Original Research Article

PHYSICAL AND CHEMICAL PROPERTIES OF FOUR CONTRASTING SOILS UNDER DIFFERENT LAND USE SYSTEM

Abstract

This study was undertaken to evaluate the physical and chemical properties of four contrasting soils under two land use systems. The land use types considered were fallow and cultivated. Four soils from Nsukka Hill (Entisol), Nsukka poultry site (Ultisol), Eha-Amufu (Inceptisol) and Ikem (Inceptisol) in Nsukka area of south eastern Nigeria were used for the study. Soil samples from the 0-25cm depth were collected from cultivated and adjacent fallow lands in the four different locations. The soil samples were air-dried at room temperature and then sieved through a 5.00mm sieve. Two hundred and fifty grams (250g) of the sieved sample were further sieved through 2mm sieve and use for the determination of physical and chemical properties of the soils. The result of the study showed that soils under continuous cultivation have low value in all the parameters assessed compared to the adjacent fallow soils. Continuous cultivation decreased the concentration of organic matter (OM), from 2.08-1.87% nitrogen (N), 0.3-0.17% and phosphorous (P) 4.30-3.80 $mgkg^{-1}$ content in all the soils studied. The pH of the soils measured in water and KCl showed low values in cultivated soils with the range 4.10-4.50 and 3.50-3.70 respectively as against fallow soils 4.60-4.90 and 3.20-4.50 respectively. Exchangeable bases, cat ion exchange capacity (CEC) and Base saturation (BS) of the soils decreased following cultivation except for K in Ikem soils, CEC in Nsukka Ultisol and BS in Ikem Inceptisol. Cultivation increased the exchangeable Al^{3+} and H^{+} in the Nsukka Entisol and thus increased the acidity. The result of this study is evidence that continuous cultivation causes depletion of soil nutrients and generally affects the physical-chemical properties of soils. This can be remedied through appropriate management practices based on organic residue incorporation, if agricultural productivity and environmental harmony are to be sustained in these soils for future generation.

Keywords: Entisol, Ultisol, Inceptisol, physical and chemical properties, Fallow, cultivated.

INTRODUCTION

Pressure mounted on available agricultural land due to increased population densities has affected agricultural development especially in Nigeria and South east in particular. These available lands are put into continuous cropping leading to severe depletion in their fertility status. On the other hand, fallows allow the accumulation of easily degradable organic matter (O M) and some dust to regenerate soil fertility (Gaiser 1993, Herrmann 1996). Even more harm is being exerted on these lands by the introduction of mechanized farming system with different tillage implements, all in a quest to increase agricultural productivity. All these exert different impacts on soil productivity. An abundant harvest is always obtained from a forested land when newly cleared, burnt and cultivated in the first few years. Successive cropping of the same piece of land however results in decrease in yield. When the land is cropped continuously productivity declines fast (Brabant *et al.* 1996). Hence Nye and Green land, (1964) reported that a soil cannot be productive except it has desirable quality, physical characteristics and enough nutrients that will meet the plant needs. Agricultural soil must be kept in aggregated and well-aerated conditions so that crop growth will not be adversely affected (Braunack et al 1979).

Cultural practices such as cutting and burning of tropical forests quicken loss of nutrients by leaching and erosion (Ahn, 1970, Nye and Greenland 1964), cause nutrient cycle to deteriorate and affect the sustainability of the agricultural land (Kang, 1990). Also cultural practices have profound effect on the physical properties of soils, such as bulk density, porosity and water retention (Page and Willard 1946). Lal and Kimble, (1997) reported that continuous cropping and cultivation of many of the world’s soils which had previously been under forest or grass land, are the major cause of substantial decline in soil organic matter and soil structure. Soil organic matter content is considered important indicator of soil productivity in agricultural soils. It binds mineral particles into stable aggregates (Tisdall and Oades, 1982). Soil structural stability and soil organic carbon content usually decrease with cultivation (Eynard *et al.*, 2004). Cultivation reduces soil carbon content and changes the distribution and stability of soil aggregates (Six *et al.* 2000a). Shepherd *et al*. (2001) and Hayness *et al*. (1997) reported significant correlation of aggregate stability with soil organic carbon due to the binding action of humus substances and other microbial by products. Though in some cases soil organic carbon may be only moderately (Skoien, 1993) or weakly (Holeplass et al, 2004) correlated with aggregate stability. Therefore, the decline of food production in Nigeria may be attributed to the farmer’s inability to identify and replenish nutrients lost in the soil following different land use systems with a view of managing the soils according to their capabilities and limits. Thus this study was conceptualized to evaluate the physical and chemical properties of four contrasting soils under different land use systems.

