5α6

SOIL SCIENCE SOCIETY OF NIGERIA

NIGERIAN JOURNAL OF SOIL SCIENCE

VOLUME 22 (1), 2012

EDUCATION TRUST FUND

FUNDED BY: EDUCATION TRUST FUND

Published by the Soil Science Society of Nigeria

DEGRADATION EFFECT OF PALM OIL MILL EFFLUENT (POME) ON PHYSICAL AND CHEMICAL PROPERTIES OF THE SOILS OF UGA, SOUTH EASTERN NIGERIA.

PATIENCE. O. UMEUGOCHUKWU[1], VICTOR O. CHUDE[2] AND EZEAKU P.[1]
[1]Department of Soil Science University of Nigeria, Nsukka.
[2]National Programme for Food Security (NPFS)
Email: obyumeh@yahoo.com, ezeakup@yahoo.com, vchude@yahoo.co.uk
08033945009, 07066725984

ABSTRACT

This study investigated the impact of long term application of palm oil waste on physical and chemical properties of a sandy Ultisols (Arenic Kandiustult) in Uga, Nigeria. Soil samples were collected from the surface (0-10cm) and subsurface (15-25cm) of palm oil polluted site. Another surface (0-10) and subsurface (15-25) samples were collected 15 meters away in the palm oil unpolluted (control site). Core samples were from both soils. All the samples were analyzed for selected physical and chemical properties. The result showed that both soils were loamy sand but varied in the other physical properties as bulk density and total porosity. The two soils were strongly acidic, but had more carbon, nitrogen and phosphorus in the palm oil polluted soils than in the unpolluted soils. The result indicated that the area affected with the palm oil mill effluent (POME) had more nutrient status but reduced plant growth due to clogging of water and restricted aeration. The other forms of land degradation identified in the area were erosion, deforestation, bush burning, and sand quarrying. Efforts at combating land degradation by the Uga indigenes in other to protect their land from environmental devastation should be intensified. Knowledge of the component and proper disposition of these pollutants should be made known to the people of Uga.

Keywords: Keywords: Degradation; Palm oil mill effluent; food security; Environmental hazards

INTRODUCTION

Palm oil processing is carried out in mills where oil is extracted from palm fruits. Large quantities of water are used during the extraction of crude palm oil from the fresh fruits and about 50% of the water results in palm oil mill effluents (POME). It is estimated that for 1 tonne of crude palm oil produced, 5-7.5 tonnes of water will end up as POME (Ahmed et al., 2003). It has been observed that most of the POME produced by the small scale traditional operators in Uga undergo no treatment and is discharged into the agricultural land that is used for arable farming (Umeugochukwu, 2001). This effluent is a serious land and aquatic pollutant when discharged immediately into the environment. Besides the presence of lipids and volatile compounds, the inhibitory effects of POME on living tissues, could also be due to presence of water-soluble phenolic compounds (Radzia 2001; Perez et al., 1992).

Soil is a fundamental base for agricultural production system and therefore deserves to be seriously conserved. The relationship between the cropland degradation and food production deserve to be looked at very well. Land degradation problem is a serious problem confronting the people of Uga, in Anambra State. Land degradation is the diminution of soils current or potential capacity to produce food, feed and fiber as a result of one or more degradative processes.

Understanding soil degradation, causes and processes are essential for better management of the soil. The importance of maintaining or improving the soil physical and chemical properties in agriculture has been reported by many researchers. Lal and Greenland (1977) stated that the development of stable and viable system of soil management in tropical region with a harsh climate or environment must be based on a thorough understanding of the soil physical and chemical condition, if it were to be meaningful. Ahn (1974) considered that the physics of the soil was as important as its chemistry and that any chemical shortcoming might be made good simply by adding the necessary fertilizer; but no amount of nutrient would make up for poor soil physical properties. Soil structural conditions are important if, for example, yield responses of agricultural crops to fertilizer inputs are to be optimized (Smith et al, 1989).

POME is the most polluted organic residue generated from palm oil. It is composed of high organic content. Untreated POME contains high concentration of free fatty acids, proteins and plant tissues but it is non toxic (Ngan et al., 1996). It has a high biological oxygen demand BOD which makes it more polluting than other domestic sewage (Okwute et al, 2007). Palm oil mill effluents had been discovered by the people of Malaysia as better organic compost for agricultural production than chemical fertilizer after treatment to remove the oil in the effluent (APOC, 2004). The situation at Uga is contrary as no plant was found growing on the area where the effluents were disposed. This study is to investigate the effect of POME on soil physical and chemical properties and suggest a better way of disposing the effluent to enhance food production and security.

