Available online www.jsaer.com

Journal of Scientific and Engineering Research, 2017, 4(7):147-155

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

Variations in Texture, Water Retention and Transmission, Organic Matter and pH of Soils under Selected Land Use Systems at Ubakala Umuahia, South-Eastern Nigeria

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Abstract Changes in selected soil physical properties, organic matter (OM) and reactivity of soils under excavation (EX), refuse dump (RD) and continuous cultivation (CC) were studied in Umuahia, south-eastern Nigeria. Soil samples were randomly collected at two depths (0-20 and 20-40 cm) from three points in each land use system. The design was a randomized complete block (RCBD). Data generated were statistically analysed using SPSS version 20 software. Analysis of variance was used to compare the influence of land use on the physical properties, OM and pH of the soils at two depths. Significant means were separated using least significant difference at 5% probability level. Regression analysis explained the control of organic matter over the physical properties. Soil texture under EX was sandy clay whereas RD and CC were sandy clay loam and sandy loam, respectively. Clay contents increased with depth, while sand and silt contents decreased. Refuse dump site retained more water as available water content (0.217 at 0 – 20 and 0.222 m^3/m^3 at 20 – 40cm) than the continuously cultivated land (0.126 at 0 – 20 and 0.133 m^3/m^3at 20 – 40cm) and excavation site (0.097 at 0 – 20 and 0.105 m^3/m^3 at 20 – 40).The saturated hydraulic conductivity (Ksat) reduced with depth but was fastest under RD (0.99 – 1.04 cm min^{-1}) and slowest under EX (0.22 – 0.26 cm min^{-1}).Organic matter under excavation site was low ranging from 0.40 to 3.10 g/kg while ranging from 19.30 to 58.80% under CC and RD, respectively. The pH of the soils ranged from very strongly acidic to moderately acidic. Organic matter exerted greater influence on soil physical properties under RD than CC and EX.

Keywords Particle size, water retention, transmission, regression, land use, pH

Introduction

Land use system involves the modifications, arrangements, activities and inputs people undertake in certain land cover type to produce food and raw materials, change or maintain such land [1]. Modifications in land use introduce changes in soil properties and productivity overtime [2]. The distribution and supply of nutrients in the soil are affected by land use systems through directly altering soil properties and by influencing biological activities [3]. Some land use systems include urbanization (which consists of housing, industry, commercial enterprises, roads, etc.) [4], livestock ranching and forestry [5], continuous cropping and bush fallowing [6], refuse dumping [7] and excavation [8].

Excavation has caused reduction in the accumulation of organic matter [9], thereby increasing the susceptibility of soils to erosion [10].The use of land for refuse dump has caused modifications in the soil physical properties through increase in the aggregate stability with a corresponding decrease in the bulk density [7].

In Umuahia, land is put to many uses driven by the increasing demand for industrialization and development, yet studies are scanty in the effects of land use on soil properties. The dearth of information has not addressed the impacts of continuous cultivation, excavation activities and dumping of household and municipal wastes on soil properties. Therefore, the objective of the study was to investigate the effects of continuously cultivated land, refuse dump and excavation sites on some physical properties, organic matter and pH of soils.

Materials and Methods

Study Area

The study was carried out in Ubakala Umuahia, southeastern Nigeria. The area is located within latitude $5^{0}30^{'}$N and longitude $7^{0}28^{'}$E [11]. The location has a mean annual rainfall of 2201.92mm [12]. The rainfall is bimodal, starting in March and ending in October with peaks in June and September [12].Within the location, continuously cultivated land (CC), refuse dump (RD) and excavation (EX) sites were investigated. These sites were within Ubakala metropolis. The refuse dump site had been used for more than 12 years for dumping household and municipal wastes while the excavation site had been used for more than 7 years for mining of laterites for road construction and housing. The continuously cultivated land had been under continuous cultivation of crops such as cassava, maize, melon and fluted pumpkin.

Soil Sampling

Under each land use system, three sampling points were located randomly. Around each of the sampling points within a land use, soil samples were collected at 0 – 20 and 20 – 40 cm depths using soil auger. This constituted a total of 6 samples for each land use and a grand total of 18 bulk samples for the three land use systems. Two replicate core samples were collected at 0 – 20 cm and 20 – 40cm depths from each of the 3 sampling points making a total of 12 core samples in each land use. A grand total of 36 core samples were collected from the three land use systems for laboratory analysis.

Sample Preparation

The auger samples were air-dried and sieved through 2mm sieve size. The Sample for organic matter was further crushed after sieving with 2mm sieve size. The base of the core samples were covered with cheese cloth and saturated in water for determination of saturated hydraulic conductivity and moisture retention.

