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SOIL STRUCTURAL AND CHEMICAL PROPERTIES OF A FALLOWED FIELD SOIL FOLLOWING CASSAVA-COWPEA INTER CROP

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ABSTRACT

An experiment was conducted to evaluate soil structural and chemical properties of a ten years fallowed field soil following cassava-cowpea intercrop in Micheal Okpara University of Agriculture, Umudike in South Eastern Nigeria. Soil sample was randomly collected four meters apart from two depths (0-15cm and 15-30cm), and in triplicate for laboratory analysis to assess horizontal (space) and vertical (depth) variability on the selected soil properties, as well as evaluate if the fallow period had restored soil quality status by comparing observed values with established critical minimum for soil fertility indices. The soil structural and chemical properties analyzed were moisture content, aggregate stability, bulk density, total porosity, organic matter content, exchangeable acidity, exchangeable cations, percent base saturation and soil pH. Results showed that horizontal variations in soil exchangeable acidity and moisture content were statistically significant at P=0.05, while depth significantly (P=0.05) influenced the organic matter content, there was a decrease proportional to depth of sampling. Moisture content decreased with depth and significantly varied horizontally along sampling points. Generally the soil water properties (moisture content and total porosity) and organic matter were higher in the top soil than in the subsoil, while bulk density and exchangeable acidity were higher in the subsoil than in the top soil. Comparison of soil values with established critical minimum indicate that chemical properties (organic matter and base saturation) had values that indicate the soil maintains moderate class in the range of chemical quality index while structural properties (Ksat, AS, and TP) suggest that soil has attained the quality of the high fertility class range.

KEYWORDS: Fallowed field, cassava cowpea intercrop, soil water properties, exchangeable acidity, bulk density, total porosity.

INTRODUCTION

The increasing population pressure on land has resulted in application of different mechanisms to conserve and make better use of the available land space especially in the Southeast agro ecological zone. Shifting cultivation is one of the frequently applied options and is commonly applied to a wide range of cropping systems. However according to FAO convention, it refers to "a system in which relatively short periods of continuous cultivation are followed by relatively long periods of fallow" (FAO/University of Ibadan, 1982). Conceptually during the fallow period an exhausted land (soil) rests, protects itself with natural vegetation and rebuilds its native fertility for periods between 15 – 20 years. An exhausted soil manifest mainly in poor soil organic matter status and as a consequence of this loss in organic matter, soil structure could be modified to a great extent thus reducing the number of granules of sand, clay, and silt percent in affected soil, thus the efficiency of the soil for crop production is reduced (Wanapat, *et al.*, 2005).

The major gain in fallowing is the recovery of depleted soil organic matter by cultivation, according to studies of Schroth, *et. al.* (1994), soil under fallow, forest and low-input agriculture had larger exchangeable acidity than that under high-input agriculture, but the Al concentrations in the soil solution were very small because there were few cations available for exchange and less nitrification. In this study, the structural and chemical properties of the study site after ten years fallow will be compared with established critical minimum for soil in the tropics. The aim is to establish if the soil has returned to quality conditions to support crop productivity after years of fallow.

MATERIALS AND METHODS

STUDY AREA

The experiment was conducted at Michael Okpara University of Agriculture, Umudike. This area lies within latitude 05�29�N and longitude 07^{0}3�E in the rain forest area of Southeastern Nigeria. The zone is characterized by mean annual rainfall range of 1512-2731mm, with maximum and minimum temperatures of 32�C and 23�C respectively and relative humidity of 63-80%. Umudike lies about 122m above sea levels (NRCRI, 2005).

SAMPLING SITE

The ten-year fallowed field consisting of a total area of 21m x 24m was randomly sampled four meters apart at two depths (0-15cm and 15-30cm) in triplicate with core and auger samplers. All soil samples collected were labeled, bagged and air dried for laboratory analysis.