Materials and Methods

Study area and sample collection

Soil samples from the 0-25cm depth were collected from cultivated and adjacent fallow lands in four different locations in Nsukka area of south eastern Nigeria. Care was taken to minimize disturbance during sampling and transportation. The area has a rainforest savannah type of vegetation with a mean annual temperature of 24^{oc}. The area lies within latitude 06^0 61^1N and longitude 07^0 25^1E of Nigeria. Eha-Amufu and Ikem locations from which soil samples were collected are hydromorphic type. The soil cracks when dry and becomes sticky when wet, presenting problems to tillage operations. The soils sampled for the study are classified according to soil taxonomy as an Ultisol, belonging to the sub-group, typic kandiustult (Nkpologu series), Entisol belonging to lithic ustorthent (Uvuru series), while the other two soils belong to vertic inceptisol (SSS, 1992). These soils have been under cultivation for relatively eight (8) years, while fallow soils varied from 3 – 4 years. The cultural practices is by slashing and burning and fertilizer application is occasional and mainly NPK.

Table 1 Location, Classification and Land use type

Location	Classification	Treatment symbol	Land use type
Nsukka Hill	Lithic Ustorthent	ENsk (F)	Fallow
Site	(Uvuru series)	ENsk (C)	Cultivated
Nsukka	Typic Kandiustult	UNsk (F)	Fallow
Poultry Site	(Nkpologu series)	UNsk (C)	Cultivated
Eha-Amufu	Inceptisol	IEh (F)	Fallow
Site	(with vertic properties)	IEh (C)	Cultivated
Ikem Site	Inceptisol	Iik (F)	Fallow
	(with vertic properties)	Iik (C)	Cultivated

The soil samples were air-dried at room temperature and then sieved through a 5.00mm Sieve. Clods were carefully crushed by hand along lines of natural cleavages to pass the sieve. Two hundred and fifty grams (250g) of the sieved sample was further sieved through 2mm sieve and continued until enough quantity was collected for further analysis.

Laboratory method

The Bouyocous hydrometer method described by Day (1965), were used to determine the particle size distribution of the soils. Walkley and Black's method (1935) as modified by Allison(1965) was used to determine organic carbon and organic matter was determined from Walkley and Black's method by multiplying the determined percentage organic carbon by the conventional Van Bemmeler factor of 1.724. The Kjedahl method (Bremner, 1965) using $CuS0_4$, $1Na_2S0_4$ catalyst mixture was used to determine total Nitrogen. Available phosphorus was determined by Bray and Kurtz (1945), Bray II method. The available phosphorus was read off from standard curve after obtaining the optical density from a photo-electric colorimeter. The pH of the soils was determined in solution using a soil: liquid ratio of 1:2.5 and read off using a Beckman Zeromatic pH meter (Peech, 1965). Mclean (1965) method was used to determine the Exchangeable acidity. Cat ion Exchange Capacity (CEC) was determined based on the principle described by Chapman (1965). The complexion-metric titration method was used to determine Ca and Mg while Na and K were determined from 1N ammonium acetate (NH4 OAC) using flame photometer (Chapman, 1965). While Base saturation of the sampled soils was calculated using the formula

$$BS\,\% = \frac{TEB}{CEC} \quad x \quad 100$$

Data analysis

Data generated from the study were subjected to the analysis of variance procedure according to Steel and Torrie (1980) and least significance difference (LSD) at 0.05 was used to compare treatment means.

