*Original Research Article***Comparative Effects of Vetiver Grass (*Chrysopogon zizanioides*) Strips, Vetiver Mulch and Veticompost on Soil Quality and Erodibility of a Sloping Land**

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Abstract

This study investigates the influence of vetiver grass strips (VGS), vetiver mulch (VGM) and composted vetiver prunes (veticompost) on soil quality of an eroded land in the Institute of Agricultural Research and Training, Ibadan (7° 22' N; 3° 50' E), Nigeria. The treatments were 3-m wide VGS established at 10-m inter-row spacing, VGM imposed at 5 Mg ha⁻¹, veticompost applied at 5 Mg ha⁻¹ and a control (no-vetiver grass). All quality indicators including physical, chemical and biological indices and soil erodibility (*K*) factors were determined between 2008 and 2011. Results show that soil organic matter (SOM) and associated nutrients play a major role in soil quality variation. VGM had the highest impact on soil quality (76.5%) but not significantly different ($P < 0.05$) from veticompost (72.5%). Soil quality ratings were in the order of VGM > veticompost > VGS > control. Significant and positive relationship ($r = 0.92^*$) exist between soil quality ratings and maize yield, with 70% of grain yield variability accounted to the soil quality. *K* factor ranged from 0.013 to 0.030 Mg h MJ⁻¹ mm⁻¹ with the VGM and control plots having the least and highest *K* factors, respectively. Although the soil quality under veticompost is lower than vetiver mulch but the SOM and associated nutrients under veticompost enhanced better soil productivity, and thus accounted for higher crop yields than other treatments.

Keywords: *Chrysopogon zizanioides*, erodibility; vetiver mulch; soil quality; veticompost; vetiver grass strips.

INTRODUCTION

Over-exploitation of soils due to demographic pressure on agricultural land has increased to the point where fallows are rare and farmers have no alternative than to make use of marginal and steep lands for agriculture where nutrient loss is high and the reliance on fertilizer to improve soil fertility is paramount (Are et al., 2011). However, among the land degradation processes soil erosion constitutes a major threat to sustainable use of soil and water resources (Lal, 2001). Erosion influences several soil properties, including topsoil depth, soil organic carbon (SOC) content, nutrient status, soil texture and structure, available water holding capacity (AWC) and water transmission characteristics, all culminate in regulating soil quality and determine crop yield (Kaihura et al., 1999).

Doran and Parkin (1994) defined soil quality as the “capacity of the soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental quality, and promote plant and animal health”. It is a manifestation of the inherent and dynamic properties of the soils (Karlen et al., 1994). However, integrated soil quality indices based on a combination of soil properties provide a better indication of soil quality than individual parameters. Karlen et al. (1994) developed a soil quality index (SQI)

based on four soil functions, namely the ability of the soil to: (1) accommodate water entry, (2) retain and supply water to plants, (3) resist degradation and (4) support plant growth. Each soil function was explained by a set of indicators that include soil physical, chemical and biological properties, such as soil texture, bulk density, infiltration rate, total C and N content, pH, electric conductivity, microbial biomass, etc. All of the above function-based soil quality assessments were developed for use with temperate soils, whereas soil quality research on tropical soils, particularly in erosion-prone land of Nigeria requires investigation.

As the need to reduce nutrient loss in an eroded land and improving soil quality are attracting global interest, several soil conservation measures have been put into trial, of which most are not adoptable due to technicalities involved. In Nigeria and most other tropical soils of sub-humid Africa, considerable number of technologies including contour bund, no-till, terracing, alley-cropping, agro-forestry, crop rotation and mulching have been deployed, depending on localities (Aina, 1989; Babalola et al., 2007). However, the cost, technicality involved, adaptability and effectiveness of the identified technologies limit the adoption of most of them by farmers in Nigeria (Babalola et al., 2007).

Vetiver grass system (VS) is becoming rapidly a global household name in soil conservation. However,

the information on the comparison of the conservation-effectiveness of vetiver grass strips, vetiver mulch and composted vetiver prunes for the reduction of soil erodibility as well as improving soil quality of an erosion-induced degraded land is rare. Thus, an important challenge is to identify appropriate vetiver management system to achieve sustainable agriculture through the building up of soil quality of eroded lands. This will help in improving soil nutrients, reducing soil erodibility, and concomitantly improve the overall health status of the soil under vetiver grass system. This study, therefore, was set out to quantify changes in soil quality of an eroded land as influenced by composted vetiver grass prunes (veticompost), vetiver grass strips and vetiver mulch.

