STRUCTURAL AND CHEMICAL PROPERTIES OF SOILS OF DIFFERENT AGRICULTURAL LAND USETYPES WITH DEPTH IN OWERINTTA, ABIA STATE.

Okechi, Onwuka[1*], Eneje, Roseta C[1] and Oguike, P.C[1]
[1]Department of Soil Science and Meteorology, College of Crop and Soil Sciences, Michael Okpara University of Agriculture Umudike, PMB 7627 Umuahia, Abia State, Nigeria.
Email:onwukaokechi@gmail.com

ABSTRACT

The experiment was conducted to determine the structural and chemical properties of soils of different land uses in Owerrinta at different depths. The experiment was a 4 x 3 4 x 3 factorial in a randomized complete block design with three replications. The factor A was the four land uses (oil palm plantation, forest, arable crop land and fallow) and factor B the three depths (0-15cm, 15-30cm and 30-45cm).The properties assessed were texture, Mean weight diameter (MWD), Bulk Density (BD), Total Porosity (TP), Clay Dispersion Index (CDI), Clay flocculation index Dispersion Ratio(DR) and other physical properties. Soil organic carbon, pH, total nitrogen, available phosphorus and other chemical properties were also determined. The soils generally had higher sand fraction compare to clay and silt. Organic matter was generally low in all the soils. The arable soil had the lowest organic matter content while the soil of the forest had the highest organic matter content compared to other land uses. The low organic matter content of the soils indicates poor aggregate stability and predisposes the soil to dispersion. The soil organic matter decreased with depth for all the soils with soil depth of 30-45cm having the lowest organic matter content. The CFI of the soils are 69.85%, 54.51%, 44.55% and 36.62% for oil palm, fallow, forest and arable farm. The DR of the soils in terms of landuse types were 42.14%, 40.82%, 35.98% and 35.22% for arable crop, fallow, oil palm and forest respectively.The CDI for the soil in terms of land use type were 66.18%, 45.98%, 30.48% and 25.79% for arable crop, fallow, palm and forest respectively. The forest soils were significantly lower in terms of CDI and DR while the arable farm had the highest CDI and DR. The low CDI and DR in forest soils may be due to high organic matter content and low translocation of clay compared to the arable farm land.From the findings, the soil of Owerrinta were generally low in pH, organic matter, base saturation and Effective Cation Exchange Capacity. This is an indication that the soils are highly leached and under the influence of erosion due to high rainfall and temperature which is predominant in the area. From the study, low organic matter content was one of the major factor that predisposed the soil to low structural stability and degradation. The use of organic manure should be encouraged especially in the continuously cultivated arable soils. Deep tillage operations should also be discouraged to avoid the disruption of the fragile soil structure, which predisposes the soils to deterioration and degradation.

Keywords: soil structure, soil chemical properties,Landuse types, soil degradation

INTRODUCTION

Owerrinta in Isialangwa South Local Government Area of Abia state is predominantly agricultural community. Most of the forest has been converted to different agricultural land uses due to pressure on land. This has resulted to overuse and unsustainable land use practices which have led to soil deterioration. The dominant parent materials is alluvium, the soils are mainly ultisols and are acidic. The soils are not particularly fertile and are prone to much leaching because of heavy rainfall. The main ecological problems in Owerrinta are soil degradation and erosion.The common land used system of the area include oil palm plantation, grassland, short duration bush fallow, forest and arable farming cultivated with cassava, maize, yam and vegetables in a mixed cropping system. The objective of this research is to determine the soil structural and chemical properties of the soils and how they are influenced by the different land uses. This will provide deeper insight on the influence of the different land uses on the soil structural and chemical properties, thereby help in developing proper soil management system in Owerrinta.

MATERIALS AND METHODS

SOIL SAMPLING AND PREPARATION

Undisturbed soil samples for the study were collected from four land use systems: oil palm plantation (OP), forest (FO), arable crop (AC) and land fallow(FA) at three depths, 0-15cm, 15-30cm and 30 – 45 cm with a core sampler for the determination of bulk density and hydraulic conductivity. The auger samples from the different sampling units were divided into two portions. The first portion was air dried and sieved through 2mm mesh for determination of particle size distribution, organic carbon, and selected chemical properties. The other portion was air dried and passed through a 4mm mesh for the determination of water stable aggregates (WSA) and mean weight diameter (MWDA).

LABORATORY STUDIES.

