Direct RESEARCH JOURNALS

Vol. 5 (1), pp. 13-20, January 2017
ISSN 2354-4147
International Standard Journal Number (ISJN) e-ISJN: A4372-2604
Article Number: DRJA112590487

Direct Research Journal of Agriculture and Food Science
http://directresearchpublisher.org/aboutjournal/drjafs

ISJN

Research Paper

Evaluation of Fertility Status of Proposed Site for St. Gabriel Coconut Plantation and Refinery, Akwa Ibom State, Nigeria

***[1]Imogie A., [1]Odewale J.O., [1]Eziashi E.I. and [2]Ndon B. A.**

[1]Nigerian Institute for Oil Palm Research (NIFOR), P.M.B. 1030 Benin City, Edo Edo State,Nigeria.
[2]Department of Crop Science , P.M.B. 1017, University of Uyo, Akwa Ibom State,Nigeria.
*Corresponding author E-mail: imogie@yahoo.com.

Received 4 October 2016; Accepted 28 November, 2016

Information on the fertility status of the soils on which coconuts are grown and possible fertilizer recommendation is not common. Since coconut yield is generally related to the fertility status of the soil, a study was conducted to evaluate the fertility status of proposed sites for establishment of coconut plantation by the Akwa Ibom State Government. The soils were sampled at four depths 0 – 15 cm, 15 – 30 cm, 30 – 60 cm and 60 – 120 cm. The soil samples collected were subjected to physical and chemical analysis using standard analytical procedures. The soil physical properties do not constitute any major limitation to good coconut growth and yield. The soils at St Gabriel Coconut plantation texture was dominated by the sand fraction which accounted for an average 889 to 914 gkg^{1}. The sandy nature of the soils makes the soils very susceptible to water erosion, low cation exchange capacity (CEC) and low buffering capacity resulting in low fertility status, multiple nutrient deficiency and nutrient imbalance. The water table was high which was responsible for poorly drainage of the area leading to waterlogging of some location within the plantation site. The soil pH both in water and potassium chloride revealed that the soil acidity ranged from slightly acidic to strongly acidic which highly favour coconut palms cultivation. The exchangeable cations capacities were relatively very low. The values all fall below the critical limits for fertile soils, which may adversely affects optimum growth and development of the coconut palms.The values of soil fertility parameters were predominately low, indicating decline of soil physical and chemical properties due to soil degradation. The evaluation showed that the soils suffer from multi-nutrient deficiency. Nutrient levels of the soils are low to very low, and will not support good coconut growth and yield. Liming to improve the exchangeable basic cations and *p*H of the soils is recommended. Use of rock phosphate is also recommended for raising the levels of both phosphorus and some basic cations.

Key words: Coconut, Fertility, Physical and Chemical Properties

INTRODUCTION

Food security is the most important factors that determine the survival of mankind. Without food security a nation cannot expect better life for its people. As a developing country, agriculture has been the mainstay of Nigeria economy since its inception. The situation has not changed even now in spite of the revenue from the oil industry. However, food production in Nigeria cannot sustain the heavy population; hence there is massive importation of food items to the country. Efforts have been made by successive governments towards food self sufficiency in Nigeria. Even with all these efforts, Nigeria still has a long way to go to attain food self sufficiency. Prices of food items continue to increase and it is obvious that large proportion of the population cannot afford the price of the food of their choices, thus there is need today for our government both at the national, state and local government to invest on agriculture.

Soil quality in relation to food production is anchored on how the fertility of soils is being managed. Soil quality is defined as the capacity of a specific soil to function, within natural or managed ecosystem boundaries, to sustain plant and animal productivity, maintain or enhance water and air quality, and support human health and habitation (Brady and Weil, 1999). Soil fertility therefore, is the capacity of the soil to supply nutrients that enhance crop growth and ensure sustainable food production. However, soils are exposed to one form of disturbance or the other.

The associated problems culminate to soil degradation which depicts a loss in the quality or productivity of soils. Degradation is attributed to changes in soil nutrient status, loss of organic matter, deterioration of soil structure, and toxicity due to accumulations of naturally occurring or anthropogenic materials. Depending on their inherent characteristics and the climate, soils vary from highly resistant, or stable, to those that are vulnerable and extremely sensitive to degradation. The economic impact of soil degradation is extremely severe in densely populated regions, and sub-Sahara Africa. The ability of any soil to supply the required quantity of plant nutrients is mostly affected by the soil genetic composition (parent material), the degree to which the parent material has been altered by forces of weathering and the management of the soil by man. Soil fertility, especially plant nutrient availability is of paramount importance, if the agricultural land is to remain capable of sustaining crop production at an acceptable level.