MATERIALS AND METHODS

Site Description and Soil

The research study was conducted on erosion demonstration plot at the Institute of Agricultural Research and Training (IAR&T), Ibadan (7° 22'N; 3° 50'E and 160 m above mean sea level), Nigeria. The area is characterized by a tropical climate marked with wet and dry seasons. The mean annual rainfall recorded for a period of 10 years was 1382 mm (IAR&T, 2010). Rainfall peaks occur mostly in June and September. Annual temperature ranges from 21.3 °C to 31.2 °C. There are two cropping seasons: early (March/April – early August) and late (mid-August – October/November) seasons. The site has a uniform slope of 7% and had been under continuous maize (*Zea mays* L.)

Table 1: Soil physico-chemical properties of the experimental site (0 – 15 cm)

Soil property	Values
Sand (g kg ⁻¹)	786
Silt ((g kg ⁻¹))	90
Clay (g kg ⁻¹)	124
Textural class	Sandy Loam
Bulk density (Mg m ⁻³)	1.42
Total porosity	0.464
Soil strength at 5 cm depth (kPa)	125
Saturated water content (m ³ m ⁻³)	0.430
WSA > 0.250 µm (%)	49.5
MWD (mm)	0.714
pH (1:2.5 soil : water suspension)	6.5
SOC (g C kg ⁻¹ soil)	12.2
Total N (g kg ⁻¹)	1.21
Available (Bray 1) P (mg kg ⁻¹)	7.85
Exch. K (cmol kg ⁻¹)	0.34
Microbial C (mg kg ⁻¹)	11.4
Microbial N (mg kg ⁻¹)	0.11

cultivation for more than 10 years before this intervention study.

The soil of the study site belongs to Alfisol, classified as Typic Kanhaplustalf according to USDA classification, and locally classified as Iwo series (Smyth and Montgomery 1962). The surface soil is sandy loam. Prior to this study, evidence of soil erosion was shown by the presence of rills in some parts of the study site. Details of the physico-chemical properties of the soil are shown in Table 1.

Experimental Setup and Treatments

The trial comprised four treatments: (i) 3-m wide vetiver grass strips (alley) established at surface intervals of 10 m down the slope (VGS), (ii) vetiver grass mulch imposed at 5 Mg ha⁻¹ (dry matter) (VGM), (iii) composted vetiver prunes (veticompost) applied at 5 Mg ha⁻¹ and (iv) a control (no-vetiver grass). The treatments, laid out in a randomized complete block design, were replicated thrice. The field was initially disc ploughed and harrowed in April 2008, and thereafter partitioned into three blocks with each block having four plots. Each plot measured 30 m long and 3 m wide, was uniformly lied on 7% slope. Vetiver strips were established immediately after field preparation in May 2008 by planting the vetiver slips at 0.10 m apart in a 0.15 m deep trench across the 3-m wide plot. The roots of the grass slips were pre-treated with cow tea (cow dung slurry), whereas 150 kg ha⁻¹ of single superphosphate was applied at planting for faster establishment and tillering. Spacing between plots was 0.5 m within each block and 1.0 m between blocks (Fig. 1). Erosion pins were installed in June 2008 at 0.15 m away from the vetiver strips to evaluate soil accumulation. The erosion pin (0.3 m long and 0.005 m thick) was driven vertically into 0.15 m soil depth by hammer, whereas 0.15 m remained outside the soil surface to give a firm stable reference point. For other plots with no vetiver strips (VGM, veticompost and control plots), erosion pins were positioned at every 10 m interval down the slope to measure changes in the soil surface level. The erosion pins remained in the same locations throughout the three-year study period.

After which the vetiver strips had fully established (between 0.4 m and 0.5 m in width) in April 2009, the plots were cropped with maize (*Zea mays* L. var. SUWAN – 1-SR-Y). In each growing season (early 2009, late 2009, early 2010, late 2010 and early 2011), vetiver mulch and composted vetiver grass prunes were imposed each time on selected plots (VGM and veticompost plots, respectively) 3 weeks after maize planting. As part of routine management of the vetiver grass hedges, the grass strips were pruned every 3 months while using them for the preparation of veticompost and for mulching. Veticompost was prepared by composting vetiver grass prunes, which was stabilized

Figure 1. Experimental layout showing the arrangement of the treatments

prior to application to reduce mineralization loss. The constituents of the veticompost were shown in Table 2.