Particle size distribution was determined by Gee and Or (2002) method, using sodium hexametaphosphate as dispersing agent. Microaggregatestability was determined using the amount of silt and clay in calgon – dispersed as well as water –dispersed samples during particle size analysis described by Gee and Or (2002). Mean weight diameter (MWD) and waterstable aggregates (WSA**)** were determined by the wet-sieving method of Kemper and Rosenau (1986). Saturated hydraulic conductivity (Ksat)was determined by the constant head method explained by Klute and Dirksen (1986). Bulk Density (BD)was determined using the core method as described by Anderson and Ingram (1993). Field capacity (FC), permanent wilting point (PWP) and available water content (AWC)were determined following the procedure outlined by Mbagwu (1991). The soil pH was measured in water using a glass electrode pH meter at a soil liquid ratio of 1: 2.5 (Thomas, 1996). Organic carbon was determined using the wet oxidation method of Walkley and Black (1934). Total nitrogen in soil was determined by Kjeldahl digestion method (Kjeldahl. 1983). The exchangeable bases were obtained by leaching the soil sample with normal ammonium acetate at pH 7 to extract the basic cation (Ca^{2+}, Mg^{2+}, K^{+} and Na^{+}). Exchangable acidity of the soil was determined by titration method, McLean (1965). Effective Cation Exchange Capacity was calculated as the sum of exchangeable base (Ca, Mg, K and Na) and exchange acidity. The available phosphorus was determined using the Bray and Kurz (1945) No2 method.

Data Analysis

The laboratory data were statistically analyzed using a 4 x 3 factorial in a randomized complete block design with three replications. The factor A was the four land uses (oil palm plantation, forest, arable crop land and fallow) and factor B the three depths (0-15cm, 15-30cm and 30-45cm). Fisher's Least Significant Difference (LSD) was used to separate significanttreatment means.

RESULTS AND DISCUSSIONS

The physical properties of the soils studied are shown in table 1. There were differences in physical properties of the soils under different land uses at different depths. Sand sized particles dominated. The high value of the sand fraction compared to the silt and clay fractions is typical of soils of Southeastern Nigeria. The high dominance of sand in the area implies that higher particles of silt, clay and other colloidal materialsare carried away leaving the heavier sand particles with poor nutrient (Obi and Asiegbu, 1980). This is an indication that the soils will be erodible under high rainfall. Ugwu*et al* (2016) reported that soils with high percentage sand are more erodible because of low binding and inter-binding forces that help in resisting detachability of soil by water.Clay content increases with depth with the highest clay content found in 30-45cm in all the land uses.The mean percentage total porosity for the soils were 43.32%,38.12%, 36.73%, and 28.68 for forest, oil palm, arable farm and fallow, respectively. The mean saturated hydroconductivity were 10.87cm/hr, 7.76cm/hr, 6.22cm/hr and 3.47cm/hr for oil palm, fallow, arable farm and forest respectively.Porosity influences rate of infiltration and percolation and both are factors which affect the disposition of a soil to erosion (Idah*et. al*., 2008).Low porosity encourages water erosion because it seriously restricts water entry into the soil. Porosity less than 50% is not desirable (Chris-Emenyonu, and Onweremadu, 2011).The bulk densities of soils under different land use types were significantly different ($p<0.05$). The bulk densities of the soils were 1.89mg/m^3, 1.68mg/m^3, 1.67mg/m^3, and 1.50mg/m^3 for fallow, arable crop, oil palm and forest, respectively. The low bulk density of the soils under the forest land use may be due to the high organic matter content. This is in line with findings of Godberge and Forster, (1990) who opined that soils with high organic matter content has improved microaggregation and low bulk density. There was significant increase in bulk density with depth. At average, the soil depth 0-15cm had lowest bulk density while the highest bulk density was found in soil depth of 30 -45cm. The low bulk density at the top soil (0-15cm) may be due to relatively higher organic carbon and low clay content at the top soil. This is because clay may have been translocated from top soil to subsoil via lessivage (Ojanuga, 2003). Oguike and Mbagwu (2009) reported that increase in Organic carbon decreases soil bulk density significantly. The MWD of the land uses are 3.55, 3.55, 3.27 and 3.25mm for forest, fallow, oil palm and arable farm, respectively. The forest land showed the highest MWD while the arable farm had the lowest MWD. This might be as a result of high organic matter content and low clay translocation in the forest compared to that of arable farm. In terms of soil depth, 30 – 45cm had the highest MWD .The increase in MWD in deeper soils might be because of higher clay content with depth increase. Le Bissonnas (1990) opined that soils with high clay content have greater structural stability and higher MWD. Igwe *et al.(*1995)claimedthatCFI ranked highest among other micro and macro aggregate indices in predicting potential soil loss in some soils of Southeastern Nigeria. The soils of the different land uses were also significantly different in CFI as follows: 69.85%, 54.51%, 44.55% and 36.62% for oil palm, fallow, forest and arable farm. The DR of the soils in terms of landuse types were 42.14%, 40.82%, 35.98% and 35.22% for arable crop, fallow, oil palm and forest respectively. The CDI for the soil in terms of land use type were 66.18%, 45.98%, 30.48% and 25.79% for arable crop, fallow, palm and forest respectively. The forest soils were significantly lower in terms of CDI and DR while the arable farm had the highest CDI and DR. The low CDI and DR in forest soils may be due to high organic matter content and low translocation of clay compared to the arable farm land(Chris-Emenyonu, and Onweremadu, 2011). Soils with lower DR and CDI were more aggregated and less susceptible to soil erosion. Igweand Udegbunam (2008) stated that the higher the CDI and DR the more the ability of the soil to disperse while the higher the CFI the better aggregated the soil. Both CDI and DR decreased with soil depth. The decrease in CDI and DR with depth may be as result of low clay content at the top soil compared to the subsoil. The ASC were 18.79%,16.79%,14.77% and 10.78% for forest, fallow, oil palm, and arable farm respectively. The soil of the forest showed high ASC while the soil of the arable farm showed low ASC. Le Bissonnais,.(1990) stated that soil high in ASC are less susceptible to rain splash and erosive forces than soil low in ASC. The ASC of the soils increased with depth. The AWC among the land use types were 16.51%, 14.22%, 12.75% and 12.45% for oil palm, forest, arable farm and fallow respectively. The soils of the oil palm had relatively higher AWC while the soil of the fallow had the lowest. The FC in terms of land use types were 26.27%, 23.62%, 21.79%, and 21.26% for oil palm, forest arable farm and fallow respectively. The soil depth of 30-45cm had the highest field capacity followed by the depth of 15-30cm, The increase in FC with depth can be due to higher clay content of soils with depth due to clay translocation and higher bulk density at the deeper part of the soils studied.