MATERIAL AND METHODS

The area under investigation is located within longitude70 4'E and latitude 63 56'N. It is about 32km south of Awka, Anambra state capital. The study area falls within humid tropical zone. The two major seasons in the area are wet and dry season with the former lasting for 8 months (April- October) and the latter for 4 months (November-March). The average annual rainfall is 1485.2mm with maximum temperature of 350 C. The temperature is generally high and rarely falls to 210 C throughout the year. The mean annual temperature ranges from 270C-350C (Badiane, 2009). The relative humidity ranges from 40%-92%. The vegetation of the area is rain forest with mainly grassland and savannah vegetation. The dominant land uses are cereal and arable cropping systems. The soils are classified as an ultisol (Arenic Kandiustult) bases on USDA soil classification system (Umeugochukwu, 2010). Soils of areas affected with palm oil effluents and another area not affected by the effluent were collected and analyzed.

Soil sampling method

Soil sampling: Soils of the two sites (polluted and unpolluted) were collected from 0-15 and 15-25cm depth. For purposes of analysis, the surface samples were composite separately from the sub surface samples. Undisturbed core samples were collected from the surface (0-10cm) and subsurface (15-25cm) of palm oil polluted and unpolluted site. The unpolluted samples were collected 15 meters away from the palm oil polluted site and all were analyzed for selected physical and chemical.

Laboratory Analysis Methods

The samples were taken to the laboratory in well labeled polyethene bags. They were air dried and sieved to pass through 2mm sieve. The fine earth fraction was analyzed for the following physical and chemical properties; physical properties selected include: Particle size distribution- Sand, Silt and Clay; Bulk Density, Porosity. Chemical properties were pH, Organic Carbon, Total Nitrogen, Available P, C.E.C, and Exchangeable Cations (Ca2+, Mg2+84 , Na+ and K+85).

Particle size analysis was determined by Gee and Bauder (1986) method. The textural classes were determined from the USDA soil textural triangle. Bulk density was obtained by the method of Blake and Hartge (1986). Total Porosity was calculated from the values of the bulk density using the method described by Vomicil (1965).

Soil pH was obtained in 1:25 soil/water extract of the composite samples according to Mclean (1982) method. Available P was determined by the Bray 2 extract Olsen and Sommers (1982). Cation Exchange Capacity (CEC) was determined by the NH4OAC displacement method and exchangeable acidity by titrimetric method after extraction with 1.0N KCl (McLean, 1982). Total exchangeable bases (Ca2+, Mg2+, Na+ and K+92) were determined using 1N NH4OAC extrantant method (Thomas, 1982), where Ca2+ and Mg2+ 93 were obtained on an Atomic Absorption Spectrometer; Na+ and K+ 94 by flame photometer. Base saturation was calculated from TEB/CEC x 100, where TEB = total exchangeable bases. Soil organic carbon (OC) was determined by Nelson and Sommer (1982) method. Soil organic matter was obtained by multiplying percentage carbon by 1.724. Total nitrogen was determined by the macro-Kjeldhal method of Bremmer and Mulvaney, (1982).

Statistical Analysis

The statistical analysis consists of descriptive statistics and paired sample T-test. Descriptive statistics shows the means of the chemical and physical properties of the different soils (polluted and unpolluted soils.) The paired t-test compared the differences in mean among the two sites.

RESULTS AND DISCUSSION

Impact of the POME on the Soil.

Preliminary observation shows that pollu of the soil with palm oil waste and o domestic wastes was prominent in the st area. It affected land use in terms of p growth. There was little or no plant s growing on the area polluted with POME e though it contained more nutrients than unpolluted site. There was more siltation the polluted site which was as a result clogging of the pore sizes which of cou restricted aeration. The lack of air in these a as predicted could possibly result to lack plant growth despite the nutrients containec the POME. The impact of this pollution mostly felt in wet season when it form suitable breeding ground for most vectors diseases.