CROPPING HISTORY OF STUDY SITE

The study site is a ten years old fallow site previously under continuous cassava cowpea intercrop. Cassava (Manihot esculenta), also called yuca or manioc, is a woody shrub of the Euphorbiaceae (spurge family) native to South America that is extensively cultivated as an annual crop in tropical and subtropical regions for its edible starchy tuberous root. It is the third largest source of carbohydrates for human food in the world (Philips, 1983; Claude and Denis; 1990) Cassava is classified as "sweet" or "bitter" depending on the level of toxic cyanogenic glucosides. Improper preparation of bitter cassava causes a disease called konzo. Nevertheless, farmers often prefer the bitter varieties because they deter pests, animals, and thieves. At the same time that underground storage of cassava is advantageous for managing work schedules, it may also lead to reduced

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quality of the roots, sometimes leaving the roots unsuitable for many types of processing. In some areas farmers have come to increasingly rely on dried Cassava chips. The report of Nweke *et al*., (1997) revealed that about 42% of harvested cassava roots in West and East Africa are processed into dried chips and flour.

Cowpea is an annual legume that belongs to the family Papilionaceace, with several species being from all over the world. Cowpea is a grain legume that constitutes an important source of plant protein for man and livestock (Opeke, 2006). The crop can be grown in regions of annual rainfall of 500–1500 mm. However, for seed purpose cowpea reasonably performs well on soil low fertility and also on well drained sandy loam or clay loam when the soil pH is in the range of 5.5 to 6.5. It is very important food science in developing countries where animal protein is limited. The dried edible seeds of cowpea for which the crop is cultivated in most areas contains about 23 – 25 % protein, 1.9 % fat, 6.3 % fiber, 63.6 % carbohydrate, 0.0014 % niacin (Tenbe *et al*., 1995). It is a drought-tolerant and warm-weather crop, and well-adapted to the drier regions of the tropics, where other food legumes do not perform well. It also has the useful ability to fix atmospheric nitrogen through its root nodules, and it grows well in poor soils with more than 85% sand and with less than 0.2% organic matter and low levels of phosphorus. In addition, it is shade tolerant, and therefore, compatible as an intercrop with maize, millet, sorghum, sugarcane, and cotton. This makes cowpea an important component of traditional intercropping systems, especially in the complex and elegant subsistence farming systems of the dry savannas in sub-Saharan Africa.

LABORATORY ANALYSIS

Soil structural properties analyzed in the laboratory include; particle size distribution, determined using the hydrometer method (Bouyoucous, 1951), bulk density by the method of Anderson and Ingram (1993). Aggregate stability was determined using the wet sieving method as described by Kemper and Chepil (1965). Aggregate stability was assessed at micro aggregate (WSA < 0.06mm) and expressed as percentage weight of aggregate in the various size fraction over that of original soil, as follows:

Selected soil chemical properties analyzed in the laboratory include: soil PH which was measured electronically with a glass electrode pH meter in water using liquid suspension ratio of 1:2.5 as modified by Jones (2001), soil organic carbon was determined by method of Nelson and Sommers (1982).

Other chemical properties analyzed include exchangeable acidity determined by the method of Mclean (1965) while exchangeable K, Ca, Mg, and Na were determined by extracting soil sample with IN NH_4OAc (Jones 2001). The

$$AS(\%) <0.06mm = \frac{\text{Weight of aggregate in the <0.06size fraction}}{\text{Weight of original sample}} \times \frac{100}{1} \quad \text{……….Eqn. 1}$$

Soil total porosity (TP) was calculated from the bulk density and based on assumption of 2.65 of g/cm3 particle density

$$Tp\ (\%) = \left\{ \frac{1 - \text{Bulk density}}{\text{Particle density}} \right\} \times \frac{100}{1} \text{………………………Equation 1}$$

Saturated hydraulic conductivity (K_{sat}) was determined by constant head permeameter method (Stoite, 1997). The saturated hydraulic conductivity (K_{sat}) was calculated using Darcy's equation for vertical flow of liquid as explain by Young (2001) as follows.

$$K_{sat} = \frac{QL}{(AT \times DH)} \text{ ………………………… .Equation 2}$$

Where;

Ksat = saturated hydraulic conductivity
A = Cross sectional area of core sampler (cm2)
Q = Volume of water flowing through the core sample per unit time (cm3)
T = Time of flow (sec)
DH = Hydraulic Head difference
L = Length of core sampler (cm).