Soil chemical properties.

Soil chemical constituents affect the resistance of soils to forces generated by agents of erosion(Chris-Emenyonu, and Onweremadu, 2011). Data obtained on chemical properties are presented on Table 2. The mean pH, for the land use types were 5.57, 4.90, 4.17, and 4.10 for forest, fallow, oil palm and arable farm, respectively. The relatively high acidity observed in the arable crop soils might be due to leaching of basic cation and loss of nutrient through continuous crop harvest (Isirimah and Dickson, 2003). Low soil pH characterizes tropical soils that have always been subjected to severe weathering and leaching due to high rainfall and ambient temperature (Lal, 1979). The organic matter content was generally low in all four land use types.The organic matter was 2.06%, 1.48%, 1.78% and 1.18% for forest, oil palm, fallow and arable farm respectively. The forest soils showed the highest level of organic matter content while the arable crop farm showed the lowest level of organic matter content. The relative high organic matter content of the forest soils could be attributed to high biomass production and their subsequent return to the soil. Soil organic matter has been reported to act as an aggregating or disaggregating material in soil (Mbagwu and Bazzoffi, 1998). Therefore, a soil with high organic matter will be resistance to soil crusting and compaction, have high fertility status, better root growth of crops, and improved crop yields. The low organic matter content of the soils indicates poor aggregate stability and predisposes the soil to dispersion (Brady and Well, 2002). The soil organic matter decreased with depth for all the soils. Soil depth of 0-15cm had the highest level of organic matter while 30-45cm depth had the lowest organic matter content. The decrease in organic matter content down the depths under each land use could be related to high residue concentration at the top soil by leaf falls, plant deposits and root density (Balesdent*et al*, 2000). The total nitrogen of the soils was below the critical level of 0.15% except for the soil under the forest. The high total nitrogen found in forest soils might be due to good vegetative cover, reduced leaching/volatilization and increased in organic matter through litter fall. The phosphorus level of the soils of the different land use types were 16.03mg/kg, 11.37mg/kg, 10.37mg/kg and 9.80mg/kg for forest, fallow, arable farm, fallow, and oil pam respectively. The reason for the relatively higher concentration of available p in the forest soils is due to high organic matter content and low leaching. It can also be due to their relatively reduced level of acidity which discourages P fixation. Oil palm had the lowest p level. Aweto&Ekiugbo (1994) observed that oil palms tend to deplete soil nutrients due to long term nutrient immobilization in the trees and the harvesting of palm fruits which constitute a drain on soil nutrient capital.The soils were low in exchangeable K. The potassium values of the soils were below the critical level of 2.0cmol/kg for optimum crop production. This might be as a result of low organic matter contents of the soil and high leaching and weathering caused by high rainfall and temperature which is predominant in the Southeastern Nigeria. The soils were low in CEC and base saturation for all the land use types. Cation exchange capacity and base saturation decreases with depth. This might be due to decrease in organic matter content with depth.

