Continuous cultivation of maize (*Zea mays, l*) under vetiver grass (*Vetiveria nigritana*) strip management: runoff, soil loss, nutrient loss and crop yield.

Babalola O., S. O. Oshunsanya and K. Are
Department of Agronomy, University of Ibadan Nigeria.
E-mail profobabalola@yahoo.com

Abstract

Soil erosion is undoubtedly the biggest problem under continuous cultivation in most tropical environments .Although the use of the vetiver system technology for combating it is simple and cheap ,its use in Nigeria is very limited and in many parts of the world ,its use is recent but now gaining grounds .Experiments were conducted on runoff plots over five growing seasons to determine the efficacy and sustainability of the technology under continuous cultivation. There were two treatments: Vetiver grass strips at surface intervals of 20m (V) and no Vetiver strip (NV) replicated three times on runoff plots long and *40m 3m wide in a randomised complete block design. Runoff and soil loss were consistently and significantly lower under vetiver than non-vetiver plots. Mean values were 124.5 percent and 121.7 percent lower under vetiver plots, respectively .Mean plant heights of maize were consistently and significantly higher than non-Vetiver plots by 24.4 percent. Maize grain yield was significantly different and higher on Vetiver plots than non Vetiver plots only during one out of five growing seasons. Drought stress during the flowering stages of maize obliterated treatment effects in the late seasons. Nevertheless mean grain yield was 49.1 percent higher on Vetiver plots .Fertilizer use efficiency was higher under Vetiver strips. Nutrient loads of eroded sediments on Vetiver plots were consistently lower under Vetiver plots than non-Vetiver plots for N, C,P Ca, Mg and K contents. Vetiver plots kept back a range of 17.2 to 57.3 percent of these nutrients. Zn and Fe contents of the eroded soils were 4.2 to 19.5 percent lower for Vetiver plots. Vetiver plots retained 146 percent more $N0_3$-N than non-vetiver plots*

Introduction

Shifting cultivation, the traditional system of farming, where the land is left to fallow or rest in order to regenerate its fertility, has given way to continuous cultivation necessitated by demographic pressure in most of the humid tropics. The same land pressure has encouraged the cultivation of marginal land, most of which are steep to very steep. All these have resulted in a rapid depletion of soil nutrients, a breakdown of soil structure and have engendered accelerated soil erosion all culminating in a degradation of the soil. The need therefore to mitigate soil degradation which is due largely to soil erosion cannot be overemphasized. Despite the fact that many technologies to combat the problem have been introduced into the agricultural systems, most farmers have not made much conscious and concerted effort to curb erosion on the land. It is inconceivable that many farmers still cultivate up and down the slope. Although technologies such as mulching, conservation tillage, alley cropping, contour farming, and contour bunding have proved effective largely on experimental plots, they have found little adoption by farmers. Many reasons may be responsible for this. One, the level of education of most peasant farmers may be a hindrance. Two, perhaps extension work has not been adequate and meaningful. Three, the farmers may consider some of the technologies as cumbersome, tedious or expensive. There is no doubt that for ease of adoption of any technology, it should be simple, effective, replicable and sustainable. This is the greatest attraction for the introduction and use of vetiver system technology. The efficacy of the technology which is little known in Nigeria and in many African countries is just gaining ground in some parts of the world. The impetus given to this technology by the World Bank dates back to 1993 (National Research Council, 1993, Grimshaw, 1993). Since then, increasing number of reports have demonstrated the efficacy of the technology (Bharad & Bathkal, 1990; Kon and Lim, 1991; Laing & Ruppenthal, 1991; Rao et al, 1991; Yoon, 1993; Grimshaw, 1995; Xia et al, 1996, Hu et al, 1997; LevanDu & Truong, 2003 and Babalola et al, 2003). Most of these studies used the exotic variety, *Vetiveria zizanioides.*

Under continuous cultivation of the land over several growing seasons, how sustainable are these advantages over a no-Vetiver intervention? Fertilizer application is still the commonest practice to boost production of many degraded soils. To what extent does the imposition of vetiver grass strip influence the efficient use of such fertilizer in terms of crop yield? Although it has been shown that vetiver grass has phytoremedial properties (Kong et al, 2003), not much has been reported on the effect of vetiver grass strips on the nutrient status of eroded sediments on runoff plots. Panchaban et al (2003) reported that nitrogen, phosphorus, and potassium concentrations in the soil sediments which were leached into farm ponds were not significantly affected when 0 to 3 rows of vetiver grass were planted. This experiment was carried out, therefore, to examine the effect of vetiver grass strip (*Vetiveria nigritana*) under continuous cultivation on soil loss, runoff, nutrient load of eroded sediments, fertilizer use and the growth and yield of maize.

