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Influence of Tillage and Vetiver Grass Strips Spacing on Soil Physical and Chemical Properties from Eroded Soil in Southern Guinea Savanna, Nigeria

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Abstract
Field studies were conducted to evaluate changes in soil properties on eroded soil under vetiver grass strips and different tillage practices. Split plot experiments with a randomized complete block design were established on a 6% slope in Ogbomoso. Main plot treatments consisted of manual tillage (MT), plough tillage (PT), and conventional tillage (CT). Subplot treatments were vetiver grass strips (VGS) spaced at 5 and 10 m intervals and no- vetiver (NV). Soil samples from the plots were, in the laboratory, analysed for bulk density, macroporosity, microporosity, saturated hydraulic conductivity (Ks), soil pH, organic carbon, N, P, K and exchangeable cations after the first, second and third growing seasons. Data were analysed using Analysis of Variance at p = 0.05. Physical properties: bulk density, macroporosity, microporosity, and saturated hydraulic conductivity were neither significantly affected by tillage nor VGS in all the growing seasons. However, PT and CT compared to MC respectively, reduced soil bulk density (4 and 1%), macroporosity (2 and 9%) but increased microporosity (4%) and Ks (6 and 10%). Ks on 5 m VGS was higher than NV by 10%. Organic carbon was significantly (p<0.05) higher on CT compared to MT, available phosphorus increased on PT and CT than MT, while PT had higher exchangeable Ca than MT in the second year. Vetiver grass spaced at 5 m interval had higher Ks, and significantly higher organic carbon than NV. Thus, deterioration of soil properties caused by erosion on a sloping land through conventional tillage can be ameliorated by planting vetiver grass strips.

Keywords: Tillage, Vetiver Grass strips, Soil properties, Eroded soil

Introduction
Soil is the most basic of all natural resources. It is non-renewable; once lost it cannot be replaced within the foreseeable future (Lal, 1990). The risk of the complete destruction of the soil as a natural resource, increased simultaneously with soil structural degradation (IFPRI, 1995). Soil degradation is becoming one of the severest environmental issues in the world, especially in developing nations. Soil erosion by water is a serious environmental problem representing a much greater threat to agricultural production than soil erosion by wind (Lal, 2010). One of the major causes of soil degradation in the tropics is soil erosion which occurs at a very high rate when inappropriate cultivation practices are adopted (Lal, 1997). It is a major problem of rainfed agriculture throughout the world (Greenfield, 2002).

In the savanna regions of Nigeria, the fine sandy and silty soils of these regions commonly have compacted subsoils and surface soils that are susceptible to crusting that will require mechanical tillage. The majority of Alfisol available for crop production in the tropics especially, in the southern-guinea savanna is strongly weathered and inherently low in organic matter and nutrient status (Nottidge et al., 2005).Therefore, intensive cultivation and mechanical clearance without proper soil management can lead to soil degradation.

Tillage method is considered one of the major factors for increasing the yield of crops on a unit per area basis. This is applicable to the Southern guinea savanna where arable crops, such as cereals and root crops (cassava, yam and sweet potatoes) are produced. Soils are tilled to create a soil environment favourable to plant growth and development. In this region, large-scale production of a crop is synonymous with tractor cultivation that involves ploughing, harrowing or ridging operations. An attempt to use such sophisticated system on tropical soil have deleterious effects that can lead to soil wash and rapid breakdown of organic matter (Agboola, 1981). Tillage practices result to a cumulative effect of soil loosening. This degree of loosening may depend upon the soil type, soil moisture content, and type of tillage operation. The influence of tillage practices on soil properties have been known to either improve or deteriorate it depending on the intensity of tillage

(Osunbitan et al., 2005). It also initiates soil erosion which can eventually lead to depletion of soil nutrients and finally to physical and chemical degradation of soil properties. Tillage practices have profound effect on physical and chemical properties of the soil.

The influence of tillage on soil bulk density is inconsistent. Some studies observed significant reduction in bulk density with conventional tillage than no-tillage practices (Anwar et al., 2007; Roldan et al., 2007). In contrast, some reports observed no differences in bulk density among tillage practices though conventional tillage had lower bulk density than no- tillage (Agboola, 1981; Ewetola et al., 2016; Ishaq et al., 2002).

