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EFFECTIVENESS OF SOIL AMENDMENTS IN RESTORING THE CHEMICAL PROPERTIES OF SOILS SUBJECTED TO DIFFERENT INTENSITIES OF EROSION IN NSUKKA, SOUTH EASTERN NIGERIA

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Abstract

The effectiveness of soil amendments in restoring the chemical properties of soils subjected to different intensities of erosion in S.E Nigeria was studied in the field. The experiment was arranged as a split-plot in a randomized complete block design. The main plot treatments were the four erosion levels viz, E_1 (slightly eroded with average annual soil loss of 3.28 t/ha/yr), E_2 (slightly eroded with average annual soil loss of 3.96 t/ha/yr), E_3 (eroded with average annual soil loss of 46 t/ha/yr) and E_4 (severely eroded, with average annual soil loss of 147 t/ha/yr). The sub-plot treatments were: control (no amendment), inorganic fertilizer, NPK (F), poultry manure (PM), rice shavings mixed with poultry manure (RS+PM), rice shavings mixed with fertilizer (RS+F) and rice shavings alone (RS). Poultry manure (PM) alone and RS + PM significantly increased the soil organic carbon, total nitrogen, exchangeable bases and cation exchange capacity. Generally, organic residues proved superior to inorganic fertilizers in restoring the chemical properties of the eroded soils. However, PM restored the chemical properties of the eroded (E_2) and severely eroded (E_3) soils to the level obtained in the very slightly eroded soil (E_1).

Key words: *soil amendments, chemical properties, restoring, erosion*

INTRODUCTION

Soil erosion has become a concern worldwide, causing serious problems for food production and other agricultural crops. Soil erosion occurs when environmental factors wear on and remove soil particles. It is also at the heart of other environmental issues. The extent and damage caused by soil erosion in southeastern Nigeria have reached an alarming proportion that the result is untold hardship and frustration to the people of the affected areas. Soil erosion implies the physical removal of topsoil by various agents, including falling raindrops, water flowing over and through the soil profile, wind velocity, and gravitational pull. Soil erosion, therefore, is a serious and widespread problem in many tropical developing countries [17]. Accelerated erosion is one of the most prevalent forms of soil degradation in the world [26]. Every minute, an estimated 10 hectares of agricultural land is lost to erosion throughout the world [19].

The damages caused by soil erosion are manifested in detrimental changes in the chemical properties of the residual eroded soils. Soil loss also results in loss of Ca, Mg, Na, K and O.M. in runoff and eroded sediments [12] as well as an exposure of very acidic subsoils.

Studies on soil management practices for restoring the properties of eroded soils lag far behind those aimed at measuring the amount of soil loss per se. Restoration of degraded soils is a high priority in global scale. When soil carbon pool in degraded cropland increased by one ton, crop yield would increase by 20–40 kg ha^{-1} for wheat, 10–20 kg ha^{-1} for maize, and 0.5–1 kg ha^{-1} for cowpeas. Substantial studies have reported the restored productivity of de-surfaced soils by amending with fertilizer or manure [26]. The use of waste materials as soil amendments has received increased attention in recent years for agronomic applications as well as soil reclamation projects. Adding these materials to soils can be viewed as serving a dual purpose: (1) for disposal of solid waste from municipalities and agricultural operations and (2) as a means to improve chemical and physical soil properties which in turn promotes improved crop performance [24]. [25] found that using crop residues and animal manure on crop almost always has the desired effect, because both contain nitrogen, potassium, and other essential elements [10]. [13] also reported that rice shavings and poultry manure increased the organic carbon and total nitrogen concentrations of a degraded soil and the plots amended with organic wastes had about 90% higher mineralization rate than the unamended or inorganic fertilizer-treated plots. He further observed that rice shavings and poultry manure were important sources of exchangeable bases and organic carbon which contributes significantly to the CEC of soils [8]. [5] noted that crop residues and animal manure not only fertilize the soil, but also provide other benefits that are not immediately evident such as increased soil aggregation which will make the soil to be tilled more easily, increased nutrient and water movement, and enhance root penetration thereby increasing substantially the productivity of the soil [24]. The objective of this study is to determine the relative effectiveness of soil amendments in restoring the chemical properties of different levels of erosion in SE Nigeria.