Results and Discussion

The result of particle size analysis indicated variations in the parent materials of these soils. The UNsk had more sand than the other soils (Table 2a), probably because it may have been formed from granite parent material. Cultivation had effect on the texture of the ENsk, IEh and Iik, but had no effect on the texture of UNsk. The other three soils (ENsk, IEh, Iik), whose parent material are of finer grains had clayey textures. According to Fisher and Binkley (2000) soil texture is the most fundamental quantitative soil physical property that control water, nutrient and oxygen exchange, retention and uptake. It is a master soil property that influences most other properties and processes.

Table 2a Particle size distribution of the 0-25cm depth of the soils

Property	ENsk (F)	ENsk(C)	UNsk (F)	UNsk (C)	IEh (F)	IEh (C)	Iik (F)	I ik(C)
Sand %	45	40	55	60	15	15	20	25
Silt %	15	15	20	15	50	40	50	45
Clay%	40	45	25	25	35	45	30	30
Textural Class	SC	C	SCL	SCL	SiCL	SiC	SiCL	CL

C = Clay, SC = Sandy Clay, SCL = Sandy Clay Loam, CL = Clay Loam, SiCL = Silt Clay Loam, SiC = Silt Clay F = Fallow, C = Cultivated, ENsk = Entisol at Nsukka, UNsk = Ultisol at Nsukka, IEh = Inceptisol at Eha-Amufu, Iik = Inceptisol at Ikem

The organic matter (OM) concentration of the fallow soils was generally higher (2.06%-2.08%) than those of the cultivated soils; 0.97%-1.87% (Table 2b) and the values obtained were also significantly difference (P=0.05) when compared to the values of cultivated soils except for UNsk (F). However among the fallow soils there was no significant difference on the values obtained, while IEh (C) and Iik (C) showed significant differences among the cultivated soils. This is a clear indication that cultivation caused a decline in the OM concentrations of these soils. Elliot, (1986), made similar observation on grassland soils of the USA. While Yousefifard, (2007) and Fallahzade and Hajabbasi, (2011) reported negative effect of organic matter following land use changes especially cultivation of native land. The reduction in the OM concentration due to cultivation may be attributed to the mineralization of soil OM binding micro aggregates into macro-aggregates (Elliot, 1986 and Gupta and Germida, 1988). Though Six *et al* (2000) observed that if oxides, rather than soil are the dominant agents in aggregate stabilization in weathered soil, the relation between OM and macro-aggregates might not be as strong as the soils with dominant clays. Soil organic matter is the primary source of energy and nutrient for many soil organisms, water holding capacity, cat ion exchange capacity and the formation of stable aggregates (Creswell and Lefroy 2001). Tillage practices disrupt soil aggregates, exposing more OM binding to microbial attack and subsequently reduced their concentration in soils (Beare *et al*., 1994). Young and Young (2001) noted that continuous cultivation exposes OM to a greater rate of decay and oxidation. The reduction of OM concentration due to cultivation can be negated through the absorption of OM to clay minerals which protect it from microbial attack (Oades 1984, Ladd *et al.*, 1985) or by reduced tillage practices which can result in greater aggregation and higher standing stocks of soil OM (Doran, 1980, Carter, 1992). Beare *et al*., (1994) observed that the formation and stabilization of macro-aggregates represent an important mechanism for the protection and maintenance of soil OM that maybe lost under cultivation. The pH values of the cultivated soils were slightly lower than those of the fallow soils both in water and in KCl (Table 2b). The low pH values in the cultivated soils may be due to a reduction in OM content which serve as a buffering agent which probable might have resulted from the oxidation of nitrogen and sulphur. Igue, (2000) reported similar results when he found a rate of decline in pH of 0.04-0.06 in cultivated soils compared to the uncultivated soils. Soil pH is important in determining the availability of many elements, because of its relationship to solubility and rates of decomposition (Schoenholtz *et al.* 2000).

