Albanian j. agric. sci. 2015;14 (2):127-136 *Agricultural University of Tirana*

RESEARCH ARTICLE **(Open Access)**

Stability and Hydrological Modifications in a Tilled Soil under Selected Organic Amendments in South-Eastern Nigeria

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Abstract

A 36 months study was carried out in Nsukka, south-eastern Nigeria to determine the effect of organic amendment on the stability and hydrological properties of a tilled fragile Ultisol. The experiment was of a Randomized Complete Block Design (RCBD) with three (3) organic amendments and a control replicated thrice. The soil amendments were comprised of Palm Oil Mill Effluent (PE), Palm Bunch Refuse (PR), Cassava Peels (CS) at 12 Mg/ha and No Amendment/control (NA). Results indicated that organic amendment of tilled plots significantly increased the stability of wet and dry soil aggregates compared to soil aggregates in un-amended plots. The amendment of tilled soils led to increased saturated hydraulic conductivity, water sorptivity, transmissivity, steady-state infiltration rate, cumulative infiltration after 90 minutes, time to attain steady-state infiltration and water retention. However, the general trend shows that highest values were obtained when soils were under PE and CS amendments, with values in PE treated soils showing relative increment of more than 100 % compared to control.

Keywords: *Ultisol*, soil tillage, organic amendments, structural stability, hydrological properties

1. Introduction

Tillage has been an important aspect of technological development in the evolution of agriculture, particularly in crop production. Among the many reasons advanced for tillage as a pre-planting practice are seedbed preparation, water and soil conservation, weed control, destruction of soil-borne pathogens and incorporation of fertilizers and organic residues into the soil. Tillage has various physical, chemical and biological effects on the soil both beneficial and degrading, depending on location, soil type and state; and appropriateness of the tillage method. [19] reported increased moisture retention on conventionally tilled compared to the no-till plots while [1] reported an 83 % increase in infiltration rate following tillage. In the same vein, [23] observed significantly lower weed growth on tilled compared to untilled plots. Tillage has also been shown to enhance fertilizer usage by plants [27, 2]. On the other hand, some researchers have reported soil structural degradation due to tillage practices. [17] reported significantly lower aggregate stability and higher susceptibility to soil erosion leading to alteration of the texture of soil under a long-term tillage experiment. Therefore the effects of tillage on soil physical properties such as aggregate-stability, infiltration rate, soil and water conservation, in particular, would have direct influence on soil productivity and sustainability.

However, due to the adverse effects of soil tillage, especially conventional tillage, some researchers have investigated and advocated the adoption of land preparation practices that are less inimical to the structural stability of the soil [19, 18, and 27]. Land preparation methods like zero, minimum and conservation tillage were therefore recommended by these researchers. These methods are however not without their inherent challenges. According to [26] annual disturbance and pulverizing caused by conventional tillage produce a finer and loose soil structure as compared to conservation and no-tillage methods which leave the soil intact. The authors further noted that this difference results in a change of number, shape, continuity and size distribution of the pore network, which controls the

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(Accepted for publication June 05, 2015)
***ISSN**: 2218-2020, © Agricultural University of Tirana*

ability of soil to store and transmit air, water and agricultural chemicals. This in turn controls runoff, erosion, and crop performance [14]. On the other hand, conservation tillage methods often result in decreased pore space [7], increased soil strength [4] and stable aggregates [8]. The pore network in soils under conservation tillage is usually more continuous because of earthworms, root channels and vertical cracks [6]. Therefore, conservation tillage may reduce disruption of continuous pores, whereas conventional tillage decreases soil penetration resistance and soil bulk density [13]. This also improves porosity and water holding capacity of the soil. Continuity of pore network is interrupted by conventional tillage, which increases the tortuousity of soil. These all lead to a favorable environment for crop growth and nutrient use [14].