MATERIALS AND METHODS

This study was carried out on run-off plots established at the University of Nigeria, Nsukka Teaching and Research Farm (Latitude 06^0 51' N; Longitude 07^0 24' E, mean elevation 400 m above sea level). The soil is an Ultisol belonging to Nkpologu series. The vegetation is derived savannah and the parent material consists of deeply weathered colluvium over false – bedded sandstone [16]. Based on years of runoff studies, the plots were demarcated into classes showing degree of degradation as in [18] as shown in Table 1.

Table 1. Main plot treatment with various erosion levels and average soil loss t ha^{-1} yr^{-1}

S/No	Level of Erosion	Treatment	Soil Loss
1	Slightly eroded soil (E_1	Grass cover (*Panicum maximum*)	Average soil loss of 3.28 t ha^{-1} yr^{-1}
2	Slightly eroded soil (E_2)	Legume cover (*Centrosema pubescens*)	Average soil loss of 3.96 t ha^{-1} yr^{-1}
3	Eroded soil (E_3)	Plots cropped to Arable crops, maize followed by cassava without surface residue	Average soil loss of 45.9 t ha^{-1} yr^{-1}
4	Severely eroded soil (E_4)	Bare plots since 1974	Average soil loss of 146.7 t ha^{-1} yr^{-1}.

Source: Ojimgba, 2013

The classification of sites as eroded is based on [22] and [18]. These plots with various degradation levels constituted the main-plot treatment. The organic amendments constituted the sub-plot treatments thus:

Control – No Amendment = C
Complete Fertilizer (alone) = F
Rice Shavings (alone) = RS
Rice Shavings + Complete Fertilizer = RS + F
Rice Shavings + Poultry Manure = RS + PM
Poultry Manure (alone) = PM

Field Methods

Table 2. Nutrient composition of the organic amendments

Nutrient Elements	Organic amendments	
	Rice shavings (RS)	Poultry manure (PM)
Total N (%)	0.73	2.86
Organic carbon (%)	32.11	22.94
Organic matter (%)	55.36	39.55
Ca^{2+} (Cmol kg^{-1})	0.80	5.40
Mg^{2+} (Cmol kg^{-1})	0.92	1.28
Avail P (Cmol kg^{-1})	0.55	1.82
Na^{+} (Cmol kg^{-1})	2.00	3.50
K^{+} (Cmol kg^{-1})	8.00	18.00
C:N	43.99	8.02
C:P	58.38	12.60

Source: Ojimgba, 2013

This was carried out on the run-off plots. Planting was done under zero tillage system. Each main plot measures length and width, 21.5 m x 3 m, while the subplot measures 3 m x 3 m.

Incubation period of 4 weeks was allowed after incorporating the soil amendments before planting. Maize (*Zea mays* L) was planted at a spacing of 75 cm x 25 cm as a test crop.

Two seeds were planted hill^{-1} and thinned down to one after one week.

Table 2 shows the nutrient contents of the organic amendments.

Details of the subplot treatments are given below:

(i) C = no treatment

(ii) F = 270 g N + 72 g P + 162 g K/9 m^2, equivalent to 300 kg N + 80 kg P + 180 kg K) ha^{-1}

(iii) RS = 9 kg RS/9 m^2 ,equivalent to 10 t ha^{-1}

(iv) RS + F = 4.5 kg RS + (135 g N + 36 g P + 81 g K/9 m^2), equivalent to 5 tons RS + (150 kg N + 40 kg P + 90 kg K) ha^{-1}

(v) RS + PM = 4.5 kg RS + 4.5 kg PM/9 m^2 equivalent to 5 tons RS + 5 tons PM ha^{-1}

(vi) PM = 9 kg PM/9 m^2, equivalent to 10 tons ha^{-1}

Data collection centered on ten (10) stands in the subplot. The data obtained were analyzed statistically according to [23]. These subtreatments were randomized within the main plots. The experiment was replicated three times.

Main Plot	(e)	=	4
Subplot Treatments	(a)	=	6
Replications (blocks)	(b)	=	3

Laboratory Studies. Before adding amendments and after harvesting, soil samples were collected from all plots, air-dried, and sieved through a 2mm mesh for routine analysis. The following properties were determined: soil reaction pH, organic carbon, organic matter, total nitrogen, exchangeable bases, cation exchange capacity, exchangeable acidity, base saturation, aluminium saturation and available phosphorus.

