LAND USE EFFECTS ON SOME PHYSICO-CHEMICAL PROPERTIES OF ULTISOL AT NDUME–IBEKU, SOUTHEASTERN NIGERIA

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ABSTRACT

Improper land use causes soil degradation with its resultant negative effects on agricultural production. A study was conducted at Ndume-Ibeku, in southeastern Nigeria to ascertain the variability in some physico-chemical properties ofUltisol under four differentland use types. Theland use types were continuously cultivated land (CC), forest land (FL), 1-year grass fallowland (GL1) and oil palm plantation (OP). The layout was a randomized complete block design (RCBD). Stratified random sampling method was applied by partitioning each landuse into three segments according to differencesin topography. Soil samples were randomly collected at 0-15cm depth within each segment and bulked to obtain a composite sample. Hence, three composite samples were obtained from each land use representing three replicates, totaling 12 bulk soil samples from the four landuse types. Also, three replicate core samples were collected from each landuse, giving a total of 12 core samples from the four land use types.The samples were analyzed using standardlaboratory procedure. Data obtained were statistically analyzed using SPSS version 20 software.Across the land use types, the physico-chemical properties varied significantly ($P \leq 0.05$). FL had the best ratings for pH (5.60), total N (0.18g/kg), avail.P (45.07Mg/kg), Mg (2.87Cmol/kg), K (0.22Cmol/kg) and CEC (7.91Cmol/kg) while OP was the best in organic carbon (2.11g/kg), Ca (3.73Cmol/kg), exchangeable acidity (0.75Cmol/kg), and % BS (89.90%). The highest sand (857.00g/kg) and lowest clay (74.00g/kg) fractions were observed in FL while CC and GL1 hadthe highest clay (161.00g/kg) and lowest sand (750.00g/kg) fractions, respectively. The lowest bulk density (1.26Mg/m^3) and highest field capacity (21.24%) and available water content (12.16%) under OP reflected its highest OC (21.10g/kg). The very rapid K_{sat}(3.62cm/min) under CC suggested high permeability which was revealed in its low water retention (FC=9.96%, AWC=8.17%). It is therefore necessary to improve the organic matter status of the continuously cultivated land by mulching and manure application. Further use of heavy machineries on the land should be reduced or eliminated to avoid aggravating degraded conditions.

Keywords: Land use, Ultisol, particle size, hydraulic properties, exchange properties.

INTRODUCTION

The use to which a land is put greatly influences the physical, chemical as well as biological properties of the soil. Soil physical properties deteriorate with changes in land use especially from forest to arable. Cropping usually results in losses of soil organic matter and reduced soil aggregate stability, increased bulk density and compaction (Chisci and Zanchi, 1981). Intensity of landuse has influence on the microbial processes that lead to soil aggregation and structural stability (Gupta and Germida, 1988). Oguike and Mbagwu (2009) reported that changes in landuse, such as conversion of natural forest to cropland, contributed to land degradation that manifested in losses of soil organic matter and total nitrogen. Landuse greatly influences the soil reactivity, available phosphorus, exchangeable acidity (H^+ and Al^{3+}) and exchangeable bases (Mbagwu and Auerswald, 1999). Soils under conventional tillage practices become poorly structured and are easily eroded (Chisci and Zanchi, 1981).

Continuous cultivation results in increase in sand fraction and bulk density, reduced soil nutrient status and water retention capacity while increasing soil acidity as against bush fallow land (Malgwi and Abu, 2011). The world cultivated soils have lost 50 – 70% of their original carbon stock (Schwartz, 2014). Holland (2004), showed how effective land restoration through bush fallow and conservation tillage could be in sequestering carbonand slowing down climate change.

Intensive soil tillage due to continuous cultivation, increases soil aeration and changes the climate (temperature and moisture) of topsoil and thus, often accelerates soil organic matter decomposition rates and loss of nitrogen by volatilization and leaching (Balesdent*et al*., 2000). Reduced tillage is therefore considered a measure to sequester carbon in soils as it has proven to be effective in conserving soil organic matter at the top soil (Holland, 2004). Blaire *et al*. (2006) revealed, in a comparative study on grass and crop lands, that there was a significant difference in the amount of carbon stored in grassland than that in cropland under similar site conditions such as climate and topography. At Ndume-Ibeku near Umuahia, information on land use effects on soil properties is scarce. Such information will redirect conservation practices to be adopted by the farmers in the area.Therefore, the objective of this study was to ascertain the variability of selected physical and chemical properties ofUltisol under four different land use types.