Physical properties

The particle size distribution results in tabl indicated that the fine earth fractions w dominated mainly by sand followed by c and silt in both soils. The textu classification of the two soils was loamy sa The mean values of the clay (11.0%), to sand (81.5), and coarse sand (32.0) collec from both soils indicated that the high values were obtained from the unpollut soils. The polluted soil had higher mean s content of (7.5) than the unpolluted soil (1.5). The top soil of the polluted site record more sand fraction than its sub layer which the same trend with the unpolluted site. T subsurface layers in both soils had more cl content. Their clay mean values were 11.0 a 12.5 in the polluted and the unpolluted so respectively. The trend of the silt conte varied. It was more in the top soil of t polluted site than the unpolluted site (Table 1

Bulk Density, Total Porosity and Pore si distribution: The bulk density values we obtained from both top and sub soils of t two soils. The bulk density value obtain from the top soil of the polluted site (1 g/cm3) was lower than that of the top soil the unpolluted soil (1.4 g/cm3). The bu densities and total porosity values averag

1.2 g/cm3, 52%, 35%, 17% respectively and the unpolluted soil values were 1.45 g/cm3, 43%, 53%, 10% respectively. The mean bulk density of the polluted soil is lower than the mean bulk density of the unpolluted soil Table 2. The polluted soil with lower bulk density recorded higher . total porosity than the unpolluted soil with higher bulk density.

Chemical properties

The soil pH was generally low. It ranged from 4.8-4.9 H_20 for all the soils. The mean value of the pH for the two soils was the same (4.3) (table 3). The soils were extremely acidic. There was no significant difference in the pH of the two soils.

The mean values of soil organic matter (1.82%) was higher in the palm oil polluted soil than in the unpolluted soil (0.86%). The values increased with depth in the palm oil polluted soil and decreased with depth in the unpolluted soil (Table 1). The topsoil of the palm oil polluted soil had 1.72% and 1.93% organic matter in the sub layer while the unpolluted soil had 0.97% in the topsoil and 0.76% in the subsurface. The differences in mean was significant ($P>0.05$). the values of the polluted soil and the unpolluted soils were statistically different.

The two soils had high amounts of available phosphorus. The mean values of the two soils were 62ppm and 56ppm for polluted and unpolluted soils respectively. The polluted had more P than the unpolluted soil. There was no difference in the trend of distribution of phosphorus in the top soil and the sub soil of the polluted and unpolluted soils. There was no significant difference in the available phosphorus of the two soils.

The mean values of the ACEC and ECEC in the polluted soil was 1.15, 2.3 and 1.47,2.5 in the unpolluted sample respectively. The differences were not significant at $P>0.05$. The base saturation had mean value of 73% in the polluted soil than in the unpolluted soil (57%). The exchangeable acidity mean value for the both soils was of the same value (2.0).

For both soils in the polluted and unpolluted sites, mean exchangeable Na was 0.15meq/100g and 0.10meq/100g, 0.45 meq/100g and 0.35 meq/100g of K, 0.5 meq/100g and 0.4 of Ca, in polluted and unpolluted soils respectively. Mg had mean value of 0.3 in both soils. Na, K and Ca had higher mean values in the polluted soils than in the unpolluted soils.

DISCUSSION

The relatively high sand content in the area is the reflection of the effect of the sandy parent material. The dominance of sand size particles would have emanated from the presence of such particles in the parent material of the soils. The parent materials of the soils of eastern Nigeria have been noted to influence the texture of the soils derived from them (Akamigbo and Asadu cited in Asadu and Agudosi (1994).

The relatively higher clay content in the subsurface layers in each site may have resulted from the process of eluviation from the upper horizons. The low clay content observed in the upper layers of these soils may further indicate the degree of weathering and leaching that the soil has undergone (Asadu et al; 2008). The higher silt content observed in the upper layer of the polluted soils may be due to the effect of palm oil mill effluent. This can be attributed to reduced floatation of silt particles in runoff and hence reduced carting away of silt particles by overland flow. However the soils of these areas are inherently low in silt content (Akamigbo, 1984) essentially due to low content of these particles in the original parent material.

A test of mean difference carried out to compare the mean values of the particles size analysis data between the two soils, however showed that the mean clay, silt and sand contents were significantly different at $P>0.05$. Thus the palm oil mill effluent (POME) influenced the particle size distribution in the soil significantly. Salimon (2007) noted that the impact of POME on the physical properties of soil depends on the method of application.

POME retards growth of cowpea at the early stage, enhances nodulation when applied in a controlled manner and inhibits nodulation when applied in a large quantity. He also noted that it can be used as organic fertilizer material to improve degraded sandy and low organic matter soils.