Table 2b **Organic matter, total nitrogen, available phosphorous and pH of the 0-25cm depth of the soils**

Property	OM%	N%	Avail.P Mgkg^{-1}	pH H_20 (1:2.5)	pHKCL (1.2.5)
ENSK (F)	2.06	0.3	4.30	4.60	3.20
ENSK (C)	1.0	0.12	3.80	4.30	3.50
UNSK (F)	1.03	0.10	3.80	4.90	4.50
UNSK (C)	0.97	0.09	3.80	4.10	3.70
IEh (F)	2.08	0.15	3.80	4.70	4.10
IEh (C)	1.92	0.12	2.70	4.50	3.30
IiK (F)	2.05	0.19	3.20	4.90	3.80
IiK (C)	1.87	0.17	3.20	4.40	3.50

LSD	0.26	0.09	0.55	0.40	0.63

LSD= Least significance difference, F = Fallow, C = Cultivated, ENsk = Entisol at Nsukka, UNsk = Ultisol at Nsukka, IEh = Inceptisol at Eha-Amufu, Iik = Inceptisol at Ikem

The total nitrogen content of the cultivated soils were generally lower than those of the fallow soils (Table 2b), which implies that cultivation reduced the total nitrogen content. The value of total N obtained from ENsk (F) showed significant difference (P=0.05) among the values obtained from the other soil types and land use systems. Khrisat *et al* (2008), Khormali *et al* (2005) and Lemenin (2004) made similar observation when they reported significant reduction in N content of cultivated soils compared with forest soils. Cultivation substantially decreases N mineralization (Majaliwa *et al* 2010). Su *et al* (2004) observed that even short cultivation had a significant effect on soil N, C and biological properties with lower basal soil respiration and enzyme activities than the native grassland soils. Faniran and Areola (1978) reported that the total nitrogen content of tropical soils is usually low because of high leaching rates occurring in these soils. The results of available P are shown in Table 2b.The available P concentrations of the ENsk and IEh were higher than those of the other soils but there was no increase in the available P concentration of the cultivated UNsk and Iik compared to the fallow soils. Nonetheless, cultivation had effect on the available P content of the soils especially ENsk and IEh soil locations.

The values of the exchangeable bases (Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}) obtained for the soils are given in Table 3. A range of 0.08-0.14 $Cmolkg^{-1}$ for the fallow soils and 0.07 - 0.13 $Cmolkg^{-1}$ for the cultivated soils was obtained for Na^{+}. The range for K^{+} was 0.08 - 0.13 $Cmolkg^{-1}$ for the fallow soils and 0.06 to 0.12 $Cmolkg^{-1}$ for the cultivated soils. The values for Ca^{++} varied between 0.70 to 1.30 $Cmolkg^{-1}$ for the fallow soils and 0.40 to 0.80 $Cmolkg^{-1}$ for the cultivated soils where as the range for Mg was 0.60 to 0.90 $Cmolkg^{-1}$ and 0.10 to 0.60 Cmolkg-1 for the fallow and cultivated soils, respectively. The amount and distribution of exchangeable cat ions are influenced by kinds and nature of soil parent materials. The data obtained showed that the exchange complexes were occupied mainly by Ca and Mg. Adamu (1996) made similar observations for some Nigerian soils. The exchangeable bases values of the fallow soils were higher than those of the cultivated soils, which imply that cultivation reduced the concentration of the exchangeable bases of these soils. However, this is contrary to the result for Na obtained from IEh where the cultivated soil value was slightly higher than that of the fallow soil. The value of K obtained from Iik showed that cultivation had no effect on this exchangeable base concentration. Lemenin, (2004) and Hajabbasi *et al,* (2007) reported that intensive cultivation diminishes available Potassium content of soils. While Khormali *et al.* (2009) observed that lack of permanent vegetative cover and water erosion may be the major possible reasons for loss of available potassium in the deforestation.