Materials and method

The experiment was conducted at the Teaching and Research Farm of the University of Ibadan ($7^0 24^1$N $3^0 54^1$E) in Nigeria. The rainfall pattern is bimodal and averages 1230mm per annum. Rainfall peaks occur in June and September and there are 175 total wet days in the year. There are two growing seasons: early season runs from March/April to August and late season, from mid-August to October / November. Annual temperatures range from a high of 31.2^0 C to a low of 21.3^0C. Ibadan has a percentage sunshine that ranges between 16% in August to 59% in February and December with an average of 44%. The soil of the area is an Alfisol of the order Oxic Palueustalf according to the USDA classification. It is classified locally as Iwo series (Smyth and Montgomery, 1962).

There were two treatments imposed on a 6% slope: (1) Vetiver grass strips established at surface intervals of 20m (V) and (2) no-vetiver (NV) on runoff plots measuring 40m long and 3m wide. There were three replications in a randomized complete block design. Vetiver grass strips were planted at 10cm intervals on each strip at the beginning of the rains. A close hedge was established by the end of the first growing season. Maize was planted as test crop at 90cm x 30cm spacing in the early and late growing seasons of 2003, 2004 and early growing season of 2005. Soil and runoff-water collecting devices were installed at the bottom of each plot using two interconnected oil drums, 90cm high and 58cm wide, per plot. The two drums were connected such that an overflow from the first drum ran into the second drum. Runoff and soil loss were initially collected in a trough from which one-third of the runoff was channeled into the drum (Fig 1). Soil losses were estimated from the soil collected in the trough and also from sediments in the runoff water. First, the wet soil in the trough was collected and weighed. The moisture content of the soil was determined gravimetrically using a small sample and the value obtained was used in converting the wet weight of eroded soil to oven dry weights. Also, an aliquot of 100 ml of soil suspension in the drum, after thorough stirring, was oven-dried to determine the dry matter content. This was used to compute the total sediment loss in the runoff. The addition of the latter to the weight of oven dry soil in the trough gave an estimate of the total soil loss from each runoff plot. Volume of runoff water was estimated from the height of water in each drum and later converted to depth (mm) of water. Soil loss and runoff data were collected after each storm throughout the early and late growing seasons of 2003 and 2004 and the early season of 2005. An aliquot of 100ml of soil suspension was also collected for $N0_3$-N analysis. Eroded soils were analyzed for organic carbon, total nitrogen, phosphorus, the base elements (Ca, Mg, K and Na) and the micronutrients (copper, zinc, iron and manganese) using standard methods as described by IITA (1979). In the early season of 2003, 100kgN/ha in form of urea was applied to all the plots. Four tons per hectare of an organomineral fertilizer was applied to all the plots in the early season of 2004 and this was intimately mixed with

