SUITABILITY EVALUATION OF SOME SOILS OF SOUTH-EASTERN NIGERIA FOR OIL PALM (*Elaeis guineensis*) AND COCOA (*Theobroma cacao*) CULTIVATION

Ahukaemere C. M
Department of Soil Science, Federal University of Technology, Owerri, P.M.B 1526.
mildredshine@yahoo.com

Abstract
Selected soils of South-eastern Nigeria were evaluated for oil palm and cocoa production using FAO land suitability classification. Data were obtained from six oil palm and cocoa producing areas namely Ikom, Nwangele, Okpala, Okigwe, Nto-Ndang and Bende in South-eastern Nigeria. Results of the physico-chemical properties of soils showed that sand and clay contents ranged from 89 g kg^{-1} in Bende to 851 g kg^{-1} in Nto-Ndang; and 72 g kg^{-1} in Okigwe to 730 g kg^{-1} in Bende. Soil pH was very strongly (4.28) to moderately (5.60) acidic. Available phosphorus, exchangeable calcium and magnesium were rated low to moderate. From the land suitability results, soil texture was not suitable at Ikom, Nwangele, Okpala, Okigwe and Nto-Ndang (pedons 1-5, but marginally suitable at Bende (pedon 6) for cocoa cultivation. Soil texture placed pedons 1-5 in S3 (marginally suitable) class and pedon 6 in N1(currently not suitable) class for oil palm cultivation. For soil fertility characteristics, the major limitation for cocoa production at sites 1-5 was the organic matter which placed these sites in suitability class N1, while total nitrogen was a serious constrain to oil palm cultivation in sites 1 and 2. Soil total nitrogen placed sites 4 and 6 in suitability class S1 (highly suitable), site 3 in suitability class S3 (marginally suitable) and site 5 in suitability class S2 (moderately suitable) for oil palm cultivation. The result of aggregate suitability rating under current evaluation showed that all pedons are currently not suitable for cocoa cultivation. In sites 1-5, soil texture and fertility (organic matter) were the major constrains while at site 6, drainage and available phosphorus were the major constraints for cocoa production. For oil palm cultivation, sites 1,2,5 and 6 are currently not suitable (N1fw), with soil fertility and drainage being the major constraints in these soils while sites 3 and 4 were marginally suitable (S3sf) with soil texture and fertility imposing major limitations to these soils. Generally, from the results, texture is the most severe soil physical characteristic limiting both cocoa and oil palm production in the study sites.

Keywords: Cocoa, oil Palm, Land evaluation, Land suitability, Soil fertility.

Introduction

The population of Nigeria depends on agriculture to provide food and support their livelihood (IITA, 1994). In order to make an adequate and strategic plan towards sustaining the food needs of the country's growing population, serious attention is required in the area of the country's productive potential for major crops that the agro ecology supports. A major problem of agricultural development in Nigeria is poor knowledge and appraisal of the suitability of parcels of land for agricultural production. In farming, risk is minimized by matching the requirements of land use to land qualities which is the role of land evaluation (Alves and Notcliff, 2000; Udoh *et al.*, 2011). Application of the Food and Agricultural Organization (FAO) framework for land evaluation (FAO, 1976), can identify the most limiting land qualities and provide a good basis for advising farmers on appropriate management practice for optimum production in a particular agro-ecological zone.

Oil palm and cocoa serve as major commodities of international trade and support the economy of the producing countries and also provide gainful employment for many people. Ajiboye *et al*. (2015) stated that oil palm, rubber, cocoa and coffee are the major economic tree crops that had contributed immensely to the external earnings of the country in the past. Recently, the government of Imo, Abia and Akwa Ibom states in Southern part of the country in collaboration with the Federal government of Nigeria have embarked on large-scale production of oil palm and cocoa. In order to achieve success in large scale cultivation of these crops by the government and individual, more lands have to be brought under cultivation. However, there is a dearth of information in the study area on the extents to which the land qualities of soils of Southeastern Nigeria can satisfy the agronomic requirements of oil palm and cocoa. In light of this, the study was carried out to evaluate the suitability and limitations of these soils for the optimum and sustainable productivity of cocoa and oil palm. This is with a view to bringing these lands under intensive and commercial production of these crops for the agro-industrial development of the eastern region.

