KFRI Research Report 449 ISSN 0970-8103

A FIELD STUDY TO EVALUATE THE EFFICACY OF LEMON GRASS IN CONTROLLING RUNOFF AND SOIL EROSION

Thomas P. Thomas
S. Sankar
K.K. Unni

Kerala Forest Research Institute
(An Institution of Kerala State Council for Science, Technology and Environment)
Peechi 680 653, Kerala, India

June 2012

KFRI Research Report ISSN 0970-8103

A FIELD STUDY TO EVALUATE THE EFFICACY OF LEMON GRASS IN CONTROLLING RUNOFF AND SOIL EROSION

(Final report of the project KFRI 543/08)

Thomas P. Thomas
S. Sankar
K.K. Unni

Kerala Forest Research Institute
(An Institution of Kerala State Council for Science, Technology and Environment)
Peechi 680 653, Kerala, India

June 2012

CONTENTS

PROJECT PROPOSAL

1. Project code : KFRI 543/08

2. Title of the project : A field study to evaluate the efficacy of lemon grass in controlling runoff and soil erosion

3. Objectives : To compare the shoot and root growth pattern of different varieties of lemon grass with that of vetiver grass

   To compare the effectiveness of these grasses in controlling soil erosion

   To ascertain the impact of these grasses on soil properties

4. Date of commencement : April 2008

5. Duration : 3 years

6. Funding agency : Planning and Economic Affairs (E) Department, Govt. of Kerala.

7. Investigators : Thomas P. Thomas

   S. Sankar

   K.K. Unni

ACKNOWLEDGEMENT

We are grateful to Dr. R.Gnanaharan, former Director for his support and encouragement during the initial stages of the project and Dr. K.V. Sankaran, present Director for continued support and guidance.

The support received from Sri. Unni, K.K., Officer- in -charge and the staff of the Field Research Centre, Velupadam especially Sri. Suresh, M.K., Sri. Thankachan and Sri. Zakkeer is remembered with gratitude. The sincere hard work and commitment of Sri. Sutheesh, V.K., Project Fellow deserves special mention and we record our gratitude.

The assistance received from Sri.Hussain, K.H., Assistant Librarian and Sri. Prasanth. K.M., Smt. Kripa, P.K., and Sri. Sreejesh, K.K., Research Scholars during preparation of the manuscript is greatly acknowledged.

We are also indebted to the editors Dr. M. Balagopalan, Dr. K.V. Bhat and Dr. S. Sandeep whose sincere efforts have helped in improving the manuscript very much.

ABSTRACT

A field study to evaluate the efficacy of lemon grass in controlling runoff and soil erosion was conducted at the Field Research Centre of KFRI at Velupadam. Runoff plots of 12mx3m were laid out on a sloping terrain with about 20^0 slope and strips of *Cymbopogon flexuosus, Cymbopogon albescens* and *Vetiveria zizanioides* were planted in contour strips to control runoff and soil erosion. During the summer rains of 2010, about 25% of the rain water was lost from the plots of *C. flexuosus* and *C. albescens* while 60% loss was recorded from the control plots. *V. zizanioides* was more effective during this period; it reduced the runoff loss to 13 percent of the rainfall (286mm) received. It can be seen that *C. flexuosus* was equal to *V. zizanioides* in establishment and could contain runoff as effectively as *V. zizanioides* during the following period of intense south west monsoon. *C. albescens* was less effective during this period. Runoff from *C. flexuosus* and *V. zizanioides* was within the minimum of 5% of the rainfall of 1980mm received during the heavy rainfall months of June to September. Runoff loss during the same period from control plots was 42% in June,92% in July, 45% in August and 77% in September. *C. albescens* plots lost 25,39,18 and 16 percent of rainfall during these months. Intense rain was again received during October with 638mm rainfall from the north east monsoon. *C. flexousus* permitted 21% rain to runoff the plots while *C. albescens* plots lost 32% and *V. zizanioides* plots lost 12%; the loss from control plots was to the tune of the 77 percent. No appreciable loss was recorded during the months of November which received 385mm rainfall. Thus it was seen that *C. flexousus* was as effective as *V. zizanioides* is reducing runoff losses, even during the intense rains of south west monsoon.

Soil loss as suspended sediment from the runoff plots was also effectively reduced by *C. flexuosus*. During the intense south west monsoon, this species of lemongrass was able to reduce soil loss by 80 percent as compared to control and was equal to *V. zizanioides* in this respect. Annual soil loss from the plots was 1.43, 3.83 and 1.01 tons/ha from *C. flexuosus, C. albescens and V. zizanioides* plots compared to 5.37 tons/ha from the control plots.

Lemongrass, especially *C. flexuosus* could control runoff and soil loss very effectively; it produced enough shoots and roots to achieve this performance. The tillers and the fallen leaves reduce the velocity of runoff permitting more time for infiltration. The fine fibrous roots that extend far and deep enmeshing the soil particles encourage soil aggregation and consequent greater porosity which further helps in infiltration and permeability. Lemongrass also has the added advantage that its economic part is the leaf rather than the root as is the case with vetiver and hence does not disturb the soil during harvest. Considering the high returns from lemongrass oil, it is to be encouraged as a choice species in soil and water conservation, especially on degraded slope.

INTRODUCTION

Soil erosion by water is one of the major causes of land degradation in Kerala since the land is sloping and the rainfall is of high erosive capacity. But the natural vegetation covers and protects the land from the beating action of rain drops, helps reduce the velocity of flowing water and also encourage quick infiltration of water into the soil. Disturbance to the natural multi-storeyed protective vegetation disrupts the balance and accelerates soil erosion necessitating adoption of conservation practices. Among the conservation practices, vegetative measures are preferred over mechanical ones. Among the vegetative practices, establishing grass strips along the contour is the often recommended practice.

Vegetative barriers impede soil and water movement downslope, are semipermeable and terraces may form naturally over time. The Sloping Agricultural Land Technology System (SALTS) is a complete conservation production system in which hedgerows act as the frame work, between which crops are grown (Critchley *et al.,*2004). Grass hedges of *Pennisetum alopecuroide* and *Arundinella hirta* were tried on sloping croplands in Northern China. Pennisetum hedges reduced soil loss by 84% and overland flow by 68% while Arundinella hedges reduced soil loss and overland flow by 55% and 38% respectively (Xiao-Bo *et al.,* 2010). Effectiveness of grass strips on cultivated slopes of 9% in northern part of Somali region of Ethiopia revealed significant reduction in runoff and soil loss compared to control. Lowest runoff and soil loss was recorded from vetiver grass (Welle *et al.,*2006). Narrow strips of vetiver (*Vetiveria zizanioides*) and napier (*Pennisetum purpureum*) grass reduced runoff by an average of 54 and 12% respectively from a clay loam soil in Kenya (Owino *et al.,*2006). Rodriguez (1998) compared the efficiency of vetiver, lily, fern and lemongrass with mulching in Venezuela by providing simulated rainfall of 55.6 mm/hr on 15 and 26% slopes and reported that hedge rows of vetiver and fern and mulch were good conservers of soil. Vegetative barriers of vetiver, gautemala grass, fern, african lily and lemon grass were compared for their efficiency in conserving soil on 15-20% slopes using erosion plots of 10m x 1m size on an aquic paleudult soil of Venezuela. Ten year old vetiver was found to be the most efficient species in reducing soil, nutrients, organic matter and water losses (Andrade & Rodriguez, 2002).