MATERIALS AND METHODS

Study area

The study was conducted at Ndume-Ibeku, near Umuahia, southeastern Nigeria. The area lies within latitudes 5°29'N to 5°31'N and longitudes 7°30'E to 7°32'E with mean annual rainfallof 2200mm (NRCRI, 2007). The area is characterized by rainy and dry seasons. The rainy season starts from March and extends to October with bimodal peaks in July and September, and a short break in August. The dry season starts in November and lasts till February. The mean annual temperature is about 28°C (NRCRI, 2007). The landscape is flat to gently undulating. Coastal plain sand is the dominant parent material, although, there are localized regions of the area where the parent material is alluvium. The soil of the area is of the order "Ultisol" (Soil Survey Staff, 2010) and vegetation type is tropical rainforest. The common land use types in the area include bush fallow, oil palm plantation, grassland and arable farm land cultivated to cassava, maize, yam and vegetables in a mixed cropping system,

Land use types

The four landuse types studied included arable farmland under continuous cultivation (CC), oil palm plantation (OP), forest land (FL) and 1 - year grass fallow land (GF1). The forest land was secondary vegetation established for over 20years at the upper slope on the landscape. The 1-year grass fallow land, was at upper slope on another landscape,and previously ploughed, harrowed and ridged and then sown to cassava. The grass species was elephant grass (*Panicum maximum*).The oil palm plantation, established for over 20years was growing at the bottom slope on the landscape while the continuously cultivatedland at the mid slope was sown to cassava (*Manihotesculentus*), yam (*Dioscorea spp.*) and pumpkin (*Telferiaoccidentalis*). The soil fertility was managed by the application of both mineral (NPK) fertilizerand organic manure. Weed control was by the manual method of hoeing and hand picking.

Soil sampling and preparation

Topsoil samples (0-15cm)were collected from each landuse type using stratified random sampling method of partitioning each land use into three segments according to differences in topography. The soil sampleswere randomly collected from each segment and bulked to obtain a composite sample. Hence, three composite samples were obtained from each land use, representing three replications. A total of 12 composite sampleswere therefore collected from the four landuse types. Also, three replicate core samples were collected from each landuse type, totaling 12 from all four. The bulksamples were air-dried and passed through a 2mm mesh while the core samples were saturated in water for laboratory analyses.

Laboratory analyses

Particle size distribution was by the method outlined by Gee and Or(2002). Saturated hydraulic conductivity (K_{sat}) was by the constant head method ofKlute(1986) and was calculated using Darcy's equation as explained by Youngs (2001). Bulk density (Bd) was by method ofAnderson and Ingram (1993). Soil water retention atfield capacity (FC) and permanent wilting point (PWP) were determined by the estimation method outlined by Mbagwu (1991). Available water content was deduced from the difference between FC and PWP. Soil pH was by the method of McLean(1982). Total nitrogenwas determined by the micro Kjeldahl method (Bremner, 1996).Organic carbonwas determined by the dichromate oxidation procedure of Walkley and Black as modified by Nelson and Sommers (1982). Exchangeable Acidity was determined by the method of Mclean(1982).Exchangeable cations were by ammonium acetate (NH_4OAC) method of Tel and Hagarty(1984). Exchangeable calcium and magnesium were determined by titration while exchangeable sodium and potassium were determined using flame photometer. Available phosphorus was determined using Bray II method(Oslen and Sommers, 1984).Cation Exchange Capacity (CEC) was by the method of Rhoades (1982).Percentage base saturation (BS %) was calculated as the ratio of exchangeable bases to cation exchange capacity.

Statistics analysis

Theexperiment was laid out in a randomized complete block design (RCBD) with three replications in each landuse type. This gave a total of twelve (12) observational units. Data generatedwere subjected to analysis of variance (ANOVA) and treatment means were separated using Fisher least significant difference at 5% probability level ($LSD_{0.05}$).

RESULTS AND DISCUSSION

Soil physical properties

The sand fractions varied significantly ($P \leq 0.05$) across the land use types with the forest land (FL) having the highest value of 857.00g/kg (Table 1). The lowest value of 750.00g/kg was observed under GL, which was not significantly different from OP (756.00g/kg) and CC (752.00g/kg). The silt and clay fractions of the soils varied significantly ($P \leq 0.05$) across the land use types with the highest value of siltfraction observed under GL (133.00g/kg) while the lowest (69.0g/kg) was observed under FL. The highest value of clay fraction (161.00g/kg) was observed under CC and the lowest (74.00g/kg) was observedunder FL.