The lower bulk density in the palm oil polluted soil can be attributed to the accumulation of palm oil effluent in this soil. The bulk density value was lowest on top of the polluted site showing that the effect is more at the zone of application. As you go down the sub layers, the effect reduced. Palm oil mill effluent contains a lot of organic materials of low bulk density (Harrison, 1995) and so impacts this property to the soil. There was increase in the values of the bulk density down the layers both in the polluted and the unpolluted soils.

Increase in total porosity is often correlated with decrease in bulk density. This was observed in the samples of the polluted and unpolluted soils where the mean total porosity was lower in the polluted soil than the unpolluted soil. The paired t-test showed significant difference in the samples from polluted and unpolluted soils. The mean t-test of porosity was significantly higher in the unpolluted soil than in the polluted soil at $P>0.05$.

It has been reported that when raw POME is discharged, the pH is acidic (Hemming, 1977) but seems to gradually increase to alkaline as biodegradation takes place. Soil acidity is one of the principal factors affecting nutrient availability, therefore availability of major nutrients (N,P,K) cannot effectively promote high yields of crops if soil pH is not correct. The uniformity in the soil pH indicated that the POME had started undergoing degradation. The low pH noticed in the POME could be as a result of presence of phenolic acids and oxidation of the organic acid compounds (Nwoko, 2010).

The higher values of organic matter in the polluted soil confirms the report of (Falodun **et al, (2010). He observed that POME contains** relatively high amount of plant nutrients. may also be due the accumulation of effluent on the soil. This is the reason PC can be used for growing crop and amen soil fertility depletion. Nwoko (2010) repo that POME amended plots gave higher m height that significantly differed from tha control. Similarly, POME application \ resultant positive yields may be attribute the ability of the pome to stimulate the acti of micro organism in the subsisting soil/p environment.

The available phosphorus is more in polluted soil than in the unpolluted soil. palm oil mill effluent affected the availabi of phosphorus in the polluted soil. The hig mean value of phosphorus in the polluted is in line with the work of Haun (1987) wh suggest possibly high absorption in the soil a possible precipitation of phosphate. He a said that there is a good evidence that sugge that phosphorus is the dominant elem controlling carbon and Nitro immobilization. The uniformity in the reflected in the available P as acid soils tenc fix phosphorus.

According to Rhodes (1982) CEC usua expressed in meq/100g is a measure quantity of readily exchangeable catic neutralizing negative charges in the soil. T high values of the CEC in the POME show that the soil is enriched with the followi exchangeable bases: Ca, Mg, Na and K due the presence of POME in the soils. Increase CEC could be attributed to increase in dependent charges as well as addition organic matter from the effluent as observ by Okwute (2007). The CEC and t exchangeable acidity had no difference in t two soil but the base saturation show significant difference at $p>0.05$ in the t soils. The base saturation average value more than 50% confirms the reason the soil fertile. The higher value of B.S in the pollut soil is an evidence of higher fertility than t unpolluted soils.

CONCLUSION

The first impression that could be got from POME soil environment was that of bareness and a wasted land. The absence of vegetation was not surprising since the POME soil's ability to retain water could cause clogging of soil pores and hence water logging of the soil (Chan et al, 1980). Excess water in the soil restricts micro-organisms and their activities by preventing oxygen movement into and through the soil in sufficient quality to meet the oxygen demand of the organism.

From the data generated in the study, it is obvious that the physical and chemical properties of the POME soils is different from that of the non POME. Since the POME has been shown to be acidic in nature, it is advisable to be treated before application to the soil. Proper use of POME could lead to improved soil fertility and soil structure.

Table 1: The selected physical properties of the polluted and unpolluted soils

	Designation	Depth (cm)	Clay (%)	Silt (%)	T.sand (%)	F.S	C.S	B.D	T.P	T.C
Polluted Soil	Top polluted	0-10	10	8	82	48	36	1.2	54	Loamy
	Sub polluted	15-15	12	7	81	40	28	1.3	50	Sand
Unpolluted Soil	Top unpolluted	0-1	11	1	88	44	36	1.4	47	Loamy
	Sub unpolluted	15-25	14	2	84	40	32	1.5	43	Sand

Table 1.2: The chemical properties of the polluted and unpolluted soils.