Experiments in the degraded hills of the Eastern Ghats of India by Susama (2008) with sambuta (Saccharum spp.) and vetiver (*Vetiveria zizanioides*) revealed that sambuta and vetiver barriers on 11% slope reduced runoff and soil loss by 63.4 and 68.6% respectively over control (runoff 25.9% and soil loss 14.0 t /ha). Sambuta barriers resulted in increased yield of finger millet (*Eleusine coracana*) and enhanced organic carbon accumulation and available potassium in the soil. Overall performance was highest in the case of sambuta. Vetiver barriers were found effective in conserving soil and water in many countries of the world (Susama Sudhishri *et al.,* 2008; Madhu *et al*., 2011; Xiao Bo *et al.,* 2010; Owino *et al.,* 2006; Critchley *et al.,*2004; Mane *et al.,*2009; Nwachokor and Bergsma, 2011; Poudel *et al.,*2000; Suyatmo and Howeler, 2004; Tscherning *et al.,*1995; Andrade and Rodriguez, 2002; Rodriguez,1998; Singh, R.S. 2000; Shah *et al.,*2000; Welle *et al.,*2006; Donjadee *et al.,*2010). *Vetiveria zizanioides* with strong roots and a rooting depth of upto 5m has been identified by the World Bank as the most promising green technology against erosion(Mengozzi, 2001).

Vetiver has always been the choice species and hence no alternative species were tried in its place for the purpose. The present study was taken up to test the efficacy of lemongrass, a promising species that was always preferred by upland farmers while converting natural vegetation for raising agricultural crops. It has the advantage over vetiver due to the fact that it's economic part is the foliage and hence does not cause any soil disturbance while harvesting. In the case of vetiver, it is the root portion that is extracted. Lemongrass oil fetches good price and hence cultivation of lemongrass is highly remunerative. Lemongrass species *Cymbopogon citratus* and *C. flexuosus* has been successfully utilized as vegetative barriers on sloping terrain in several other countries also to control runoff and soil erosion (Andrade and Rodriguez,2002; Mane *et al.,*2009; Nwachokor,2011; Poudel *et al.,*2000; Rodriguez,1998; Shah,2000; Singh, 2000; Suyamto and Howler, 2004; Tscherning *et.al* (1995)

Lemongrass is an aromatic tropical grass with clumped, bulbous stems bearing leaf blades. It has a branched cluster of stalked flowers and grows in clumps upto 1.8m height; when crushed, the fragrance resembles the scent of lemon. The strap like leaves are 1.25-2.5cm wide, 90cm long and have gracefully drooping tips. Cymbopogon belongs to the family Poaceae and the major species of commercial importance are *Cymbopogon flexuosus*,(DC.) Stapf. which is known as East Indian lemongrass and *C. citratus* (DC. ex Nees) Stapf. which is known as West Indian lemongrass. Both species are considered to be native of India. *C. flexuosus* is also known as Cochin or Malabar grass. Lemongrass is commercially cultivated in India, Guatemala, China, Paraguay, England, Sri Lanka, Indo-China, Africa, Central America and South America. It requires a temperature regime of 18- 38^0C and a rainfall of 700- 4100 mm. *C. flexuosus* grows well in soils with a pH of 5-6 while *C.citratus* can tolerate a wider pH ranging from 4.3 to 8.4. Lemongrass oil extracted from the plant has wide applications in food, perfume, medicine, soaps, detergents, insecticides, preservatives, etc. It has also been found to be effective in destroying cancer cells without affecting normal cells by virtue of its citral content. Stems and leaves are used for cooking in Surinam while Tom Yum Goon soup served in Thai restaurants contains lemongrass leaf base that floats in the soup. Lemon grass oil is considered as Kerala's own product and it used to be exported under the trade name Cochin oil.

MATERIALS AND METHODS

The experiment was carried out at the Field Research Centre of the Institute situated at Velupadam in Thrissur district. The land is undulating with moderate to steep slopes. Runoff plots were laid out in an area with around 20^{o} slope that has a history of plantation activity. The area has been planted recently with mahogany (*Swietenia macrophylla* King) at 3m x 3m spacing. The soil is fairly deep but degraded due to plantation activities in the past. The top soil has been eroded away exposing the subsoil in many places and the process of laterisation has been initiated in a few localities. Details of soil properties are given in Table 1. The area enjoys humid tropical climate with 2500-3000 mm rainfall received during south west and north east monsoons. Most of the rain falls during the SW monsoon of June – August. The rainfall is of high intensity and kinetic energy and hence, capable of detaching the soil particles and also transporting them down the slope once the soil gets saturated and the infiltration gets slowed down. Runoff plots were established at this site and these plots of size 12m along the slope and 3m across the slope were separated by G.I. sheets of 25cm width which were inserted 15cm deep into the soil along the plot boundaries to separate the plots and prevent water from one plot entering the neighbouring plot. The bottom boundary wall was provided with 15 slots of 10cm vertical and 2cm cross sections that were equally spaced. Out of these 15 slots, 3 were provided with spouts (10x2x20cm) made of G.I. sheet itself to deliver runoff to the collection cisterns kept in trenches kept downslope. Water that flows out through the rest of the 12 slots were diverted out. Thus only 1/5th of the runoff was collected in the cisterns. The runoff collection area on the lower part of the plots was roofed with thatched coconut fronds to avoid direct rainfall. Three replications were provided for each of the species as also for control. Thus there were 15 runoff plots in series on a uniform slope with similar soil and vegetation cover.

Fig. 1 Runoff plots in the initial stages

Fig. 2. Gregarious growth of planted grass in the runoff plots

Slips of *Vetiveria zizanioides*, *Cymbopogon flexuosus* and *Cymbopogon albescens* were planted along the contour in randomly selected plots. These were planted in strips with 3 rows, each row spaced at 20cm. The slips in each row were also spaced at 20cm. The grass strips were spaced at 100cm. Watering had to be provided in summer during the establishment phase. Casualties had to be replanted in the initial stages to ensure stock. The area was protected with nylon net all around to a height of about 2m to protect the plots from deer and wild boar.