Soil macroporosity w found not to be different among land clearance methods, as pore size distribution was not affected by tillage systems (Hulugalle, 1994). Similarly, Osunbitan et al., (2005) in a study that lasted for 8 weeks on four tillage systems, No tillage (NT); manual tillage (MT), plough-plough (PP) and plough-harrow (PH) reported that the proportion of macropores (> 67 µm) at 8 weeks of sampling was highest in MT plots, while it did not differ amongst the three other plots. He attributed this to the fact that under no tillage, the channels and pore spaces from root growth and activities of soil fauna in previous years are not disturbed by tillage process and was responsible for higher macroporosity of the reduced tillage (NT and MT) treatments. Tillage practices had varied effects on saturated hydraulic conductivity (Ks). Some reported that Ks decreased with the intensity of tillage (Osunbitan et al., 2005; Bhattacharyya et al., 2006). However, others observed that Ks was greater under tilled soil than conservation tillage (Khan et al., 2007; Rahman et al., 2008).

Soil pH was reported to show no significant differences between conventional and zero tillage systems up to 50 cm depth (Rodriguez and Lal, 1979). Similar finding was reported by Agbede and Ojeniyi (2009) in southwestern Nigeria, that soil pH show no significant difference among tillage practices in the first year under sorghum cultivation. However, there was significant effect of tillage in the second year with less decline on untilled/manual plots compared to conventionally tilled plots. This was attributed to leaching of cations such as K, Ca, and Mg.

Tillage practices have been reported to influence soil chemical properties. The effect of tillage on soil chemical properties is dependent on the intensity of tillage. Decline in soil organic matter, N, P, K, Ca and Mg was found to be lower on zero/minimum tillage compared to conventionally tilled soils (Agbede, 2006; Agbede and Ojeniyi, 2009). Decline in the nutrient reserve of the conventional tillage was attributed to high destruction of the soil structure during the land preparation which encouraged soil erosion that preferentially removes colloidal fraction with high "enrichment ratio".

Mechanical tillage has been reported to induce soil erosion due to its compaction effect on the soil. However, the introduction of vetiver grass technology among other conservative methods has been proven effective in ameliorating soil properties. Vetiver grass strips planted across the slope has been found to slow down the velocity of runoff (Babalola et al., 2003; Babalola, 2007; Ewetola, 2017), improved soil properties (Oku et al., 2012; Oshunsanya, 2013) and increased soil nutrient (World Bank, 1990).

The production of food on large scale to meet the growing population makes mechanical clearance inevitable. The need to sustain the soil while going on large scale agriculture makes it imperative to identify ameliorative way of maintaining the soil properties. This study was therefore a modest attempt to bridge this gap in knowledge with regard to sustainable soil management practices under a tillage-vetiver cropping system in southern guinea savanna ecology of Nigeria. Therefore, the objectives of this work are to quantify the effect of tillage practices on soil properties, and determine the extent to which vetiver grass strips can ameliorate such effect.

Materials and Methods

Description of Experimental Site

The study was conducted at Ladoke Akintola University of Technology Teaching and Research Farm Ogbomoso. Ogbomoso is located on Latitude 8°10'N and longitude 4°10'E in the Southern guinea savanna ecological zone of Nigeria. The climate of Ogbomoso is mostly influenced by the northern and southwest trade wind. The former is cold with drying effect which starts from November to March, while the latter is warm and very moist and it starts from April to October each year. The mean monthly rainfall data for Ogbomoso over the study period of 2004 to 2006 is shown in Fig. 1.