In tropical areas, especially in West Africa, where the practice of shifting cultivation and bush fallow is giving way to continuous cultivation of diminishing agricultural lands lost to infrastructural expansion; it becomes impelling to investigate ways of reducing tillage or its impact on the soil. One way of achieving this end is to study the effects and potentials of organic amendment intilled soils, particularly in degraded tropical soils (*Ultisols*). [3] reported that the *Ultisols* of south-eastern Nigeria are low in organic matter, fragile and showed high susceptibility to erosion. In this vein, organic amendment which is known to cement soil particles together and act as a binding and absorptive base for nutrients and water respectively; is an important tool for the management of this soil. Therefore the objectives of this study were to evaluate the effect of three (3) organic wastes/amendments on aggregate stability, some hydrological properties of a sandy-loam *Ultisol* and rank the organic materials according to their effectiveness for soil amendment.

2. MATERIALS AND METHODS

2.1 Site description

This experiment was conducted from April 2009 to April 2011 in the University of Nigeria Nsukka Teaching and Research Farm, located by latitude $05^0$52'N and longitude $07^0$24'E and at an elevation of 400m asl. The mean annual maximum temperature in this location ranges between 27^0C and 32^0C in the period from March to May while the mean daily sunshine hours in the area are between 5 and 6 hrs in the dry season and 3 to 5 hrs in the wet season [11]. Rainfall in the area occurs between March and October. More than 80 % of the total annual rainfall is received between the months of May and October, with mean annual total in excess of 1600 mm [9]. The soil is an *Ultisol* belonging to the Nkpologu series [22]. It is coarse to medium textured, granular in structure, acid in reaction and low in nutrient status. Its mineralogy is composed mainly of kaolinite and quartz [3].

2.2 Field Methods

2.2.1 Experimental design

The design of the experiment was a Randomized Complete Block Design (RCBD) with three (3) organic amendments and a control. The soil amendments were comprised of Palm Oil Mill Effluent (PE), Palm Bunch Refuse (PR), Cassava Peels (CS) at 12 Mg/ha and No Amendment/control (NA) 0 Mg/ha. Each treatment was replicated three (3) times giving a total of 12 plots.

2.2.2 Field studies

A land area of 0.0256 ha was used for this study. The plots measured 15.125 m^2 (5.50 m x 2.75 m). Soil samples were collected in a grid of 4 m x 2 m bulked and a composite sample taken for laboratory analyses to determine the initial physico-chemical properties of the site. Then, Glyphosate, a post emergence herbicide (a.iisopropylamine) and butachlor, a pre-emergence herbicide (a.i. 2-chloro-2, 6- diethyl – N (butoxy methyl) acetanilide) were used for initial weed control while subsequent weed control was by hand picking. Plots were tilled only at the commencement of the experiment whereas the organic amendments were applied once yearly. Bulk and core samples were collected from top soil (0 – 30 cm depth) of each plot at 90, 180, 360, 540, 720, 900 and 1080 DAT (Days After Treatment) for determination of aggregate stability, saturated hydraulic conductivity and water retention.

2.3 Laboratory studies

2.3.1 Aggregate stability

Aggregate size distribution (wet) was estimated by the wet-sieving technique of (12). The method of [28] as modified by [12], was used to determine the mean weight diameter of the water–stable aggregates thus:

$$\text{MWD} = \sum_{i=1}^{n} X_i \text{W}_i \qquad (1)$$

Where: MWD = mean weight diameter of stable- aggregates

X_i = mean diameter of each size fraction (mm)

W_i = proportion of the total sample weight in the corresponding size fraction.

The determination of the mean weight diameter of dry aggregates followed same procedures as stated above with the only difference being that rotary sieving technique as described in detail by [12] was used rather than the wet sieving technique. Higher values of MWD indicate the dominance of the less erodible, large aggregates of the soil [25].

For ease of comparing the effects of the treatments on aggregate stability (AS), the change in MWD between control and the treated soils was normalized as follows:

$$PSEI = [1-(MWD_c / MWD_t)] \times 100 \quad \textbf{(2)}$$

Where PSEI is the Potential Structural Enhancement Index, MWD_c is the mean weight diameter for control, and MWD_t is the mean weight diameter for treated soil. Positive value indicates contribution to structural enhancement whereas negative value means no contribution.