Table 1: Structural and water characteristics of different land use studied

Land uses	Depth	Sand (%)	Silt (%)	Clay (%)	Texture	TP(%)	Ksat Cm/hr	BD	MWD	CFI	DR	CDI	ASC	AWC	FC
Oil palm	0-15cm	85.2	5.4	9.4	Loamy sand	36.22	12.26	1.69	2.89	86.77	46.12	33.55	13.44	16.74	26.09
	15-30cm	89.2	1.4	9.4	Loamy sand	35.47	11.02	1.72	3.13	50.16	44.63	30.17	15.45	16.76	26.63
	30-45cm	73.2	13.4	13.4	Sandy loam	42.67	9.34	1.6	3.73	72.62	35.68	27.72	15.41	16.03	26.08
Mean		**82.53**	**6.73**	**10.73**		**38.12**	**10.87**	**1.67**	**3.25**	**69.85**	**42.14**	**30.48**	**14.77**	**16.51**	**26.27**
Fallow	0-15cm	75.2	15.4	9.4	Sandy loam	24.15	10.72	2.01	2.69	50.17	25.34	50.17	13.45	10.45	19.04
	15-30cm	65.2	17.4	17.4	Sandy loam	18.49	7.96	2.16	3.96	50.16	46.67	50.16	19.46	10.24	19.15
	30-45cm	75.2	7.4	17.4	Sandy loam	43.39	4.59	1.51	4.01	63.19	35.93	37.13	17.45	16.65	25.59
Mean		**71.87**	**13.40**	**14.73**		**28.68**	**7.76**	**1.89**	**3.55**	**54.51**	**35.98**	**45.82**	**16.79**	**12.45**	**21.26**
Arable Farm	0-15cm	85.2	3.4	11.4	Loamy sand	44.15	9.19	1.48	2.42	26.06	47.92	81.35	7.42	13.86	23.37
	15-30cm	87.2	1.4	11.4	Loamy sand	39.62	6.12	1.6	3.29	47.51	40.16	52.85	13.45	14.09	23.87
	30-45cm	87.2	1.4	11.4	Loamy sand	26.41	3.36	1.95	3.27	36.29	34.39	64.33	11.48	10.31	18.14
Mean		**86.53**	**2.07**	**11.40**		**36.73**	**6.22**	**1.68**	**3.94**	**36.62**	**40.82**	**66.18**	**10.78**	**12.75**	**21.79**
Forest	0-15cm	31.2	33.4	35.4	Clay loam	42.41	4.67	1.52	2.69	31.58	44.64	28.74	23.47	14.05	23.27
	15-30cm	47.2	21.4	31.4	Sandy clay	41.88	3.06	1.54	3.96	46.01	35.68	24.37	13.45	14.63	24.31
	30-45cm	65.2	17.4	17.4	Sandy loam	45.66	2.69	1.45	4.01	56.06	25.34	24.25	19.46	13.97	23.27
Mean		**47.87**	**24.07**	**28.07**		**43.32**	**3.47**	**1.50**	**3.55**	**44.55**	**35.22**	**25.79**	**18.79**	**14.22**	**23.62**
LSD(0.05) Depth		**12.5**	**2.53**	**3.07**		**6.35**	**1.31**	**0.29**	**0.61**	**9.08**	**6.62**	**7.66**	**2.66**	**2.39**	**3.94**
LSD(0.05) Land Use		**14.4**	**2.92**	**3.55**		**7.34**	**1.52**	**0.33**	**0.70**	**10.49**	**7.64**	**8.84**	**3.08**	**2.76**	**4.55**
LSD(0.05) Depth & Land Use		**25.01**	**5.05**	**6.14**		**12.70**	**2.63**	**0.57**	**1.22**	**18.16**	**13.23**	**15.31**	**5.33**	**4.78**	**7.89**