Table 1: Particle size distribution

Land use	Sand (g/Kg)	Silt (g/Kg)	Clay (g/Kg)	Texture
CC	752.00	87.00	161.00	SL
FL	857.00	69.00	74.00	LS
GL1	750.00	133.00	117.00	SL
OP	756.00	101.00	143.00	SL
LSD($_{0.05}$)	8.70	10.40	5.90	-

CC=continuously cultivated land; FL=forest land; GL1= one-year grass fallow land; OP= oil palm plantation

The relatively high sand and low clay fractions under FL were probably due to its position at the upper slope. In contrast, the relatively high clay content under CC and OP may be attributed to their position at the mid and bottom slopes on the landscape. This agreed with Ojanuga (2003) who reported that soils formed at the upper elevation on a landscape contained higher sand fraction and lower clay while soils at the lower elevation formed by the same parent material and on the same landscape contained higher clay due to the lateral translocation of clay particles from the higher elevation to the lower via erosional and depositional processes. However, the low sand fraction and relatively high clay and silt fractions under GL compared to FL that were on similar elevation may be attributed to the mechanical manipulation of the soil during the previous tillage operations. These tillage operations may have contributed to illuviation of silt and clay as well as sand fraction being crushed to silt and clay sizes due to abrasion thereby leaving little sand fraction at the surface (Nwite, 2015).

Bulk density (Bd), saturated hydraulic conductivity (K_{sat}), field capacity (FC), permanent wilting point (PWP) and available water content (AWC) varied significantly across the land use types although, K_{sat} was only significantly different between CC and GL and between FL and GL (Table 2). The highest value of K_{sat} (3.62cm/min) was observed under CC, while the lowest of 2.56cm/min was observed under GL. The K_{sat} of CC corresponded with its low Bd revealing minimum compaction, reminiscent of good structure. The highest value of Bd (1.55Mg/m^3) was observed under GL, which differed significantly ($P \leq 0.05$) from the other landuse types. The lowest (1.26Mg/m^3) was observed under OP, indicative of good structure with less compaction, reflecting the high organic carbon (OC) content (Table 3). The relatively low Bd and rapid K_{sat} observed under CC, compared to the other landuse types, were probably the result of the pulverization of the soil during tillage operations leading to the loosening of the soil and development of macropores confirming the report of Nwite (2015). These values suggested high permeability which was reflected in the low moisture retention capacities (FC and AWC) under CC. Conversely, the relatively high Bd and slow K_{sat} observed under GL were attributable to the compaction of the soil as a result of traffic with heavy farm machineries during previous mechanized tillage operations, despite the somewhat high OM content. This concurred with Kutilek (2005) who reported that long use of machinery during tillage operation caused an irreversible soil compaction.

Table 2: Bulk density and hydraulic properties

Land use	Bd (Mg/m^3)	K_{sat} (cm/min)	FC (%)	PWP (%)	AWC (%)
CC	1.35	3.62	9.96	1.78	8.17
FL	1.41	3.38	20.90	8.86	12.04
GL1	1.55	2.56	15.28	5.23	10.05
OP	1.26	2.88	21.24	9.08	12.16
$LSD_{0.05}$	0.03	0.77	1.25	0.81	0.44

CC, FL, GL1, OP are as denoted in Table1 above

The soils varied significantly ($P \leq 0.05$) in their moisture retention characteristics. The highest values of 21.24%, 9.08% and 12.16% for field capacity (FC), permanent wilting point (PWP) and available water content (AWC), respectively, were observed under OP. These parameters varied significantly ($P \leq 0.05$) acrossthe landuse types. The lowest of 9.96%, 1.78% and 8.17% for FC, PWP and AWC, respectively, were recorded under CC, differing significantly from the other landuse types. The higher water retention characteristics of soil under OP may be related to its high clay fraction (Table 1) and OC content (Table 3) whose large charged surfaces attracted and retained the charged surfaces of water molecules. Under FL, with low clay fraction, the moisture retention characteristics were probably due to its relatively high OC content which may have improved the stability of the soil macro aggregates thereby providing large charged surfaces for the attraction and retention of water molecules (Malgwi and Abu, 2011).

