slope end of each plot. The pins were fixed at the same time as the grass strips were established (at the end of September 2003). The sediment deposition depth on the front and rear pins of the each of the four treatments were measured in cm per season.

Statistical analysis

The analysis of variance and mean comparison using Least Significant Difference (LSD) test for Randomized Complete Block Design (RCBD) was executed for various parameters such as runoff depth and soil loss, growth rate of grasses in width and height, and sediment deposition depth per the procedure described by Gomez and Gomez (1984) using ‘Minitab’ computer package. Correlation analysis and regression equations were performed to test the relationships between runoff and soil loss.

RESULTS AND DISCUSSION

Annual runoff and soil loss results

The annual runoff and soil loss results of the four treatments in 2004 and 2005 study years are presented in Table 2 and Table 3 respectively. In both study years, the depths of runoff and soil loss from the three grass treatments were significantly lower than that of the control treatment. The lowest runoff and soil loss was recorded from the vetiver. This was because of a combination of several factors. First, the vetiver grass reduced the velocity of runoff due to a relatively highest roughness presented to the flow by its stems and leaves. This might gave rise to increased rate of infiltration in to the soil. Secondly, the vetiver grass limited the capacity of runoff to detach and transport soil particles, both through its relatively highest retardance effect on runoff volume and velocity, and through the physical protection of the soil from the runoff. Thirdly, decayed (degraded) leaves, stems and roots of the vetiver grasses by microbial activity increased stability of soil aggregate. This increased aggregate stability of a soil increased permeability and infiltration which, in turn, reduced runoff and soil loss, because the stability of the soil aggregates affected their detachability by rain drop impact and their detachability and transportability by runoff (Styczen and Morgan, 1995).

Runoff and soil loss reduction

Figure 3 and Figure 4 show the percentage reduction in runoff and soil loss respectively. When compared with control treatment in both 2004 and 2005 study years, vetiver, desho and setaria grass treatments reduced the depth of runoff by 62, 45 and 31 % respectively (Figure 3).

Comparing the three grass treatments with control, the vetiver, desho and setaria reduced the soil loss by 62, 43 and 30 % respectively during the year 2004 and by 56, 46 and 32 % respectively

Table 2 Means of runoff depth from the four treatments.

Treatment	Mean runoff depth in millimeters[1/]	
	Year 2004	Year 2005
Control	55.10[d]	67.10[d]
Setaria	38.05[c]	46.40[c]
Desho	30.43[b]	37.00[b]
Vetiver	20.68[a]	25.50[a]
LSDT (P<0.05)	1.37	4.68
CV (%)	2.38	6.70
Rainfall in millimeters	308.5	590.7
Number of storms	15	23

[1/] Means within column followed by different letters are significantly different from each other (P<0.05)

Table 3 Means of soil loss from the four treatments.

Treatment	Mean soil loss in tons per hectare[1/]	
	Year 2004	Year 2005
Control	2.650[d]	3.045[d]
Setaria	1.860[c]	2.058[c]
Desho	1.500[b]	1.642[b]
Vetiver	1.000[a]	1.342[a]
LSDT (P<0.05)	0.095	0.16
CV (%)	3.4	5.0
Rainfall in millimeters	308.5	590.7
Number of storms	15	23

[1/] Means within column followed by different letters are significantly different from each other (P<0.05) during the year 2005 (Figure 4). In general, a considerable difference was observed between the three grass strips in reducing runoff depth and soil loss. The vetiver grass distinctively showed highest reduction in annual runoff and soil. This was attributed to the fact that the erect and rather stiff leaves and stems of vetiver grass retarded more runoff flow and acted as filter to more sediment. Also, growth rate in width and height of vetiver grass was faster than that of the other two grasses, enabling it to develop a more effective barrier against runoff and soil loss. Rao *et al*. (1991) at