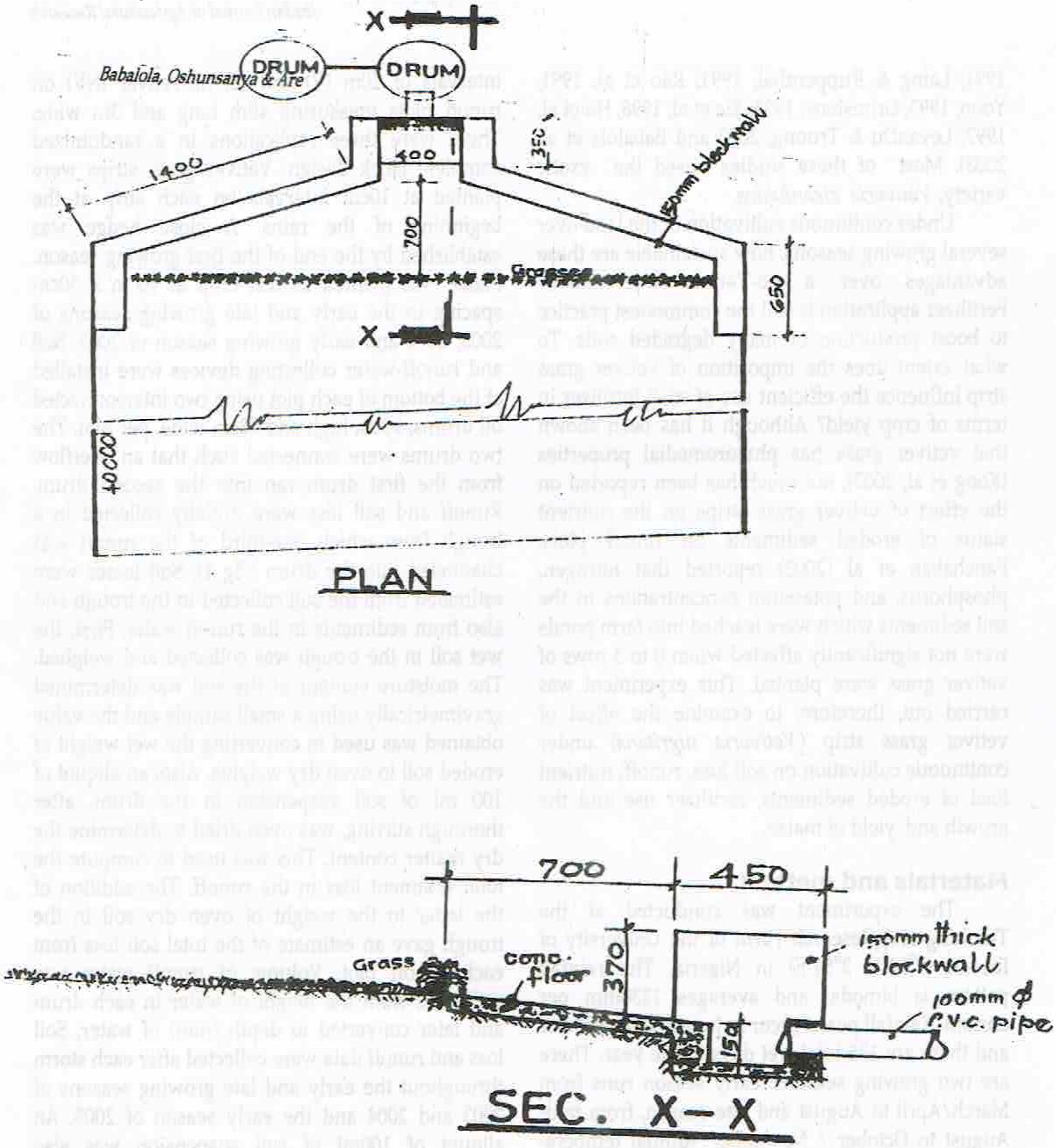

Fig 1 :Sections of the runoff plots and soil and water collecting devices.

the top soil. Maize plant heights were measured at the tasseling stage with a measuring tape. Maize grain yields were determined at maturity. Statistical analysis was carried out using ANOVA.

Results and discussion

The experimental site had been under fallow for about three years before it was put to cultivation in 2001. Table 1 shows some physical properties of the soil on the site. The surface soil is a loamy sand with a sandy to gravelly clay loam in the subsoil. There is generally a layer of angular and subangular quartz gravel layer below the soil surface at the 30-60cm depth. The soil bulk density varied from 1.62g/cm^3 at the surface to 1.80g/cm^3 within the gravelly layer at 30-45cm. Saturated hydraulic conductivity varied from 8.46cmhr^{-1} at the 45-60cm layer to 0.45 cmhr^{-1} at the 15-30cm depth.

Table1: Some physical properties of the soils on the experimental site.

Soil Depth (cm)	Gravel	Sand	Silt	Clay	Bulk Density g/cm^3)	Porosity (%)	Saturated Hydraulic conductivity
	←	g/kg	g/kg →		(g/cm3)	(%)	(cm/hr)
0-15	352.60	816	90	94	1.62	39	4.18
15-30	317.75	776	100	124	1.69	37	0.44
30-45	451.10	656	120	221	1.80	33	0.46
45-60	435.60	546	110	344	1.55	42	8.46
60-90	370.80	536	100	364	1.69	36	0.82

The fertility status is moderately high with a surface soil organic matter varying from 1.5 to 1.8 percent and a soil pH of 6.0. Total nitrogen and available phosphorus are 5.88g/kg and 16.5 mg/kg, respectively. Exchangeable potassium was 5.71 cmol/kg.

Rainfall during the period varied from year to year. Late season rains were erratic and ceased abruptly usually at the tasseling and silking stages of the crop which affected yield adversely.

Runoff

Runoff was consistently lower under vetiver grass plot (V) than no-vetiver (NV) plots. (Fig 2). With the exception of the late season runoff of 2004, the differences between V and NV were significant at the 5% level. The mean runoff over the five growing seasons were 13.24 and 29.72 mm for V and NV plots, respectively. Thus, runoff under the vetiver plot was on the average 44.5 percent of that of the no-vetiver (NV) plots. From year to year the values ranged from 28.7 percent in the early growing season of 2003 to 57.8 percent in the early season of 2005 (Table 3). The differences in runoff rates are associated with a reduction in runoff velocity, the spreading of runoff water and greater infiltration of water into the soil on the vetiver plots. Thus, vetiver grass reduced runoff by 124.5 percent. This beneficial effect is higher than the 57% reported by Rao et al (1991) and the 32.7% reported by Hu et al (1997) and Xia et al (1996).