These chemical properties of the soil were also measured on the treated plots after harvesting. The procedures that were used for these determinations were outlined below:

Soil Reaction (pH)

Soil pH was determined in O.1 N potassium chloride (KCI) solution using a soil:liquid ratio of 1:2:5. After 20g of soil sample was weighed into plastic beakers, distilled water of KCI was added and stirred for 30 minutes, then the pH values were read off using a glass electrode pH meter [21]; [14].

Organic Carbon (OC)

This was determined by the Walkley and Black method as modified by [3] in which the soil organic matter was oxidized using 1N $K_2Cr_2O_7$ solution and conc. H_2SO_4, and the percentage organic carbon found by titrating with IN ferrous ammonium sulphate solution [15].

Organic Matter (OM)

This was determined from Walkley and Black method. The organic matter content was determined by multiplying the percentage organic carbon by the conventional "Van Bemmelen factor" of 1.724. The use of this factor is based on the assumption that soil organic matter contains 58% carbon [3].

Total Nitrogen (N)

This was determined by the micro-Kjeldahl method [7] using $CuSO_4/Na_2SO_4$ catalyst mixture. The ammonia (NH_3) from the digestion was distilled with 45% NaOH into 2.5% boric acid and determined by titrating with 0.05N HCl.

Exchangeable Bases

Calcium (Ca) and magnesium (Mg) were determined by the complexometric titration method described by [9]. Sodium (Na) and potassium (K) were determined from 1N ammonium acetate (NH_4 OAC) using the auto electric flame photometer [4].

Cation Exchange Capacity (CEC)

CEC was determined by the neutral normal ammonium acetate leaching method [8]. O.1N KCl solution was used to counter – leach, and from the KCl leachate, cation exchange capacity was determined by titration with standard O. 1N NaOH solution.

Exchangeable Acidity (EA)

Exchangeable acidity (H^+ and Al^{3+}) was determined using the titrimetric method of

[14]. The Effective Cation Exchange Capacity (ECEC) was determined by calculation. (ECEC = ∑ bases + KCl – extractable (Al + H) values).

Base Saturation (BS)

Base saturation (BS) was calculated by multiplying total exchangeable bases (TEB) by 100 and dividing by the corresponding cation exchange capacity value.

$$\text{Percentage base saturation} = \frac{TEB \times 100}{CEC}$$

Aluminum Saturation

Aluminum saturation was also calculated by multiplying exchangeable aluminum value by 100 and dividing by the corresponding cation exchange capacity (CEC) value.

$$\text{Al. saturation} = \frac{\text{Exch } Al^{3+} \times 100}{CEC}$$

Available Phosphorus

Available phosphorus was determined by the [6] extractant method – Bray's Method 11 (0.03N ammonium fluoride x 0.1N HCI). The ppm phosphorus was determined using a photo-electric calorimeter [20].

RESULTS AND DISCUSSIONS

Chemical Properties of the Amendment Materials

The nutrient concentrations in the poultry manure and rice shavings are presented in Table 2. Chemical analysis carried out showed that poultry manure had more nitrogen (N) than rice shavings. The values obtained were 2.86 and 0.73% for poultry manure and rice shavings, respectively. Organic matter derived from organic carbon was higher in rice shavings than poultry manure. However, poultry manure had higher base concentrations (Ca, Mg, Na and K) than rice shavings. The values of C:N and C:P ratios obtained were 43:99 and 58:38 for rice shavings, and 8.02 and 12.6 for poultry manure, respectively. The low C: N ratio of poultry manure accounts for its higher rate of mineralization than rice shavings.

Amount of Nutrients Added to the Soil from Amendments

The amount of nutrients supplied by amendments to the soil varied from one treatment to the other. Generally, RS supplied the least amount of N, P, and K, while PM almost supplied greater amount of N, P, Ca, Mg and Na, except that the N concentration was a little lower than that of RS + F. The order in which the nutrients were supplied is PM > RS + PM > RS + F > F > RS.