Table :2 Chemical properties ofstudy soils of different land use

Location	Depth	pH	O.M(%)	N %	P mg/kg	K cmol/kg	Ca cmol/kg	Mg cmol/kg	Na cmol/kg	TAE	TEB	ECEC	B.S (%)
Oil palm	0-15cm	4.5	1.42	0.1	10.9	0.17	3.00	0.61	0.08	1.3	3.86	5.16	74.8
	15-30cm	4.1	1.16	0.08	9.5	0.12	2.60	0.55	0.06	1.02	3.39	4.41	76.87
	30-45cm	3.9	0.95	0.08	9.0	0.11	2.00	0.52	0.04	0.9	2.67	3.57	74.78
Mean		**4.17**	**1.18**	**0.09**	**9.80**	**0.13**	**2.55**	**0.56**	**0.06**	**1.07**	**3.31**	**4.38**	**75.48**
Fallow	0-15cm	5	2.98	0.18	11	0.25	4.90	1.71	0.09	1.9	6.95	8.85	78.53
	15-30cm	4.9	2.25	0.11	10.1	0.15	3.11	1.07	0.07	1.3	4.4	5.7	77.19
	30-45cm	4.8	0.94	0.1	10	0.14	2.54	0.88	0.05	1.11	3.61	4.72	76.48
Mean		**4.9**	**2.06**	**0.13**	**10.3**	**0.18**	**3.52**	**1.22**	**0.07**	**1.44**	**4.99**	**6.42**	**77.40**
Arable Farm	0-15cm	4.5	2.02	0.07	12.5	0.1	2.49	1.30	0.07	1.24	3.96	5.2	76.15
	15-30cm	3.9	1.08	0.06	11.4	0.09	2.22	1.00	0.04	0.96	3.35	4.31	77.72
	30-45cm	3.7	1.14	0.06	10.2	0.07	2	0.81	0.04	0.67	2.92	3.59	81.33
Mean		**4.03**	**1.41**	**0.06**	**11.3**	**0.09**	**2.24**	**1.04**	**0.05**	**0.96**	**3.41**	**4.37**	**78.40**
Forest	0-15cm	5.9	2.36	0.25	18.5	0.3	5.8	3.34	0.51	1.9	9.95	11.8	83.96
	15-30cm	5.7	1.98	0.19	15.7	0.23	4.7	2.9	0.44	1.4	8.27	9.67	85.52
	30-45cm	5.1	0.99	0.14	13.9	0.14	3.8	2.7	0.12	1.4	6.74	8.14	82.8
Mean		**5.57**	**1.78**	**0.19**	**16.0**	**0.22**	**4.77**	**2.98**	**0.36**	**1.57**	**8.32**	**9.87**	**84.09**
LSD(0.05) Depth		**1.19**	**0.44**	**0.03**	**3.08**	**0.04**	**0.88**	**0.44**	**0.05**	**0.33**	**1.39**	**1.71**	**19.95**
LSD(0.05) Land Use		**1.38**	**0.51**	**0.03**	**3.56**	**0.05**	**1.02**	**0.51**	**0.06**	**0.38**	**1.60**	**1.96**	**23.04**
LSD(0.05) Depth & Land Use		**2.38**	**0.88**	**0.07**	**6.17**	**0.07**	**1.76**	**0.88**	**0.10**	**0.66**	**2.77**	**3.42**	**39.90**

CONCLUSION

This research work determined Structural and chemical properties of soils of different agricultural land use types with depth in Owerintta, Abia State. There were differences in physical properties of the soils under different land uses at different depths. Sand sized particles dominated in all the land use types. The high dominance of sand in the area implies that higher particles of silt, clay and other colloidal materialsare carried away leaving the heavier sand particles with poor nutrient. From the findings, the soilof Owerrinta were generally low in pH, organic matter, base saturation and Effective Cation Exchange Capacity. This is an indication that the soils are highly leached and under the influence of erosion due to high rainfall and temperature which is predominant in the area. The soil under forest showed higher base saturation and ECEC compared to other land uses. The forest soils had lower bulk density (BD), dispersion ration(DR), and clay dispersion index (CDI)compared to other land use types. The arable farm had the lower ASC, CFI and MWD. This might be due to low organic matter content and destabilized soil structure due to constant cultivation. The forest soils also had relatively higher mean weight diameter (MWD), Aggregated silt+clay (ASC), clay flocculation index(CFI) and saturated hydraulic conductivity(Ksat).From the study, low organic matter content was one of the major factor that predisposed the soil to degradation. The use of organic manure should be encouraged especially in the continuously cultivated arable soils. Deep tillage operations should also be discouraged to avoid the disruption of soil structure, which predisposes the soils to deterioration and degradation.Unsustainable practices like trash and burn should be discouraged as it reduces organic matter content of the soil in this area.