Soil loss

Soil loss followed the same pattern as runoff throughout the five growing seasons (Fig 2). In all the seasons, soil loss was significantly lower under V than NV plots. The mean soil losses over the five growing seasons were 503.49kg/ha for V plots and 1116.2kg/ha for the NV plots. Soil loss under vetiver plots was, thus, on the average, 45.1 percent of that the no-vetiver plots. From year to year, the values ranged from 28.2 percent for the late season of 2003 to 60.4 percent for the early season of 2005.Vetiver plots on the average have reduced soil loss by 121.7 percent over no-vetiver. This value is slightly outside the range of 63.7 to 92.7% reductions in soil loss reported by Hu et al (1997) and Xia et al (1996).It however confirmed the results of the preliminary work by Babalola et al (2003).

Plant height of maize

With the exception of the early growing season of 2005, vetiver grass strip significantly influenced maize plant height. Vetiver plots had consistently higher plants than no-vetiver plots (Fig 2). The mean of the plant heights over the five growing seasons were 160.85cm and 130.88cm for V and NV plots, respectively. Thus, the mean plant heights under V plots were 22.9 percent higher than plants under NV plots. Over the growing seasons, the corresponding values ranged from 19.1 percent for the early season of 2005 to 44.1 percent for the late season of 2003 (Table 3).Similar results have been reported by Sagare and Meshram (1993) that average leaf area in Vetiver hedgerow treatment was 20.6% and 12.5% greater than across the slope and graded bund cultivation, respectively.

Plant heights were generally higher for the early season crops when fertilizers were added than the late season crops. The percent reduction in plant height between early and late seasons were 41.7 percent and 51.43 percent for V plots and NV plots, respectively in 2003. Similar values in 2004 were 33.2 percent and 48.0 percent for V and NV plots, respectively. These values show that V plots were able to maintain higher yields than NV plots. This demonstrates a higher residual effect of fertilizer application on V plots than NV plots (Table 3).

Table 2: A summary of the mean effect of vetiver grass strip at 20m surface interval (V) and no vetiver strip (NV) on runoff, soil loss, plant height of maize and grain yield over five growing seasons . *Within each growing season ,dissimilar letters signify significance at 5% level .*

Season Year	Treatment	Runoff (mm)	Soil loss (kg/ha)	Plant height (cm)	Grain yield (kg/ha)
Early	V	4.86a	332.67a	165.68a	140.48a
2003	NV	16.69b	650.30b	135.09b	85.67a
Late	V	8.79a	276.34a	96.62a	421.99a
2003	NV	22.22b	978.92b	67.06b	25.00a
Early	V	21.76a	625.57a	226.51a	980.23a
2004	NV	43.79b	1383.09b	187.79b	652.60b
Late	V	12.68a	518.82a	151.24a	108.53a
2004	NV	34.26a	1304.78b	115.14b	51.75a
Early	V	18.12a	764.06a	174.19a	397.84a
2005	NV	31.67b	1264.176b	146.30a	305.29a