Some Chemical Properties of Eroded Residual Soils

Table 3 shows the changes in soil chemical properties as a result of erosion before adding soil amendments. Generally, the observations made from the results show that the chemical properties of the soils were low and the values decreased with increase in erosion depth so that E_3 and E_4 had lower values than E_1 and E_2. The soils are generally acidic in soil reaction. In all cases, soil pH in water was greater than the corresponding pH in 0.1N KCl solution. The pH values obtained ranged between 4.70 and 4.23, and 4.27 and 3.71 for soil pH in water and KCl, respectively. The soil pH as shown in Table 3 was strongly to very strongly acidic. These low pH values were partly because the soils were heavily leached due to heavy rainfall. According to [2] low acidity may influence the rate of soil erosion in that basic element which influence aggregation is leached resulting in increased erosion. This confirms that removal of topsoil by erosion consequently exposed very acidic subsoils [18]. Therefore, increase in soil loss results in a decrease in the nutrients status of the soils. However, the values of the total exchangeable bases Na^+, Ca^{++}, Mg^{++}, K^+) were relatively low as well as nitrogen and organic carbon. The low values of the total exchangeable bases in all the erosion levels are because of high rainfall which leaches these nutrients out of the soil solum. [11] working in northern Nigeria and [12] Western Nigeria also observed losses of Ca, Mg, Na and total N in runoff and eroded sediments. The differences were significant at $P<0.05$. The available phosphorus obtained was low values of less than 7 ppm, was recorded for the eroded soils. Therefore, the more hazardous the erosion is on soils, the lower the values of phosphorus. The eroded soils $E_1$and E_2 gave statistically higher nutrient values than the highly eroded E_3 and severely eroded E_4 in the following significant order : $E_1 = E_2 > E_3 > E_4$.

Table 3. Some chemical properties of the eroded soils before adding amendments (0-20 cm depth)

Erosion levels	H_2O	PH KCl	O.C.	O.M.	N	C:N	Na^+	Ca^{++}	Mg^{++}	K^+	Al^{++}	H^+	EA	CEC	ECEC	BS	Al.Sat	Avail. p
			%	%	%		Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	Cmol (+)kg^{-1}	%	%	ppm
E_1	4.70	4.27	1.04	1.79	0.12	8.67	0.12	1.6	0.95	0.25	0.8	0.4	1.2	4.5	4.12	65	17.7	6.6
E_2	4.69	4.23	1.08	1.86	0.13	8.31	0.11	1.5	0.97	0.25	0.6	0.4	1.0	4.3	3.83	66	14.0	6.0
E_3	4.52	3.97	0.91	1.57	0.09	10.11	0.12	1.0	0.60	0.13	1.2	0.4	1.6	3.5	3.45	53	34.3	4.8
E_4	4.23	3.71	0.62	1.07	0.07	8.86	0.12	0.6	0.56	0.10	2.0	0.4	2.4	3.4	3.78	41	58.8	3.7
F-LSD$_{0.05}$	0.16*	0.18*	0.15*	0.25*	0.02*	0.55*	0.00*	0.33*	0.16*	0.06*	0.44*	0.0^{NS}	0.44*	0.39*	0.19*	8.31*	14.4*	0.91*

EA = Exchangeable acidity, CEC = Cation Exchange Capacity, ECEC = Effective Cation Exchange Capacity, BS =Base Saturation, E=Erosion,
* = Significant at 5% level of probability
Source: Ojimgba, 2018

Effects of amendments on chemical properties of soils

(A)Organic Carbon, Total Nitrogen, pH and Available Phosphorus

There were changes in organic carbon, total nitrogen, pH and available P due to incorporation of inorganic fertilizer and wastes (Table 4). Some increase in pH of the amended soils was observed for some treatments. For example, the pH of the slightly eroded soil (E_1) with average soil loss of 3.28 t ha^{-1} yr^{-1} treated with Poultry Manure was raised slightly from 4.69 to a mean of about 5.02 (H_2O) and 4.33 to 5.01 (KCl).