Materials and Methods

Description of the Study Sites

The study was conducted in the major oil and cocoa producing states in eastern part of Nigeria namely; Imo (Nwangele, Okpala, Okigwe), Akwa-Ibom (Nto- Ndang), Abia (Bende) and Cross river (Ikom) States of Nigeria. These states lie between latitudes 4^0 40^1 and 8^0 50^1 North; and longitudes 6^0 40^1 and 8^0 15^1 East. Soils of the study sites are derived from Coastal plain sand (Nwangele and Okpala), Sandstones (Okigwe and Nto-Ndang),

Basalt (Ikom) and Shale (Bende) (Orajaka, 1975). These areas belong to the humid tropics with total mean annual rainfall ranging from 1500-3000 mm and total mean annual temperature ranging from 21-35^{0}C. The relative humidity of the area is high (above 75 %) throughout the year, especially during the rainy season. (NIMET, 2014; National Root Crop Research Institute (NRCRI) Umudike Meteorological Unit, 2014).

Field Work

Six cocoa and oil palm producing areas (Ikom, Nwangele, Okpala, Okigwe, Nto-Ndang, Bende) were randomly selected for the study. One profile pit was dug at each location. A total of six (6) profile pits were used for the study. These profile pits were described according to FAO, (2006) guidelines and samples were collected according to horizons. Four (4) representative soil samples were collected from each of the various identified genetic horizons of the profiles for laboratory analyses.

Soil Analysis

Bulked soil samples collected were air-dried, gently crushed and passed through 2 mm sieve to obtain fine earth separates. The processed soil samples were analyzed for some physico-chemical properties following procedures outlined by Van Reeuwijk (2002). Particle size analysis was determined by hydrometer method, soil pH in 1:2.5 water suspension was measured with pH meter and organic carbon by Nelson and Sommer method. The available P was determined according to Bray No. 11 method, total N1 was determined by micro-Kjeldahl digestion method. Exchangeable bases were extracted using neutral ammonium acetate (NH4OAc of pH 7). Calcium and magnesium were determined by ethylene diamine tetra-acetic acid (EDTA) titration while sodium and potassium were determined using flame photometer. Exchangeable sodium percentage (ESP), aluminum saturation, effective cation exchange capacity (ECEC) and Base saturation were calculated.

Land Evaluation and Data Analysis

Means of the data generated from soil laboratory analyses were calculated. The land suitability evaluation was carried out using the conventional method of land evaluation as described by FAO (1976) modified by Sys, (1985; 1991). Key environmental factors considered in the evaluation were climate (annual rainfall relative humidity and temperature), topography (slope) and soils. The criteria employed for the evaluation of soils were soil depth, soil texture, drainage, pH, available P, organic carbon, total Nitrogen, exchangeable cations, effective cation exchange capacity, soil toxicity and base saturation. The identified soil units were placed in suitability classes by matching their characteristics with requirements of the test crops. The most limiting characteristics dictated overall suitability for each soil. The suitability of each factor for respective soil unit was classified as highly suitable (S1), moderately suitable (S2), marginally suitable (S3) and currently not suitable (N1).

Results and Discussion

Land Qualities / Characteristics of the Soils

The land characteristics are presented in Table 1. The texture of the soils ranged from sandy loam, loamy sand to clay. The clayey texture at site 6 (Bende) is characteristic of soils derived from shale parent material and that probably gives its characteristically poor drainage and high organic matter. According to Wayne *et al*. (2007), soil texture influences numerous soil properties such as drainage, water holding capacity, aeration, organic matter, soil erodibility, cation exchange capacity and soil tilth. The mean pH of the soils ranged from 4.28 – 5.6. The pH values of the soils were very strongly to moderately acidic according to Foth and Ellis (1997). Strongly acid soils may have resulted due to leaching from high rainfall, organic acid formation and mainly from the oxidation of sulfidic material (Tabi *et al.*, 2012). The organic matter contents ranged from 5.75 – 33.00 g kg^{-1}. However, sites 1, 2, and 3 have organic matter values less than the critical value of 10 g kg^{-1} reported by Esu, (1991). The low organic matter in these soils is a reflection of less recycling of organic matter as well as loss of oxidized organic matter from the soil. High organic matter (33 g kg^{-1}) in pedon 6 is an indication of poorly natural drainage which may slow the rate of decomposition. The total nitrogen content of the soils was low compared to the critical value of 2 g kg^{-1} recommended by FPDD, (1990). However, pedon 6 contained higher total nitrogen compared to other sites and this value corresponds to organic matter content of the soil. The relationship between organic matter and total nitrogen has been established (Adeyanju, 2005).