Laboratory Analysis

The parameters determined in the laboratory were particle size distribution (Bouyoucos hydrometer method) [13], water retention (field capacity (FC) and permanent wilting point (PWP)) by the estimation method [14], saturated hydraulic conductivity (Ksat) by the constant head method [15]. Infiltration rate was determined at the sites using double ring infiltrometer [16] while available water content (AWC) was deduced from the difference between FC and PWP thus:

$$AWC = FC - PWP.$$

Organic matter (OM) was determined by Walkely and Black method [17] while soil pH was determined in 1: 2.5 soil-water suspension ratio [18].

Statistical Analysis

Analysis of variance (ANOVA) for randomized complete block design (RCBD) was used to compare the influence of the land use system and depth on the measured soil properties. Significantly different means were separated using least significant difference at 5% probability level ($p \leq 0.05$). Regression analysis was used to explain the control of organic matter on the selected soil physical properties among the land use systems.

Results and Discussion

Particle Size Distribution

The particle size distribution of the soils studied is shown in Table 1. At the two depths of 0 – 20 and 20 – 40cm, the texture of soils under the refuse dump site (RD) was sandy loam and sandy clay loam under continuously cultivated land (CC). However, excavation site (EX) was observed to have a sandy clay texture at both depths. At both depths of 0 – 20 and 20 – 40 cm, respectively, the highest sand contents of 724.1and 711.7 g/kg were observed under RD while EX had the lowest with values of 519.7 and 517.5 g/kg. With regard to the silt content, RD had the highest at the two depths (107.2 and 91.3 g/kg). The lowest silt and highest clay contents were observed under EX at both depths. The values ranged from 24.0 to 48.7 g/kg for silt and 431.6 to

458.5 g/kg for clay. The lowest clay contents at both depths were observed in refuse dump site (168.7 and 197.0 g/kg).

Generally, the sand and silt contents decreased with depth while the clay contents increased. However, the silt content under continuously cultivated land increased with depth. As shown in Table 1, and with regard to depth, sand and silt particles were statistically similar, whereas clay was significantly ($P \leq 0.05$) different. With regards to the land use systems and depths, the sand and clay particles under EX were significantly ($P \leq 0.05$) different from RD and CC although, the silt content under EX was statistically similar to CC at 0 – 20 cm depth. The sand, silt and clay particles under CC were significantly ($P \leq 0.05$) different from EX and RD at both depths, but the sand particles under CC was statistically similar to RD at 0 – 20 cm depth.

The high sand contents of the soils could be attributed to their being derived from unconsolidated sand deposits formed over coastal plain sands [19; 20]. The removal of vegetative cover and top soil as a result of excavation exposed the sub soil thereby contributing to the high clay contents at the excavation sites giving rise to its sandy clay texture. The high sand, low clay and silt contents, observed in refuse dump sites, corroborated the report of Ideriah *et al*. (2006) [21], who reported sandy loam texture for a refuse dump site in Port Harcourt, Rivers State. Anikwe and Nwobodo (2002) [7] and Ideriah *et al.* (2006) [21] observed that dumping of household and municipal wastes resulted to high sand, low clay and silt contents leading to a sandy loam texture.

Table 1: Particle size distribution of soils studied

Land use	**Soil Properties**			
	Sand	**Silt**	**Clay**	**Texture**
	→	**(g/kg)**	←	
		0– 20 cm		
EX	519.7	48.7	431.6	Sandy clay
RD	724.1	107.2	168.7	Sandy loam
CC	705.7	61.3	203	Sandy clay loam
Mean	649.8	72.4	267.8	
		20 – 40 cm		
EX	517.5	24	458.5	Sandy clay
RD	711.7	91.3	197	Sandy loam
CC	685.7	67	247.3	Sandy clay loam
Mean	638.3	60.8	300.9	
$LSD_{0.05}$				
Land use	18.9	19.1	21.3	
Depth	20.2	14.8	12.6	
L × D	11.4	20.6	18	

EX = excavation site, RD = refuse dump site, CC = continuously cultivated land,
L × D = Interaction of land use × depth.

On the contrary, Shepherd *et al.* (2000) [22] observed that changes due to land use do not show easily for particle size.The increase in clay with soil depth maybe due to translocation [6], dissolution and leaching of clay materials as a result of intense torrential rainfall, argillation of clay, lessivage and sorting of soil materials [23]. Jaiyeoba (2003) [24] observed that increased clay contents at lower depths were due to increase in cultivation. This may be as a result of either increase of clay translocation from the surface to subsurface horizons or removal of clay from the surface by runoff.