pH, OC, total N, and avail. P

The pHvalues observed under the various land use types indicated moderate acidity (Table 3). The highest pH value of 5.6 observed under FL was significantly different ($P \leq 0.05$) from the other land use types except OP (pH 5.4). The lowest pH value of 5.2 obtained under CC was significantly different from that under FL but not different from the other land use types. The acidity of the soils may be due to the nature of their parent material (coastal plain sands) as well as their highly weathered conditions. This observation corroboratedLekwa and Whiteside (1986) who reported that highly weathered soils of the coastal plain sands were acidic. However, the relatively higher acidity recorded at CC compared to the other land use types, was probably as a result of leaching of thecations possibly due to increased porosity of the soil induced by pulverization as a result of continuous tillage operations. This agreed with the report of Isirimah and Dickson (2003) who stated that the leaching of the exchangeable bases due to excessive drainage increased soil acidity. Also, the higher acidity under CC, compared to the other land use types, may be attributed to frequent plant uptake of thecations coupled with continuous crop harvesting (IITA, 1999). Conversely, the relatively lower acidity observed under FL and OP was possibly the result of reduced leaching ofcations as well as the fall and decay of plant residues which returned absorbedcations to the soil through mineralization of the added OC. This agreed with the report of Isirimah and Dickson (2003).

Table 3: Soil pH, totalN, OC and Avail. P

Landuse	**pH (H_2O)**	**TN (g/kg)**	**OC (g/kg)**	**Avail. P (Mg/kg)**
CC	5.20	1.20	13.50	32.97
FL	5.60	1.80	18.70	45.07
GL1	5.30	1.50	18.80	31.63
OP	5.40	1.50	21.10	39.63
LSD($P \leq 0.05$)	0.26	0.10	6.30	3.51

CC, FL, GL1, OP as indicated in Table 1

The highest value of OC (21.10g/kg) observed under OP was not significantly different ($P \leq 0.05$) from that of FL (18.70g/kg) and GL (18.8g/kg). The OC contents of the soils under FL, GL and OP were significantly different from that of CC. The very low concentration of organic carbon (OC) observed under CC was probably related to the increased oxidation of the soil organic matter (SOM) stimulated by increased disturbance of the soil by continuous and intensive tillage operations coupled with low vegetation cover that exposed the soil to intense heat of the sun. This observation was consistent with the report of Balesdent*et al.* (2000) who stated that soil aeration was increased by tillage while the climate of the topsoil, with respect to temperature and moisture, was altered leading to an increased rate of SOM decomposition. Low turnover of residues to the soil due to frequent crop removal may have added to this effect. Contrarily, the highest concentration of OC recorded under OP may be attributed to the frequent return of biomass to the soil by the periodic slashing of the over - grown plants as well as the high ground cover contributed by the vegetation canopy of the palm fronds as well as reduced soil disturbance. This confirmed the finding of Holland (2004) that little or no disturbance to the soil was effective in conserving SOM at the topsoil and therefore served as a measure to sequester carbon in the soil.

The soils under the different landuse types were significantly different ($P \leq 0.05$) in total nitrogen (total N) content. The highest value of 1.80g/kg was observed under FL while the lowest value of 1.2g/kg was recorded under CC. The relatively very low value of total N observed under CC may be due to the volatilization of nitrogen resulting from increased oxidation of nitrogenous compounds in the soil. This may have been triggered by high exposure of the soil to air and increased temperature by frequent tillage operations. Also, the increased mobility of nitrogen caused by incessant pulverization of the soil possibly resulted to losses by leaching. Oguike and Mbagwu (2009) reported similar result, stating that continuous cultivation of soils caused a substantial loss of nitrogen due to increased volatilization and leaching effects. On the other hand, the relatively high value of total N observed under FL and OP may be due to the micro climate created by adequate vegetation cover which moderated the soil temperature, air and moisture against total N loss by volatilization. Due to the undisturbed state of the soils under FL and OP, there was a significant reduction in loss of total N through leaching. Similar observation was reported by Oguike and Mbagwu (2009).

The soils were significantly different ($P \leq 0.05$) in available P with the highest value of 45.07Mg/kg observed at FL. The lowest value of 31.63Mg/kg was observed under GL, and this varied significantly from the other land use types except CC (32.97Mg/kg). High concentration of avail.P under FL and OP compared to CC and GL1 was perhaps due to the reduced level of acidity under the later than under the former land use types indicated by low values of exchangeable Al.Ano (2004) had reported that Al formed mineral complex with avail. P in acid soils thereby leading to P – fixation with its resultant effect on P unavailability.