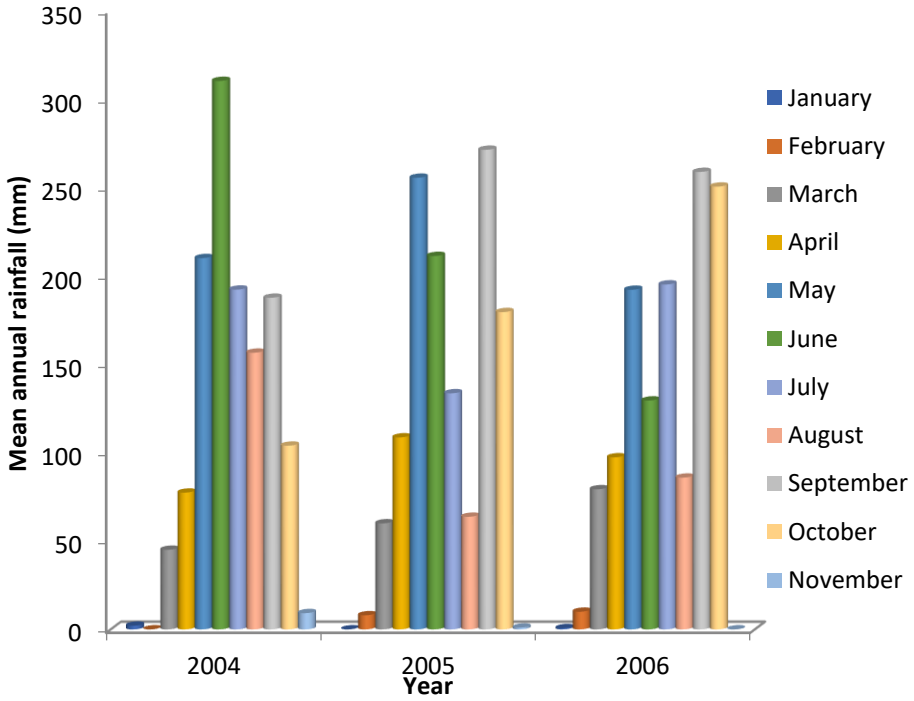


Figure 1: Rainfall distribution during the period of the experiment in 2004, 2005 and 2006.

The soil at the study site is classified as Alfisol in the USDA classification (Soil Survey Staff, 2006). It is a moderately drained, ferruginous soil with a sandy loam texture. The landscape (terrain) is a gentle slope of 6%. The vegetation cover of the site is characterized by scattered trees, shrubs, Cynodon spp and Imperata clyindrica, and was under cassava cropping prior to this study.

Field Experiment and Treatment Application

The land was manually cleared and the debris was packed away from the field. The land was demarcated into designated plots. The field experiment which lasted for three years (2004-2006) was a split plot experiment located on a 6 % slope was laid out in a Randomized Complete block Design. The main plot treatments were tillage practices; Manual tillage (MT), Plough tillage (PT), and Conventional tillage (CT). The sub plots treatments consisted of vetiver grass strips (VGS) spaced at 5 m and 10 m surface intervals with a control; No-vetiver (NV). Tillage treatments were imposed on each plot allotted to different tillage treatments. Manual clearing was done without tilling so as to minimally disturb the soil. Plough tillage plots were ploughed once (with a tractor mounted disc plough) to about 30 cm soil depth in 2004. In subsequent years, ploughing was imitated using a special local hoe ("Ganmbu") to till the plot to 30 cm soil depth. Conventional tillage was ploughed once (with a tractor mounted disc plough) and further disc harrowed to about 30 cm soil depth. In the subsequent years, ploughing and harrowing were simulated using local hoe to till the plots to about 30 cm soil depth and rake was used to break the soil clods. This was done to circumvent the difficulty of the passage of tractor within the vetiver grass strips.

Soil Sampling and Analyses

The initial soil sampling was carried out during field demarcation prior to tillage imposition. The soil samples were randomly collected from eight sampling points within each demarcated plot (giving a total of 24 samples from 3 replicates across the whole field) and mixed thoroughly before the initial composite sample was taken. Sampling was done at 0-15 cm depth. Subsequent soil samplings were carried out on a plot basis at the end of the each growing season. In addition, Magnitude of change (%) was calculated relative to nutrient status after the first growing season. All samples were air-dried and passed through a 2 mm sieve. The sieved soil samples were analysed for pH in a 2:1 soil water ratio using the Coleman's pH meter (IITA, 1982). Particle size analysis was done by the hydrometer method (Bouyoucos, 1962). Organic carbon was determined by the Walkey and Black procedure (Nelson and Sommers, 1982) while total N was determined by the Macrokjeldahl method (Bremner, 1965). Available P was extracted by Bray P-1 method (Bray and Kurtz, 1945) and read on the spectrophotometer. Exchangeable cation (K, Mg, Ca and Na) were first extracted using 1N NH4 OAC (Jackson, 1962). Thereafter, K and Na were

determined the Flame photometer while Ca and Mg were read from Atomic Absorption Spectrophotometer.

Bulk density was determined by core method as described by Blake and Hartage (1986). Saturated hydraulic conductivity was determined as described by Klute, (1986). Total porosity (TP) was determined from the relationship between the bulk densities (Db) and the particle density (DP) assumed as 2.65 mg/m^3; Macroporosity of the soil was determined as described by Danielson and Sutherland (1986). Microporosity of the soil was determined by subtracting the macroporosity from the total porosity.