Water retention

Soil water retention characteristics such as field capacity (FC), permanent wilting point (PWP) and available water content (AWC) of soil studied are shown in Table 2. Among the land use systems and at the two depths (0

– 20 and 20 – 40cm), refuse dump site (RD) retained the highest amount of water at FC with values of 0.323 and 0.328 m^3/m^3. The continuously cultivated land (CC) was observed to retain the lowest at both depths with values ranging from 0.184 to 0.196 m^3/m^3. With regard to PWP, excavation site (EX) retained the highest at both depths with values of 0.177 and 0.175 m^3/m^3, while CC retained the lowest with value of 0.058 m^3/m^3atboth depths. The highest available water contents (AWC) were observed in RD at both depths with values ranging from 0.217 to 0.222 m^3/m^3whereas EX retained the lowest with values of 0.097 and 0.105 m^3/m^3. The FC and AWC increased with depth, while PWP decreased. As shown in Table 2 and with regards to land use systems, at both depths, the FC under RD was significantly ($P \leq 0.05$) higher than EX and CC, while CC was significantly ($P \leq 0.05$) lower. At both depths, water retained at PWP was significantly ($P \leq 0.05$) higher under EX than the other two land use systems, while CC was significantly ($P \leq 0.05$) lower. The EX had significantly ($P \leq 0.05$) lowest AWC compared to RD and CC at both depths, whereas the AWC was significantly ($P \leq 0.05$) highest under RD.

The higher field capacities observed under EX and RD than CC may be attributed to the higher clay (EX) (Table 1) and organic matter (RD) (Table 4) which provided large surface area required for the absorption and retention of water molecules [25]. The high water retention capacity of soil under RD was similar to the findings of Okolo *et al*. (2013) [26] whose research was based on the assessment of selected physicochemical properties of soil for site suitable for waste disposal in Abakiliki. They attributed this to the high organic matter (OM) content of refuse dump sites. The low available water content of soils under CC and EX may be attributed totheir low structural stability. Yihenew and Ayanna (2013) [27] who made similar observation reported that continuous cropping and excavation deteriorated the stability of soil aggregates, thereby reducing their available water contents. It is apparent however, that soils with clayey texture have high moisture retention at FC and PWP, making the available water for crops lower than those of loamy textures [28].

Table 2: Water retention characteristics of soils studied

Land use	**Soil Properties**		
	FC	**PWP**	**AWC**
	→	**(m^3/ m^3)**	←
		0 –20 cm	
EX	0.274	0.177	0.097
RD	0.323	0.106	0.217
CC	0.184	0.058	0.126
Mean	0.26	0.114	0.147
		20 – 40 cm	
EX	0.28	0.175	0.105
RD	0.328	0.106	0.222
CC	0.196	0.058	0.138
Mean	0.268	0.113	0.155
$LSD_{0.05}$			
Land use	0.041	0.012	0.056
Depth	0.071	0.035	0.048
L × D	0.062	0.051	0.03

FC= Field capacity, PWP= Permanent wilting point, AWC= Available water content. EX, RD, CC,L × D are as denoted under Table 1 above.

Saturated hydraulic conductivity and infiltration rate

Saturated hydraulic conductivity (Ksat) and infiltration rate (Ir) of the soils studied are shown in Table 3. Refuse dump site had the fastest saturated hydraulic conductivity at both depths (0.99 to 1.04cm min^{-1}) while EX had the slowest (0.22 to 0.26cm min^{-1}). For the infiltration rate (measured only at 0 – 20 cm), RD was faster than EX and CC.

Table 3: Saturated hydraulic conductivity, and Infiltration rates of soils studied

Land use	Soil Properties	
	Ksat	**IR**
	cm min^{-1}	
	0–20 cm	
EX	0.26	0.01
RD	1.04	0.03
CC	0.71	0.02
Mean	0.67	0.02
	20–40 cm	
EX	0.28	0.22
RD	0.33	0.99
CC	0.19	0.62
Mean	0.27	0.61
$LSD_{0.05}$		
Land use	0.35	0.005
Depth	0.06	0.02
L × D	0.02	0.42

Ksat= Saturated hydraulic conductivity, Ir= Infiltration rate. EX, RD, CC,L × D are as denoted under Table 1 above.