Gravimetric moisture content was determined from undisturbed soil samples as described by Gardener (1965). The core samples were saturated in water and their weight at saturation were taken, the samples are oven dried at 105°C for 24 hours. Dry samples were cooled in desiccators and reweighed again, moisture content (MC) was computed as:

$$MC = \frac{Ww - Dw}{Dw} \times \frac{100}{1} \text{……………… ………………Equation 3}$$

Where,

Ww = Wet weight of soil
Dw = weight of soil.

amount of K, Ca, Na in the filtrate was determined using a flame photometer, Mg was determined using an atomic absorption spectrophotometer, percent base saturation was computed thus;

$$BS\ (\%) = \frac{Ca + Mg + Na}{ECEC} \times \frac{100}{1} \quad \text{.............................. Equation 6}$$

DATA ANALYSIS

Data collected was subject to analysis of variance (ANOVA). Means were separated using Fishers least significant difference (F_{LSD}) at 5% probability level.

RESULT AND DISCUSSION

Results showed (Table 1) significant (P=0.05) decreases in organic matter content with depth. This may be due to the fact that the top soil contained more organic matter or that there was organic matter deposition in the soil surface due to the fallowing of soil. The decrease in organic matter with depth may also be attributed to soil compaction which hampers circulation of air and water and hinders microbial activity down the soil profile. Exchangeable acidity however increased with depth and varied horizontally along sampling area (Table 1), this observation supports the report of Schroth *et. al*., (1994), that soils under fallow fields were higher in exchangeable acidity than that under high input of manure. Moisture content decreased with depth and significantly varied horizontally along sampling points. Soil organic carbon had positive correlations (Fig 1a and 1b) with the effective cation exchange capacity (ECEC) of the and exchangeable acidity (EA) at both soil depth, however the ECEC had higher coefficient of correlation of 75% at deeper depth compared to the shallow depth (R^2= 46% and 53% for ECEC and EA respectively). Assessment of the relationships between structural properties irrespective of depth of sampling, indicated that aggregate stability explained over 62% of the variability in soil saturated hydraulic conductivity of the fallowed field soil (Fig 2a) but explained only between 23% to 26% variability in the other soil properties (Tp, BD,), however at shallow depth percent AS explained over 40% (44-51%) variability observed in soil structural properties (Tp, BD, Ksat) (Fig. 2b).These observation indicate that the soil structural property of the fallowed field soil has undergone structural remediation probably due to increased accumulation and deposition of organic matter which is associated with fallow periods. Therefore the immediate effect manifested on the surface layer of the soil and would probably extend with length of fallow period to deeper soil layers.

Generally the observed values for the structural and chemical properties of the fallowed field soil studied indicated that the soil fertility status will sustain agricultural productivity since the soil had a high to moderate index rating (Table 2) for selected structural properties (Ksat, PT, BD and AS) and a moderate index rating for organic carbon, percent base saturation and soil reactivity (low pH). Also the texture of the soil was loamy sand and this study observed that organic matter was higher in the top soil than the subsoil, though exchangeable acidity of the soil samples was low; such low exchangeable acidity values for soils with low pH suggest that the soils had high capacity of basic cation, therefore the soil under proper agronomic practices can be put into sustainable crop production.

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Table 1: The physico-chemical properties of the study site.