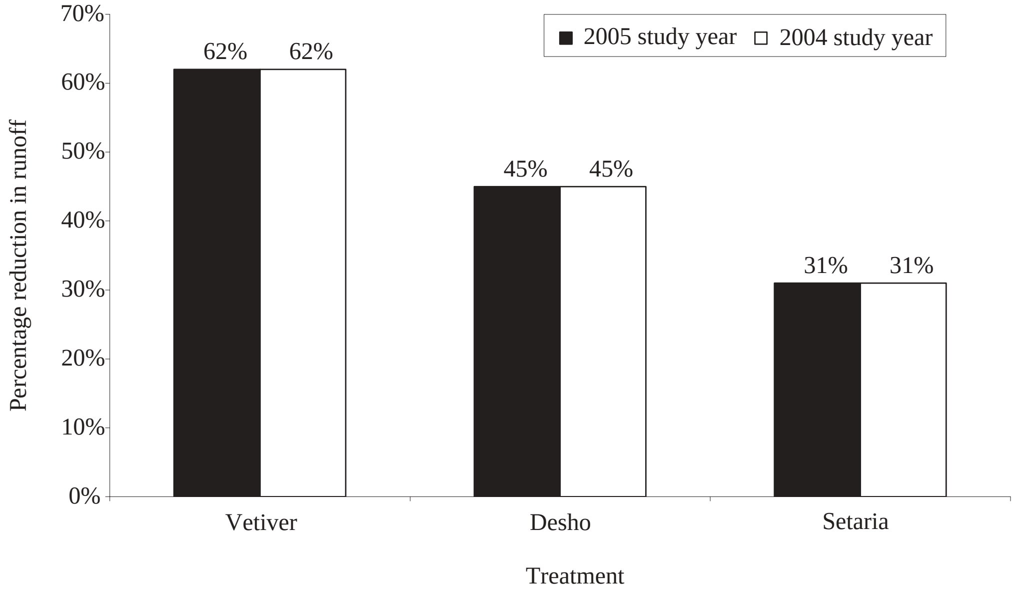

Figure 3 Reduction percentage in runoff during the study periods.

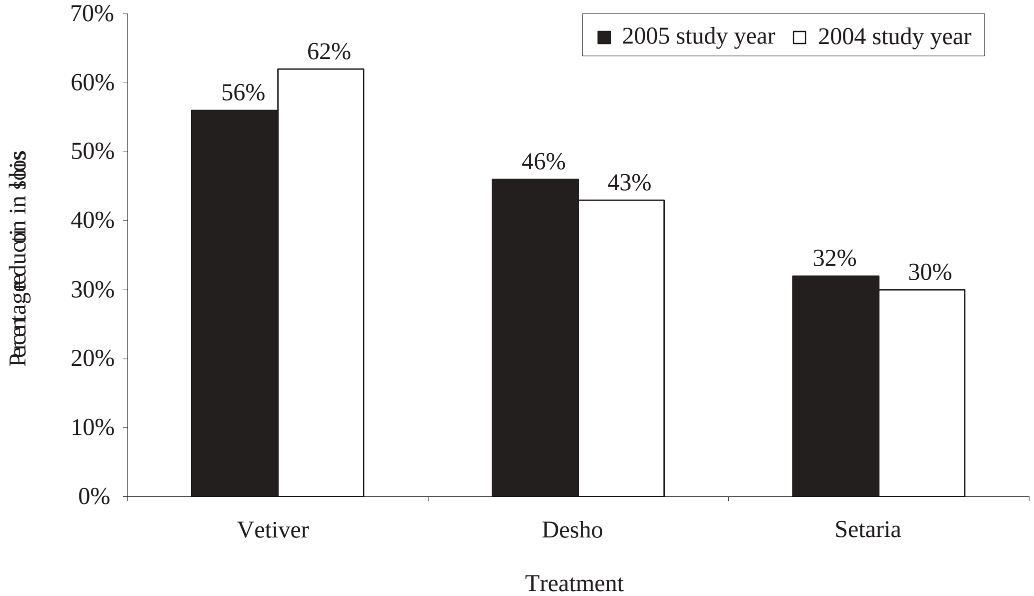

Figure 4 Reduction percentage in soil loss from treatments during the study period.

ICRISAT, India, compared vetiver grass strip with stone barriers, lemon grass and bare ground (control) under natural (total rainfall of 689 mm) and artificial rainfall conditions and found that vetiver grass could reduce runoff by 57 % and soil loss by over 80 %. Similarly at CIAT, Colombia, Laing and Rupenthal (1991) compared Vetiver grass to other vegetative systems (rainfall of 1240 mm) and found that at 11 months period vetiver hedges were able to reduce runoff from 11.6 % to 3.6 % and soil loss was reduced from 142 t/ha for bare fallow to 1.3 t/ha for vetiver.