Table 4. Changes in organic carbon, total nitrogen, phosphorus and pH levels of eroded soils following amendmen

Erosion Levels	Amendments	pH H_2O	pH KCl	O.C %	O.M %	Total N %	Avail P (ppm)	C:N
E_1 (3.28 t/ha/yr)	C	4.69	4.33	1.00	1.72	0.11	7.0	9.09
	F	4.67	4.33	1.68	2.90	0.20	84.8	8.40
	RS	4.91	4.48	2.29	3.95	0.27	56.4	8.48
	RS + F	4.79	4.31	2.17	3.74	0.28	70.6	7.75
	RS + PM	5.00	4.95	2.38	4.10	0.30	113.0	7.93
	PM	5.02	5.01	2.50	4.31	0.36	169.5	6.94
	F-LSD$_{0.05}$	0.1*	0.2*	0.3*	0.6*	0.1*	31.6*	0.4*
E_2 (3.96 t/ha/yr)	C	4.62	4.29	1.02	1.76	0.15	6.4	6.80
	F	4.77	4.39	2.00	3.45	0.32	50.8	6.25
	RS	4.97	4.40	2.36	4.07	0.34	56.1	6.94
	RS + F	4.83	4.38	2.20	3.79	0.37	56.5	5.95
	RS + PM	4.98	4.43	2.48	4.28	0.43	113.0	5.77
	PM	5.01	4.99	2.60	4.48	0.45	169.0	5.78
	F-LSD$_{0.05}$	0.1*	0.2*	0.3*	0.6*	0.1*	32.7*	0.3*
E_3 (45.9 t/ha/yr)	C	4.26	3.62	0.93	1.60	0.09	5.1	10.33
	F	4.57	4.01	1.76	3.03	0.18	36.7	9.78
	RS	4.69	4.11	1.94	3.35	0.20	39.6	9.70
	RS + F	4.62	4.03	1.84	3.17	0.23	34.0	8.00
	RS + PM	4.96	4.40	2.10	3.62	0.27	45.0	7.78
	PM	5.40	5.13	2.21	3.81	0.31	50.3	7.13
	F-LSD$_{0.05}$	0.2*	0.3*	0.3*	0.5*	0.04*	9.1*	0.8*
E_4 (146.7 t/ha/yr)	C	4.42	3.60	0.58	1.00	0.06	3.4	9.67
	F	4.47	3.90	1.76	3.03	0.15	31.0	11.73
	RS	4.79	4.00	1.84	3.17	0.18	17.5	10.22
	RS + F	4.69	3.98	1.79	3.09	0.20	22.6	8.95
	RS + PM	4.97	4.32	1.92	3.31	0.23	42.4	8.35
	PM	5.03	4.93	2.07	3.57	0.27	50.9	7.67
	F-LSD$_{0.05}$	0.2*	0.3*	0.3*	0.5*	0.04*	10.0*	0.88*

Source: Ojimgba, 2018

However, the severely eroded soil (E_4) bare plots since 1974 with average soil loss of 146.7 t ha^{-1} yr^{-1}, that is the control, was raised from 4.42 to 5.03 (H_2O) and 3.60 to 4.93

when treated with poultry manure.

[1] opined that the application of different types of organic manures reduced the acidic levels of the soils. Generally, all the amendments increased the organic carbon concentration of the soil, but the magnitude of increase was more for poultry manure than the other amendments (Fig. 2). The total nitrogen content of the soil also increased in the same trend as organic carbon content. Generally, organic carbon content increased from 1.00 to 2.50, 1.02 to 2.60, 0.93 to 2.21and 0.58 to 2.07% for E_1, E_2, E_3 and E_4, respectively following amendments. The C:N and C:P ratios of PM, RS+PM, and RS+F were lower than those obtained for the rest of amendments. The amendments also increased P values from 28.3 to 169.5, 42.0 to 169.0, 21.1 to 50.3 and 15.0 to 50.9 ppm for E_1, E_2, E_3 and E_4, respectively (Table 4).

PM was better than the other amendments in supplying phosphorus as shown in the Table.

[1] observed an increase in soil nutrients with the application of organic manures to the acid soil and nutrient depleted soil. Also, the authors added that the application of different types of organic manures enhanced soil organic C, total N, available P, exchangeable K and CEC better than NPK fertilizer in the soils.