Spacing	Depth (cm)	OM (%)	ECEC (Cmol/kg)	BS (%)	EA (cmol/kg)	AS (%)	Ksat (cm/s)	BD (g/cm3)	MC (%)	TP (%)
A	0-15	2.85	8.49	60.68	3.33	53.49	0.76	0.76	18.04	9.06
	15-30	1.32	9.10	51.59	4.48	29.47	3.40	0.78	17.56	8.43
B	0-15	3.22	10.16	46.49	5.28	35.09	2.97	0.74	16.93	9.94
	15-30	2.78	9.67	47.01	5.52	40.39	3.67	0.76	16.57	8.93
C	0-15	2.98	9.98	50.95	4.96	50.32	1.77	0.81	14.73	7.23
	15-30	2.36	9.55	57.44	3.95	32.37	2.87	0.79	14.2	7.8
D	0-15	2.48	9.89	48.40	5.15	46.51	3.33	0.79	16.81	7.8
	15-30	1.66	9.87	37.29	6.24	51.82	7.10	0.80	16.73	7.42
FLSD(0.05)		D=0.929	NS	NS	D=0.913	NS	D=1.596	NS	D=1.158	NS
		S=0.657			S=1.291		S=2.257		S=1.63	
		DxS=1.314			DxS= 1.825		DxS=3.192		DxS=2.315	

Table 2: Analysis of variance table showing significant properties.

Source of variation	Df	SS	MS	Ftab	Fprob
			Moisture content (MC; %)		
Replication	2	2.121	1.061	0.61	-
Depth	1	0.788	0.788	0.45	0.51
Spartial var.	3	35.664	11.888	6.80	0.01
DXS	3	0.180	0.060	0.03	0.99
Error	14	24.473	1.748	-	-
Total	23	63.226	-	-	
		Saturated hydraulic conductivity (Ksat) cm/s			
Replication	2	39.94	19.971	6.01	-
Depth	1	25.277	25.277	7.61	0.02
Spartial var.	3	36.689	12.23	3.68	0.04
DXS	3	9.036	3.012	0.91	0.463
Error	14	46.55	3.323	-	-
Total	23	157.45			
		Organic matter content (OM; %)			
Replication	2	3.26	1.63	2.90	-
Depth	1	4.37	4.37	7.76	0.050
Spartial var.	3	3.76	1.254	2.23	0.130
DXS	3	1.03	0.344	0.61	0.619
Error	14	7.88	0.563	-	-
Total	23	20.30	-		
		Exchangeable acidity (EA; cmol/kg)			
Replication	2	3.154	1.577	1.45	-
Depth	1	0.814	0.814	0.75	0.40
Spartial var.	3	12.345	4.115	3.79	0.05
DXS	3	4.558	1.519	1.40	0.28
Error	14	15.207	1.086	-	-
Total	23	26.078	-	-	-

Table 3: Comparison of observed values in study site with established critical minimum values of soil quality rating

Soil parameter	Sampling depth	A	B	C	C	Critical minimm*	Rating*
		Observed value	Observed value	Observed value	Observed value		
OC (%)	0-15	2.85	3.22	2.98	2.48	1-3	Moderate
	15-30	1.34	2.78	2.36	1.66		
ECEC (Cmol/kg)	0-15	8.49	10.16	9.98	9.89	6-12	Low
	15-30	9.10	9.67	9.55	9.87		
BS (%)	0-15	60.68	46.49	50.95	48.40	40-60	Moderate
	15-30	51.59	47.01	57.44	37.29		
EA (Cmol/kg)	0-15	3.33	5.28	4.96	5.15		Moderate
	15-30	4.48	5.52	3.95	6.24		
BD	0-15	0.76	0.74	0.81	0.79	<1.3Mg/m3	High
	15-30	0.78	0.76	0.79	0.80		
TP (%)	0-15	9.06	9.94	7.23	7.80	<10	Low
	15-30	8.43	8.93	7.80	7.42		
AS (%)	0-15	53.8	35.09	50.32	46.51	50-75	High
	15-30	29.47	40.39	33.37	51.82		
Ksat (cm/s)	0-15	0.76	2.97	1.77	3.33	0.2-2 (cm/h)	High
	15-30	3.40	3.67	2.87	7.10		