Statistical analysis

All data on soil properties were subjected to Analysis of Variance (ANOVA) using SAS procedure (2002). Means were compared using the Fisher's Least Significant Difference test at 5% probability level. Simple and interactive effects of tillage and VGS were separated and evaluated by the F-protected least significant difference test.

Results

The initial soil properties of the site before the experiment are presented in Table 1. The soils had 794.1 g/kg sand, 79.5 g/kg silt and 126.4 g/kg clay with sandy loam texture. Bulk density and total porosity were below the critical values for plant growth (Lal and Shulka, 2005). The soil was slightly acidic. It was generally low in organic carbon, available phosphorus, total nitrogen and exchangeable bases when compared with the critical values for soils in south western Nigeria (Akinrinde and Obigbesan, 2000).

Table 1: Initial Soil Properties of the Experimental Site at 0- 15 cm Depth

Properties	Value
Sand (g/kg)	794.1
Silt (g/kg)	79.5
Clay (g/kg)	126.4
Textural class	Sandy Loam
Bulk density (Mg/m^3)	1.33
Total porosity (%)	40.32
Macroporosity (%)	26.42
Microporosity (%)	13.89
Saturated hydraulic conductivity (cm/hr)	49.35
pH (H_2O)	6.78
Organic carbon (g/kg)	6.70
Total nitrogen (g/kg)	1.40
Available P (mg/kg)	5.19
Ca (cmol/kg)	0.23
Mg (cmol/kg)	0.14
K (cmol/kg)	0.16

Soil Physical Properties

Soil bulk density was not affected by tillage practices as presented in Table 2. However, plough tillage (PT) and conventional tillage (CT) recorded lower soil bulk density than manual tillage (MT) by 4 and 1%, respectively, average over the three years. Vetiver grass strips spacing had no significant effect on bulk density of soil. Tillage practices had no significant effect on macroporosity of soil as shown in Table 2. The average data for the three years shows that macroporosity was lower on PT and CT tilled plots compared with MT respectively, by 2 and 9%. Vetiver grass strips spaced at 10 m interval had higher soil macroporosity than no- vetiver though not significant. Microporosity of soil did not differ significantly among tillage practices (Table 2). Average data over the three years show decrease in microporosity by 4% compared with PT and CT relative to MT. Similarly, no effect of vetiver grass strips spacing was recorded in soil microporosity. Saturated hydraulic conductivity (Ks) of soil was not affected by tillage practices (Table 2). However, Ks were higher on MT by 6 and 10% respectively, when compared with PT and CT average over 3 years. Vetiver grass strips spaced at 5 m interval increased Ks by 8% compared with 10 m and no-vetiver.

Chemical Properties

Tillage practices had no significant effect on soil pH (Table 3). Corresponding decline in pH values at the end of the first growing season on MT, PT and CT were 6.29, 3.46, and 5.70% respectively. Vetiver grass spacing did not affect soil pH significantly throughout the period of the experiment (Table 3). Corresponding decline in pH values at the end of the third growing season, were 3.99, 5.22 and 6.51%, respectively on 5 m, 10 m and NV.

Soil organic carbon (SOC) was not affected by tillage treatments after the first growing season (Table 3). In contrast, SOC on MT plot was significantly lower than CT plot by 8 %, but similar to P plot.

Table 2: Main Effect of Tillage Practices and Vetiver Grass Strips Spacing on Soil Physical Properties after Erosion