Soil analyses

Soil physical, chemical and biological properties were measured in July 2011 on each replicated plots after three years of continuous cultivation. Soil properties measured were those used for soil quality indicators that are most important factors limiting crop production.

Physical properties

Undisturbed soil cores were taken from soil surface (0 – 0.15 m depth) with cylindrical core sampler (0.05 m in height and 0.05 m diameter). The soil cores were soaked into water overnight to saturate the soil and thereafter weighed at saturation. Water retention characteristics

between saturation and 10 kPa matric potential (–100 cm water) were determined using tension plate apparatus. Pressure was also imposed between 10 and 1500 kPa for the determination of available water capacity (AWC). Bulk density was estimated by dividing the oven-dry mass of the soil by the volume of the soil as described by Grossman and Reinsch (2002). Gravimetric moisture contents (Lowery et al. 1996) at FC and PWP were calculated on dry mass basis. AWC on volume basis was calculated by multiplying the gravimetric moisture content between FC and PWP by the corresponding bulk density, calculated as:

$$AWC = (FC_{\theta} - PWP_{\theta}) \rho_b$$

where θ is the gravimetric moisture content (%) and ρ_b is the bulk density at the required depth in $Mg\ m^{-3}$.

Pore size distribution and total porosity (TP) were calculated using the water retention data and capillary rise equation as described by Flint and Flint (2002). Macropores (pores > 30 μm), taken as drain pores were estimated at 10 kPa matric potential.

Total porosity was estimated as water content at saturation using the following relationship:

$$TP = (M_{sw} - M_{ds})/V_b$$

Where M_{sw} is the mass of soil at saturation, M_{ds} is the mass of dry soil at 105 °C and V_b is the volume of the soil. Particle size distribution of the surface soil was carried out using hydrometer method as described by Gee and Or (2002). Water stable aggregates (WSA) of the soils were determined using a modified Kemper and Rosenau wet sieving method as described by Nimmo and Perkins (2002). Fifty grams (50 g) of air dry soil taken at 0 – 15 cm depth was placed on a set of sieves (5.00, 2.00, 1.00, 0.25 and 0.045 mm) attached to a dipping machine. The set of sieves was cycled through a column

Table 2: Proximate analysis for the veticompost

Nutrient element	Value
Total Nitrogen (%)	6.78
Phosphorus (P_2O_5) (%)	5.34
Potassium (K_2O) (%)	1.56
Sodium (%)	0.53
SO_4 -S (%)	0.17
Organic Carbon (%)	15.44
C/N	2.28
Calcium (%)	4.03
Magnesium (%)	0.63
Iron ($mg\ kg^{-1}$)	5915.0
Zinc ($mg\ kg^{-1}$)	172.1
Copper ($mg\ kg^{-1}$)	30.5
Manganese ($mg\ kg^{-1}$)	304.0

of water for 10 min (30 cycles per min, 4.0 cm stroke length). The percentage of WSA as fraction of the total sample and Mean weight-diameter (MWD), a statistical index of aggregation, were calculated from aggregate size distribution data, after correction had been made for sand fractions by dispersion with sodium hexametaphosphate (HMP). Penetration resistance (PR) was measured using a field penetrometer (Rimik CP20, Agridy Rimik Pty Ltd, Toowoomba, Australia) with a steel cone of 6.3 m² (diameter = 1.28 cm, angle = 30°) inserted into the soil up to 15 cm depth.

Infiltration rates were measured using a double-rings infiltrometer (Reynolds et al. 2002). The inner ring is 30 cm long with a diameter of 30 cm while the outer ring (buffer cylinder) has the same length as the inner ring with a diameter of 50 cm. A constant head of 0.10 m water was maintained in the measuring cylinder in the course of measurements. Grass residues were put on the soil in the inner surfaces of the rings prior to water application to minimize surface disturbance when applying water. The amount of water infiltrated was recorded at 1 min for the first 10 min and then every 5 min for 1 h. In each case, steady-state infiltration was attained within the measurement period.