1.2.3.2 Saturated hydraulic conductivity

Saturated hydraulic conductivity (K_{sat}) was determined according to [5]. The transposed Darcy's formula for vertical flows of liquid was used to calculate K_{sat} thus:

$$K = \frac{Q}{At} \cdot \frac{L}{\Delta H} \quad \textbf{(3)}$$

Where: Q = steady state volume of outflow (cm^3)

A = interior cross sectional area of core sample (cm^2)

T = time of flow (h)

L = Length of core sample (cm)

ΔH = change in hydraulic head (cm)

1.2.3.3 Infiltration and water retention studies

Infiltration test was conducted using the double ring infiltrometer and the data generated fitted into [24] and [16] models and analyzed to estimate the sorptivity and transmissivity parameters thus:

Philip's model $I = At + St^{1/2}$ **(4)**

Where *I* = cumulative infiltration (cm), *S* = soil water soptivity, *A* = soil water transmissivity, and *t* = time elapsed (min.). To estimate the *A* and *S*parameters, both sides of equation (2) were divided by $t^{1/2}$ giving

$I/t^{1/2} = At^{1/2} + S$ **(5)**

A graphical plot of $I/t^{1/2}$ against $t^{1/2}$ gives *S* as the intercept and *A* as the slope.

Kostiakov'smodel $I = Kt^a$ **(6)**

Where *K* = a soil-dependent parameter which is closely related to the transmission characteristics of the soil and '*a*' is another soil-dependent parameter whose value varies from 0 to 1.To estimate these parameters, equation (6) was linearized thus:

$Log_{10} I = log_{10} K + a\, log_{10} t$ **(7)**

A graphical plot of $Log_{10}\ I$ against log_{10} *t*gives$log_{10} K$ as the intercept and '*a*' as the slope from which the actual value of *K* can be obtained from the antilog. The cumulative infiltration was obtained after 90 min. By differentiating equation [4] we obtain:

$dI/dt = i = A + 1/2St^{-1/2}$ **(8)**

where*i* = instantaneous infiltration rate at time *t*. The lowest value of *i* is the equilibrium infiltration rate, which has practical implications for water management studies. At the end of the 36 months of this field experiment *in- situ* moisture content was determined at 2 and 10 days after saturation by the method of [10].

3. RESULTS

3.1 Initial Soil Properties

Table 1 shows thatthe texture of the experimental site was sandy-loam whereas the organic carbon content, pH, P, and ECEC were generally low to very low. The nutrient status of the organic amendments indicated PE > PR > CS while the C/N ratio followed the order PR > CS > PE and been more than 3 times higher in PR and CS compared to PE.

3.2 Aggregate stability

The stability of dry soil aggregates deteriorated due to tillage as observed in the control (NA) soils (Table 2). However, 3 months following soil amendment, dry soil aggregates in plots amended with PE and CS showed significant difference ($P < 0.05$) from control with mean weight diameter (MWD) of 1.61 and 1.29 mm respectively, beyond values of 1.25 mm prior to tillage while 12 months elapsed for a similar observation in PR treated plots.

In the first 6 months of the experiment, dry aggregates in PE treated soils showed higher MWD compared to other amendments whereas in the last 6 months there was no difference in the effect of the amendments. One of the remarkable features observed with respect to the organic amendments was on the duration to significant treatment effect on MWD of dry soil aggregates which followed the order PR > CS > PE. The results obtained for MWD of wet soil aggregates (Table 3) were similar to that obtained for MWD of dry aggregates except for the observation that in the last 6 months of the experiment the effect of PE amendment did not differ from that of CS while that of CS did not also differ from that of PR ($P \leq 0.05$).

Table 1: Some characteristics of the top soil (0 – 30 cm depth) of the experimental site and the organic materials

Parameter	**Soil**	**PE**	**CS**	**PR**
Sand %	67	-	-	-
Silt %	15	-	-	-
Clay%	18	-	-	-
Textural class	Sand loam	-	-	-
pH (1:2.5 H_2O)	4.7	-	-	-
pH (0.01MKcl)	3.8	-	-	-
Organic Carbon (%)	1.32	36.4	48.7	60.0
Total N (%)	0.085	2.7	1.0	1.1
C/N ratio	15.5	13.5	48.7	54.6
Available P ($mgkg^{-1}$)*/ % P^a	8.67*	1.2^a	0.7^a	1.1^a
*Exchangeable bases ($cmolkg^{-1}$)				
Na	0.55	-	-	-
K*/ % K^b	0.02*	2.5^b	1.1^b	1.5^b
Ca	1.14	-	-	-
Mg	3.10	-	-	-
Exchangeableacidity ($cmolkg^{-1}$)				
Al^{+3}	1.20	-	-	-
H^+	2.40	-	-	-
ECEC ($cmolkg^{-1}$)	8.41	-	-	-