This productive capacity of a soil depends often on complex and sometimes little understanding of the interactions between the biological, chemical and physical properties of the soil. However, intensification, increased agricultural productivity and improved rural livelihoods cannot occur without investment in soil fertility. In recent times, emphasis is on proper management of the soil resource base, restoration of degraded soils, and halting the decline trend in agricultural production.

This is predicated on the study of soil properties and characterization of soils and farming systems in a particular area. Good farm practice aims to manage the various factors that make up each of these three properties to optimize the yields of crop in environmentally friendly ways.The three importance steps in managing the nutrients required by plants to optimize the yields of crops are as follows: Soil and plant tissues sampling and analysis, interpretation of the analytical data and recommendations for nutrient additions, as fertilizers or manures to optimize crop yields, while minimizing any adverse environmental impact from their application. This study was carried out with the aim of providing information on the native nutrient status of the soils, determines the soils suitability for coconut palm production and provides management requires for optimum coconut production.

MATERIALS AND METHODS

Study location

The study was carried out in a 200 ha out of the proposed 11,000 ha for the coconut plantation by the Akwa Ibom State Government (Plate 1). Akwa Ibom State in the Niger Delta region is located in the Coastal Southern Nigeria, lies approximately between latitude 4° 32^1 and 5° 53^1 N and longitudes 7° 25^1 and 8° 25^1 E with a total land area of about 8,412 km^2. The state is bordered on the east by Cross River State and on the West by Rivers State. Generally, the state falls within the palm belt, hence the climatic conditions are optimum for palm cultivation. The Coconut plantation and refinery covering 11,000 ha of land is located between Ikot Abasi, Mkpat Enin and Eastern Obolo Local Government Areas of Akwa Ibom State.

Plate 1. The Proposed 11,000 ha for the Coconut Plantation by the Akwa Ibom State Government.

The area is on the coastal, south western part of Akwa Ibom State in the Niger Delta Area of Nigeria. It is generally flood plains consisting of leaves (crest and slopes) basins and basin swamps. The area is well dissected by streams, pods, lakes and network of creeks. The climate is humid tropical with high annual rainfall of ranges from 3000 to 4000 mm, mean temperature of about 27°C and the relative humidity above 80%. It has a bimodal rainfall pattern with peaks around July and September with almost no month without rainfall. The climate is marked by two distinct seasons. The dry season (November – March) and the wet season (April – October).

Field work

A total reconnaissance visit was made to the project site to familiarize with the peculiarities of the problems to be faced in terms of the extent, heterogeneity of terrain, density of vegetation, accessibility. Available relevant information (e.g geology, physiography and climate) on the project site were also collected during the visit. These were used as basis for formulating the appropriate sampling procedure or methods to be adopted. The site was divided into three locations that is plantation site, nursery site and refinery site while the plantation site was sub divided into three location that is lower, middle and upper for soil samples collection.

Soil samples collection and preparation for laboratory analysis

Soil samples were collected from five sites (three locations within the cleared 200 ha, for the coconut establishment and one location each from the proposed nursery site and the proposed factory site. In each location soil samples were collected from various depth. A total of sixteen composite soil samples were collected using stainless steel auger.

The breakdown is as follows from the cleared plantation site soil samples were collected at four depths namely 0 - 15, 15 - 30, 30 - 60 and 60 -120 cm, thus a total of 12 composite samples were collected while at the nursery and refinery sites samples were collected at two depth each 0 - 30 and 30 – 60 cm respectively. Auger points were located within each unit based on differences on such factors as landform, soil surface and degree of wetness etc. Composite samples were placed in clean, well labeled polythene bags and transported to Nigerian Institute for Oil Palm Research (NIFOR) for soil laboratory analysis.

Laboratory analysis

Laboratory analyses of soil samples were carried out using appropriate standard procedures. Particle size distribution was determined by hydrometer method according to the procedure of Gee and Or (2002). Soil pH was measured in 1:2.5 soil water and soil IN KCl suspension using the EEl pH meter with glass calomel electrodes.

Available phosphorus was determined by Bray P-1 extractant as described by Udo *et al.* (2009). Exchangeable acidity (H^+ and AL^{3+}) was extracted with IN KCl and titrated against 0.05m NaOH (Thomas, 1996). The exchangeable hydrogen was obtained by subtracting exchangeable aluminum from exchangeable acidity. The organic matter and organic carbon was determined by dichromate wet oxidation method as described by Nelson and Sommers (1996), and the value was multiplied by 1.732 to obtain organic matter content.