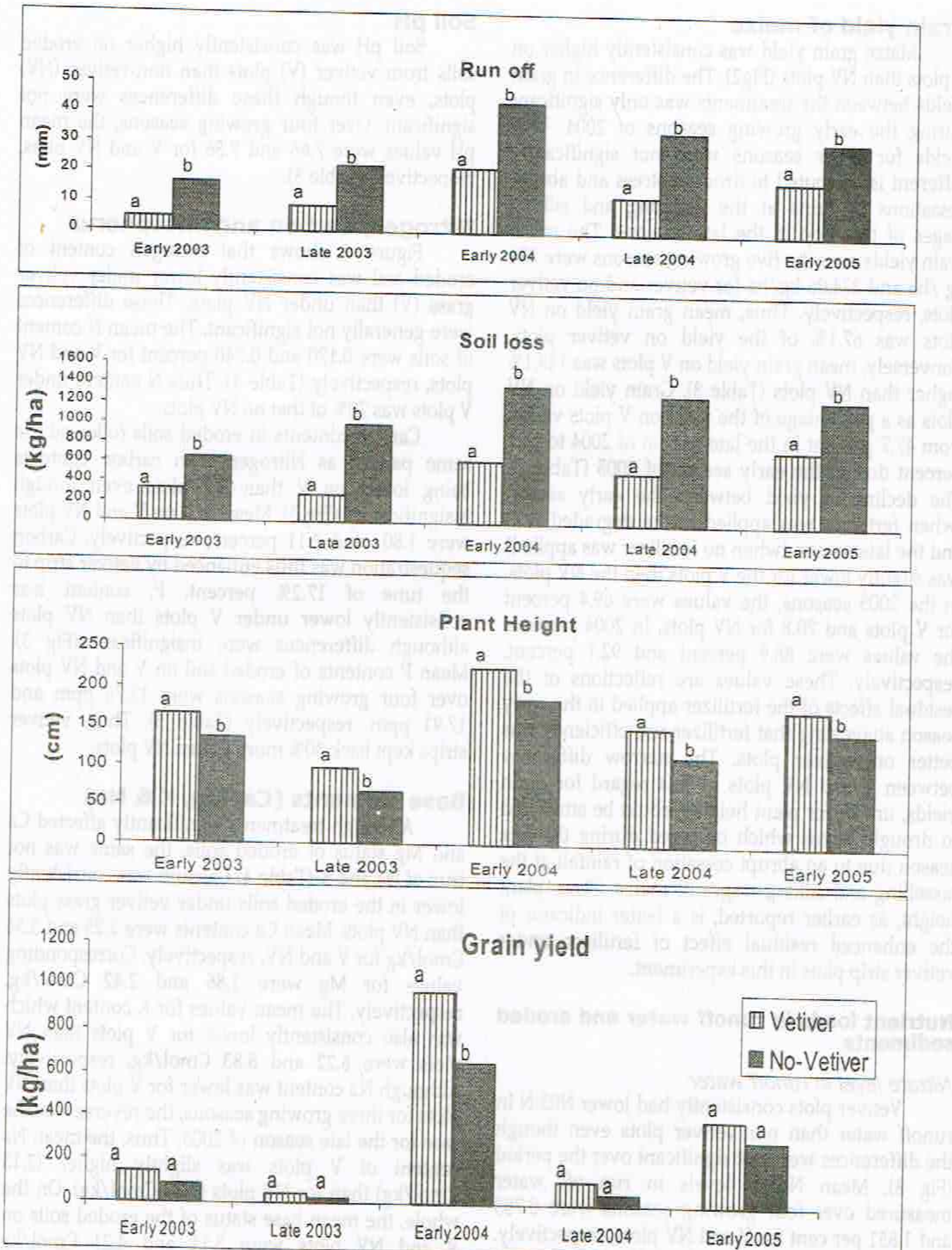

Fig 2: Effect of vetiver grass strip at surface interval of 20m and no vetiver strip on (a) runoff (mm) (b)soil loss (kg/ha) (c) plant height (cm) and (d) grain yield of maize(kg/ha) during five growing seasons .*(Bars having dissimilar letters show significance at the 5% level).*

Grain yield of maize

Maize grain yield was consistently higher on V plots than NV plots (Fig2). The difference in grain yields between the treatments was only significant during the early growing seasons of 2004. That yields for other seasons were not significantly different is attributed to drought stress and abrupt cessations of rains at the tasseling and silking stages of the crop in the late seasons. The mean grain yields over the five growing seasons were 334 kg /ha and 224.06 kg/ha for vetiver and no vetiver plots, respectively. Thus, mean grain yield on NV plots was 67.1% of the yield on vetiver plots. Conversely, mean grain yield on V plots was 149.1% higher than NV plots (Table 3). Grain yield on NV plots as a percentage of the yield on V plots varied from 47.7 percent in the late season of 2004 to 76.7 percent during the early season of 2005 (Table 3). The decline in yield between the early season (when fertilizer was applied to the degraded soil) and the late season (when no fertilizer was applied) was slightly lower for the V plots than the NV plots. In the 2003 seasons, the values were 69.4 percent for V plots and 70.8 for NV plots. In 2004 seasons, the values were 88.9 percent and 92.1 percent, respectively. These values are reflections of the residual effects of the fertilizer applied in the early season suggesting that fertilizer use efficiency was better on vetiver plots. The narrow difference between V and NV plots in this regard for grain yields, unlike for plant heights, could be attributed to drought stress which occurred during the late season due to an abrupt cessation of rainfall at the tasselling and silking stages of maize. Thus, plant height, as earlier reported, is a better indicator of the enhanced residual effect of fertilizer under vetiver strip plots in this experiment.

Nutrient loads in runoff water and eroded sediments

Nitrate level in runoff water

Vetiver plots consistently had lower N03-N in runoff water than non-vetiver plots even though the differences were not significant over the period (Fig 3). Mean No3-N levels in run off water measured over four growing seasons were 0.753 and 1.851 per cent for V and NV plots, respectively. Thus mean N03-N level and on V plot was only 40.1% of the loss on NV plots (Table 3).In other words,Vetiver plots kept back 146% more No3-N on the plot than non-Vetiver plots.

Soil pH

Soil pH was consistently higher on eroded soils from vetiver (V) plots than non-vetiver (NV) plots, even though these differences were not significant. Over four growing seasons, the mean pH values were 7.66 and 7.56 for V and NV plots, respectively (Table 3).