Table 1: Land/Soil Characteristics of the Sites

Land characteristics	Ikom Pedon 1	Nwangele Pedon 2	Okpala Pedon 3	Okigwe Pedon 4	Nto-Ndang Pedon 5	Bende Pedon 6
Climate (c)						
Annual rainfall (mm)	1700-3000	1700-3000	1700-3000	1700-3000	1700-3000	1700-3000
Relative humidity (%)	70 – 85	70 – 85	70 - 85	70 – 85	70 – 85	70 – 85
Temperature (^oC)	26-35	26-35	26-35	26-35	26-35	26-35
Topography (t)						
Slope (%)	< 3	<3	<2	3.5	<3	<3
Wetness (w)						
Drainage	Well drained	Well drained	Well drained	Well drained	Well drained	Poorly drained
Soil physical characteristic (S)						
Sand (g kg^{-1})	631	794	761	764	851	89
Silt (g kg^{-1})	235	18	37	168	88	181
Clay (g kg^{-1})	134	188	202	72	61	730
Texture	SL	SL	SL	LS	LS	C
Soil depth (cm)	150	200	200	180	120	150
Soil fertility (f)						
ECEC ($cmol_+kg^{-1}$)	3.69	6.00	5.60	5.00	1.48	5.43
BS (%)	89.50	87	82	79	44	69
Organic matter (g kg^{-1})	5.75	7.96	13.52	15.80	3.55	33.00
pH	4.62	5.60	5.51	4.91	4.28	4.89
Total nitrogen (g kg^{-1})	0.24	0.40	0.73	2.42	0.14	1.58
Av. Phosphorus (mg kg^{-1})	5.69	5.13	8.97	16.28	13.20	2.18
Calcium ($cmol_+kg^{-1}$)	1.79	2.95	2.19	2.40	0.41	2.36
Mg ($cmol_+kg^{-1}$)	1.20	2.14	2.26	1.52	0.51	1.20
Potassium ($cmol_+kg^{-1}$)	0.11	0.10	0.10	0.02	0.04	0.15
Toxicity (x)						
ESP (%)	13.03	0.77	0.88	4.13	14.40	0.97
Al. Sat (%)	4.62	5.42	7.08	7.21	36.60	18.85

Source: Field survey (2017). SL = Sandy loam, LS = Loamy sand, C = Clay, ESP = Exchangeable sodium percentage

With exception of site 4, available phosphorus was generally low compared to the critical level of 15 mg kg^{-1} (Enwezor *et al.*, 1990) (Table 1). Phosphorus is the second most important nutrient limiting crop yield and it has been reported to be deficient in most Nigerian soils due to high P fixation capacity of these soils (Idigbor *et al.*, 2008). The proportions of exchangeable calcium (Ca^{+2}) and magnesium ($Mg^{+2)}$ were rated low to moderate in all the pedons. However, Adeoye and Agboola, (1984) reported critical levels of 2.00 and 1.2 $cmol+kg^{-1}$ respectively, for calcium and magnesium in soils of Nigeria while Landon (1991) reported the critical level of 0.5 $cmol+kg^{-1}$ of magnesium for tropical soils, a concentration less than these values would require an application of calcium and magnesium fertilizer accordingly. Exchangeable sodium percent (ESP) which identifies the degree to which the exchange complex is saturated with sodium (Na) was low ranging from 0.77 - 14.40 % in all the pedons. Low ESP observed in this study indicated that none of the soils was sodic and could be a consequence of low sodium content, rainfall pattern and the acidic condition of the soils. Aluminum saturation range from 6 - 36 % across the sites. In view of the low aluminum saturation (< 60 %) in the soils, there is little risk of aluminum concentration attaining toxic level.. Al+++ (aluminum) toxicity is recognized as one of the dominant chemical constraints affecting cocoa and oil palm growth in acid soils (Udo *et al.*, 2011). Balaji *et al.* (2003) stated that among phyto-toxic species, Al+++ is the most potent and inhibits root growth and uptake of nutrients, which ultimately reduce crop yield.