Saturated hydraulic conductivity reduced with depth. The reduction in Ksat with depth may likely be due to the decreasing OM with depth (Table 4). This observation was a reflection of the influence of OM on soil properties. With reduced OM content, Ksat reduced [29].As shown in Table 3, and with reference to the two depths, the values indicated that Ksat significantly ($P \leq 0.05$) differed. With reference to the land use systems at both depths, the Ksat under EX was significantly ($P \leq 0.05$) slower than RD and CC, although under the RD and CC, the Ksat were significantly similar. At the depth of 0 – 20cm the infiltration rate under EX was significantly ($P \leq 0.05$) slower than those of RD and CC. However, the Ir under CC was significantly ($P \leq 0.05$) different from that under RD.

The slow Ksat and Ir observed under EX were similar to the findings of Musah (2013) [10]. He observed that the loss of vegetative cover from the soil and the large scale use of machineries on such sites led to the loss of OM which resulted to the slow Ksat and Ir. The rapid Ksat and Ir observed under RD may be as a result of the high organic matter content of the RD (Table 4). This concurred with the findings of Okolo *et al.* (2013) [26] who reported that the high level of OM in the refuse dump sites of Abakaliki favoured transmission of water under saturated conditions. The slow Ksat observed under CC may be attributed to frequent tillage that may have resulted to low mean weight diameter, possibly leading to disruption of the pore arrangements [30].

Organic matter and pH

At both depths of 0 – 20 and 20 – 40 cm, refuse dump site (RD) was observed to have the highest organic matter (OM) with values of 58.80 and 58.60 g/kg, respectively (Table 4). The excavation site (EX) was observed to have the lowest OM at both depths with values of 3.10 and 0.40 g/kg. With regard to pH, at both depths, RD had the highest pH values ranging from 6.27 to 6.57, while EX was observed to have the lowest pH values ranging from 4.57 to 4.90.The values for the continuously cultivated land (CC) were 5.70 at 0 – 20 and 4.97 at 20 – 40 cm. These land use systems were very strongly acidic for EX, slightly acidic for RD and moderately acidic at topsoil and very strongly acidic at subsoil for CC [31]. With respect to depth, EX was very low in organic matter whereas RD and CC were high [32].

As shown in Table 4 and referring to depth, the means indicated significant ($P \leq 0.05$) decrease in OM and pH. With respect to land use systems at both depths the OM and pH under EX were significantly ($P \leq 0.05$) lower than the other land use systems.

Table 4: Organic matter and pH of soils studied

Land use	**Soil Properties**	
	OM	**pH**
	(g/kg)	
0–20 cm		
EX	3.1	4.9
RD	58.8	6.57
CC	19.8	5.7
Mean	27.23	5.72
20–40 cm		
EX	0.4	4.57
RD	57.6	6.27
CC	19.3	4.97
Mean	25.77	5.27
$LSD_{0.05}$		
Land use	7.1	0.21
Depth	1.02	0.98
L × D	8.01	0.38

OM= Organic matter. EX, RD, CC, L × D are as denoted under Table 1 above

At both depths, these parameters under RD were significantly ($P \leq 0.05$) higher than EX and CC. Also, the CC was significantly ($P \leq 0.05$) different from EX and RD at both depths. Under RD and CC, the decrease in OM with depth may be attributed to the continuous accumulation of slowly decaying and partially decomposed plant and animal residues on the surface soil [33]. The low OM observed in excavation sites may be attributed to the soil disturbance which altered soil profile by destroying vegetation, roots, soil microbes and soil horizon [10]. These excavation activities exposed the soil surface to increased wind and water erosion. Rab (2003) [34] who made similar observation reported that the low organic matter may be due to the level of removal of litter and mineral top soil. The high organic matter observed under RD may be attributed to the use of the site for dumping wastes [7]. Amos-Tauta *et al*. (2004) [35] in their work on the assessment of some heavy metals and physicochemical properties in surface soil of municipal open waste dump sites in Yenagoa, made similar observations of high organic matter content under refuse dumpsites. They attributed the high organic matter to the presence of degradable and compostable wastes. The lower organic matter observed in continuously cultivated land may be due to the effects of continuous cultivation that possibly aggravated organic matter oxidation [36-38].

The decrease in pH with increase in soil depth may be as a result of larger organic matter content observed at the top soils which became tightly bound with aluminium ions and reduced their activity in the soil solution which thereby raised the soil pH and reduced acidity [33]. The decreased soil pH with depth may also be attributed to the increase in clay contents with depth (Table 1) which have the tendency to furnish hydrogen ions from clay colloidal surface to the solution thereby reducing soil pH. The slightly and moderately acidic nature of the soils under refuse dump sites and continuously cultivated land could be attributed to the high exchangeable bases (not analysed) as a result of the presence of municipal wastes, litter fall and roots [36].