Chemical properties

Total N was determined using the kjeldahl method (Bremner and Mulvaney 1982), available P was determined as described by Bray and Kurtz (1945) and exchangeable bases (Ca, K, Na, Mg) and Cation exchange capacity (CEC) were determined as described by Thomas (1982). Soil pH was measured in distilled water (1:2.5 soil : water) using pH meter.

Organic matter, N-mineralization and biological properties

Soil organic C (SOC) was determined by loss-on-ignition as described by Cambardella et al. (2001). SOC mineralization rates were determined by incubating 10 g of the soil samples from 0 – 15 cm depth at 25 °C for 28 days. Soil samples were kept at 55% of their field capacity in sealed 1 L jars containing NaOH 0.2 M traps for respired CO₂. Traps were periodically titrated with HCl to determine the C evolved as CO₂ (CO₂ – C). The accumulated CO₂ – C in days 14 and 28 of the incubation (CO₂ – C_{14d} and CO₂ – C_{28d}, respectively) were used for this study. After 28 days of incubation, 2 M KCl extracts (1 g soil:5 ml solution) of the samples were used to determine the amounts of N in the form of ammonium (NH₄–N) and nitrate (NO₃–N) by absorbance measurement (Nelson 1983). The fraction of organic matter corresponding to particulate organic matter (POM) <53 µm sieve size was isolated by dispersion and

sieving of 10 g of air-dried soil, using a method described in Virto et al. (2007).

Soil microbial biomass in the above sieved soil was estimated by the fumigation-extraction (FE) technique (Ross 1990). In the 0.5 M K₂SO₄ extracts (1 g soil: 4 ml solution), organic-C was determined by dichromate oxidation, and soil microbial biomass-C (µg g⁻¹ soil) calculated as:

$$\text{Microbial biomass} - C = \Delta \text{Organic} - C / k_{EC}$$

using a k_{EC} factor of 0.33 (Ross 1990) and where $\Delta \text{Organic} - C$ is the difference inorganic-C content between the fumigated and the unfumigated sample. A ninhydrin assay for biomass α -amino-N and ammonium-N was used to estimate microbial-N (µg g⁻¹ soil) which was calculated as:

$$\text{Microbial biomass-N} = \Delta \text{Ninhydrin reactive-N} / k_{\text{ninhN}}$$

using a k_{ninhN} factor of 0.20 (Joergensen and Brookes 1990) and where $\Delta \text{Ninhydrin reactive-N}$ is the difference in ninhydrin reactive-N content between the fumigated and the unfumigated sample.

For earthworm activity determination, earthworms were sampled by hand sorting from soils taken with a shovel on each plot. The number of earthworms present in the soil sample taken and their fresh weight were recorded immediately after collection.

Erodibility factor

Soil erodibility, a measure of the susceptibility of soil particles to detachment and transport by rainsplash and overland flow, was determined after five growing seasons of continuous cultivation (from October 2008 to July 2011). Data collected on soil physical properties and organic matter content on the soil surface (0 – 10 cm depth) were used in computing erodibility factor, taking into account silt content (for soil containing less than 70% silt), very fine sand content, and other parameters, according to universal soil loss equation (USLE) (Wischmeier and Smith 1978). The mathematical equation is as follows:

$$K = (1.292) [2.1 \times 10^{-6} M^{1.14} (12 - a) + 0.0325 (b - 2) + 0.025 (c - 3)]$$

Where $M = [\% \text{Silt} + \% \text{very fine sand}] \times [100 - \% \text{clay}]$

where K = soil erodibility factor (Mg h MJ⁻¹ mm⁻¹)

a = percentage organic matter

b = soil structure index

c = profile permeability class factor

Factor (1.292) is used for the conversion of K-factor from English units to the metric units.

Growth parameters and the yield of maize

The maize plant heights were measured with measuring tape graduated in centimetre (cm) from the soil surface to

Table 3: Minimum data set (MDS) used for soil processes and quality indicators relating to crop productivity and their relative weights