Fig.3. The process of runoff collection through multislot divisors

Runoff water was partitioned through multislot divisors. Three of the spouts leading from the slots were diverted to the collection cisterns kept down slope. Water coming in through the rest of the 12 slots were allowed to run off through the GI channel provided for the purpose. The amount of water collected in the cisterns was measured daily and recorded. Samples of 5ℓ from each cistern were collected after thorough mixing. A small quantity of alum solution was added and kept overnight for sedimentation. The sediment was then transferred to petridishes, oven dried at 105^{o} for 48 hours, allowed to cool and weighed. Data on suspended sediment load was processed and analysed.

Fig. 4. Sediment sample collection

Vetiver and the two species of lemongrass were also planted separately in blocks for destructive sampling and estimation of shoot and root production. Biomass production was estimated when the plants were 24 months old. Roots were excavated by digging trenches around the clumps and carefully separating the roots from the soil causing minimum breakage of roots. Number of roots and length of roots as well as number of tillers and length of tillers in a clump were estimated. Dry matter yield of each species was estimated by taking fresh weight of shoot and roots separately and oven drying samples at 70^{o} C for 48 hours.

Soil samples to a depth of 60cm were collected from the runoff plot area before starting the experiment and analysed for various properties following standard procedures. Soil samples to the same depth were also taken from blocks established for biomass estimation and analysed for organic carbon and aggregate stability to understand the positive influence, if any, of these species on the soil health. Big clods were taken to estimate aggregate stability by wet sieving.

Fig. 5. Root Excavation

Soil texture was determined by hydrometer method, bulk density by core sampling, particle density by standard flask method, water holding capacity by saturation and drainage of unsieved soil, porosity by calculation Po=(1- BD/PD)x100, pH in 1:2.5 soil : water suspension, exchange acidity by 0.5N barium acetate method, exchangeable bases by 0.1N HCl method and organic carbon by Walkley and Black(1934) method. Aggregate fractions were determined by wet sieving using a Yoder type sieve with a set of sieves of size BSS 4,9,16 and 25. Mean weight diameter (MWD) an index of aggregate stability was calculated using the formula $MWD = \sum_{i=1}^{n} x_i w_i$ where x_i = mean diameter of particular size class and w_i = weight in that range as a fraction of total sample weight.

The soil formed from charnockites which are crystalline, dark colored granulitic rocks containing hypersthene, a rhombic pyroxene are grouped under ferralsols / ultisols. These soils are deeply weathered, well drained, yellowish red/ reddish yellow in colour and almost uniform down the profile except for the surface layers that are dark due to the presence of organic carbon. They are rich in sesquioxide and poor in silica and bases. Thus they are moderately acidic, medium in organic carbon and have low exchange capacity. These soils, though poor in crystalline clays are coarse textured, well drained and amenable to organic inputs which prompt good aggregation, water holding capacity and thus encourage luxurious plant growth. The properties of soil at the experimental site is given in Table1 below.

It can be seen from the Table 1 that the surface soil (0-20cm) had a coarse texture with 85% sand, 10% silt and 5% clay. Bulk density was 1.28 gcm^{-3}, porosity 42 % and water holding capacity was 22 percent. The soil was moderately acidic (pH 5.1) and with moderate organic carbon of 1.2 percent. Exchange acidity and exchangeable bases were 7 and 8 me%, respectively. There was not much variation in properties down the profile

Table 1. Soil properties at the experimental site

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	PD gcm^{-3}	BD gcm^{-3}	Porosity (%)	WHC (%)	pH	OC (%)	EA me%	EB me %
0-20	85	10	5	2.2	1.28	42	22	5.1	1.2	7	8
20-40	82	10	8	2.2	1.34	40	24	5.0	0.8	8	7
40-60	82	10	8	2.2	1.34	40	24	5.2	0.3	8	7

PD = Particle Density; BD = Bulk Density; WHC = Water Holding Capacity;
OC = Organic Carbon; EA = Exchange Acidity; EB = Exchangeable Bases

except that there was an increase in bulk density and sharp decline in organic carbon content. Lower bulk density in the surface horizon is caused by the higher organic carbon content and the activity of roots and other soil flora and fauna that loosen the soil on the one hand and also promote soil aggregation by pressing and cementing soil particles. Better aggregation results in lower bulk density and higher porosity.

RESULTS AND DISCUSSION

The results obtained from the experiment are presented below under the major heads- growth and productivity, efficacy in reducing runoff and soil loss and impact on soil organic carbon and aggregate stability of the three species, namely *Cymbopogon flexuosus, Cymbopogon albescens* and *Vetiveria zizanioides.*

Growth and Productivity

C. flexuosus, C. albescens and *V. zizanioides*, raised in blocks to study their growth patterns were assessed for their growth. Growth attributes such as number of tillers and roots, length of shoot and root and biomass production are presented in Table 2. *Vetiveria zizanioides* produced almost the double number of tillers as that of *C. flexuosus* and *C.albescens*. There was significant difference between the two species in their growth pattern. *C.flexuosus* had greater number of tillers and roots. Shoot length and shoot biomass were also more in the case of *C.flexuosus* as compared to *C.albescens* but root biomass was slightly more in *C.albescens*. These differences were slight and not significant.

Table 2. Growth attributes of lemon grass and vetiver

Growth attribute	Species		
	C. flexuosus	*C.albescens*	*V.zizanioides*
No. of tillers	43±7	37±7	72±16
No. of roots	585±115	540±117	655±120
Shoot length (cm)	190±32	180±34	162±23
Shoot biomass (g)	1340±524	1042±505	1320±547
Root length (cm)	134±40	132±38	144±47
Root biomass (g)	240±57	245±58	325±65
Root : Shoot ratio	0.26±0.14	0.31±0.15	0.31±0.14