PE = palm oil mill effluent, CS = cassava peels and PR = palm bunch refuse, *figures with a and b indicate unit of Parameter for corresponding values.

Table 4 shows that only PR of the organic amendments did not contribute to increased MWD of dry soil aggregates 3 months after soil amendment, however as the experiment progressed beyond 3 months all the organic amendments increased MWD of dry soil aggregates by varying degrees following PE > CS > PR trend. The influence of PE amendment on increased MWD of dry aggregates was about 100 % higher than that of CS and PE in the first 6 months.

Table 2: Effects of organic amendment on mean weight diameter (mm) of dry aggregates of a tilled top soil

	Months							
Organic amendments	0	3	6	12	18	24	30	36
NA	1.25^a	1.15^c	1.15^c	1.12^d	1.10^c	1.08^c	1.05^b	1.03^b
PE	1.25^a	1.61^a	1.65^a	1.65^a	1.72^a	1.74^a	1.78^a	1.83^a
CS	1.25^a	1.29^b	1.37^b	1.50^a	1.52^b	1.63^a	1.73^a	1.84^a
PR	1.25^a	1.14^c	1.22^c	1.31^c	1.40^b	1.48^b	1.63^a	1.78^a

NA = No Amendment, PE = Palm Oil Mill Effluent, CS = Cassava Peels and PR = Palm Bunch Refuse.
*Figures followed by the same letters within the same column are not significant at $P \leq 0.05$ using Duncan's multiple range test.

There was however a slight deviation from the trend considering the contributions of the organic amendments to the increase in MWD of wet soil aggregates (Table5) which indicated that all the amendments increased the MWD of the aggregates at all sampling dates. It was generally observed that the contribution of PE amendment to increased MWD of wet aggregates increased rapidly in the first 6 months following soil amendment and increased gradually consequently, whereas the reverse was observed for CS and PR amendments.

Table 3: Effects of organic amendment on mean weight diameter (mm) of wet aggregates of the top soil

	Months							
Organic amendment	0	3	6	12	18	24	30	36
NA	1.30[a]	1.18[c]	1.16[c]	1.12[c]	1.12[d]	1.11[c]	1.10[c]	1.08[c]
PE	1.30[a]	1.75[a]	1.82[a]	1.83[a]	1.93[a]	1.98[a]	2.04[a]	2.11[a]
CS	1.30[a]	1.35[b]	1.46[b]	1.62[b]	1.65[b]	1.75[b]	1.87[ab]	1.96[ab]
PR	1.30[a]	1.20[c]	1.25[c]	1.32[c]	1.45[c]	1.66[b]	1.73[b]	1.81[b]

NA = No Amendment, PE = Palm Oil Mill Effluent, CS = Cassava Peels and PR = Palm Bunch Refuse.

Table 4: Effects of organic amendment on potential structural enhancement index of dry aggregates of the top soil

	Months							
Organic amendment	0	3	6	12	18	24	30	36
NA	-	-	-	-	-	-	-	-
PE	-	29.0	30.0	32.0	36.0	38.0	41.0	44.0
CS	-	11.0	16.0	25.0	28.0	34.0	39.0	44.0
PR	-	-0.9	6.0	14.0	21.0	27.0	36.0	42.0

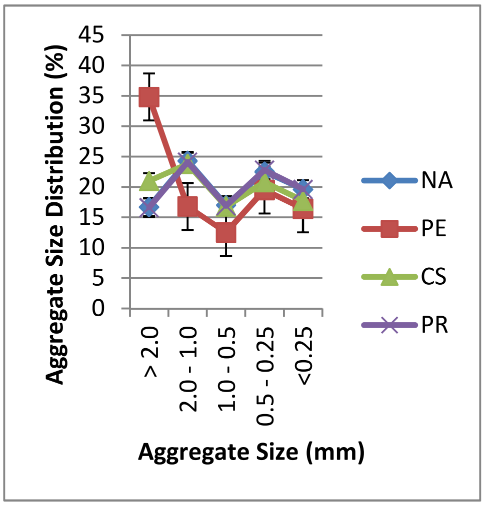
NA = No Amendment, PE = Palm Oil Mill Effluent, CS = Cassava Peels and PR = Palm Bunch Refuse.