Suitability of sites for cocoa production

The land and soil requirements for cocoa production are presented in Table 2. All the sites evaluated were highly suitable (S1) for cocoa production when the slope and climatic (average annual rainfall, temperature and relative humidity) requirements for cocoa (Table 2) were matched with the land qualities of the study area (Table 1). This result indicates that the study sites are currently optimum or nearly so, in terms of climate and topography for the cultivation of cocoa. For soil wetness (drainage), the result showed that all soils were highly suitable with exception of Bende soils (pedon 6) that is currently not suitable for the cultivation of cocoa (Table 3). Soil depth was moderately suitable at Ikom, Nto- Ndang and Bende (pedons 1, 5 and 6), but highly suitable at Nwangele, Okpala and Okigwe (pedons 2, 3, and 4) respectively, for the cultivation of cocoa. Soil

texture is currently not suitable in pedons 1-5, but marginally suitable in pedon 6 for cocoa cultivation when the crop requirement was matched with the texture characteristic of the soils. Udoh *et al*., (2011) reported that the optimum soil texture most favourable for the cultivation of cocoa is clay loam or loam. For soil fertility characteristics, the major limitation for cocoa production in sites 1-5 was the organic matter which made the sites to be placed in suitability class N1, indicating that the sites are currently not suitable for cocoa production. However, exchangeable calcium and magnesium made all the sites marginally suitable (S3) for cocoa production with exception of pedon 5 while exchangeable potassium was the major limitation at sites 4 and 5 respectively for the cultivation of cocoa. Aluminum toxicity was not encountered in all the sites, thereby placing the sites in class S1, that is, highly suitable for cocoa cultivation.

Table 2: Land Requirements for Cocoa

Land Qualities /characteristics	Factor suitability rating Highly suitable (S1)	Moderately suitable (S2)	Marginally suitable (S3)	Currently not suitable (N1)
Climate (c)				
Annual rainfall (mm)	1500-2500	1200-1500	1000-1200	700-1000
Relative humidity (%)	>75	60-75	< 60	< 50
Temperature (^oC)	29-32	21-29	18-21	<18
Soil physical characteristics (s)				
Soil depth (cm)	>150	100-150	80-100	< 80
Soil texture	Loam	Clay Loam	Clay	Any
Topography (t)				
Slope (%)	< 4	4-8	8-20	>20
Wetness (W)				
Drainage	1-2	1-2	1-2	3-5
Soil Fertility Status (f)				
pH	6.0-7.5	6.0 - 5.0	<5.0	Any
Total N1 (g kg^{-1})	1.5 – 2.0	1.0-1.5	0.5-1.0	< 0.5
Av. P (mg kg^{-1})	>15	5-15	<5	Any
Organic matter(g kg^{-1})	>35	25-35	<25	Any
Ex. K ($cmol_+kg^{-1}$)	>0.31	0.11-0.31	<0.11	Any
Ex. Ca ($cmol_+kg^{-1}$)	6-12	3-6	<3	Any
Ex. Mg($cmol_+kg^{-1}$)	6-12	3-6	<3	Any
Toxicity (x)				
Al. sat (%)	0-10	10-25	>25	Any

Source: Akwa-Ibom State ministry of Agric. Publication (2003); Udoh *et al* (2011).
Drainage: 1 = Well drained, 2 = Moderately drained, 3 = Imperfectly drained, 4 = poorly drained, 5 = very poorly drained

Table 3 : Suitability Assessment of the Sites for Cocoa cultivation

Land characteristics	Ikom Pedon 1	Nwangele Pedon 2	Okpala Pedon 3	Okigwe Pedon 4	Nto- Ndang Pedon 5	Bende Pedon 6
Climate (c)						
An. Rainfall (mm)	S1	S1	S1	S1	S1	S1
Rel. humidity (%)	S1	S1	S1	S1	S1	S1
Temperature (^oC)	S1	S1	S1	S1	S1	S1
Topography (t)						
Slope (%)	S1	S1	S1	S1	S1	S1
Wetness (w)						
Drainage	S1	S1	S1	S1	S1	N1
Soil physical characteristic (S)						
Texture	N1	N1	N1	N1	N1	S3
Soil depth (cm)	S2	S1	S1	S1	S2	S2
Soil fertility (f)						
pH	S3	S2	S2	S3	S3	S3
Organic matter (g kg^{-1})	N1	N1	N1	N1	N1	S2