Regression analysis between organic matter (independent variable) and moisture characteristics (dependent variables)

Table 5 revealed the regression analysis between organic matter and soil moisture retention characteristics. The OM control over the soil moisture retention characteristics were predicted to range from 2–14 % in excavation sites, 71 – 90 % in refuse dump sites and 19 – 57 %in continuously cultivated land.

Table 5: Regression analysis of organic matter versus moisture retention characteristics

Land use	Regression properties (Y)	(X)	Regression equation	R^2
EX	FC	OM	$Y = 17.70\chi^2 - 9.65\chi + 31.47$	0.05
	PWP	OM	$Y = 6.07\chi^2 - 9.40\chi + 25.73$	0.02
	AWC	OM	$Y = 1.63\chi^2 - 0.25\chi + 5.74$	0.14
RD	FC	OM	$Y = -9.47\chi^2 + 108.06\chi - 285.49$	0.9
	PWP	OM	$Y = -2.26\chi^2 + 29.46\chi - 86.51$	0.71
	AWC	OM	$Y = -7.21\chi^2 + 78.60\chi - 198.98$	0.8
CC	FC	OM	$Y = -9.06\chi^2 + 34.23\chi + 13.17$	0.43
	PWP	OM	$Y = 18.77\chi^2 - 69.99\chi + 70.39$	0.57
	AWC	OM	$Y = -27.83\chi^2 + 104.22\chi - 83.55$	0.19

EX, RD, CC, FC, PWP, AWC, OM are as denoted under Tables 1- 4 above.

Table 6 showed the regression analysis between organic matter, saturated hydraulic conductivity and infiltration rate. The influence of organic matter on saturated hydraulic conductivity was predicted to be 10 % under excavation site, 87% under refuse dump site and 23% under continuously cultivated land. Organic matter controlled variations in infiltration rate by6 % under excavation site, 87 % under refuse dump site and 38 % under continuously cultivated land.

Table 6: Regression analysis of Organic matter vs Ksat and Infiltration rate

Land use	Regression properties (Y)	(X)	Regression equation	R^2
EX	Ksat	OM	$Y = 0.32\chi^2 + 0.23\chi + 0.22$	0.1
	Ir	OM	$Y = -0.03\chi^2 + 0.02\chi + 0.01$	0.06
RD	Ksat	OM	$Y = -2.72\chi^2 + 31.98\chi - 92.89$	0.87
	Ir	OM	$Y = 0.51\chi^2 + 5.89\chi - 17.14$	0.86
CC	Ksat	OM	$Y = 1.02\chi^2 - 3.74\chi + 4.07$	0.23
	Ir	OM	$Y = 0.03\chi^2 - 0.42\chi + 0.13$	0.38

EX, RD, CC, Ksat, Ir, OM are as denoted under tables 1 – 5 above.

From the results presented in Tables 5 and 6, the regression equations revealed that the influence of organic matter on these moisture retaining and transmitting properties was less predictive in excavation site(R^2= 0.02 to 0.14) and continuously cultivated land (R^2= 0.19 to 0.57) and highly predictive in refuse dump site (R^2= 0.71 to 0.90).Therefore organic matter exerted greater influence on these parameters under the refuse dump site than the excavation site and continuously cultivated land. This may be attributed to the very low organic matter content of the soils under EX and CC compared to RD. Musah, (2013) [10] made similar observations. Igwe (2005) [39] reported that organic matter increased the rates of hydraulic conductivity and infiltration, thereby increasing the moisture content of soils.

Conclusion

The soil properties varied with different land use systems. The excavation site was clayey while the refuse dump site and continuously cultivated land were loamy soils. Moisture retention and conduction varied across the land use systems under the influence of organic matter. Higher soil moisture was retained under the refuse dump site than the excavation site and continuously cultivated land. The pH of the soils ranged from very strongly acidic to moderately acidic. Organic matter was generally low in excavation site and continuously cultivated land (CC) but high in refuse dump site. The regression analysis indicated that organic matter exerted greater influence on the soil physical properties under the refuse dump site than the excavation site and continuously cultivated land.
The problem of soil degradation that may emanate from improper land use requires adequate global attention to avert destruction of valuable agricultural soils which can lead to food insecurity and environmental problems. Therefore there is need to develop a long term land use and soil conservation plan that will ensure agricultural sustainability. These plans should include using crop residues as mulching or application of organic wastes to

enhance organic matter and optimize the soil physical properties. However land users/owners should be involved and made to participate in any conservation plan.

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