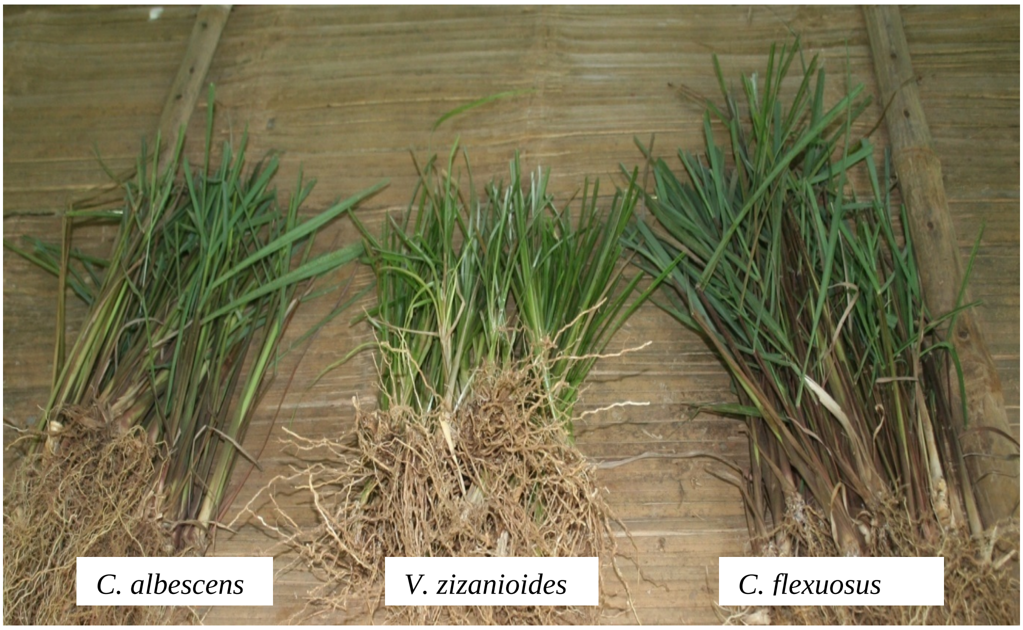

Fig. 6. Initial stages of growth of the three species

There was not much difference between the species in the production of roots. *C. flexuosus* produced 585 roots, *C. albescens* produced 540 roots and *V. zizanioides* produced 655 roots. Both the lemon grass species were similar in shoot length. *C. flexuosus* was 190cm while *C. albescens* was 180cm in height. *V. zizanioides* was shorter. The vetiver clumps recorded an average of 162cm in height. Root length followed an opposite pattern. *V. zizanioides* had longer roots as compared to *C. flexuosus* and *C. albescens*.

Fig. 7. *V. zizanioids* Fig. 8. *C. flexuosus*

Thus, it was seen that vetiver had more number of tillers and longer roots but was shorter compared to the lemon grass species. Number of roots did not vary much between species. Biomass production of shoot was not significantly different between *V. zizanioides* and *C. flexuosus* but *C.albescens* produced lesser shoot biomass compared to these two species. *V. zizanioides* produced more root biomass than both the species of lemongrass; there was not much difference between the lemongrass species in root yield.

Root: shoot ratio was less in the case of *C. flexuosus* (0.26) compared to *C. albescens* (0.316). There was not much difference between the two species in this respect. This does not mean that root length or root biomass of *C. flexuosus* was less than that of *C.albescens*. The ratio was lower because shoot biomass of *C. flexuosus* was comparatively more. *Vetiveria zizanioides* definitely had greater root length and biomass.

Root and shoot biomass are maintained by plants within a certain balance that is characteristic of each species under normal conditions. This pattern is affected under stress, when roots proliferate more to support and maintain the above ground growth. Thus species that respond better under stress will have greater root:shoot ratio. *C. flexuosus* was less efficient in this respect compared to *C.albescens and V. zizanioides*. At the same time, it is interesting to note that *C. flexuosus* had almost the same root length and root biomass as the others and it could produce greater shoot length and biomass. It seems *C. flexuosus* was able to support shoot growth better with the same root biomass. Its roots were finer than the other two species which is seen reflected in the lower root biomass though number of roots and root length were midway between that of *V. zizanioides and C. albescens*. Roots of *V. zizanioides* were much thicker and stronger than both the lemongrass species indicating its superiority in anchoring soil mass where chances of slippage are present. On the other hand, fineness of roots of the lemongrass species facilitates greater penetration through smaller pores; any root can only enter pores that are equal to or bigger than its soft root tip. After entering the pores, roots can exert huge pressure through expansion of cells, pressing soil particles and encouraging adhesion and formation of aggregates. Thus, lemongrass species can penetrate more soil volume compared to vetiver especially in compacted, degraded soil.

Efficacy of lemon grass in reducing runoff

It can be seen from Table 3 that both the lemon grass species and vetiver could reduce runoff significantly as compared with the control. But there was no significant difference between the lemongrass species, *C.flexuosus* and *C.albescens* in this respect. *V. zizanioides* was more efficient than both the lemon grass species in reducing runoff except in the month of October when all the three species were similar. There was no runoff during November and December and no rain during January – May period. Run off was found to be 84.8mm from *C. flexuosus* plots while it was 111.2mm from *C.albescens* plots and 43.9mm from *V.zizanioides* plots in the month of June 2009. Control plots lost 278mm during the same month. Pattern did not vary much between the three locations. The corresponding runoff in the month of July with the higest rainfall was 360mm from

C. flexuosus plots, 326mm from *C.albescens* plots, 300mm from *V.zizanioides* plots while control plots lost about 900mm during this month.

Table 3. Total rainfall and runoff from plots in 2009

Month	Total Rainfall (mm)	Runoff (mm)			
		C.flexuosus	*C.albescens*	*V. zizanioides*	Control
Jan	-	-	-	-	-
Feb	-	-	-	-	-
Mar	-	-	-	-	-
Apr	-	-	-	-	-
May	-	-	-	-	-
Jun	597.2	84.8^{b}± 11	111.2^{b}± 12	43.9^{a}± 5	278.1^{c}± 35
Jul	1096.2	360.0^{b}±44	326.3^{b}± 36	299.8^{b}±35	899.0^{c}± 108
Aug	511.6	134.8^{b}±15	134.8^{b}± 15	87.9^{a}± 10	269.6^{c}± 31
Sep	323.4	51.5^{b}± 5	61.5^{b}± 6	48.0^{b}± 5	170.1^{c}± 18
Oct	57. 8	30.4^{a}± 3	35.9^{a}± 3	27.2^{a}± 2	38.7^{b}± 4
Nov	127.4	-	-	-	-
Dec	23.6	-	-	-	-

Dissimilar superscript indicates significant difference

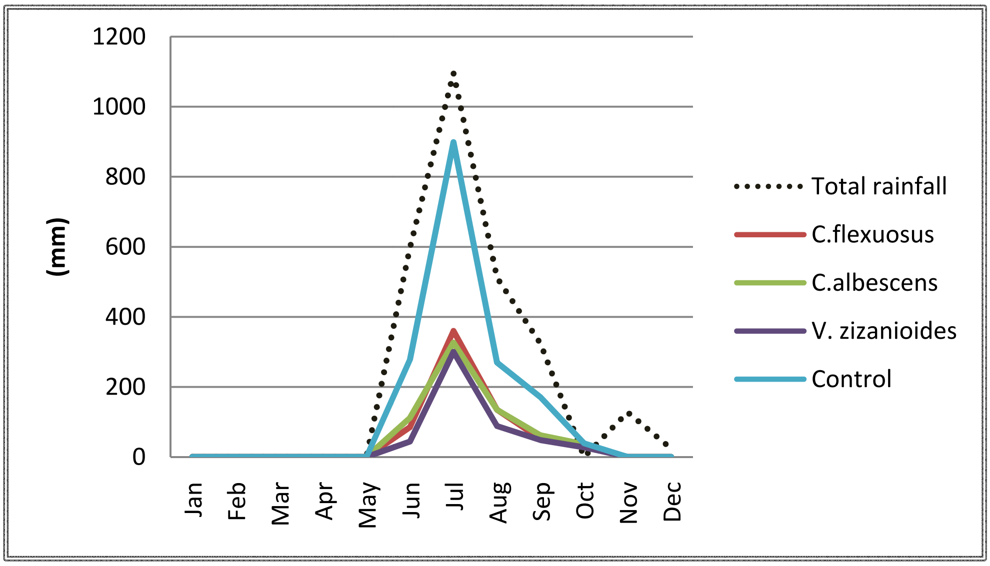

Fig.9. Rainfall and runoff pattern in 2009

It can be seen from Table 4 that runoff coefficient in June with 597.2mm rain was 0.14 and 0.19 for *C. flexuosus* and *C. albescens* and 0.07 for *V. zizanioides* plots while the control plots recorded a value of 0.47. This means that 47 percent of the rain ran off the control plots while only 14 %, 19% and 7% runoff occurred from *C. flexuosus, C. albescens* and *V. zizanioides* plots.