Av. P	S2	S2	S2	S1	S2	N1
Ex. K ($cmol_+kg^{-1}$)	S2	S2	S2	N1	N1	S2
Ex. Ca ($cmol_+kg^{-1}$)	S3	S3	S3	S3	S3	S3
Ex. Mg ($cmol_+kg^{-1}$)	S3	S3	S3	S3	N1	S3
Toxicity (x)						
Al. sat (%)	S1	S1	S1	S1	S1	S1
Aggregate suitability						
Current suitability	N1(sf)	N1(sf)	N1(sf)	N1(sf)	N1(sf)	N1(wf)
Potential suitability	S3(f)	S3(f)	S3(f)	S3(f)	S3(f)	S3(sf)

Suitability of sites for oil palm production

All the sites evaluated were highly suitable (S1) for oil palm production when the slope, base saturation and climatic requirements for oil palm (Table 4) were matched with the land quality of the study area (Table 1). For soil wetness (drainage), the result showed that all soils were highly suitable with exception of Bende soils (pedon 6) that is currently not suitable for the cultivation of oil palm. Soil depth was optimum for oil palm production in all the sites. Resultantly, soil depth does not pose a limitation to oil palm production in the area. For soil texture, sites 1-5 were marginally suitable (S3) while site 6 is currently not suitable (N1) for oil palm cultivation when the crop requirement was matched with the texture characteristic of the soils. Sys, (1985) reported that the optimum soil texture most favourable for oil palm cultivation is loam. For soil fertility characteristics, total nitrogen was a serious constrain to oil palm cultivation at Ikom and Nwangele as values were low when compared to the requirements of oil palm (FAO, 1983). Also, soil total nitrogen placed Okigwe and Bende soils in suitability class 1 (S1), Okpala soils in suitability class S3 (marginally suitable) and Nto- Ndang soils in suitability class S2 (moderately suitable) for oil palm cultivation. Pedons 3, 4 and 6 were highly suitable, pedons 1 and 2 moderately suitable while pedon 5 marginally suitable when the organic matter requirement for oil palm (Table 4) was matched with the land qualities of the sites (Table 1). Soil reaction was rated moderately suitable (S2) in pedons 2 and 3, and marginally suitable (S3) in pedons 1, 4, 5 and 6 respectively. The pH values of 4.62, 4.91, 4.28 and 4.89 recorded in pedons 1, 4, 5 and 6 may pose a problem for uptake of most plant macronutrients especially phosphorus. However, according to Halving *et al*., (2005), pH value less than 6.0 may limit the availability of essential macronutrient elements. Also, Ajiboye *et al*. (2011) reported that a pH value above 6.0 may limit the availability of micronutrients such as Fe, Zn, Mn and Cu. In view of this, soil reaction observed in this study may encourage the availability of these trace elements to crop.

Table 4: Land Requirements for Oil Palm

	Factor suitability rating			
Land Qualities /characteristics	**Highly suitable (S1)**	**Moderately suitable (S2)**	**Marginally suitable (S3)**	**Currently not suitable (N1)**
Climate (c)				
Annual rainfall (mm)	1700-2500	1450-1700	1300-1450	1300-1250
Relativehumidity (%)	>75	65-75	62-65	60-62
Temperature (^oC)	>22	20-22	18-20	<16
Soil physical characteristics (s)				
Soil depth (cm)	>125	75-125	50-75	< 50
Soil texture	CL,L	SCL	LS, SL	Any
Topography (t)				
Slope (%)	< 8	8-16	16-30	>30
Wetness (W)				
Drainage	Well drained	Moderately drained	poorly drained	Poorly drained
Soil Fertility Status (f)				
pH	6.0-7.0	5.0 - 6.0	4.0-5.0	< 4.0
Total N1 ($g\ kg^{-1}$)	>1.5	1.0-1.5	0.5-1.0	< 0.5
CEC ($cmo1_+kg^{-1}$)	>16	<10	<10	< 5
Organic matter($g\ kg^{-1}$)	>8.0	5.0-8.0	3.0 - 5.0	< 3
Base saturation (%)	>35	20-35	10-20	< 10

Source: FAO (1976) modified by Sys, (1985)

CL = Clay loam, SL = Sandy loam, LS = Loamy sand, SCL = Sandy clay loam.