Soil processes relating to crop productivity	Relative Weight	Soil quality indicators	Relative Weight
Nutrient availability	0.10	Total Nitrogen	0.25
		pH	0.25
		Avail. P	0.25
		K	0.25
Nutrient retention	0.25	Organic matter	0.35
		ECEC	0.35
		AWC	0.30
Root penetration	0.15	Bulk density	0.30
		Total Porosity	0.20
		PR (Soil strength)	0.50
Ability to resist degradation	0.25	Water stable aggregates	0.50
		Soil texture	0.15
		Infiltration capacity	0.35
Soil erodibility	0.15	Organic matter	0.70
		Particle size distribution	0.30
Biotic environment	0.10	Microbial-C	0.35
		Microbial-N	0.35
		Earthworm counts	0.30

the tip of the inner leaves and to the tip of the tassel after tasseling. The mean height of 30 maize stands randomly selected and tagged which spread across each plot was computed as the mean plant height of the maize in a plot. The stem girth was measured using vernier calliper to measure the circumference of the lower ends (about 5 cm above soil surface) of maize plants. The same plant stands for plant height were used for the measurement of stem girth. Both plant height and stem girth were measured at 4, 6 and 8 weeks after planting (WAP) in each planting season. Maize yield was determined at harvest by taking the weights of maize stovers, dehusked cobs, shelled-grains and air-dried shelled-grains (at 15% moisture content – equivalent to the moisture content of grains sold in market). Harvesting of maize involved cutting of maize stands at soil surface and weighed for the determination of stover yield.

Soil quality assessment

The soil quality indicators and their processes were integrated into quality index value (Table 3). All indicators affecting a particular process were grouped together, given scores and relative weights based on their importance. The scores for the indicators were multiplied by appropriate weights, and their summation provides soil quality rating for the process. The soil quality (s.q.) rating of each process was also multiplied by appropriate weight, producing a matrix that was summed to provide soil quality index for crop production using a model primarily developed by Karlen and Stott (1994). The model was modified as follows:

$$SQI = \sum_{e=1}^n WS = qt.nav \times wt + wt.nr \times wt + qt.rp \times wt + qt.rd \times wt + qt.be \times wt$$

where SQI is the soil quality index for crop production, W is the total weighted average of the soil quality factors, S is the relative scores of the factors, qt.nav is the soil quality rating for nutrient availability process, qt.nr is the soil quality rating for nutrient retention process, qt.rp is the soil quality rating for root penetration process, qt.rd is the soil quality rating for resisting degradation process, qt.be is the soil quality rating for biotic environment process and wt is the relative weight.

Data analyses

To evaluate the effects of vetiver systems on the soil quality factors, the quality processes were scored while analysis of variance (ANOVA) was performed on the score variables using statistical application software (SAS 2002). Factors that differed among treatments were separated using Least Significance Difference ($P < 0.05$) unless otherwise stated. The relationship between soil quality versus maize grain yield was evaluated using Pearson correlation analysis to determine whether there is significant correlation between the pair.

RESULTS AND DISCUSSION

Chemical quality indicators

Table 4 shows the chemical quality indicators as affected by vetiver grass strips, vetiver mulch and

Table 4: Chemical quality indicators as affected by vetiver grass strip (VGS), vetiver mulch (VGM) and veticompost

Treatments	Total N (g kg ⁻¹)	Org. C (g kg ⁻¹)	pH in H ₂ O	Av. P (mg kg ⁻¹)	Ca	Mg	K (cmol kg ⁻¹)	Na	H+	CEC	Zn (mg kg ⁻¹)	Mn (mg kg ⁻¹)
VGS	1.33b	12.10b	6.17ns	7.11a	1.19b	0.89b	0.21ab	0.43ab	0.07ns	2.79b	35.00ns	31.90ns
VGM	1.97a	18.53a	6.33	8.44a	1.52a	1.14a	0.24a	0.46a	0.08	3.44a	39.73	34.17
Veticompost	1.90a	17.63a	6.30	8.52a	1.56a	1.10a	0.26a	0.47a	0.08	3.46a	37.37	30.97
Control	1.10b	9.57b	6.03	5.95b	0.79c	0.64c	0.18b	0.38b	0.07	2.06c	33.23	38.90

ns means no significant difference between treatments within a column; Means followed by the different letters in a column are significantly different ($P < 0.05$)

veticompost. Following the application of 5 Mg ha⁻¹ of mulch and veticompost, the concentration of SOC, N, P, CEC in the soil under VGM and veticompost plots were improved, and they were significantly higher than those under VGS and control plots. Although the chemical quality indicators were better influenced by VGS than the control plot except CEC, there were no significant differences between the two treatments. The manurial capability of vetiver mulch and veticompost in improving soil chemical quality was reflected in the higher concentration of C, N and CEC in the two plots vis-à-vis vetiver strips and control plots. There were, however, no consistent trends in the nutrient concentrations with regard to soil reaction (pH) and micronutrients, while no significant differences were observed in their mean values (Table 4).