Table 4. Runoff coefficient in 2009 in the three different plots

Month	Runoff coefficient			
	C.flexuosus	*C.albescens*	*Vetiveria zizanioides*	Control
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	0.1418	0.19	0.07	0.47
Jul	0.328	0.3	0.27	0.82
Aug	0.2634	0.26	0.17	0.53
Sep	0.1595	0.19	0.15	0.53
Oct	0.5259	0.62	0.47	0.67
Nov	-	-	-	-
Dec	-	-	-	-

In July, with maximum rainfall of 1096.2mm, both the lemongrass species stood along with vetiver recording runoff coefficients of 0.32 and 0.30 as compared to 0.27 of vetiver. Control plots recorded an all time high value of 0.82. Similar trends were seen during the following months of August and September except that *V. zizanioides* was much more effective with significant difference from *C. flexuosus* and *C. albescens*. In October, all the three species performed almost alike since the rainfall was only 57.8mm. The control plot was always significantly different from the treated plots. When the data is considered on an annual basis this becomes more clear. It can be seen that 73 percent of rain ran off the control plots while only 24 percent each ran off *C. flexuosus* and *C. albescens* and 18 percent from *V. zizanioides* plots. In 2009, both the species of lemongrass have shown their efficacy in controlling runoff which is almost similar to vetiver that is the accepted standard species.

Table 5. Total rainfall and runoff in 2010

2010 Month	Total Rainfall (mm)	Runoff (mm)			
		C.flexuosus	*C.albescens*	*V.zizanioides*	Control
Jan	-	-	-	-	-
Feb	-	-	-	-	-
Mar	-	-	-	-	-
Apr	213.0	$45.6^{b}\pm 4$	$43.6^{b}\pm 7$	$29.1^{a}\pm 4$	$94.7^{c}\pm 10$
May	73.2	$21.8^{b}\pm 3$	$20.8^{b}\pm 3$	$9.5^{a}\pm 2$	$60.3^{c}\pm 7$
Jun	835.4	$41.9^{a}\pm 5$	$209.3^{b}\pm 31$	$45.8^{a}\pm 8$	$351.2^{c}\pm 40$
Jul	564.6	$79.1^{b}\pm 9$	$222.5^{c}\pm 33$	$36.3^{a}\pm 6$	$521.1^{c}\pm 64$
Aug	191.0	$10.1^{b}\pm 2$	$34.5^{c}\pm 5$	$8.3^{a}\pm 1$	$86.6^{c}\pm 11$
Sep	389.4	$12.6^{b}\pm 2$	$62.0^{c}\pm 11$	$7.2^{a}\pm 1$	$94.0^{c}\pm 9$
Oct	638.8	$139.3^{b}\pm 16$	$203.1^{c}\pm 21$	$79.1^{a}\pm 11$	$496.1^{c}\pm 48$
Nov	385.4	$13.2^{b}\pm 1$	$13.3^{b}\pm 1$	$5.8^{a}\pm 1$	$33.0^{c}\pm 2$

Dissimilar superscript indicates significant difference

Runoff from the plots in the year 2010 is depicted in Table 5. There was no rain in the months of January, February, March and December. It can be seen from the Table that the pattern of influence of the two species of lemongrass changed from that exhibited in 2009.

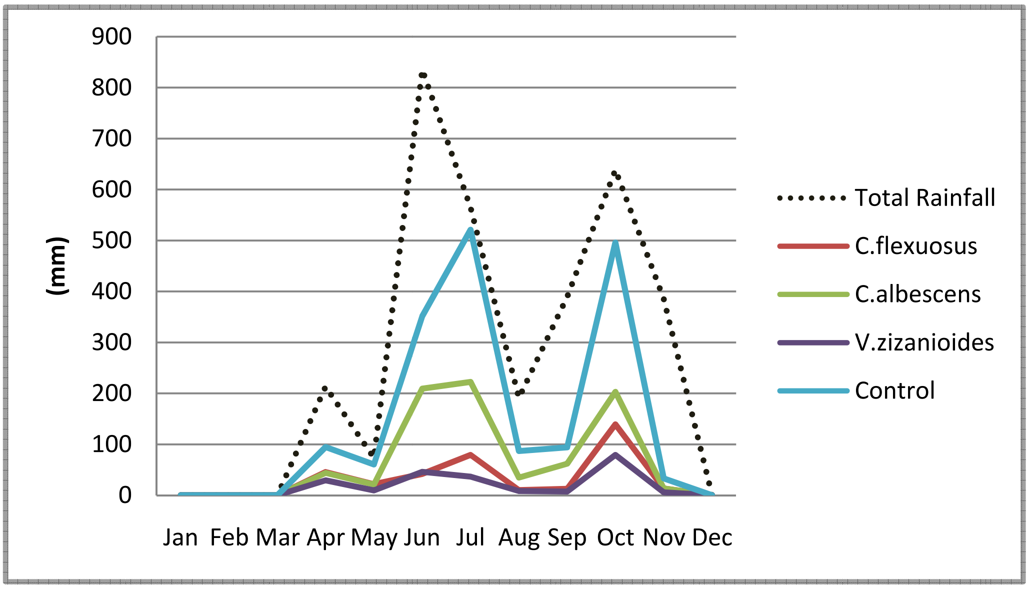

Fig 10. Rainfall and runoff pattern in 2010

C. flexuosus continued to show its efficacy in runoff control in 2010 (Table 6) and remained comparable to *V. zizanioides* while *C. albescens* could not match its previous year's performance. Rainfall also was different in the year. It started in April and the annual total was also more. It was 3290 mm compared to 2737 mm in 2009.