(B)Exchangeable Bases and Cation Exchange Capacity (CEC)

As with the organic carbon and total nitrogen contents (Table 4), application of residues increased the exchangeable bases as well as the CEC of the eroded soils (Table 5).

Table 5. Effects of amendments on exchange properties of eroded soils in Nsukka, Nigeria

Erosion Levels	Amendments	Na^+	Ca^{++}	Mg^{++}	K^+	Al^{++}	H^+	EA	CEC	ECEC	BS	Al.Sat.
		Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	Cmol $(+)kg^{-1}$	%	%
E_1	C	0.11	1.5	1.0	0.20	0.4	1.2	1.6	5.0	4.41	56	8.0
(3.28	F	0.14	2.6	2.9	0.25	0.8	0.4	1.2	7.5	7.09	78	10.7
t/ha/yr)	RS	0.33	2.9	2.3	0.30	0.8	0.8	1.6	9.5	7.43	61	8.4
	RS + F	0.38	3.1	2.7	0.36	0.8	0.4	1.2	9.0	7.74	73	8.9
	RS + PM	0.42	3.5	3.2	0.41	0.4	0.4	0.8	9.2	8.33	82	4.4
	PM	0.49	4.6	4.0	0.49	0.2	0.2	0.4	11.5	9.98	83	1.7
	$F\text{-}LSD_{0.05}$	0.1*	0.6*	0.6*	0.1*	0.2*	0.2*	0.3*	1.3*	1.1*	6.5*	1.9*
E_2	C	0.11	1.3	0.9	0.21	1.2	0.8	2.0	4.6	4.52	55	26.1
(3.96	F	0.24	2.5	2.0	0.27	0.8	1.6	2.4	6.5	7.41	77	12.3
t/ha/yr)	RS	0.27	2.9	1.6	0.31	0.8	0.4	1.2	8.0	6.28	64	10.0
	RS + F	0.29	3.3	1.9	0.33	0.8	0.4	1.2	7.8	7.02	75	10.3
	RS + PM	0.36	3.6	2.6	0.37	0.4	0.4	0.8	8.6	7.73	81	4.7
	PM	0.43	4.1	3.3	0.43	0.4	0.2	0.6	9.7	8.86	85	4.1
	$F\text{-}LSD_{0.05}$	0.1*	0.6*	0.5*	0.04*	0.2*	0.3*	0.4*	1.0*	0.9*	6.5*	4.6*
E_3	C	0.13	0.9	0.7	0.09	1.2	0.4	1.6	4.18	3.42	44	28.7
(45.9	F	0.20	1.3	1.5	0.19	1.2	0.4	1.6	4.5	4.79	71	26.7
t/ha/yr)	RS	0.22	1.8	1.3	0.22	1.2	0.4	1.6	6.9	5.14	51	17.4
	RS + F	0.26	2.1	1.7	0.25	0.8	0.4	1.2	6.5	5.51	66	12.3
	RS + PM	0.30	2.6	2.0	0.30	0.8	0.0	0.8	7.0	6.00	74	11.4
	PM	0.33	3.4	2.5	0.34	0.4	0.2	0.6	8.2	7.17	80	4.9
	$F\text{-}LSD_{0.05}$	0.04*	0.5*	0.4*	0.1*	0.2*	0.1*	0.3*	0.9*	0.7*	8.1*	5.4*
E_4	C	0.12	0.7	0.5	0.06	2.2	0.6	2.8	3.5	4.18	39	62.9
(146.7	F	0.16	1.0	1.5	0.15	1.6	0.4	2.0	4.0	4.81	70	40.0
t/ha/yr)	RS	0.19	1.7	1.1	0.19	2.0	0.0	2.0	6.3	5.18	51	31.7
	RS + F	0.23	1.9	1.8	0.22	1.6	0.4	2.0	6.0	6.15	69	26.7
	RS + PM	0.27	2.5	2.1	0.24	0.4	0.8	1.2	7.3	6.31	73	5.5
	PM	0.29	2.9	2.2	0.25	0.4	0.4	0.8	7.5	6.44	75	5.3
	$F\text{-}LSD_{0.05}$	0.04*	0.5*	0.4*	0.04*	0.5*	0.2*	0.4*	1.0*	0.5*	8.4*	12.6*

* = Significant at 5% level of probability
Source: Ojimgba, 2018.