Treatment	Bulk density (Mg/m^3)				Macroporosity (%)				Microporosity (%)				Saturated hydraulic conductivity (cm/hr)			
	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean	2004	2005	2006	Mean
Tillage																
MC	1.44	1.55	1.17	1.39	28.79	19.32	17.92	23.01	17.06	22.13	38.05	25.74	38.92	27.34	16.68	27.65
PT	1.34	1.58	1.09	1.34	29.49	18.03	20.41	22.65	18.93	22.45	38.33	26.71	46.42	22.91	9.85	26.28
CT	1.37	1.64	1.13	1.38	26.16	19.33	17.60	21.03	22.17	18.66	39.51	26.78	38.82	19.22	11.77	23.27
$LSD_{(0.05)}$	0.42	0.19	0.12		7.14	6.40	2.85		20.29	4.75	7.36		21.83	10.96	10.86	
VGS Spacing																
No vetiver	1.36	1.49	1.13	1.33	28.39	19.63	18.68	22.23	19.54	24.21	38.61	27.45	43.13	19.61	12.60	25.11
5 m	1.38	1.67	1.20	1.42	27.41	18.32	20.08	21.94	19.95	18.29	34.51	24.25	42.77	25.86	12.93	27.19
10 m	1.40	1.62	1.06	1.36	28.65	18.76	18.68	22.03	19.68	20.74	42.76	27.72	38.26	23.99	12.77	25.01
$LSD_{(0.05)}$	0.05	0.27	0.25		2.78	4.56	2.45		4.78	9.87	7.44		16.74	8.42	2.58	
ANOVA																
Tillage(T)	ns	Ns	ns		ns	ns	ns		ns	ns	ns		ns	ns	ns	
VGS	ns	Ns	ns		ns	ns	ns		ns	ns	ns		ns	ns	ns	
T X VGS	0.05	Ns	ns		ns	ns	ns		ns	ns	ns		ns	ns	ns	

MC: Manual clearing; P: Ploughing; CT: Conventional tillage; VGS: Vetiver grass strips; ns: non-significant; Ksat: saturated hydraulic conductivity.

Relative to the initial soil organic carbon at the beginning of the experiment, soil organic carbon on MT, PT and CT plots decreased by 5.68, 9.13 and 12.34%, respectively after the third growing season. Vetiver grass strips spacing had no influence on SOC at the end of the first and second growing seasons (Table 3). However, after the third growing season, SOC on 5 m VGS plots was significantly higher than NV plots by 3.32%. Relative to the initial SOC, SOC on 5 m VGS, 10 m VGS and NV plots decreased by 6.99, 10.84, and 12.28%, respectively.

Total nitrogen was not influenced by tillage treatments throughout the period of study (Table 3). At the end of the third growing season in 2006, total N on PT and CT plots were higher than MT plots by 14.84 and 5.47%, respectively. When total N from all plots at the end of the third season was compared with the initial soil total nitrogen content, total N decline by 6.02% on MT, 10.04% on PT, and 14.51% on CT. Soil total nitrogen was not affected by vetiver grass strips spacing during the study period (Table 3). However, after the third year, total N on 5 m VGS plot was higher than NV plots by 2.61% whereas total N on 10 m VGS was lower than NV plots by 2.69%.

Tillage had no significant effect on soil available P at the end of the first growing season (Table 3). Soil available P was lowest on CT plots (7.01 mg/kg) and highest on P plots (7.09 mg/kg).

Table 3: Effect of Tillage and Vetiver Grass Spacing on Soil Chemical Properties in 2004, 2005 and 2006 at 0-15 cm Soil Depth

Treatment	Soil pH	Org C (g/kg)	Total N (g/kg)	Avail P (g/kg)	Exchangeable Cations (cmol/kg) K	Ca	Mg	Na
			2004					
MT	6.08	7.58	1.45	7.04	0.21	1.04	0.93	0.50
P	6.07	7.77	1.58	7.09	0.21	1.09	0.97	0.46
CT	6.03	8.05	1.43	7.01	0.21	1.05	0.94	0.51
LSD(P < 0.05)	ns	ns	ns	ns	ns	ns	ns	ns
NV	6.07	7.92	1.43	7.02	0.21	1.05	0.94	0.48
5m VGS	6.12	7.93	1.55	7.03	0.21	1.09	0.94	0.49
10m VGS	6.00	7.75	1.48	7.09	0.22	1.05	0.95	0.49
LSD(P <0.05)	ns	ns	ns	ns	ns	ns	ns	ns
			2005					
MT	6.08	7.40	1.28	6.69	0.19	0.97	0.86	0.46
P	5.98	7.67	1.50	7.00	0.20	0.95	0.83	0.44
CT	6.03	8.02	1.35	6.98	0.20	0.98	0.86	0.48
LSD(P <0.05)	ns	0.50	ns	0.08	ns	0.02	0.07	0.07
NV	6.05	7.65	1.33	6.99	0.26	0.95	0.85	0.45
5m VGS	6.00	7.77	1.43	6.76	0.21	0.97	0.86	0.47
10m VGS	6.05	7.67	1.33	6.92	0.19	0.98	0.85	0.46
LSD(P <0.05)	ns	ns	ns	ns	ns	ns	ns	ns
			2006					
MT	5.72	6.98	1.13	5.57	0.15	0.93	0.83	0.39
P	5.78	6.97	1.17	5.83	0.15	0.92	0.82	0.38
CT	5.70	7.05	1.15	0.62	0.17	0.92	0.81	0.39
LSD(P <0.05)	ns	ns	ns	ns	ns	ns	ns	ns
NV	5.68	6.92	1.15	5.68	0.14	0.93	0.83	0.40
5m VGS	5.77	7.15	1.18	5.87	0.17	0.92	0.82	0.39
10m VGS	5.75	6.92	1.12	5.68	0.15	0.92	0.81	0.38
LSD(0.05)	ns	0.09	ns	ns	ns	0.03	0.04	0.03