Table 6. Runoff coefficient in 2010 in the three different plots

2010 Month	Runoff Coefficient			
	Cymbopogon flexuoses	*Cymbopogon albescens*	*Vetiveria zizanioides*	Control
January	-	-	-	-
February	-	-	-	-
March	-	-	-	-
April	0.21	0.2	0.14	0.44
May	0.3	0.28	0.13	0.82
June	0.05	0.25	0.05	0.42
July	0.14	0.39	0.06	0.92
August	0.05	0.18	0.04	0.45
September	0.03	0.16	0.02	0.24
October	0.21	0.32	0.12	0.77
November	0.34	0.03	0.02	0.08
December	-	-	-	-

During the summer rains of April, only 20 percent runoff occurred from both the lemon grass plots while double the quantity was lost from control plots. Vetiver permitted only 14 percent of the rain to be lost as runoff. Runoff from lemongrass plots increased to 30 percent in May while control plots lost 82 percent and vetiver 13 percent. There was change in the pattern from June. *C. flexuosus* kept match with *V. zizanioides* and these two species could keep the runoff much low with around 5 percent or less upto September except in July when 14 percent runoff was recorded from *C. flexuosus* plots. Corresponding loss of rainfall from control plots was 42 percent in June, 92 percent in July, 45 percent in August and 24 percent in September. Runoff loss was 25%, 39%, 18% and 16% respectively in June, July, August and September from the *C. albescens* plots. During October with 638.8mm rainfall, there occurred a runoff of 21 percent from *C. flexuosus* plots, 32 percent from *C. albescens* plots and 12 percent from *V. zizanioides* plots. Control plots lost 77 percent of rain as runoff during October. In November, runoff loss was negligible in all the plots including control plots. There was no rain in December. Thus it was seen that *C. flexuosus* was able to reduce runoff almost as effectively as *V. zizanioides* which is considered as one of the most efficient species. This is especially remarkable during the intense rains of south west monsoon when the soil is almost saturated throughout and the runoff encouraged as is seen from the value of 92 percent loss from control plots. When the annual total figures are considered, the overall performance becomes clearer. Runoff coefficient was only 0.11 in the case of *C. flexuosus* which was as good as 0.07 of *V.zizanioides.* Corresponding figures were 0.24 for *C. albescens* and 0.53 for the control.

Efficacy of lemongrass in reducing soil erosion

Lemongrass has been found to conserve soil also as effectively as vetiver in the present study which is being evidenced in the data given in the tables 7 and 8 given below.

Table 7. Soil loss from runoff plots in 2009

2009 Month	Total Rainfall (mm)	Soil loss (kg/ha)			
		C.flexuosus	*C.albescens*	*V. zizanioides*	Control
Jan	-	-	-	-	-
Feb	-	-	-	-	-
Mar	-	-	-	-	-
Apr	-	-	-	-	-
May	-	-	-	-	-
Jun	597.2	191.2^{b}± 23	210.1^{b}± 27	48.2^{a}± 6	525.1^{c}± 54
Jul	1096.2	2825.8^{b}± 242	2966.1^{b}± 324	2342.8^{a}± 300	7415.2^{c}± 627
Aug	511.6	897.1^{b}± 7	954.4^{b}± 87	720.7^{a}± 85	2386.1^{c}± 210
Sep	323.4	422.7^{b}± 38	437.3^{b}± 45	262.8^{a}± 29	6565.0^{c}± 515
Oct	57.8	218.6^{b}± 17	256.7^{b}± 27	142.8^{a}± 15	301.7^{c}± 14
Nov	127.4	-	-	-	-
Dec	23.6	-	-	-	-
Total	2737.2	4555.4	4824.6	3517.3	17193.1

Dissimilar superscript indicates significant difference

Table 8. Percent reduction in soil loss in 2009

Month	Total Rainfall (mm)	Percent reduction in soil loss from control plots		
		C.flexuosus	*C.albescens*	*V.zizanioides*
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	-	-	-	-
May	-	-	-	-
Jun	597.2	63.6	60	91.0
Jul	1096.2	61.9	60	68.4
Aug	511.6	62.4	60	69.8
Sep	323.4	93.6	93	96.0
Oct	57.8	27.6	15	52.7
Nov	127.4	-	-	-
Dec	23.6	-	-	-

Soil loss from runoff plots in the year 2009 depicted in table 7 show that there was no significant difference between the two species of lemongrass, namely *C.flexuosus* and *C. albescens* in conserving soil. But soil loss from plots of both these species were significantly different from control plots. *V.zizanioides* was significantly different from *C.flexuosus* and *C. albescens* in reducing soil loss. These patterns were consistent throughout the months of the year. Annual soil loss from the plots were found to be 4.555 tons/ha from *C.flexuosus* plots, 4.824 tons/ha from *C.albescens* plots, 3.517 tons/ha from *V.zizanioides* plots and 17.193 tons/ha from the control plots. Thus it was seen that in the first year of establishment both the lemongrass species were significantly different from control plots but not between themselves. Vetiver was much more efficient during this period in conserving soil.

It can be seen that *C. flexuosus* and *C. albescens* were almost similar when soil loss was considered except that *C. flexuosus* lost slightly less than *C. albescens*. *V. zizanioides* plots lost lesser quantity than both the lemon grass species. Reduction in soil loss in comparison with control was around 60 percent for both the lemon grass species during the heavy rains of June, July and August. *V.zizanioides* could reduce soil loss by 91 percent in June and around 70 percent each in July and August. In September, *C. flexuosus* could reduce soil loss to the tune of 94 % , *C. albescens* could do so by about 93% and *V. zizanioides* could reduce soil loss by 96% as compared to control. In October, the figures were 28%, 15% and 53% respectively. When the annual total was taken into account, it was seen that 4.556 tons per hectare of soil was lost from *C. flexuosus* plots, 4.826 tons per hectare from *C. albescens* plots, 3.517 tons per hectare from *Vetiveria zizanioides* plots and 17.193 t/ha from control plots. This means that *C. flexuosus* could reduce runoff by 74% and *V. zizanioides* could do so by 79.5 percent. Thus it can be seen that all the three species were efficient in conserving soil though vetiver exhibited its supremacy in conserving soil in the first year itself.

Soil loss from runoff plots in the year 2010 is given in Table 9 below. It can be seen that there was no significant difference between the two species of lemon grass during April-May, but *C.flexuosus* was significantly better than *C.albescens* during the following months of June-October when the rainfall was heavy. It was as good as *V.zizanioides* in conserving soil during this period. All the three grass species were significantly different from control plots in this respect. *C. flexuosus* plots lost 1.427 tons/ha soil, *C.albescens* 3.828 tons/ha, *V.ziznioides* 1.012 tons/ha while control plots lost 5.365 tons/ha soil in the year 2010.