Table 5 : Suitability Assessment of the Sites for Oil Palm cultivation

Land characteristics/qualities	Ikom Pedon 1	Nwangele Pedon 2	Okpala Pedon 3	Okigwe Pedon 4	Nto-Ndang Pedon 5	Bende Pedon 6
Climate (c)						
Annual rainfall (mm)	S1	S1	S1	S1	S1	S1
Mean Relative. humidity (%)	S1	S1	S1	S1	S1	S1
Average Annual Temp. (^oC)	S1	S1	S1	S1	S1	S1
Topography (t)						
Slope (%)	S1	S1	S1	S1	S1	S1
Wetness (w)						
Drainage	S1	S1	S1	S1	S1	N1
Soil physical characteristic (S)						
Texture	S3	S3	S3	S3	S3	N1
Soil depth (cm)	S1	S1	S1	S1	S1	S1
Soil fertility (f)						
ECEC ($cmol_+kg^{-1}$)	N1	S2	S2	S2	N1	S2
Base Saturation (%)	S1	S1	S1	S1	S1	S1
Organic matter ($g\ kg^{-1}$)	S2	S2	S1	S1	S3	S1
pH	S3	S2	S2	S3	S3	S3
Total nitrogen ($g\ kg^{-1}$)	N1	N1	S3	S1	S2	S1
Aggregate suitability rating						
Current suitability	N1(f)	N1(f)	S3(fs)	S3(fs)	N1(f)	N1(s)
Potential suitability	S3(sf)	S3(s)	S3(sf)	S3(sf)	S3(sf)	S3(f)

Aggregate suitability rating

The result of aggregate suitability rating under current evaluation showed that all pedons are currently not suitable for cocoa cultivation (Table 3). In pedons 1-5, soil texture and fertility (organic matter) were the major constraints while in pedon 6, soil drainage and available phosphorus were the major constraints for cocoa cultivation. On the other hand, the result of potential aggregate suitability showed that all the pedons were marginally suitable for cocoa production with soil fertility imposing the major limitation on these soils. For oil palm cultivation, the result of aggregate suitability under current evaluation showed that pedons 1,2,5 and 6 are currently not suitable, with soil fertility and drainage being the major constraints (Table 5). Pedons 3 and 4 were marginally suitable (S3sf) with soil texture and fertility imposing major limitations to these soils. For potential aggregate suitability evaluation, the result showed that all the sites were marginally suitable for oil palm production due to soil fertility and soil texture limitations. However, these soils can be made moderately suitable by applying appropriate fertilizer technology to correct the soil fertility deficiency. Olaleye (1998) reported that poorly textured soils well supplied with fertilizer (nutrient) produced superior crop yield. The negative influence of texture could be overcome by proper fertilizer application provided soil moisture is adequate (Babalola, 2011).

Conclusions

Generally, from the results, soil texture was the most severe soil physical characteristic limiting both cocoa and oil palm production in the sites investigated. However, since the texture of the soil is considered to be an inherent property and changing it is not a viable option for soil management, other management practices such as conservational tillage and manure application that enhance the physical and fertility conditions of the soils should be adopted.

References

Adeoye, G.O., and Agboola, A.A. (1984). Critical Levels for Soil pH, Available P, K, Zn and Mn and Maize Ear – Leaf Content of P, Cu and Mn in Sedimentary Soils of Southwestern Nigeria. Fertilizer Research, 6,65 – 75

Adeyanju, A. (2005). Evaluation of the potential of some soils around university of Ado-ekiti state for arable crop production. Unpublished project report. Department of Crop, Soil and Environment. 117 pp

Ajiboye, G.A., Alabi, K.O., Aiboni, V.U., Okeleye, K.A and Adesodun, J.K. (2011). Classification and suitability evaluation of the soils of a toposequence at Odeda Ogun State for the production of rice. Nigerian Journal of Soil Science 21(2): 142-155.

Ajiboye, G.A., Jaiyeoba, J.O., Olaniyan, J.O. and Olaiya, A.O. (2015). Characteristics and suitability evaluation of the soils of some major cocoa growing areas of Nigeria: Etung LGA of Cross river . Agrosearch, 15 (1), 101-116.

Akwa-Ibom State ministry of Agriculture Publication (2003). Annual Crop Production Report.

Alves, H.M.R and Nortcliff (2000). Assessing potential production of maize using

simulation models for land evaluation in Brazil. Soil Use and Management. 16: 49-55.

Babalola, T.S., Oso, T., Fasina, A.S and Godonu, K. (2011). Land evaluation studies of two wetland soils in Nigeria. International Research Journal of Agricultural and Soil Science 1(6) 193-204.