Table 3 **Chemical Properties ($cmolkg^{-1}$) of the fallow and cultivated soils**

Property	Na	K	Ka	Mg	CEC	Exch.acidity $AL^{3+}+H^{+}$	BS%
ENSK (F)	0.14	0.13	1.30	0.90	10.0	1.8	23.0
ENSK (C)	0.12	0.09	0.60	0.40	3.5	2.0	21.0
UNSK (F)	0.08	0.08	0.70	0.60	2.5	2.4	50.0
UNSK (C)	0.07	0.06	0.40	0.50	2.5	2.2	49.0
IEh (F)	0.12	0.13	0.90	0.80	5.0	2.0	55.0
IEh (C)	0.13	0.08	0.40	0.10	3.0	2.0	27.0
IiK (F)	0.13	0.12	0.90	0.80	4.0	2.4	46.0
IiK (C)	0.12	0.12	0.80	0.60	4.0	2.4	46.0
LSD	0.04	0.04	0.19	0.19	1.26	NS	5.8

BS= Base Saturation, LSD = Least significance difference, NS = Non- significance, F = Fallow, C = Cultivated, ENsk = Entisol at Nsukka, UNsk = Ultisol at Nsukka, IEh = Inceptisol at Eha-Amufu, Iik = Inceptisol at Ikem

In two soils (ENsk and IEh), the cat ion exchange capacity (CEC) of the fallow soils were higher than those of the cultivated soils. In two other soils (Iik and UNsk), cultivation had no effect on their CEC (Table 3). The CEC values ranged from 2.5-10 $Cmolkg^{-1}$ for the fallow soils and 2.5-4.0 $Cmolkg^{-1}$ for the cultivated soils. The lowest values of the CEC occurred in the UNsk. This low CEC value could be due to low clay and organic matter concentration in this soil (Table 2b) or probably the kind of clay mineral and sesquioxide present. Enwezor *et al*., (1990) reported that greater amount of kaolinite and sesquioxide leads to the lower CEC in soils. Khormali *et al*. (2009) observed that decrease in CEC reflects the textural and organic matter changes in deforestation. The decrease in soil cat ion exchange capacity following cultivation is in line with Igue (2000), Lemenin, (2004) and Yousefifard *et al*., (2007).

The base saturation (BS) values of the fallow soils were higher than those of the cultivated soils with the exception of the cultivated Iik which had the same value as the fallow soil (Table 3). The values for the fallow soils are 23.0% 50.0% and 46.0% for ENsk, UNsk, IEh, and Iik soils, respectively as against cultivated soil values of 21%, 49.0%, 27.0% and 46.0% for the respective soils. The magnitude of the different values may be due to the CEC contents as well as the composition of the clay mineral and organic matter content of the individual soils. This is because the presence or absence of alkalis and alkaline earths, especially potassium and magnesium and the amount of time they remain in the environment of alteration are important factors in determining which clay minerals will be produced in the soils (Keller, 1956). Kaolinite seems to develop where leaching is intense and where strong oxidation of inorganic and organic matter prevails, while partial or incomplete leaching tends to yield montmorillonite, it requires an environment in which Mg, Fe and Ca are present (Holeman, 1970). Cultivation had no effect on the exchangeable Al^{3+} and H^{+} of the IEh and Iik (Table 3), as the values obtained showed non-significant differences among the soil types and land use systems. In the ENsk, cultivation increased the Al^{3+} and H^{+} content of the soil and consequently increased the acidity. The limited effect of cultivation on Al^{3+} and H^{+} may be due to increased organic matter content in these soils which buffer any serious changes in acidity.

Conclusion

The result of this study is evident that cultivation diminishes soil nutrients, available P, exchangeable bases and CEC, organic matter and organic carbon as well as total N and cause fluctuation in soil pH. Therefore to ensure optimum production in the studied soils, management practices based on plant and animal residues, compost manure in corporation, planting of cover crops and crop rotation will build up soil organic matter, soil nutrients and reduce to the barest minimum environmental degradation.

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