The soil available total nitrogen was determined by regular macro-Kjeldahi method. Exchangeable bases (K, Na, Ca and Mg) were extracted with neutral normal NH4OAc. Potassium and sodium in the extract were determined by flame photometry while Ca and Mg were read by atomic absorption spectrophotometer. Effective cation exchange capacity (ECEC) was obtained by summation of exchangeable bases and exchangeable acidity.

The electrical conductivity was measured in the extract obtained from 1: 2.5 soil and water suspension using a conductivity meter as described by AOAC (1999). Heavy metals /micronutrients (Cu, Fe, Mn, Zn and SO_4) were determined using total elementary analysis of perchloric and nitric acid digestion and read using atomic absorption spectrophotometer (AAS).

RESULTS AND DISCUSSIONS

A total of sixteen composite soil samples were collected, processed and analysed. Details of the soil physical and chemical properties as analysed are presented in (Tables 1, 2, 3 and 4).

Soil physical properties

The results of the soil physical properties of the soil samples are presented in (Table 1). Particle size analyses of the soils revealed the levels of sand (gkg^1) in the five areas ranges from 884 gkg^1 (88.4 %) to 914 gkg^1 (91.4 %) respectively. Levels of silt ranged from 57 gkg^1 (5.7 %.) to 82 gkg^1 (8.2 %) and clay ranged from 29 gkg^1 (2.9%) to 34 gkg^1 (3.4%). In general the results revealed that the soils texture fall within sandy soils or sandy loam.

The soil physicochemical properties pH

The results of the soil pH, organic carbon, matter, total nitrogen and available phosphorus are presented in (Table 2). Results of the chemical analyses shown that the values of the soil pH both in water and potassium chloride ranged from 4.5 to 5.5 in water and 4.0 to 5.0 in KCL. The soil pH is a physiochemical factor that determines the acidity or alkalinity of the soil. Based on the soil pH the coconut plantation site is strongly acidic except the nursery site which is slightly acidic with mean values of 5.4 to 5.5 respectively. There were no measurable variations in soil pH values with soil depth. The acidic nature of the sites is highly suitable for coconut palm cultivation because coconut palms thrive under acidic soils with soil ph as low as 3.5 to 6.0. It should be noted that the low soil pH of the locations may be influenced by salt water marsh (of the Atlantic Ocean) thus when air penetrates, the pyrites are oxidized to basic ferric sulphides and H_2SO_4 thus producing acid sulphates

Table 1.Soil particle size fraction of the coconut plantation.

Location	Depth (Cm)	Sand (gkg^1)	Silt (gkg^1)	Clay (gkg^1)	Texture
Base	0 -15	904	67	29	S
	15 – 30	894	77	29	S
	30 – 60	884	82	34	LS
	60 -120	894	77	29	LS
	Mean	894	75.8	30.2	
Middle	0 -15	914	57	29	S
	15 – 30	914	57	29	S
	30 – 60	914	57	29	S
	60 -120	914	57	29	S
	Mean	914	57	29	
Top	0 -15	907	67	29	LS
	15 – 30	904	67	29	LS
	30 – 60	904	67	29	LS
	60 -120	894	77	29	LS
	Mean	901.5	69.5	29	
Nursery Site	0 -30	894	77	29	LS
	30 -60	889	82	29	LS
	Mean	891.5	79.5	29	
Factory site	0 -30	889	82	29	LS
	30 -60	889	77	34	LS
	Mean	889	79.5	31.5	

soils (Okusami, 2003).

Organic matter

The organic matter contents at various depths were very low and less than 2% except at 0 – 15 cm. The value ranges from 0.73% to 2.7% (7.3 to 27 gkg^1) respectively. High organic matter content in the soils increases the binding processes in the soil. Such binding reduces water erosion and improves water retention ability of the soil (Radojevic and Baslkin, 1999). The major roles of organic matter in soils are adding nutrients and improving the soils structure and water holding capacity. Soils with low organic matter usually have poor structure, poor water retentions /water holding capacity and erode or leaching of nutrients easily as the results of the soil assessments indicated. The low organic matter of the project site may be attributed to the mechanical tillage that was carried out before the soil sampling because the organic matter content of the nursery site and the factory site were relatively high than the coconut plantation site. Good organic soil matter should not be less than 2%. The results shown that the organic matter at various locations decreases with depth respectively.