Table 9. Soil loss in 2010 from different plots

Month	Total Rainfall (mm)	Soil loss (kg/ha)			
		C.flexuosus	*C.albescens*	*V.zizanioides*	Control
January	-	-	-	-	-
February	-	-	-	-	-
March	-	-	-	-	-
April	213.0	$142.5^{b}\pm 16$	$152.1^{b}\pm 19$	$88.7^{a}\pm 11$	$257.5^{c}\pm 30$
May	73.2	$43.5^{b}\pm 5$	$73.6^{b}\pm 8$	$6.7^{a}\pm 0.87$	$130.6^{c}\pm 15$
June	835.4	$142.1^{a}\pm 15$	$717.9^{b}\pm 78$	$153.7^{a}\pm 18$	$1048.9^{c}\pm 115$
July	564.6	$342.3^{a}\pm 39$	$1474.4^{b}\pm 162$	$229.8^{a}\pm 25$	$1991.2^{c}\pm 228$
August	191.0	$27.5^{a}\pm 2$	$139.4^{b}\pm 15$	$78.8^{a}\pm 9$	$180.9^{c}\pm 20$
September	389.4	$84.8^{a}\pm 9$	$274.4^{b}\pm 31$	$62.0^{a}\pm 7$	$536.5^{c}\pm 59$
October	638.8	$623.6^{b}\pm 68$	$960.7^{c}\pm 105$	$380.3^{a}\pm 41$	$1099.9^{c}\pm 120$
November	385.4	$21.1^{a}\pm 2$	$36.3^{b}\pm 4$	$12.9^{a}\pm 1$	$120.3^{c}\pm 13$
December	-	-	-	-	-
Total	3290.8	1427.4	3828.8	1012.9	5365.8

Dissimilar superscript indicates significant difference

Soil loss from runoff plots in the year 2010 are shown in Table 9. It can be seen that as the plants grew up and the strips became more compact by closing in of tillers from all sides, the pattern in soil conserving efficiency underwent some changes. *C. flexuosus* started showing up its efficacy more compared to *C. albescens*. In the summer months of April – May with scanty rain, there was only slight difference between the two species. *C. flexuosus* could reduce soil loss by 44.6 and 66.7% respectively in these months while *C. albescens* could do so only to the tune of 40.9 and 43.6 percent. *V. zizanioides* could cause 65.5 and 94.8 percent reduction in these months (Table 10). But during the succeeding rainy season, *C. flexuosus* was found to be as effective as *V. zizanioides* in conserving soil. It can be seen that in almost all the rainy months, percentage reduction in soil loss was more than 80% in the case of *C. flexuosus* and *V. zizanioides* except the month of October when the values dipped to 43.3% and 65.4% respectively. *C. albescens* was less efficient throughout with values around 23 to 49 percent during June – September and 12.6% and 69% in October and November respectively. Thus it was seen that *C. flexuosus* is almost as good as *V. zizanioides* in reducing soil loss.

Table 10. Percent reduction in soil loss in 2010 from different plots

Month	Total Rainfall (mm)	Percent reduction in soil loss		
		C.flexuosus	*C.albescens*	*V.zizanioides*
Jan	-	-	-	-
Feb	-	-	-	-
Mar	-	-	-	-
Apr	213.0	44.6	40.9	65.5
May	73.2	66.7	43.6	94.8
Jun	835.4	86.5	31.5	85.3
Jul	564.6	82.8	25.9	88.4
Aug	191.0	84.8	22.9	56.4
Sep	389.4	84.9	48.8	88.4
Oct	638.8	43.3	12.6	65.4
Nov	385.4	82.4	69.08	89.2
Dec	-	-	-	-

Influence of lemon grass in soil improvement

Improvement in soil physical properties particularly with respect to organic matter enrichment and its manifestation in aggregate formation and stability as well as the overall impact on soil moisture regime is discussed below. This was assessed after 3 years of establishment. It can be seen from the Table 11 that there was appreciable increase in soil organic carbon due to planting of lemon grass.

There was an increase of 11% organic carbon in *C. flexuosus* plots compared to control, 10% in *C.albescens* plots and 10 % in *V. zizanioides* plots in the surface 0-10cm soil layer. The corresponding values were 50% each for all the three species in the 10-20 cm layer. In the next 20-30cm layer, these figures were 66, 55 and 60% respectively. It can also be understood from the table that there was practically no difference between the three species in this respect in any of the soil depth class. The decrease in organic carbon down the soil layers also was similar when the impact of the species is considered.

Table 11. Influence of lemongrass growth on soil organic carbon

Soil depth	Organic carbon content (%)			
	C.flexuosus	*C.albescens*	*V.zizanioides*	Control
0-10	1.34±0.30	1.32±0.32	1.32±0.32	1.20±0.36
10-20	0.82±0.14	0.82±0.12	0.80±0.13	0.53±0.14
20-30	0.75±0.12	0.70±0.12	0.74±0.12	0.45±0.12

Growth of lemon grass was shown to exert greater influence on soil aggregate formation and its stability than its impact on soil organic carbon content. It can be seen from Table 11 that in the 0-10cm layer, 69% of aggregates fell in the bigger clod size of 4.76 – 6 mm in the case of C. *flexuosus.* The corresponding values were 64 and 67 % for *C. albescens* and *V. zizanioides.* Control plots had only half the quantity (31%) of larger aggregates. When the lower layer of 10-20cm was considered, the corresponding values of bigger aggregates were 31% in C. *flexuosus* plots, 26% in *C. albescens* and22% in V. *zizanoides* plots. Control plots had 20% aggregates in the 4.76 – 6.00mm size category.

Table 12. Influence of lemongrass growth on aggregate formation and stability

Soil layer (cm)	Species	Aggregates in different size class (%)				MWD
		0.21-1mm	1-2mm	2-4.76mm	4.76-6mm	
0-10	C.flexuosus	0.40	1.36	4.30	69.0	3.88
	C. albescens	0.37	1.24	4.50	64.25	3.63
	V. zizanioides	0.40	1.40	5.24	67.50	3.83
	Control	3.18	12.43	25.40	30.63	2.71
10-20	C.flexuosus	2.65	12.54	30.16	31.45	2.92
	C. albescens	2.06	13.65	22.36	26.52	2.40
	V. zizanioides	3.65	15.23	24.52	22.43	2.29
	Control	2.42	13.56	22.67	20.00	2.06

MWD=Mean Weight Diameter

There was not much difference between the species in the other aggregate size classes of 2-4.76mm, 1-2mm and 0.21-1mm at 10-20cm depth. The values were 30.16, 22.36, 24.52 and 22.67 % respectively in the 2-4.76mm class for *C. flexuosus, C. albescens, V. zizanioides* and control in the 10-20cm layer of soil.

When the 1-2mm size class was considered, there was around 1-12 % of such aggregates in the 0-10 cm layer and around 12-15 % in 10-20cm soil layer. There was no notable difference between species as also control. In the 0.21- 1mm class, there was very little stable aggregates. Only 2-3 percent of such aggregates were present irrespective of species and soil depth. Thus it can be seen that all the grass species were able to create larger water stable aggregates (4.76-6.00 mm) especially in the 0-10cm layer; the quantity of such aggregates was found to be twice that of control plots. Influence of lemongrass in creating water stable aggregates, especially in the bigger size fraction is thus reflected in the higher mean weight- diameter values, especially in the top 0-10 cm soil layer.