As noted in this Table, PM and RS+PM were important sources of these exchangeable bases (Na, Ca, Mg, and K). These bases contributed highly to the CEC of the soils. Among the different erosion levels, the highest increase in exchangeable bases was observed for Poultry Manure (PM) treatment, followed by Rice Shavings plus Poultry Manure (RS+PM), while the lowest increase was from the Fertilizer treatment (F).The percentage base saturation also increased significantly and the values obtained ranged between 56 and 83, 55 and 85, 44 and 80, 39 and 75%, for E_1, E_2, E_3 and E_4 (Table 5). Similarly, the CEC increased from 5.0 to 11.5, 4.6 to 9.7, 4.18 to 8.2 and 3.5 to 7.5 cmol (+) kg^{-1} for the erosion levels E_1, E_2, E_3 and E_4, respectively.

Organic matter influenced these chemical properties more than the unamended control (Table 6). Therefore, there was positive correlation between the selected chemical properties and organic matter content of the severely eroded soil (E_4). Hence, the table showed significant correlation at $P < 0.05$ between organic matter and the selected chemical properties of the soils.

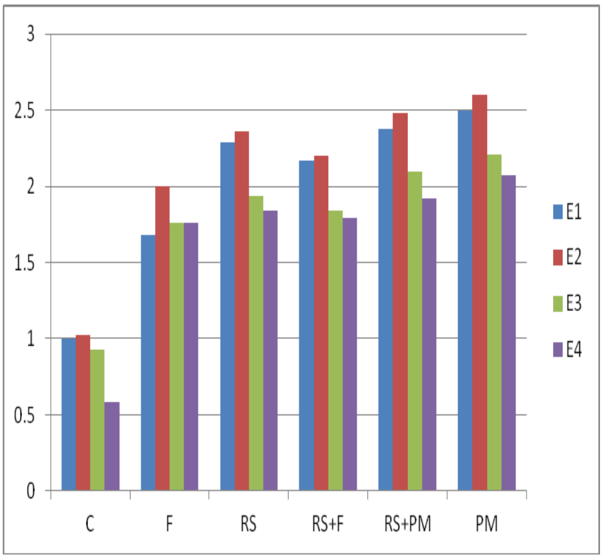

Fig. 1. Effect of amentments on organic carbon in Nsukka eroded soils
Source: Ojimgba, 2018

Table 6. Correlation between selected chemical properties and organic matter contents of the severely eroded soil (E_4)

Dependent variable	**Correlation coefficient (r)**
Total Nitrogen (%)	0.91*
Sodium (**Na**) (Cmol (+) kg^{-1})	0.79*
Calcium (Ca) (Cmol (+) kg^{-1})	0.76*
Potassium (K) (Cmol (+) kg^{-1})	0.93*
Magnesium (Mg) (Cmol (+) kg^{-1})	0.85*

* = Significant at $P < 0.05$
Source: Ojimgba, 2018

CONCLUSIONS

The major emphasis of this study was to evaluate the relative effectiveness of organic and inorganic fertilizers in improving the chemical properties of an eroded soil for better crop yield, and also to ascertain to what extent the productivity could economically be restored by the application of these amendments. The
evaluation of these amendments for use in restoring the productivity of eroded soils in the field has not been studied in Nigeria. Therefore, it may be necessary to point out that knowledge of this will contribute immensely to improving the productivity of abandoned eroded soils.

This study was conducted in the greenhouse and validated in the field. Poultry manure alone, and rice shavings mixed with poultry manure also significantly increased the soil organic carbon, total nitrogen, exchangeable bases and cation exchange capacity when incorporated into the eroded soils. The magnitude of increase was greater in organic waste-treated than on inorganic fertilizer-treated plots. The application of organic wastes restored the productivity of the eroded (E_3) and highly eroded (E_4) soils to almost the level obtained in the slightly eroded soils (E_1 and E_2). Improvements in the chemical properties of the highly eroded (E_4) soil compared to the unamended control were observed following amendments with residues.

It is strongly recommended to use poultry manure for restoring the chemical properties of the eroded soils for near optimum soil productivity, seeing that it had the best desired effect on improving the chemical properties of the eroded soils.

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