Exchange properties and percentage base saturation

Exchangeable Ca varied significantly ($P \leq 0.05$) across the land use types although, the concentrations under OP and FL were statistically similar. Table 4 revealed that the highest concentration was observed under OP while CC had the lowest concentration. With regard to exchangeable Mg, FL and OP were statistically similar but they significantly differed from CC and GL1. The highest concentration of exchangeable K was observed under FL followed by OP, GL1 and CC in the descending order. The highest concentration under FL (0.22Cmol/kg) was significantly different from those under GL1 and

CC but statistically similar to OP. The lowest concentration (0.06Cmol/kg) was observed under CC. Sodium (Na) concentration did not vary significantly across the land use types. It was highest under CC and GL1 with value of 0.23Cmol/kg while the lowest was recorded under OP (0.19Cmol/kg).The highest and lowest concentrations of exchangeable H^+ and Al^{3+} were observed under CC and OP, respectively. The values of these acidity properties indicated variation across the land use types. However, for exchangeable H^+ and Al^{3+}, CC and GL1 were statistically similar while significantly differing from OP. Cation exchange capacity (CEC) and percent base saturation (%BS) were statistically similar under FL and OP but significantly different from CC and GL1. The highest CEC was observed under FL (7.91Cmol/kg) while CC had the lowest (4.90Cmol/kg). The highest %BS was found under OP (89.90%) while the lowest was observed under CC (69.43%).

Table 4: Soil exchangeable properties and percentage base saturation

Land use	**Ca**	**Mg**	**K**	**Na**	**EA**	**Ex. H**	**Ex. Al**	**CEC**	**BS (%)**
	←			Cmol/kg				→	
CC	2.20	0.93	0.06	0.23	1.49	1.21	0.29	4.90	69.43
FL	3.67	2.87	0.22	0.20	0.95	0.87	0.08	7.91	87.93
GL1	2.93	1.87	0.13	0.23	1.31	1.07	0.23	6.46	79.77
OP	3.73	2.60	0.16	0.19	0.75	0.68	0.06	7.44	89.90
$LSD_{0.05}$	0.46	0.50	0.06	0.05	0.36	0.33	0.16	0.53	5.50

CC, FL, GL1 and OP as indicated in Table 1

The relatively low concentrations of thecations (Ca, Mg and K) under CC compared to the other land use types may be attributed to continuous crop uptake of these essential cations and low biomass turnover to the soil due to crop removal at harvest as well as increased leaching of these cations from the topsoil (Isirimah and Dickson, 2003). On the other hand, the relatively high concentrations of the essential cations under OP and FL may be related to high biomass returned to the soil via litter fall (IITA, 1999). The high OC content under OP and FL (Table 3) provided large surface area for the bonding of these cations against leaching (Isirimah and Dickson, 2003).

The relatively higher exchangeable acidity ($H^+$and Al^{3+}) under CC followed by GL1 was probably as a result of the low exchangeable cations under these land use types (Table 4). Potassium (K) and Mg may have been lost from GL1 by crop removal during previous harvest of cassava and other crops prior to the grass fallow. Continuously cultivated land (CC), apart from loss of cations by crop removal, lost considerable amount of essential cations through leaching. These inferences corroborated the report of Yagodin (1984) who stated that reduced concentration of cations in the soil resulted in decreased soil pH which by extension induced an increase in exch. H^+ and Al^{3+} at the cation exchange site.

The low values of CEC and BS observed under CC and GL1 compared to OP and FL were as a result of their relatively low OC content. This observation was consistent with the findings of Nwadialo (1991) who reported a positive relationship between OC and CEC as well as OC and BS.

CONCLUSION

Significant differences were observed in the physical and chemical properties across the landuse types studied. Organic carbon (OC) was significantly higher under the oil palm plantation (OP) than the other landuse types. On the other hand, the continuously cultivated land (CC), compared to the other land use types, was significantly lower in OC content. Soils at the upper slope on the landscape were sandier than those at the lower slope. Pulverization of soil by tillage reduced the bulk density (Bd) while increasing water transmission capacity reflecting in the relatively rapid saturated hydraulic conductivity (K_{sat}). The use of heavy machineries in farm operations left the soil with high Bd even after a short period of fallow as observed under GL1 compared to the continuous use of simple farm tools on soils under CC. Continuous cultivation of soil depleted the fertility status of the soil by significant reductions in total nitrogen, avail. P, exchangeablecations, CEC and % BS while increasing the soil acidity. Conversely, forested lands (FL and OP) significantly improved the fertility of the soils and their water retention capacities.

In order to improve moisture retention, optimize soil physical properties and to enhance the fertility status of the continuously cultivated land, mulch and manure application should be adopted as a management option. The one year grass fallow land (GL1) requiredlonger fallow period for greater OM accumulation. Therefore, to reduce soil degradation, conservation practices are the option for sustainable environmental impact.

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