Balaji M. Krishna-Reddy, B. Jogeswar, G. Reddy, L. A. and Kavi-Kishor, P.B. (2003). Alleviating effect of citrate on aluminum toxicity of rice seedlings. Department of Genetics. Osmania University. Hyderabad 500007. India Current Science. 85: 3(10).

Enwezor, W.O., Ohiri, A.C., Opuwahribo, E.E., Udo, E.J. (1990). Literature review on soil fertility investigations in Nigeria. Federal Ministry of Agriculture and Natural Resources, Lagos. P 281.

Esu, I.E. (1991). Detailed soil survey of NIHORT farm at Bunkure, Kano State, Nigeria. Institute for Agricultural Research, Ahmadu Bello University, Zaria.

FAO (Food and Agricultural Organization) (1976) - A framework for land evaluation. Soils Bulletin 32. FAO, Rome. Soils Resources Development and Conservation Service Land and water Development Division Food and Agriculture Organization of the United Nations Rome, Italy 89.

FAO, (1983). Guidelines: Land evaluation for rain-fed Agriculture. Soil Resources Management and Conservation Services, Land and water Development Division Rome. Food and Agriculture Organization Soil Bulletin, 52 pp 237.

FAO (2006). Guideline for soil description. FAO Production year book, Vol.60, Rome, Italy. Pp 109

Foth, H. D. and Ellis, B.G., (1997). Soil Fertility. CRC Press, Inc., Boca Raton FL.

FPDD (Fertilizer Procurement and Distribution Division, Federal Ministry of Agriculture and Natural Resources). (1990). Literature Review on Soil Fertility Investigations in Nigeria. Lagos. Pp 130

Halving, J.I., James, D.B., Samuel, L., Tisdale and Werner, L.N. (2005). Soil fertility and fertilizer. An introduction to nutrient management. 7th Edition. Prentice, New Jersey Delhi. Pp 515

Idigbor, C.M., Asawalam D.O., and Agbede O.O., (2008). Phosphorus forms and Psorption Capacity of Fauna Modified Soils of South-Eastern Nigeria. Journal of Agricultural Production and Technology. 4 (2): 195-210.

IITA (1994). Annual Report 1993/94.International Institute of Tropical Agriculture, Ibadan Nigeria.

Landon, J.R. (1991) Booker Tropical Soil Manual. A hand book for soil Survey and Agricultural Land evaluation in the tropics and sub-tropics. Longman Inc. New York.

NIMET (Nigerian Meteorological Agency), Nigeria,(2014). Climate Weather and Water Information, for sustainable development and safety. Annual Climatic Data.

NRCRI (National Root Crop Research Institute) Umudike Meterological unit (2014) . Abia State Climate Data from 2012-2014.

Olaleye A.O. (1998). Characterization, Evaluation, Nutrient Dynamics and Rice Yields of Selected Wetland Soils in Nigeria. Ph.D Thesis in the Department of Agronomy, University of Ibadan. Pp.202

Orajaka, S.O. (1975). Geology. In: Ofomata, G.E.K. (ed.). Nigeria in Maps: Eastern States Ethiope Publishing House, Benin City. Pp. 5-7.

Tabi F.O, Omoko M, Boukong A, Mvondo Z.A.D., Bitondo D and Fuh C. C. (2012).
Evaluation of lowland rice (Oryza sativa) production system and management recommendations for Logone and Chari flood plain – Republic of Cameroon. Agricultural Science Research Journals Vol. 2(5); pp. 261-273.

Udoh, B.T., Henry, H.B., Akpan U.S., (2011). Suitability evaluation of alluvial soils for rice and cocoa cultivation in an acid sand area of southeastern Nigeria. Journal of innovative research in engineering and science. 1(1) pp. 148-161.

Sys, C. (1985). Land evaluation part 1-111 247p publication No7 of the General Administration of Cooperative Development. Place de champs de mars 5, Biote 57, 1050 Bruxelles.

Sys, C. (1991). Land evaluation and crop production. Agricultural publication. No.7. General Admin for Development Corporation, Brosels: 247.

Van Reeuwijk, L.P (2002). Procedure for Soil Analysis. International Soil Reference and Information Center (ISRIC) / (Food and Agricultural Organization): Wageningen. Pp 120.

Wayne, B, Quirine, K., Steve, A. Steve, P, Jonathan Rusell-Anelli, Renuka Rao and Steve D. (2007). Soil texture. Nutrient management spear program. Fact sheet 29. http://nmsp. css. cornell. edu