Nitrogen, Carbon and Phosphorus

Figure 3 shows that nitrogen content of eroded soil was consistently lower under vetiver grass (V) than under NV plots. These differences were generally not significant. The mean N content of soils were 0.170 and 0.240 percent for V and NV plots, respectively (Table 4). Thus N content under V plots was 70% of that on NV plots.

Carbon contents in eroded soils followed the same pattern as Nitrogen with carbon contents being lower on V than NV plots even though insignificantly (Fig 3). Mean % C on V and NV plots were 1.80 and 2.11 percent, respectively. Carbon sequestration was thus enhanced by vetiver strip to the tune of 17.2% percent. P. content was consistently lower under V plots than NV plots although differences were insignificant (Fig 3). Mean P contents of eroded soil on V and NV plots over four growing seasons were 13.76 ppm and 17.91 ppm, respectively (Table 5). Thus, vetiver strips kept back 30% more P than NV plots.

Base elements (Ca, Mg, K & Na)

Although treatments significantly affected Ca and Mg status of eroded soils, the same was not true of Na and K (Table 4) Calcium was consistently lower in the eroded soils under vetiver grass plots than NV plots. Mean Ca contents were 2.25 and 3.54 Cmol/kg for V and NV, respectively. Corresponding values for Mg were 1.86 and 2.42 Cmol/kg, respectively. The mean values for K content which was also consistently lower for V plots than NV plots were 6.22 and 8.83 Cmol/kg, respectively. Although Na content was lower for V plots than NV plots for three growing seasons, the reverse was the case for the late season of 2003. Thus, the mean Na content of V plots was slightly higher (2.13 Cmol/kg) than for NV plots (2.03 Cmol/kg). On the whole, the mean base status of the eroded soils on V and NV plots were 3.11 and 4.21 Cmol/kg respectively, a 35.4% difference.