In spite of the relatively bigger and generally more runoff and soil loss generating storms in the year 2005 than 2004 (Table 2 and/or Table 3), however, the reduction percentage in runoff depth by each grass treatment were the same in both years (Figure 3). It was also notable that there was no marked difference in the percentage of soil loss reduction by each grass treatment in both years (Figure 4). This was attributed to the fact that the three grass strips were well-established when the measurement of runoff and soil loss was done and therefore provided effective barrier against runoff and soil loss.

Runoff and soil loss relation

Figure 5 shows the correlation between runoff and soil loss in four treatments on the data of the 2004 and 2005 study years. Correlation coefficient values for vetiver, desho and setaria grass treatments were 0.16, 0.39 and 0.42 respectively. The low correlation on the three grass strip treatments implied that greater runoff did not

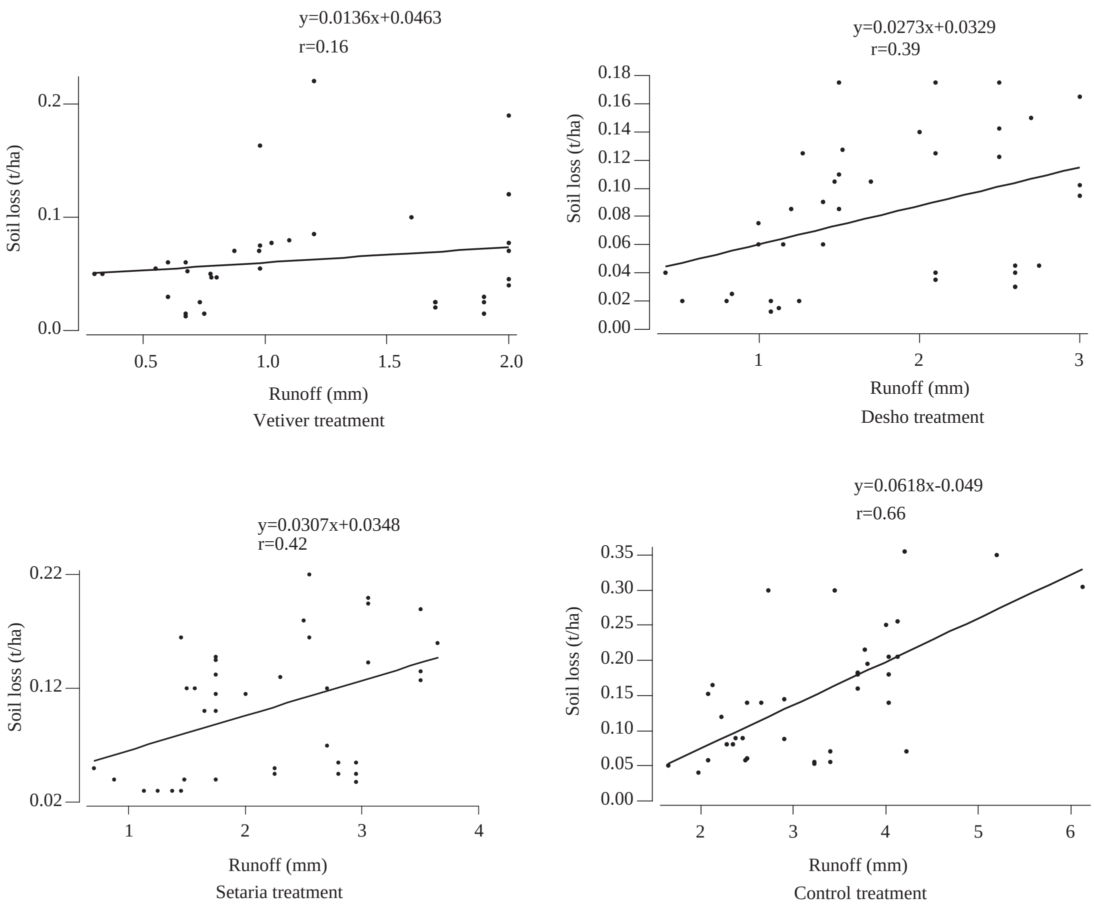

Figure 5 Correlation between runoff and soil loss on the four treatments.

result in greater soil loss on these treatments. This indicated that the grass strips were trapping sediment without reducing the runoff, a function normally expected to perform as soil conservation measure. Similarly, low correlations were observed between runoff and soil loss in grass treatment on the basis of two years' data in Maybar area of Wello Region of Ethiopia (Mulugeta, 1988).