Total nitrogen

The total available nitrogen contents were very low and their mean values ranged from 0.2 to 1.5 gkg^1 (0.02 to 0.15%) which were far below the soil critical values (1.5 to 2.0g kg^1) recommended for optimum crop growth, development and yield for most soils in Nigeria (FAO, 2000). This low value may be attributed to the low organic matter content of the project site because total N availability is influenced by the amount of soil organic matter. While Edem and Ndon, (2001) stated that high organic matter is an indication that the soil may have adequate supply of nitrogen and other soil nutrients.

Available phosphorous

The available phosphorus values ranged from 1.21 to 15.35 mg kg^1. These values were generally low except at the base within the sub soils 30 -60 and 60 -120 horizon were the available phosphorous were relatively high and adequate. The available p increases with depths except at the proposed nursery site where the value decreases with depth. The p values were far less than the critical p

Table 2. Soil physiochemical properties of the coconut plantation.

Location	Depth (Cm)	pH (H_2O)	pH (KCL)	Organic Carbon (gkg^1)	Organic matter (gkg^1)	Nitrogen (gkg^1)	Avai. P ($mgkg^1$)
Base	0 -15	4.5	4.2	13.4	23.2	0.8	1.3
	15 – 30	5.0	4.5	7.0	12.1	0.5	5.8
	30 – 60	5.3	4.6	4.2	7.3	0.5	15.35
	60 – 120	5.0	4.5	1.9	3.3	0.4	13.46
	Mean	5.0	4.5	6.6	11.5	0.6	8.98
Middle	0 -15	5.3	4.9	13.4	23.2	0.9	3.42
	15 – 30	5.3	4.6	5.4	9.3	0.4	1.62
	30 – 60	5.2	4.5	4.2	7.3	0.2	1.73
	60 – 120	5.0	4.4	3.8	6.6	0.2	1.21
	Mean	5.2	4.6	6.7	11.6	0.4	1.99
Bottom	0 -15	4.8	4.0	17.6	13.4	1.5	1.76
	15 – 30	4.8	4.3	16.0	27.7	1.3	3.87
	30 – 60	5.6	4.6	10.9	18.8	0.6	3.22
	60 – 120	5.2	4.4	9.6	16.6	0.5	2.43
	Mean	5.1	4.3	13.5	23.4	1.0	2.82
Nursery	0 – 30	5.4	5.0	11.8	20.4	0.7	3.42
	30 – 60	5.5	4.4	8.8	15.2	0.6	1.63
	Mean	5.5	4.7	10.3	17.8	0.65	2.53
Factory	0 – 30	5.2	4.3	15.4	26.6	1.3	2.57
	30 – 60	5.3	5.0	8.6	14.9	0.6	3.32
	Mean	5.3	4.7	12.0	20.6	1.0	2.95

values of 20 mg kg^1 established as optimum for palm cultivation (Agboola and Corey, 1976).The low available p status may be attributed to the high content of siliceous parent materials and the acidic nature of the soils respectively.

The exchangeable cations and acidity base

Table 3 presented the results of the exchangeable cations and acidity bases of the locations. The basic cations Ca, Mg, K and Na were very low with their mean values ranges from 0.04 K to 1.12 Ca Cmol kg^1 respectively. The exchangeable cations and acidity base were also very low resulting in low exchangeable cations exchange capacity which has mean values ranging from 1.35 to 4.74 Cmol kg^1. The ECEC in the soils were the summation of the soil CEC and EA. The ECEC measures the soils ability to hold cations by electrical attraction. The low CEC and ECEC depicted the low contents of organic matter and clay mineral which are essential colloidal materials for cations exchange absorption in soils. The low ECEC and CEC may also be attributed to intense leaching, weathering and ferrolysis hence inherent fertility status (Macro and micro nutrients). The sandy nature of the soils coupled with heavy rainfall also promotes leaching and poor drainages. These findings are in agreement with Olaleye (1998).

In ferrolysis, excessive Fe_2O in the soil solution displace exchangeable cations from the exchange complex into the soil solution and these eventually replaced by AL^{3+} from the clay lattices after oxidation as seen in (Tables 3 and 4). However, this process depends on the volume of water passing through the soil which eventually leads to clay mineral and CEC destruction. The releases of large amount of Mn^{2+} and Fe^{2+} into the soil solution during soil submergence also displace the

Table 3. Soil exchangeable cations and acidity base (cmol kg1) of the coconut plantation.