The soil organic matter (SOM) influenced virtually all the soil quality indices. A significant reduction in chemical quality indices (SOC, N, P and CEC) of the control plot was because of lack of shield that would have kept erosion on check, and consequently reduces its impact on the soil. However, the increase in SOC, total N and CEC following application of VGM and veticompost could be attributed to an increase in belowground biomass production, which was low on VGS and control plots (Manna et al., 2007).

Soil physical and biological qualities and erodibility factor

The influence of vetiver systems was shown on soil physical quality (Table 5). The size and strength of

aggregates as shown by MWD and WSA, respectively, gave a clear indication of the potentials of vetiver systems in re-building soil structural quality after initial degradation by erosion. Although, macroaggregation estimated by WSA > 250 µm was poorly formed on VGS plots, the surface soil was however better structured with the WSA > 250 µm greater than the control plot by as much as 30.6%. The contribution of organic matter in VGM and veticompost was reflected in the concentration of macroaggregation as VGM and veticompost were significantly higher ($P < 0.01$) than the control by 60.1% and 60.2%, respectively. The aggregate size distribution, expressed as MWD (Table 5), followed similar trend in WSA > 250 µm. Although the MWD under VGS plot was not significantly higher than the control plot, it was however greater than the control by 34%. The increase in soil macroaggregation under VGM and veticompost was probably the reflection of the SOM content. This is often cited as a major cause of improvements in soil tilt and structural quality (Manna et al., 2007; Mulumba and Lal, 2008). Since the addition of mulch and veticompost amounts to increase in soil organic carbon, it is not surprising that there was an increase in soil microbial activity. Few studies have reported increased microbial-C and microbial-N following addition of compost or mulch, which of course result in positive effect on both soil aggregation and macroporosity (McGill et al., 1986). This often translates to better soil structure and improved water infiltration. In this study however, the variation in aggregate size distribution due to vetiver technologies used reflected the contribution of increased soil organic matter in improving water stable aggregates.

Table 5: Physical and biological quality indicators and erodibility factor as affected by vetiver grass strip (VGS), vetiver mulch (VGM) and Veticompost

Treatments	WSA > 250 µm (%)	MWD (mm)	Bulk density (Mg m ⁻³)	Porosity (m ³ m ⁻³)	PR (kPa)	Microbial C (mg kg ⁻¹)	Microbial N (mg kg ⁻¹)	K factor (Mg h MJ ⁻¹ mm ⁻¹)	Soil loss (kg m ⁻²)
VGS	59.67ab	0.916ab	1.38a	0.479a	155.5a	14.60bc	0.14bc	0.018bc	0.028c
VGM	73.20a	1.112a	1.15b	0.566b	115.0b	19.70a	0.21a	0.013c	0.040b
Veticompost	73.23a	1.154a	1.18b	0.553b	125.5b	17.77ab	0.18ab	0.015bc	0.045b
Control	45.70b	0.683b	1.45a	0.452a	165.0a	11.13c	0.10c	0.030a	0.080a

ns means no significant difference between treatments within a column; Means followed by the different letters in a column are significantly different ($P < 0.05$)

WSA is the water stable aggregates, MWD is the mean weight diameter and PR is the penetrometer resistance at 0.10 m depth.

The response of bulk density and total porosity as soil quality indicators to the treatments followed similar trends in WSA and MWD. The imposition of mulch and veticompost reduced the density and increased pore size distribution of the soil. The bulk density and porosity of the soil under both treatments were significantly better ($P < 0.05$) than those under VGS and control plots. The influence of vetiver grass treatments on soil strength as described by penetrometer resistance (PR) was not different from the trends observed in bulk density and total porosity (Table 5).

The vetiver systems had significant effects on both soil loss and erodibility factor (K). These were reflected in the values of K in the 0 – 5 cm soil layer and the soil loss (Table 5). The vegetal cover of vetiver mulch prevented scouring capacity of erosion while contributing to the build-up of soil organic matter after decomposition. This perhaps was responsible for the lower value of K factor in the 0 – 5 cm layer VGM plot. Although, K factor of the veticompost plot is not significantly different from VGS plot, but the higher concentration of organic matter perhaps increase the resilient capacity of the surface soil under veticompost than VGS plots by as much as 16.7%. However, despite the VGS having higher K factor than both VGM and veticompost, VGS appeared to be more effective in sediment trapping than either VGM or veticompost. 65% of sediment that would have lost through erosion was held back by VGS as against 50 and 44% by VGM and veticompost, respectively. Babalola et al. (2007) obtained similar results in their study in Nigeria. The resistive capacity of VGS in sediment trapping may be due to the

higher tensile strength of the vetiver grass roots (data not shown).