Table 5: Effects of organic amendment on potential structural enhancement index of wet aggregates of the top soil

	Months							
Organic amendment	0	3	6	12	18	24	30	36
NA	-	-	-	-	-	-	-	-
PE	-	33.0	36.0	39.0	42.0	44.0	46.0	49.0
CS	-	17.0	20.0	31.0	32.0	37.0	41.0	45.0
PR	-	2.0	7.0	15.0	23.0	33.0	36.0	40.0

NA = No Amendment, PE = Palm Oil Mill Effluent, CS = Cassava Peels and PR = Palm Bunch Refuse.

Figures 1 – 7 indicate that soil amendment significantly increased aggregates in the size ranges > 0.5 mm (macro-aggregates) while ensuring a gradual decline in the < 0.5 mm soil aggregate component (micro-aggregates), relative to control. It was also observed that macro-aggregates in soils treated with PE increased more rapidly compared to those amended with CS and PR in the first 6 months (Figures 1 and 2); and subsequently followed a gradual order PE > CS > PR > NA. Notably, there was a preponderance of aggregates in the size range 0.5 – 0.25 mm in the un-amended plots as the studies progressed (Figures 3 - 7). Results obtained after 36 months of soil amendment showed that the soil aggregate fraction > 2.0 mm under PE and CS amendments did not vary (Figure 7).



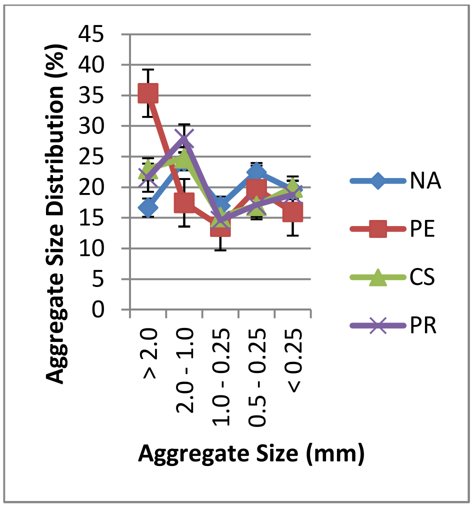
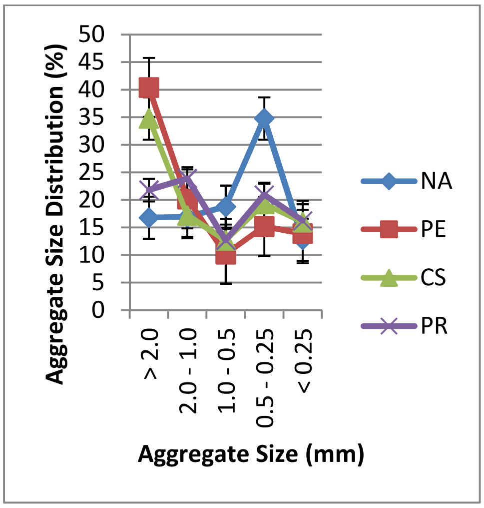


Figure 1: Aggregate size distribution (wet) as influenced by 3 months soil amendment

Figure 2: Aggregate size distribution (wet) as influenced by 6 months soil amendment

3.3 Hydraulic properties

Table 6 shows that there was generally further increase in saturated hydraulic conductivity (K_{sat}) values when the tilled soils were amended with organic materials.