MT: Manual tillage; PT: Plough tillage; CT: Conventional tillage; NV: No vetiver (control) VGS: Vetiver Grass Strips; ns: non-significance

On the other hand, soil available P was significantly different among tillage treatments at the end of the second growing season. The soil available P obtained from PT and CT plots were significantly

higher than MT plots by 4.63 and 4.34% respectively. At the end of the third growing season, available P content in the soil on MT, PT and CT plots decreased by 20.11, 20.07 and 19.73%, respectively, relative to the initial soil available P (Table 4). Similarly, vetiver grass strips did not affect soil available P during the experiment (Table 3). Soil available P after the third year, decline from the baseline soil available P on 5 m VGS, 10 m VGS and NV plots by 15.16, 21.83 and 23.06%, respectively.

Exchangeable Cations

Exchangeable K was not significantly affected by tillage treatments throughout the period of study (Table 3). Exchangeable K at the end of the third growing season decline on MC, P and CT plots by 26.67, 33.33, and 17.65%, respectively relative to the initial K content of the soil (Table 4). Vetiver grass strips spacing did not significantly affect soil exchangeable K from all plots throughout the study period (Table 3). Relative to the initial soil exchangeable K at the end of first year, there was a decrease in K on 10 m VGS and NV plots by 19.23 and 15.79% respectively, while 5 m VGS plots did not change. When K contents from all plots after the third growing season was compared with baseline status, K decreased by 23.53, 26.67 and 85.71%, respectively on 5 m VGS, 10 m VGS and NV plots (Table 4).

The exchangeable Ca after the first year was not different among tillage treatments (Table 3). Ca content ranged from 1.04 Cmol/kg on MT to 1.09 Cmol/kg on PT plots after the first growing season. However, MT had significantly higher Ca content than PT while MT and CT were not different at the end of the second growing season. Relative to the initial soil Ca on all plots decreased by 4.30% on MT, 3.26% on PT and 6.52% on CT plots after the third growing season (Table 4). Vetiver grass strips spacing had no significant effect on exchangeable Ca throughout the period of experiment (Table 3). Ca decreased by 5.43 % on 5 m VGS, 6.52 % on 10 m VGS and 2.15 % on NV plots at the end of the third growing season (Table 4).

Table 4: Magnitude of Change * (%) in Soil Nutrients Status as Affected by Different Tillage and Vetiver Grass Strips Spacing

				Available	Exchangeable cations		
Treatment	pH	Total N	Org C	P	K	Ca	Mg
MT	0.00	-13.28	2.43	-5.23	-9.52	-7.22	-8.13
PT	-1.56	-7.48	-1.30	-1.29	-4.76	-14.7	-16.86
CT	0.00	-5.92	-0.37	-0.43	-17.67	-7.14	-9.30
NV	-0.33	-7.52	-2.06	-0.43	9.23	-10.3	-10.58
5m VGS	-2.00	-8.39	-1.04	-3.99	0.00	-12.4	-9.30
10m VGS	-0.83	-11.28	-0.92	-2.46	-15.79	-7.14	-11.77
MT	-6.29	-13.27	-6.02	-20.11	-26.67	-4.30	-3.61
PT	-3.46	-25.64	-10.04	-20.07	-33.33	-3.26	-1.22
CT	-5.70	-17.39	-14.51	-19.73	-17.65	-6.52	-6.17
NV	6.42	-15.65	-12.28	-23.06	-85.71	-2.15	-2.43
5m VGS	5.71	-21.19	-10.84	-15.16	-23.53	-5.43	-4.88
10m VGS	4.17	-18.75	-6.99	-21.83	-26.67	-6.52	-4.94

MT: Manual clearing; PT: Plough; CT: Conventional tillage; VGS: Vetiver grass strips

Note: *(-) Decrease*
(+) Increase
(*) Changes are relative to the soil nutrient status after 2004 growing season

Exchangeable Mg in the soil was not significantly affected by tillage during the period of study (Table 3). Relative to the initial, exchangeable Mg on all plots decreased by 3.61% on MT, 1.22% on PT and 6.17% on CT plots after the third growing season (Table 4). Relative to the initial exchangeable Mg on all plots decreased by 4.88%, 4.94% and 2.43% respectively, on 5 m, 10 m VGS and NV plots.