The correlation of r=0.66 observed on the control treatment is probably the most useful one of all the four correlation values. It implies that soil erosion on gentle slope can be controlled to a greater extend if the amount of runoff is reduced by means of grass strips as soil conservation measure.

Growth rate of grass strips

Growth rates of the three grass treatments in width and height are presented in Table 5. The vetiver grass showed significantly fastest growth rate, followed by the desho and setaria grasses. This explained why the vetiver grass distinctively reduced annual runoff and soil loss. It was because of its fastest growth rate which allowed it to develop a more effective barrier against the runoff and soil loss. On the other hand, the probably slowest growth rate of setaria grass did not enable it to form as effective barrier as vetiver and desho grass treatments, thus resulting in the lowest runoff and soil loss reduction.

Sediment deposition depth

Table 6 shows the results of seasonal sediment deposition depth on the front and rear pins of the four treatments. The depositions of sediment on the pins in the vetiver grass strips were significantly higher than that of control, desho and setaria. This was due to the fact that the deep, strong and fibrous root system of vetiver grass

Table 5 Mean growth rate of the three grass treatments in width and height.

Treatment	Mean growth rate in cm per month[1/]	
	Width	Height
Control	0.000	0.00
Setaria	0.825[a]	18.20[a]
Desho	1.625[b]	35.60[b]
Vetiver	2.400[c]	48.30[c]
LSDT (P<0.05)	0.246	6.54
CV (%)	12.67	16.00

[1/] Means within column followed by different letters are significantly different from each other (P<0.05).

Table 6 Seasonal means of sediment deposition on the depth of treatments.

Treatment	Seasonal mean sediment deposition depth in cm[1/]			
	Kremt season 2004		Belg season 2005	
	Front rulers	Rear rulers	Front rulers	Rear rulers
Control	-0.300[a]	__	-3.00[a]	-0.425[a]
Setaria	0.100[b]	__	0.800[b]	0.325[b]
Desho	0.300[c]	__	2.475[c]	1.125[c]
Vetiver	1.100[d]	__	3.200[d]	2.100[d]
LSDT (P<0.05)	0.11	__	0.14	0.10
CV (%)	23.57	__	9.82	8.00

[1/] Means within column followed by different letters are significantly different from each other (P<0.05).

penetrated and blinded the soil particles, reinforced the soil increasing shear strength and increased surface roughness, thereby resulting in more sediment deposition. The implication of the discussion on sediment deposition depth was that the three grass strips had the potential to cause terracing. However, the preference pointed to vetiver strips because they formed terraces much quicker than the desho and setaria grass strip

CONCLUSIONS

The three grass strip treatments were effective at controlling runoff and soil loss under the rainfall conditions that existed during the two study years on the gentle land slope (9%) on which the experimental plots were constructed. Low correlation were obtained between runoff and soil loss in the three grass strip treatments, highlighting the filtering effect of the grass strips, whereas a relatively high correlation (r = 0.66) observed between the runoff and soil loss in the control treatment explained the possibility of reducing soil loss on gentle slope by using grass strips as a soil and water conservation measure. Furthermore, the result of the sediment deposition depth on the front and rear pins of the treatments showed that the three grass strips had the potential to cause terracing. However, the first choice should be vetiver grass and next for desho grass.

In general, even though the three grasses could be used as barrier against runoff and soil loss, and had potential to cause terrace formation on gentle slope, it is, however, recommended that they should be rated as: vetiver>desho>setaria in accordance with their relative effectiveness. It is also recommended that further studies are to be done to compare the three grasses under the same conditions but for a period exceeding two years.

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