Grass species, by virtue of its characteristic fibrous roots exert great influence on the soil. They penetrate far and deep enmeshing the soil particles, pressing them into closer contacts and encouraging adherence between. Humus, clay and sesquioxides and their hydroxides act on these particles further encouraging formation of water stable aggregates. The differential pressure exerted by these fine roots while sucking soil moisture also help in aggregation.

Benefits from lemongrass cultivation

It was established from the runoff plot experiment that lemongrass, especially *C.flexuosus* was very effective in controlling runoff and soil loss from sloping terrain that was comparable to *V. zizanioides*, the accepted choice species. But lemongrass has an added advantage of generating high income along with conserving soil and water. Vetiver cannot do both together because its economic part is the root which on harvesting will encourage soil erosion.

Cultivation of lemongrass does not incur any appreciable expenditure. It grows well in hilly, degraded areas and is adapted to wide climatic variations. It is cultivated on beds of 100cm width and suitable length across slopes and spaced appropriately depending on the steepness of slope. Seeds are sown in the month of June with about 50kg seeds per hectare where lemongrass is the main crop cultivated for extracting oil. Slips can also be planted at 15cm x10cm spacing. The plant starts yielding after six months. Harvest is possible every three month except during summer. Medicinal and Aromatic Plants Research Station of Kerala Agricultural University at Odakkali, Kerala provides scientific and technical support to growers. Sugandhi (OD.19) variety developed by this station yields 100-120kg oil per hectare containing 80% citral. Lemongrass oil contains citronellal, mircin, geraniol etc., in addition to citral. Aromatic Plant Growers Association, Kochi, also supports farmers in growing such species. Considering a moderate value of Rs. 500 per kg even will ensure an income of Rs. 50,000 per hectare with minimum expenditure.

CONCLUSION

It can be concluded from the present investigation that *C. flexuosus* was very effective in controlling runoff and soil erosion and its performance was seen to match that of *V. zizanioides* in this respect. Runoff could be reduced to 5 percent of the rainfall during the intense south west monsoon season by contour strips of *C. flexuosus*. Loss of soil could also be reduced to 1.4 tons per hectare per year as compared to 5.4 tons per hectare from control plots. Considering the fact that there is no soil disturbance while harvesting the foliage for extracting lemongrass oil, this species deserves to be encouraged for conserving soil and water on slopes.

LITERATURE CITED

Andrade B O del C. and Rodriguez, P O S. 2002. Assessment of efficacy of vegetative barriers as soil conservation systems on steep lands. Bioagro, 14(3): 123-133

Critchley,W.R.S., Somdatpanit, S. and Schwilch, G. 2004. Vegetative barriers: Green belts or A waste of space? Ground and Water Bioengineering for Erosion Control and Slope Stabilization, 355-364

Donjadee, S., Clemente, R.S., Tingsanchali, T. and Chinnarasri,C. 2010. Effects of vertical hedge interval of vetiver grass on erosion on steep agricultural lands. Land Degradation and Development, 21(3): 219-227

Greenfield, J.C.2002. Vetiver grass: An essential grass for the conservation of planet Earth. 241pp.

Madhu,M., Raghunath, B., Tripathi, K.P., Sam, M.J., Chandran, B., Mohanraj, R.and Haldorai, B. 2011. Vegetative barrier with contour staggered trenches for resource conservation in new tea plantations of Nilgiris, India. Indian Journal of Soil Conservation, 39(1): 33-36

Mane, M.S., Mahadkar, U.V.and Thorat, T. N. 2009. Comparative performance of different soil conservation measures on steep slopes of Konkan region of Western Maharashtra. Indian Journal of Soil Conservation, 37(1): 41-44

Mengozzi, B. 2001. Vetiver, a ‘plant engineer’ against land slips and erosion. Mondo Macchina, 10(6): 14-16

Nwachokor, M.A. and Bergsma, E. 2011. A comparative assessment of rain erosion hazard of five land use types and management practices in Mhong Chun Yen Village, Northern Thailand, using soil surface micro topographic features of erosion. American Eurasian Journal of Sustainable Agriculture, 5(3): 378-383

Owino, J.O., Owido, S.F.O. and Chemelil, M.C. 2006. Nutrients in runoff from a clay loam soil protected by narrow grass strips. Soil and Tillage Research, 88(1/2): 116-122

Pawar, P.B. 2004. Vetiver, the grass for watershed management: A case study of submontane and scarcity zones of Nasik District (Maharashtra, India). Ground and Water Bioengineering for Erosion Control and Slope Stabilization, 135-141

Poudel, D.D., Midmore, D.J. and West, L.T.2000. Farmer participatory research to minimize soil erosion on steep land vegetable systems in the Philippines. Agriculture, Ecosystems and Environment, 79 (2/3): 113-127

Rodriguez, O. S. P. 1998. Hedgerows and mulch as soil conservation measures evaluated under field simulated rainfall. Soil Technology, 11(1): 79-93

Rosacia, W.Z. and Rimanda, R.M. 2001. Controlling soil erosion with vetiver grass. Canopy International, 27(1): 3

Savudhi, C.R. and Samantaray, S.K. 2010. Soil conservation structures across drainage line in degraded watersheds for production of organic turmeric in North Eastern Ghats of Orissa. Environment and Ecology, 28(2): 743-745

Shah, P.B., Schreier, H.E. and Nakarmi, G. 2000. Rehabilitation of degraded lands. The People and Resource Dynamics Project: The First Three Years 1996-1999. Proceedings of a workshop held in Baoshan, Yunnan Province, China, March 2-5,1999, p.139-147

Singh, R.S. 2000. Revegetation on coal mine overburden dump (OBD) slopes by aromatic grasses. Journal of Medicinal and Aromatic Plant Sciences, 22(1B): 506-509

Susama Sudhishri, Anchal Dass and Lenka, N.K. 2008. Efficacy of vegetative barriers for rehabilitation of degraded hill slopes in Eastern India. Soil and Tillage Research, 99(1): 98-107

Suyatmo and Howeler, R.H. 2004. Cultural practices for soil erosion control in cassava based cropping systems in Indonesia. Ground and Water Bioengineering for Erosion Control and Slope Stabilization, 291-297

Tscherning,K., Leihner, D.E., Hilger, T.H., Muller Samann, K.M. and El Sharkawy, M.A. 1995. Grass barriers in cassava hill side cultivation: Rooting patterns and root growth dynamics. Field Crops Research, 43(2/3): 131-140

Welle,S., Chantawaramgul, K., Nontananandh, S. and Jantawat,S. 2006. Effectiveness of grass strips as barrier against runoff and soil loss in Jijiga area, northern part of Somali region, Ethiopia. Kasetsart Journal of Natural Sciences, 40(2): 549-558

Xiao Bo., Wan Qing Hai, Wu Ju Ying, Huang Chuan Wei and Yu Ding Fang, 2010. Protective function of narrow grass hedges on soil and water loss on sloping crop lands in northern China. Agriculture, Ecosystems and Environment, 139 (4): 653-664