Discussion

The reduction in soil bulk density on tilled plots could be adduced to the loosening effect of tillage and less compaction caused by tillage. Manual tillage with high soil bulk density could be ascribed to non- tillage and compaction. Similar findings were obtained by (Agbede 2006; Agbede and Ojeniyi, 2010) that low soil bulk density was due to loosening effect produced by conventional tillage. Several others (Ishaq et al. 2002; Ewetola, 2016) also reported no significant effect of tillage on bulk density though conventional tillage had lower bulk density than no- tillage. The reduced mean soil bulk density with vetiver grass strips over three years revealed its effectiveness and efficacy to improve soil condition. This can also be attributed to the ability of vetiver grass strips to slow down velocity of runoff which reduced scouring, deposit organic residues that eventually decomposed to form organic matter. The finding agrees with Oshunsanya (2008) who observed higher bulk density on non-vetiver plots than vetiver plots. No-vetiver plots had higher soil bulk density than vetiver plots which could be linked to compaction resulting from tillage.

Manual and plough tillage recorded high macroporosity and low microporosity respectively compared with convectional tillage. This was attributed to reduced intensity of tillage which could have altered the pore geometry. The preponderance of micropores on conventional tillage demonstrated that macroporosity was mostly affected by tillage treatments rather than microporosity. This supports the findings of Osunbitan et al. (2005) who observed higher macropores under no-tillage and manual tillage than plough-plough tillage and plough-harrow tillage. This was ascribed to the channels and pore spaces from root growth and activities of soil fauna in previous years which are not disturbed by tillage process and thus responsible for higher macroporosity of reduced tillage. Ewetola et al. (2016) also found that microporosity and macroporosity were not affected by tillage practices. However, no- till recorded higher macroporosity compare with tilled plots. Hulugalle (1994) in a study carried out on a tropical Alfisol in south-western Nigeria also reported that pore-size distribution was not significantly affected by tillage systems (ploughed, zero tillage and traditional). Arshad et al. (1999) also reported that total porosity was not affected by any tillage compared with conventional tillage to a depth of 0.3 m at the end of 13 years. Soil macroporosity and microporosity with low values on no-vetiver plot compared to 5 m and 10 m vetiver plots may be due to decline in soil organic matter and clay particles as a result of severe erosion. Severe erosion resulted in soil compaction, reduced infiltration and increased degree of coarseness of soil leading to reduced soil porosity (Babalola et al., 2003; Oshunsanya, 2013).

Saturated hydraulic conductivity (Ks) with higher values on MT plot than tilled plots could be attributed to the less compaction and preponderance of macropores that conferred high water movement in MT. Saturated hydraulic conductivity on loamy sand decreased with increased intensity of soil manipulation through tillage (Osunbitan et al., 2005).The highest conductivity was recorded under no-tillage and the least conductivity was under plough-harrow tillage. Ks values were higher on 5 m VGS and 10 m VGS than no-vetiver plots. The higher Ks on vetiver grass could be due to deposition of organic materials behind the strips which after decomposition led to build up organic matter, increased aggregation and improved soil structure under vetiver plots.