REFERENCES

Balesdent, J., Chenu, C., and Balabane, M. (2000) Relationship of soil organic matter dynamics to physical protection and tillage. Soil & Tillage Research 53: 215 – 230.

Brady and Well (2002).The Nature and properties of soil.Pearson Prentice Hall.

Bray, R.H. and Kurtz, L.T. (1945) Determination of Total Organic and Available Forms of Phosphorus in Soils. Open journal of soil science, vol 4, No 3. Soil Science, 59, 39-45.

Chris-Emenyonu, C. M. and Onweremadu, E. U. (2011) Indicators of Erodibility of Soils under different land use types in Imo State. Pp 43-67.

Gee, G.W and Or (2002). Particle size analysis In:Dane, J.H, and G.C Topps (ed). Methods of Soil Analysis Part 4. Physical Properties.Soil Sci. Soc Am Book series 5. Madison, WI. Pp. 223-293.

Goldberg, S. and Forster, H.S. (1990) Flocculation of reference clays and arid – zone soil clays. Soil Sci. Soc. Am. J. 54: 714 -718.

Idah P.A., Mustapha H.I., Musa J.J., Dike J. (2008) Determination of Erodibility indices of Soils in Owerri West Local Government Area of Imo State Nigeria. AU Journal of Technology 12(2) 130 – 133.

Igwe, C. A., Akamigbo, F. O. R. and Mbagwu, J. S. C. (1995) The use of some soil aggregate indices to assess potential soil loss in soils of south-eastern Nigeria. International Agrophysics, 9:95-100.

Igwe, C.A. and Udegbunam, O.N. (2008) Soil propertiesinfluencing water-dispersible clay and silt in anUltisol in southern Nigeria.International Agrophysics22, 319-325.

Isirimah, N. O. and Dickson, A. A. (2003) Introductory Soil Chemistry and Biology for Agriculture and Biotech.P. 104.

Kemper W.D. and Rosenau, R. C. (1986) Size Distribution of Aggregates. In: Methods of Soil Analysis, A. Klute (Ed.) part I.2nd Edn. Agron.Mongr. 9. ASA – SSSA, Madison, W.I., Pp. 425 – 442.

Kjeldahl.Johan Z. (1983) A new method for the determination of nitrogen in organ bodies. Analytical Chemistry 22: 366.

Klute, A. and C. Dirksen.(1986) Hydraulic conductivity and diffusivity: Laboratory methods. In: Methods of Soil Analysis Part 1: Physical and Mineralogical Methods, A. Klute, Ed. Soil Sc.Soc. of America. Madison, WI.

Lal, R. (1979). No tillage effects on soil properties and maize production in Western Nigeria. Plant Soil 40:321-331.

Le Bissonnais, Y. (1990) Experimental study and modeling of soil surface crusting processes. Catena Supplement.(17), 13-28.

Mbagwu, J. S. C. and Bazzoffi, P. (1998). Soil characteristics related to resistance of breakdown of dry soil aggregates by waterdrops. Soil Tillage Research. 45: 133-145.

Obi, M. E. and Asiegbu, B. O. (1980). The physical properties of some eroded soil of south-eastern Nigeria. Soil Sci 130:39-48.

OguikeP.C., and Mbagwu J.S.C. (2009) Variations in some Physical Properties and Organic Matter Content of soils of Coastal Plain Sand under different Land use types. World Journal of Agricultural Sciences 5 (1)63-69 IDOSI Publications.

Thomas G.W. (1996) Soil pH and Soil acidity. In: Methods of soil Analysis. Part 3 – Chemical methods. L.D. Aparks (ed), SSSA Book series. No 5.

Ugwu,E.C. Ude, V.C. Ehiomogue, P. and Onyekawa1, F.C. (2016) Investigation of Erodibility Indices of Soils in Ikwuano Local Government Area of Abia State in South-Eastern Nigeria.

Walkley.A and Black. I.A. (1934) Determination of organic carbon in soil.Soil Science 37:29 – 38.