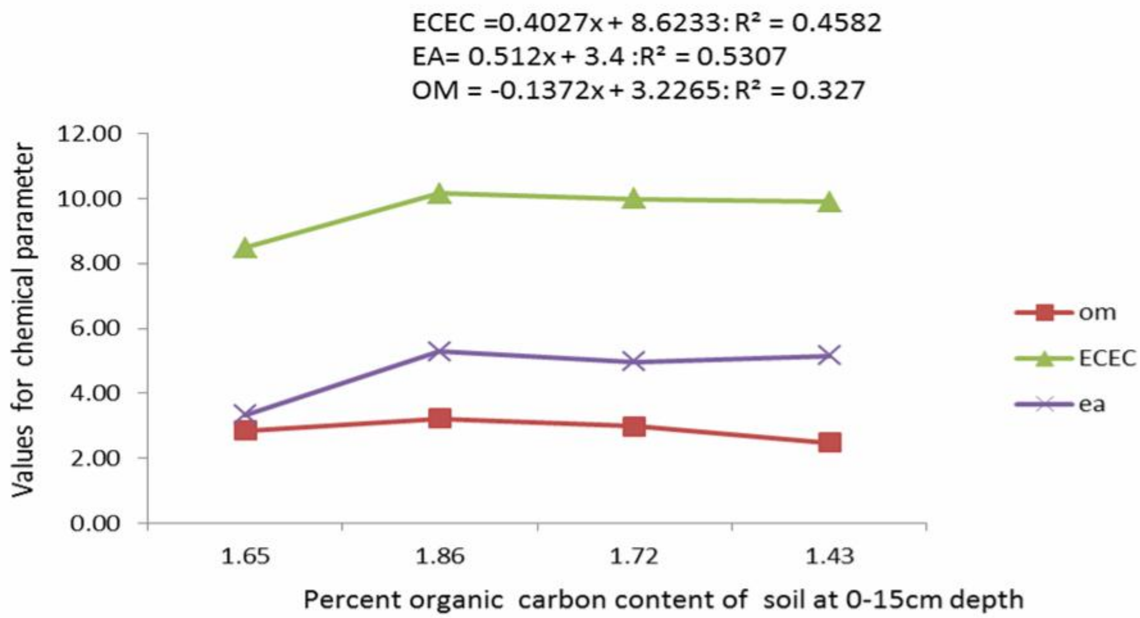

Fig. 1a: Relationship between organic carbon and selected chemical indices at 0-15cmdep

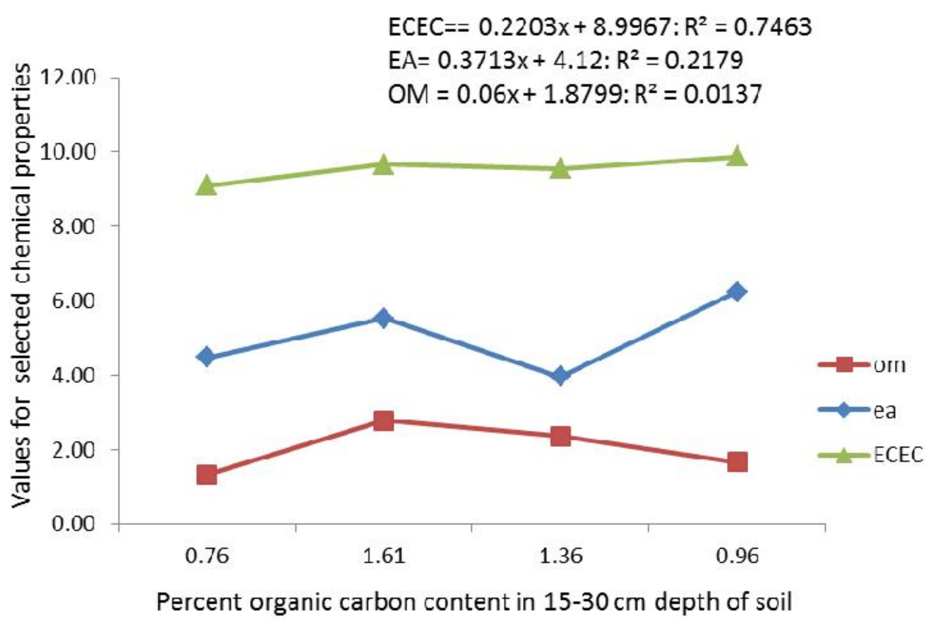

Fig 1b: Relationship between organic carbon content and selected chemical properties at 15-30cm depth of soil