Soil pH was generally lower on tilled plot than MT plots. This observation can be linked to higher erosion on PT and CT plots than MT plots as a result of loosening of soil due to tillage. This result agreed with Agboola (1981) who reported that after four years of study in south-western Nigeria, soil pH values declined generally among the tillage practices examined. Changes in soil pH range from 0.2 to 0.8 unit with the highest observed in tilled plot due to tillage effect on soil organic matter. Similar finding was reported by Agbede and Ojeniyi (2009) in southwestern Nigeria, that soil pH show no significant difference among tillage practices in the first year under sorghum cultivation. However, there was significant effect of tillage in the second year with less decline on untilled/manual plots compared to conventionally tilled plots. This was attributed to leaching of cations such as K, Ca, and Mg. Soil pH was generally lower on no-vetiver plots than vetiver plots throughout the period of study. The observation could be attributed to higher losses of runoff water and soil exchangeable cations on no-vetiver plots than vetiver plots (Babalola et al., 2003). The decline in soil organic carbon (SOC) and total N set in after the first growing season. The values, although high at the beginning indicated that SOC and N were lost or declined irrespective of the tillage practices. The observed results may be ascribed to a number of factors:

temperature, rainfall, vegetation, soil texture and land use which directly or indirectly influence SOC, and total N in tropical region (Feller, 1993). Intensive tillage has been observed to lead to increased oxidation of organic matter with resultant soil structural deterioration and reduction in the potential nutrient supply (Hulugalle, et al., 1994). The decrease of SOC on no-vetiver than 5 m and 10 m VGS at the end of the second growing season, may be ascribed to the interception of runoff water which reduced the velocity of soil carrying medium (Babalola et al., 2003; Ewetola, 2011).

Generally, available P (averaged of all tillage methods over three years) declined on all the plots. The value of P at the end of third growing season may not be able to sustain crop yield unless there is P fertilization of the soil. Based on the critical level of available P, ranging from 10-16 mg/kg Bray 1-P (Adeoye, 1986); soil of Ogbomoso could be ranked as low phosphorus soils. Available P decreased less on no-vetiver plot than vetiver plots after the second growing season. However, at the end of the third growing season, the greater decrease on no-vetiver plot than vetiver plots revealed the conservative effect of vetiver grass on the soil.

Exchangeable K dropped in the tilled plots than MT plots average over the 3 years of study. This result could be attributed to the manual and plough tillage that conserved nutrients concentrations as opposed to conventional tillage. Similar findings were reported by Agboola (1981) and Agbede and Ojeniyi (2009). They observed more decline in tilled plots than zero plot in south-western Nigeria. Exchangeable K decrease did not follow a consistent trend among vetiver grass strip spacing. Although, after the second growing season, 10 m VGS had the lowest decline in K content than 5 m VGS and NV plots. Exchangeable K decreased more steadily on no-vetiver plot than 5 m VGS and 10 m VGS plots after the third growing season. This implies that further yield on no-vetiver plot may not be sustained without K fertilization of the soil as the soil critical K values have been reported to range from 0.15 to 0.20 cmol/kg in south-western Nigeria (Adeoye 1986). After the second growing season, the exchangeable cations (Ca, and Mg) indicated a general trend of decline. On all the plots, Ca and Mg dropped more on P plots than MT and CT plots. However, at the end the third growing season, Ca and Mg declined more on PT plots than MT. The loss of Ca and Mg could be linked to leaching, uptake by the crops, loss in eroded sediment and runoff water. These findings agreed with earlier reports by Lal (1997) and Agbede (2006) on a tropical Alfisol in south-western Nigeria. At the end of the second growing season, the exchangeable cations (Ca and Mg) indicated a general decrease on all the vetiver plots. Although, the trend did not follow a consistent pattern, the decline was less on 5 m VGS for Ca and on 10 m VGS for Mg. These losses of Ca and Mg could also be ascribed to leaching (Santibhab et al., 2003). After the third growing season, the loss of Ca and Mg was more pronounced on 10 m VGS than 5 m and NV. This result was contrary to Oshunsanya (2008) who reported a more decline on no-vetiver plot than 5 m VGS and 10 m VGS plots in Ibadan. This disparity may be attributed to soil type and intensity of tillage.

Conclusion

Soil physical condition was improved under manual clearing and plough tillage than conventional tillage. Also, soil organic carbon and exchangeable cations decline were minimal under manual and plough tillage in comparison with conventional tillage. Vetiver grass strips played an important role in ameliorating soil compaction as a result of tillage practices, reduced velocity of runoff and scouring of soil surface. These translated to better soil condition such as low bulk density, increased saturated hydraulic conductivity, higher volume of macropores, less decline of soil organic carbon, available P, exchangeable K.

In an attempt to increase food production through mechanization, use of vetiver grass technology can be employed to reduce the adverse effect of tillage due to deterioration of soil properties. Therefore, vetiver grass strips spaced at 5 m or 10 m intervals can be recommended for the Southern guinea savanna zone of Nigeria.

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