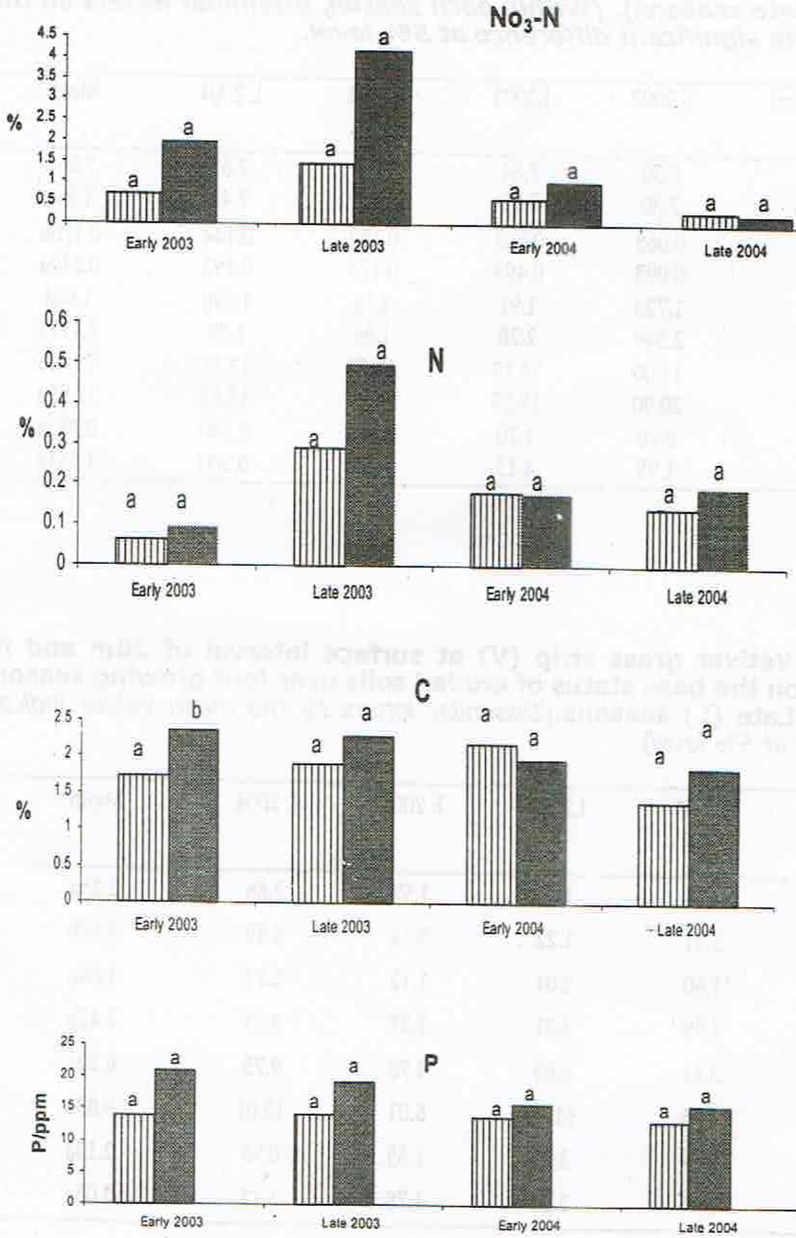

Fig 3: Effect of vetiver grass strip at surface interval of 20m and no vetiver grass on NO_3-N levels in run off water and some nutrient contents (N,C and P) of eroded soils over four growing seasons in 2003 and 2004.*(Bars showing similar letters are not significantly different at the 5% level. Bars with stripes represent vetiver plots and the dark bars represent no-vetiver plot.)*

Table 3: Effect of vetiver grass strip at surface interval of 20m (v) and no vetiver grass strip (NV) on nutrient status of eroded sediments and N03-N levels of runoff water over four growing season in 2003 and 2004. (E stands for early and L for late seasons). ***(Within each season, dissimilar letters on the mean values indicate significant difference at 5% level.***

Chemical status	Treatment	E 2003	L2003	E2004	L 2004	Mean
pH	V	7.50	7.84	7.09	7.62	7.66a
	NV	7.30	7.86	7.61	7.47	7.56a
%N	V	0.065	0.289	0.182	0.144	0.170a
	NV	0.093	0.499	0.175	0.193	0.240a
%C	V	1.723	1.91	2.18	1.390	1.80a
	NV	2.349	2.28	1.96	1.88	2.111a
P	V	14.00	14.15	13.77	13.11	13.76a
(ppm)	NV	20.90	19.25	15.85	15.65	17.91a
%N03-N	V	0.70	1.70	0.603	0.250	0.753a
	NV	1.95	4.15	1.003	0.300	1.851a

Table 4 Effect of Vetiver grass strip (V) at surface interval of 20m and no vetiver strip (NV) on the base status of eroded soils over four growing seasons for early (E) and Late (L) seasons.*(Dissimilar letters by the mean values indicate significant difference at 5% level)*

Nutrient Element	Treatment	E 2003	L2003	E 2004	L 2004	Mean
Ca	V	2.54	1.01	1.57	3.86	2.25a
	NV	3.31	1.22	5.14	4.49	3.54b
Mg	V	1.60	2.01	1.12	2.71	1.86a
	NV	1.79	3.31	1.27	3.31	2.42b
K	V	3.81	6.63	4.70	9.75	6.22a
	NV	4.76	11.54	6.01	13.01	8.83a
Na	V	2.69	3.31	1.55	0.95	2.13a
	NV	2.91	2.24	1.78	1.17	2.03a

Table 5: Effect of vetiver grass strip (V) at surface interval of 20m and no vetiver strip (NV) on the micronutrient status of eroded soils over four growing seasons. (E stands for early and L for late growing seasons). *.(Dissimilar letters by the mean values indicate significant difference at 5% level)*

Nutrient Element	Treatment	E 2003	L 2003	E 2004	L 2004	Mean
Cu	V	27.96	1.75	29.89	10.62	17.56a
	NV	18.98	1.90	18.08	11.10	12.51a
Zn	V	99.08	165.83	58.10	78.41	100.36a
	NV	115.89	161.73	115.31	87.01	119.89
Fe	V	324.86	319.19	100.81	95.84	210.18a
	NV	302.61	345.16	116.97	111.75	219.12a
Mn	V	480.32	250.69	192.05	399.18	330.56a
	NV	493.23	250.46	195.61	205.45	286.19a

Summary and conclusions

Runoff and soil loss were consistently and significantly lower under Vetiver plots than no-Vetiver plots throughout the five growing seasons. Mean runoff and soil loss were 124.5 and 121.7 percent higher on the control plots than the Vetiver plots .Mean plant height was 24.4% higher on Vetiver than non-Vetiver plots .Mean grain yield of maize over the five growing seasons was 49.1% higher on the Vetiver plots.

Fertilizer use efficiency was enhanced by Vetiver grass strip when fertilizer was applied to the degraded soil. This was demonstrated by lower yield decline under Vetiver plots than non Vetiver plots when fertilizer was not added in the late growing seasons .Reduced yield decline was more appreciable in terms of plant height than grain yield because severe moisture stress at the flowering stages obliterated treatment effects on the grain yield in the late seasons.