Depth (Cm)	pH	C (g/kg)	O.M (g/kg)	N (g/kg)	Av.P (mg/kg)	Exchangeable Bases (cmol/kg)				C.E.C (cmol/kg)		B.S (%)	Exch. Acidity (cmol/kg)	
						Na^+	K^+	Ca^{2+}	Mg^{2+}	ACEC	ECEC		AL^{3+}	H^+
	Polluted soil													
0-10	4.9	1.12	1.72	0.08	62	0.02	0.06	0.6	0.4	1.3	2.66	83	0.2	0.1
15-25	4.9	1.00	1.93	0.06	62	0.01	0.03	0.4	0.2	1.0	1.94	64	0.2	0.1
	Unpolluted soil													
0-10	4.8	0.57	0.97	0.09	56	0.01	0.04	0.4	0.3	1.05	2.10	75	0.2	0.1
15-25	4.8	0.44	0.76	0.05	56	0.01	0.03	0.4	0.3	1.9	2.94	39	0.2	0.1

Table 2: Mean value and T value/significant levels of soil physical properties of polluted and unpolluted soils in Uga.

Parameter	Mean	Std. Dev.	Std. Error	M.D	T-Value
Clay P1	11.0	1.41	1.00	-1.50	-3.00
P2	12.50	2.12	1.50	-4.50	-3.00
T. Sand P1	81.50	0.71	0.50	-2.00	-1.00
P2	86.00	2.83	2.83	6.00	6.00
C.S P1	32.00	5.66	4.00		
P2	34.00	2.83	2.00		
Silt P1	7.50	0.71	0.50		
P2	1.5	0.71	0.50		
B.D P1	1.25	7.07	5.00		
P2	1.45	7.07	5.00		
T.P P1	52.00	2.83	2.00		
P2	45.00	2.83	2.00		

Legend: T. Sand = total sand, C.S = coarese sand, B.D = Bulk Density, T.P = Total porosity.

Table 3: Mean value and T value/significant levels of soil chemical properties of polluted and unpolluted soils in Uga.

Parameter		Mean	Std. Dev.	Std. Error	M.D	T-Level	-Value/sig
pH	P1	4.9	0.00	0.00			
	P2	4.8	0.00				
Carbon	P1	1.06	8.48	6.00	0.55	111.00	
	P2	0.51	9.19	6.50			
Av.p	P1	62.00					
	P2	56.00					
Exch. Mg	P1	3.00	0.141	1.00	5.55	0.00	
	P2	3.00	0.00	0.00			
Nitrogen	P1	0.07	0.11	0.05	0.00	0.00	
	P2	0.07	0.23	0.11			
Org. M	P1	1.82	0.12	0.06	0.96	7.918	
	P2	0.86	0.12	0.06			
Exch. Ca	P1	5.00	1.41	1.00	1.00	1.00	
	P2	4.00	0.00	0.00			
Exc. Na	P1	0.015	0.005	0.002	0.005	1.732	
	P2	0.010	0.000	0.000			
B.S	P1	73.50	10.97	5.48	16.50	3.362	
	P2	57.00	20.70	10.39			

REFERENCES

Ahmad A, Ismail S, Bhatia S. (2003). Water recycling from **palm oil** mill effluent (POME) using membrane technology. *Desalination*, 157:87-95.

Ahn, P.M (1974). West African Soils, Oxford University Press, London.

Akamigbo, F.O.R (1984). The accuracy of field textures in a humid tropical environment.' Soil Survey and land Evaluation, Vol. 4

American Palm Oil Council (APOC), 2004. Sustainable palm oil practices, palm oil mill effluent (POME) and Empty Fruit Bunch Application as a nutrient Source in oil palm.

Asadu C.L.A, and Agudosi, H.C (1994). A comparative study of soils inside and outside ogbunike cave in Eastern Nigeria; Discovery and Innovation Vol.6 no 4. Pp367-371.

Asadu, C.L.A, Ucheonye-Oliobi, B. and Agada, C. (2008). Assessment of sewage application in south-eastern Nigeria: Impact on soil morphological and physical properties, outlook on Agriculture Vol 37, No 1.Pp 63-69.

Bremmer, J.M and C.S. Mulvaney, (1982). Total N,P.895-926. In Page et al (eds) Methods of Soil Analysis. Part 2. 2nd ed. Agron. Monog. 9 ASA and SSSA, Madison WI.