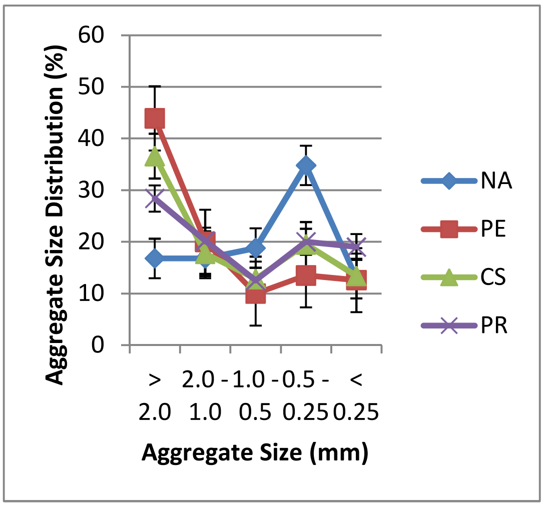
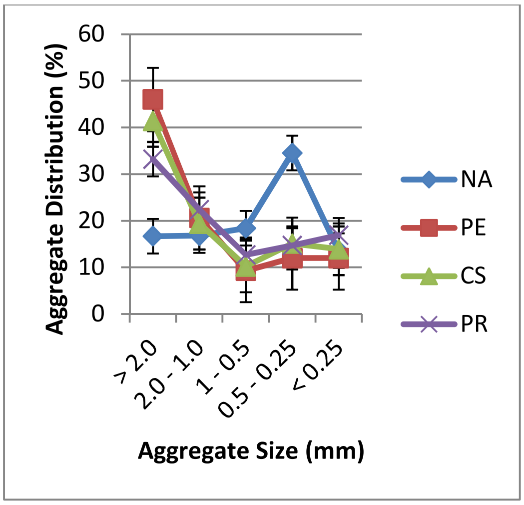


Figure 3: Aggregate size distribution (wet) as influenced by 12 months soil amendment

Figure 4: Aggregate size distribution (wet) as influenced by 18 months soil amendment



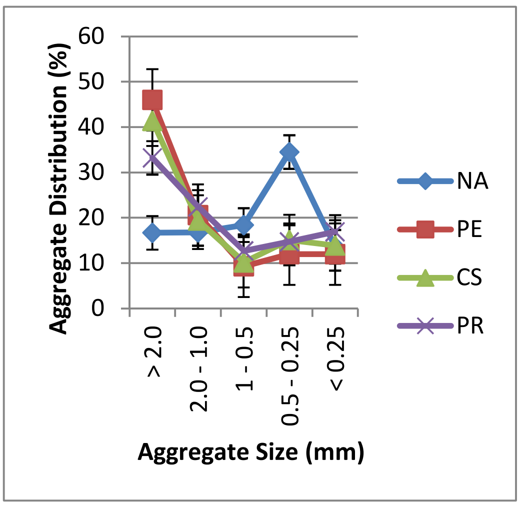


Figure 5: Aggregate size distribution (wet) as influenced by 24 months soil amendment

Figure 6: Aggregate size distribution (wet) as influenced by 30 months soil amendment

Only the initial 3 months however revealed that there was no difference ($P \leq 0.05$) in the K_{sat}values of the control (NA) soils and those amended with PR. The K_{sat}values obtained in PE treated plots were higher than what was recorded for other amended plots and control 18 months into the experiment, however in the 36th month, no difference was observed between the organic treatments. It was generally observed that K_{sat} values in amended plots increased progressively whereas values in un-amended plots declined. Though tillage increased the permeability rating of this soil from 'moderately rapid' to 'very rapid', however the permeability of un-amended soils fell to 'rapid' whereas that of amended soils remained 'very rapid' in 36 months.