Soil quality and maize yield

The influence of VGS, VGM and veticompost on soil quality is shown in Fig. 2. There was no significant difference between VGM and veticompost in relation to their soil qualities but they were significantly higher than both VGS and the control plots. Even then, the soil quality under VGS was higher than the control plots by 17.5%. The highest soil quality observed under VGM plots might not be unconnected to the influence of mulch cover on soil physical and biological properties. However, the deterioration in soil quality indicators under the control plot, especially soil organic matter and associated nutrients, has been cited as a major factor contributing to yield decline under intensive cultivation (Manna et al., 2007) and erosion-prone land (Lal, 1995).

The growth and grain yield of maize were reflections of the quality of the soils as impacted by the vetiver systems. The mean cumulative plant heights, girths, stover and grain yields of five growing seasons are shown in Table 6. Despite no significant difference in the plant heights in all the weeks, among the treatments, the quality of the soils had influence on the plant growth and yields. However, the Pearson product-moment correlation between maize grain yield and soil quality showed a significant and positive relationship ($r = 0.92^{**}$, $P < 0.01$). The correlation coefficient ($R^2 = 0.70$) calculated for the linear relationship between the two properties indicated that 70% of the

Figure 2. Soil quality ratings of the soils as influenced by vetiver grass strips, vetiver grass mulch and veticompost. Treatment means with the same letter do not differ significantly ($P < 0.05$).

Figure 3. Relationship between soil quality and maize grain yield as affected vetiver grass strips, vetiver grass mulch and 'veticompost'. *SQ* is the soil quality and *gry* is the maize grain yield.

Table 6: Mean cumulative plant heights, stem girths, stover and grain yields of maize as influenced by vetiver grass strip, vetiver mulch and veticompost between early 2009 and early 2011 growing seasons

Treatment	Plant height (cm) Weeks after planting			Stem girth (cm) Weeks after planting			Stover yield (Mg ha ⁻¹)	Grain yield (Mg ha ⁻¹)
	4	6	8	4	6	8		
VGS	55.4ns	177.1ns	211.3ns	1.02ns	1.40bc	6.05b	6.95ab	0.91ab
VGM	62.6	184.5	216.5	1.07	1.90ab	6.25ab	7.12b	1.05b
Veticompost	68.5	187.3	219.4	1.10	2.00a	6.85b	7.65c	1.57c
Control	54.6	165.7	203.6	1.01	1.30c	5.90a	6.75a	0.80a

ns means no significant difference between treatments within a column

Means followed by the different letters in a column are significantly different ($P < 0.05$)

grain yield is accounted to the soil quality ratings (Fig. 3). The grain yield under veticompost was consistently and significantly ($P < 0.05$) higher than other treatments. The early mineralization of organic matter and release of associated nutrients under veticompost enhanced better soil productivity, which perhaps accounted for higher crop yield than other treatments. It is not surprising that the cumulative grain yield on VGS and VGM plots was not significantly higher than the control plot since no soil fertility amendment was added. Even then, the mean cumulative grain yields obtained on VGS plot was 13.8% greater than the control while it was 31.3% better on VGM plot than the control. Veticompost plot has higher stover yield at harvest, and was significantly ($P < 0.05$) higher than VGS and the control but not significantly greater than the VGM plot.

CONCLUSIONS

The results of this study showed that vetiver system either as VGS, VGM or veticompost resulted in soil quality build-up as well as reducing soil erodibility in an erosion prone land. Although the resistive capacity of VGM and veticompost in trapping sediments was lower than that of vetiver strip (VGS), the application of vetiver mulch and veticompost had higher impact on soil quality than VGS. The use of vetiver filter strip alone may be insufficient to sustain continuous cropping in erosion-induce degraded land unless a nutrient released organic based material, such as veticompost and vetiver mulch, are applied for the build-up of soil organic matter to increase soil quality as well as the soil productivity.

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