Chan, K.W, Watson, I., Lim, K.C (1980). Use of Palm oil waste material for increased production. Paper presented at the Conference on Soil Science and agricultural development in Malaysia, Kuala Lumpur.

Falodun E.J, Osaigbovo A.U and Remison S.U. (2010). Effect of Palm oil mill Effluent and NPK15:15:15 fertilizer on the growth and yield of soya bean.

Gee, G.W and Bauder, J.W (1986). Particle size Analysis.P.383-411. In: Klute, A (ed). Methods of Soil Analysis part 2, 2nd ed Agronomy Monograph No 9,ASA and SSSA, Madison, WI.

Haun, K.C. (1987). Trials on long term effect of application of POME in soil properties, oil palm nutrition and yield. In; proceedings of the international oil palm, palm oil conferences (eds) 575 598.

Lal, R,and Greenland, D.J. (1977). Soil Physical properties and Crop Production in the tropics, John Wiley, New York, pp 7-9.

Mclean, E.O (1982). Soil pH and Lime Requirement. P. 199-224. In: Page et al (eds) Method of Soil Analysis part 2. Chemical and microbial properties. 2nd 288 ed. Agron. Monog. 9 ASA and SSSA, Madison WI.

Nelson, D.W., and Sommers, L.E (1982). Total Carbon, organic carbon and organic matter, in page, et al ed, method of soil Analysis, part 2, 2nd 291 ed Agronomy Monograph No 9,ASA and SSSA, Madison, WI, pp 539-579.

Ngan, M.A, Zajima, Y. Asahi M.,and Junit H (1996). A novel treatment process for palm oil mill effluent. PORIM TECHNOLOGY, October 1996.

Nwoko, C.O (2010). Evaluation of Palm oil mill effluent to maize (Zea mays. L) crop: yields, tissue nutrient content and residual soil chemical properties, Australian Journal of Crop Science.

Okwute, O.L and Isu, N.R (2007). Impact analysis of palm oil mill effluent in aerobic bacterial density and ammonium oxidizers in a dump site in Anyamgba, Kogi State. African Journal of Biotechnology Vol 6 (2) pp 116-119.

Olsen, S.R and Sommers, (1982). Phosphorus. P 403-434. In page et al (eds), method of soil Analysis, part 2, 2nd ed Agronomy Monograph No 9,ASA and SSSA, Madison, WI.

Perez J, de la Rubia T, Moreno J, Martinez J (1992) Phenolic content and antibacterial activity of olive oil waste waters. Enviro. Toxicology Chem. 11: 489-495.

Radziah O (2001) Alleviation of Phytotoxicity of Raw POME by microorganism retrieved Sept, 2005, fromwww.agri.upm.edu.my/agrosearch/v3n2/irpa3.htm

Rhodes, J.O. (1982). CEC in A.L page R.H Miller and D.R keeney (eds) methods of soil analysis, part 2, Chemical and microbial properties. Madison Wisconsin: pp 149-157.

Salimon, B.O, (2007). 'The effect of palm oil mill effluent (POME) on soil properties, growth, Nodulation and yield of cowpea (Vigna Unguiculata) in palm oil producing zone of Nigeria' paper presented at the annual meeting of the Soil and Water Conservation Society, Saddlebrook Resort, Tampa, Florida <Not Available>. 2010-06-04 from http://www.allacademic.com/meta/p174308_index.html

Smith, S. R, Hail, J. E, and Hadley, P. (1989). Composting Sewage sludge wastes in relation to their suitability for use as fertilizer material for vegetable crop production. International Symposium of Compost Recycling of wastes, 4-7 October, Athens.

Thomas, G.W. (1982). Exchangeable cations, Pp 159-165. In page et al (eds) Method of soil Analysis, part 2, 2nd ed Agronomy Monograph No 9,ASA and SSSA, Madison, WI

Umeugochukwu, O.P and Akamigbo, F.O.R. (2010). Soil Degradation as a prelude to Land degradation and Environmental Reserves in Uga, Aguata L.G.A of Anambra State. Nigeria. Proceedings of the 44th annual conference of Agricultural Society of Nigeria, 'LAUTECH,ogbomosho, 2010' pp1390-1393.

Vomicil, J. A. (1965). Porosity, In Black, C.A ed, methods of Soil Analysis Part 1, Agronomy Monograph 9, ASA and SSSA, Madison, WI, pp 299-314.