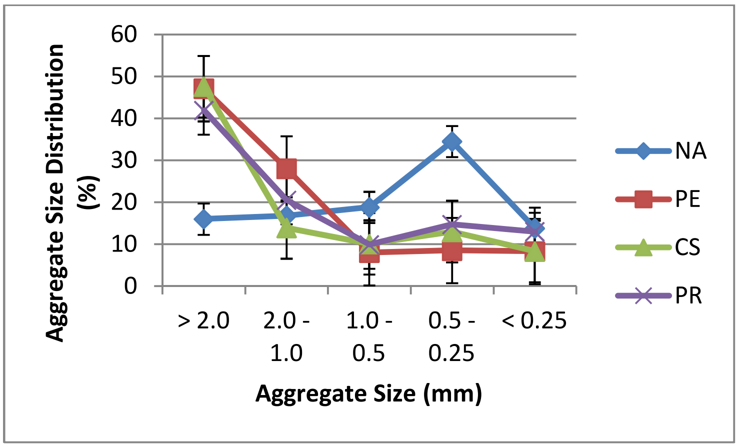


Figure 7: Aggregate size distribution (wet) as influenced by 36 months soil amendment

Table 6: Effects of organic amendment on saturated hydraulic conductivity (cm h^{-1}) of a tilled top soil

	Months							
Organic amendment	0	3	6	12	18	24	30	36
NA	5.4[a]	36.9[c]	32.3[c]	28.9[c]	22.4[d]	15.5[c]	10.7[c]	6.3[c]
PE	5.4[a]	51.5[a]	68.0[a]	73.0[a]	80.0[a]	84.0[a]	87.5[a]	90.5[a]
CS	5.4[a]	44.5[b]	49.0[b]	58.0[b]	71.0[b]	76.0[ab]	80.5[ab]	85.2[a]
PR	5.4[a]	40.0[bc]	42.0[b]	45.0[b]	56.0[c]	68.0[b]	75.0[b]	82.4[a]

NA = No Amendment, PE = Palm Oil Mill Effluent, CS = Cassava Peels and PR = Palm Bunch Refuse.

*Figures followed by the same letters within the same column are not significant at $P \leq 0.05$ using Duncan's multiple range test

Table 7: Effects of organic amendment on the water transmission characteristics of the tilled top soil

Organic amendment	Sorptivity[1] (S)	Transmmisivity[1] (K)		Equilibrum infiltration rate (cm h^{-1})	Cumulative infiltration (cm)	Time to attain equilibrium infiltration(min)
NA	3.65[c]	0.06[c]	1.32[c]	25.3[b]	47[c]	26[b]
PR	8.50[b]	0.32[b]	3.07[b]	82.5[a]	129[b]	60[a]
CS	9.09[a]	0.48[a]	5.02[a]	85.4[a]	143[ab]	62[a]
PE	9.39[a]	0.53[a]	5.47[a]	90.7[a]	156[a]	67[a]

[1]The sorptivity (*S*) and transmissivity (*A*) were obtained by analysis of Philip's (1957) infiltration model whereas the transmissivity (*K*) was obtained by analysis of Kostiakov's (1932) model. Figures followed by the same letters within the same column are not significant at $P \leq 0.05$ using Duncan's multiple range test. The organic amendments remains as earlier defined.

The data in Table 7 reveal that 36 months of amendment of tilled soils led to increased water sorptivity, transmissivity, steady-state infiltration rate, cumulative infiltration after 90 minutes and time to attain steady-state infiltration. However, the general trend shows that highest values were obtained when soils were under PE and CS amendment, with PE showing relative increment of more than 100 % over control.

Table 8 indicates that 3 years consecutive amendment of a tilled soil with PE, CS and PR increased water retention at 2 and 10 days after saturation compared to un-amended (NA) plots. There was however no statistical difference observed between treatment mean values of the organic amendments.

Table 8: Effects of organic amendment on water retention (2 and 10 days after saturation) of a tilled top soil

	Volumetric water retained (%)	
Organic amendment	2days after saturation	10 days after saturation
NA	18[b]	8[b]
PE	31[a]	23[a]
CS	29[a]	21[a]
PR	28[a]	20[a]

*Figures followed by the same letters within the same column are not significant at P ≤ 0.05 using Duncan's multiple range test while the organic amendments remains as earlier defined.