N, C, P, Ca, Mg and K contents of eroded sediments on Vetiver plots were appreciably and consistently lower under Vetiver plots than non-Vetiver plots. Vetiver plots kept back a range of 17.2 to 57.3 percent of these nutrients. Similarly, the Zn and Fe contents of the eroded soils were 4.2 to 19.5 percent lower for Vetiver plots. Mean NO_3-N load of runoff water was 146 percent higher on non-Vetiver plots than Vetiver plots.

The sustainability and replicabilty of the beneficial effects of vetiver strip has been demonstrated in this study.The reduction of runoff flow velocity by Vetiver strips, increased infiltration of water into the soil behind the Vetiver strip , increased soil nutrient quality as evidenced by that which was lost from the plots, improved fertilizer use efficiency and increased soil moisture storage as demonstrated in the preliminary report (Babalola et al., 2003) are some of the reasons for recommending a wide-scale adoption of the vetiver system technology for soil and water conservation and improved crop yield in the country.

Acknowledgment

The study was supported by funds made available to the senior author Prof. O. Babalola by the First Bank Nig Plc as the occupant of the Professorial Chair in Agriculture and Forestry at the University of Ibadan, Ibadan Nigeria.

References

Babalola O., S.C. Jimba, O. Maduako and A.O. Dada 2003. *Use of vetiver grass strips for soil and water conservation in Nigeria*. In: Truong ,P and Xia , H.P (eds) 2003 . *Proceedings of the Third International conference on Vetiver and Exhibitions: Vetiver and water* .Guangzhou, China, October 2003 .China Agriculture press Beijing pp 293-299.

Bharad, G.M and B.C Bathkal . 1990 .*Role of vetiver grass in soil and moisture conservation.* Proceedings of the Colloquium on the use of vetiver for sediment Control. April 25,1990. Watershed Management Directorate ,Dehra Dun India.

Grimshaw ,R.G.1993. *The role of vetiver grass in sustaining agricultural productivity.* Asia Technical Department ,The World Bank .Washington DC. USA.

Grimshaw, R.G and Helfer Larisa (eds) . 1995 . *Vetiver grass for soil and water conservation ,land rehabilitation and embankment stabilization.* A collection of papers and newsletters compiled by the Vetiver Network .The World Bank .Washington DC.

Hu, J.Y., H.X. Xie, C.W Zhou, 1997. *Research on vetiver for red soil development.* Agroforestry Today 5 (3). ICRISAT, Patancherous, A.P 502234, India.

IITA 1979. Selected methods for soil and plant analysis.IITA Manual series No 1 International Institute of Tropical Agriculture (IITA) Ibadan Nigeria . 70pp.

Kon, K.F and F.W lim 1991. *Vetiver research in Malaysia. Some preliminary results on soil loss ,runoff and yield* .Newsletter of the Vetiver Information Network , ASTAG. World Bank , NO. 5 March 1991.

Kong, X; W, Lin; B . Wang and F. Luo. 2003. *Study on vetiver's purification for wastewater from pig farm* . In Truong ,P and Xia , H.P (eds) Proceedings of the Third International Conference on vetiver and Exhibition :Vetiver and Water. Guangzhou, China Agric Press, Beijing pp 181-185.

Laing , D.R and M. Ruppenthal 1991.Vetiver News Letter.No 8, June 1992 .Asia Technical Department, The World Bank ,Washington D.C.

Le Van Du and P.Truong. 2003. *Vetiver grass system for erosion control on severe acid sulfate soil in southern Vietnam.* Proceedings of the Third International Conference on vetiver and Exhibition .Guangzhou , China pp 284-292.

National Research Council. 1993. *A thin green line against erosion. National Academy Press Washington* DC pp 169.

Panchaban, S , P.C. WInit Phuaphan, and M. Ta-oun 2003. *Use of vetiver for soil erosion control and better water quality in farm ponds in salt affected sandy areas of Northeast ,Thailand.* In Truong ,P., and Xia ,H.P (eds) 2003. Proceedings of the Third International Conference on vetiver and Exhibition: Vetiver and Water . Guangzhou ,China, October 2003.China

Xia,H.P; H.X Ao; and D.Q. He 1996. *The function of vetiver on soil* Agriculture Press, Beijing .

Rao, K.P.C, Cogle A.L and Srivastra K.L 1991 .*Conservation effects of porous and vegetative barriers. amelioration and water and soil conservation.*Tropical Geography 16 (3):265-270.

Sagare, B. N and S.S Meshram 1993. *Evaluation of vetiver hedgerows relative to graded bunds and other vegetative hedgerows.* PVK University, Akola, Maharashtra,India. Vetiver News Letters No. 10 October 1993. Asia technical Department, The World Bank , Washington Dc.

Smyth, A. J and R.F Montgomery 1962. *Soils and Land Use in Central Western Nigeria* .Government Printer ,Ibadan. 265p.