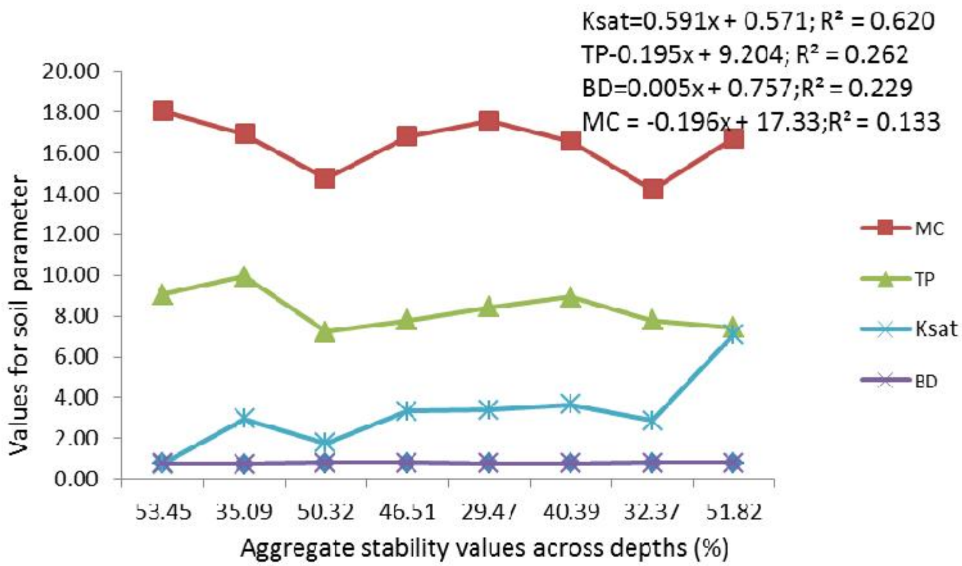

Fig. 2a: Relationship between soil structural parameters of fallowed field

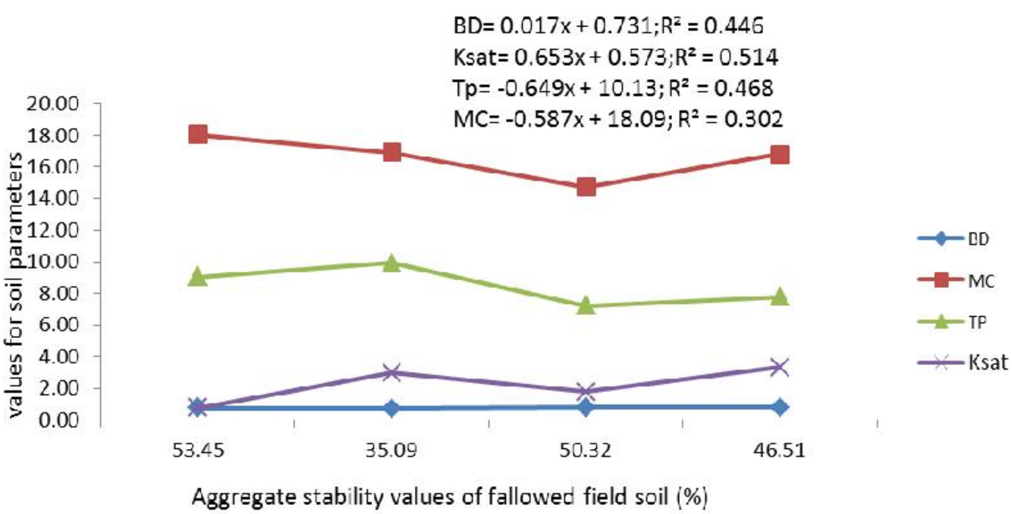

Fig 2b : Relationship between structural properties of fallowed field soil at 0-15cm depth