4. Discussion

The sandy loam texture of the experimental site is a reflection of the parent material which according to [3] is false bedded sandstone. No change in soil texture was expected following tillage and organic amendment since the dominant particles from parent materials determine soil textural class [3]. The low to very low organic carbon content, pH, P and CEC is typical of degraded tropical soils subjected to high organic matter decomposition rates and high leaching following intense rainy activities. The increase in MWD of both dry and wet aggregates following soil amendment was due to the cementing effect resulting from the decomposition of the organic materials applied which bound loosed soil particles (due to tillage) together into larger aggregates. This resulted in the preponderance of soil aggregates > 0.5 mm in the amended soils compared to the control (NA) soils where aggregates ≤ 0.5mm predominated. The yearly application of the organic amendments meant that there was the presence of decomposing organic matter in the soil as the experiment lasted, thereby protecting the soil particles against the shattering impact of raindrops and wind which accounted for the progressive increase in MWD and hence percentage aggregates > 0.5 mm in amended compared to un-amended (NA) soil. This can be construed as higher stability to water and wind erosion for amended soils. The observed differences in the effects of the organic amendments on MWD and hence on aggregate size distribution of the amended soils reflected their C/N ratio and physical presentation. The PE amendment with a lower C/N ratio and an aqueous presentation compared to the higher C/N ratio and solid presentation of CS and PR, decomposed and incorporated more readily into the soil.[20], reported a high correlation between C/N ratio and rate of decomposition of plant residues. The faster decomposition rate of PE therefore ensured quicker onset of soil aggregation observed especially in the first 6 months period of the experiment. Furthermore, this property of PE also resulted to its shorter resilience compared to CS and PR, which effect was more prominent in the last 6 months of the experiment in which there was no difference in the effect of amendments on aggregate stability. [21] reported that light application of PE caused significant increase in total heterotrophic, phosphate solubilizing, nitrifying and lipolytic bacteria counts. Therefore the metabolites produced by these reported bacteria may also have positively contributed to the comparatively higher aggregate stability observed in PE treated soils. Considering the infiltration data, even in the control soil, the cumulative infiltration rate after 90 minutes (470mm) was more than 25 % of the total annual rainfall at this location (1600 mm).Furthermore, the lowest steady (equilibrium) infiltration rate of 253 mm h^{-1} obtained in the un-amended (NA) soil was greater than the highest likely intensity of average tropical rainstorms. Hence this soil has very good water transmission characteristic and the increased infiltration obtained from the amendment of this tilled soil will not be of much significance in terms of soil loss and runoff water management. Nevertheless the decreasing K_{sat} values obtained in the un-amended soils indicate that dispersed soil particles were continuously filling the surface pores, which may pose a threat in the long-term. [17] reported significantly lower aggregate stability and higher susceptibility to soil erosion leading to alteration of the texture of soil under a long-term tillage experiment. This he attributed to dispersed silt particles which fill/seal the surface pores. A hard physical crust can develop when such soil dries leading to reduced Infiltration, which can result in increased runoff and water erosion, and reduced water available in the soil for plant growth. A physical crust can also restrict seedling emergence.

On the other hand, it is deemed that water percolation due to gravity would have stopped 2 days after saturation; the moisture content at this time then represent the field capacity which for this sandy soil, we assume to be moisture held at - 0.01 M Pa tension. Similarly the moisture content measured 10 days after saturation was assumed to represent the moisture held at - 1.5 M Pa tension (permanent wilting point). Hence between 2 and 10 days after saturation most of the water loss was due to evaporation from the soil surface. The result therefore shows that there was significant reduction in evaporative moisture loss due to soil amendment. The mechanism governing the reduction in evaporative moisture loss by organic amendments stems from the fact that they reduce (by absorption) the intensity of radiation incident on the soil with attendant reduction in the net amount of heat entering the soil. This reduction in the heat flux into the soil lowers the soil temperature and therefore the amount and rate of evaporation from the soil. The absorption and retention of water by the organic fraction of the amended soils and the gradual sealing of pore space by dispersed silt [17] in the un-amended soils also contributed to the significant moisture differences observed.

It is therefore concluded by this experiment that the organic amendments significantly increased aggregate stability and some hydraulic properties of the soil in the order PE > CS > PR. Hence this soil can be tilled once in three (3) years with yearly soil amendment without compromising the benefits of continuous yearly tillage vis-à-vis the studied soil properties. The authors recommend a combination of PE and CS as an adaptation for soil amendment in tropical areas with similar vegetation, where tillage systems predispose soils to high erodibility.

5. References

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