Location	Depth (Cm)	Ec	Ca	Mg	Na	K	H+	AL3+	ECEC
Base	0 -15	10	0.3	0.04	0.58	0.06	0.40	ND	1.35
	15 – 30	10	0.8	0.36	0.55	0.05	1.40	ND	3.11
	30 – 60	5	0.68	0.20	0.56	0.06	1.80	ND	3.30
	60 – 120	5	1.04	0.28	0.55	0.06	3.00	ND	7.03
	Mean	7.5	0.71	0.22	0.56	0.06	1.65	-	3.70
Middle	0 -15	10	0.96	0.36	0.55	0.07	2.20	ND	4.14
	15 – 30	10	0.84	0.28	0.39	0.04	1.40	ND	2.95
	30 – 60	10	0.8	0.08	0.39	0.03	2.10	ND	3.40
	60 – 120	10	0.88	0.32	0.40	0.04	3.10	0.60	4.74
	Mean	10	0.87	0.26	0.43	0.04	2.20	0.60	3.80
Bottom	0 -15	30	0.84	0.44	0.40	0.04	3.00	ND	4.72
	15 – 30	30	0.96	0.32	0.41	0.04	2.90	0.70	3.33
	30 – 60	20	0.84	0.28	0.37	0.04	2.70	ND	4.23
	60 – 120	40	0.84	0.24	0.37	0.04	2.90	ND	4.39
	Mean	30	0.87	0.32	0.38	0.04	2.40	0.70	4.16
Nursery	0 – 30	30	0.52	0.08	0.39	0.04	2.80	ND	3.83
	30 – 60	30	1.2	0.24	0.38	0.04	2.10	ND	3.86
	Mean	30	0.86	0.16	0.39	0.04	2.40	-	3.85
Factory	0 – 30	20	0.92	0.20	0.55	0.06	2.30	ND	4.03
	30 – 60	30	1.12	0.48	0.56	0.06	2.40	ND	4.52
	Mean	25	1.02	0.34	0.55	0.06	2.35	-	4.28

ND: Not detected.

Table 4. Heavy metals or micronutrients (ppm) properties of the coconut plantation.

Location	Depth (Cm)	Fe	Cu	Zn	SO_4	Mn
Base	0 -15	50.11	2.6	1.05	0.66	0.19
	15 – 30	47.42	3.06	1.05	0.58	0.32
	30 – 60	33.32	0.54	1.05	0.08	0.32
	60 – 120	51.09	0.08	1.20	0.59	0.39
	Mean	45.48	1.57	1.08	0.47	0.31
Middle	0 -15	34.35	2.29	1.04	0.50	0.13
	15 – 30	19.65	1.76	1.05	0.59	0.45
	30 – 60	35.12	1.45	2.98	0.31	0.84
	60 – 120	25.63	2.29	2.40	0.54	1.04
	Mean	26.18	1.84	1.85	0.49	0.62
Bottom	0 -15	22.73	0.15	0.79	0.45	0.42
	15 – 30	19.30	0.15	0.89	0.87	0.78
	30 – 60	23.33	0.38	0.58	0.31	0.52
	60 – 120	20.33	0.99	1.94	0.42	0.62
	Mean	21.42	0.42	1.05	0.76	0.58

Table 4. Contd.

Nursery	0 – 30	16.40	0.31	0.84	0.25	0.32
	30 – 60	17.60	0.61	1.99	0.57	0.36
	Mean	17.0	0.46	1.42	0.41	0.34
Factory	0 – 30	62.63	0.23	2.56	0.58	0.16
	30 – 60	68.01	1.38	2.09	0.58	0.03
	Mean	65.32	0.81	2.33	0.58	0.10

exchangeable cations from the soil exchange complex.

Heavy metal or soil micronutrient properties of the project site

The results of the soil heavy metal of the five locations are presented in (Table 4). The values ranged from 0.31 ppm SO_4 to 68.01 ppm Fe. The present of heavy metal particularly Fe showed evidence that the project site may be prone to toxicity which may be attributed to exploitation of crude oil within the locality. This may become a problems later if the soils are not properly managed. The heavy metals are highly concentrated in the top horizon that is 0 – 60 and decreased gradually from 60 to 120 cm depth. The present of these heavy metals or micro nutrients in adequate form especially in the top horizon may be attributed to the fact that the soils were poorly drained, thus not only having free iron oxides compared to well drained profiles but the oxides were amorphous than in the crystalline. This happened when a soil is flooded, oxygen readily used up and reduced conditions are created, thus organic matter under this conditions will decomposed to CO_2, H_2, methane, ammonia, amine, H_2S, and partially humified residue. This will lead to loss of N_2 through denitrification or by volatilization of ammonia, which causes the reduction of ferric and manganese iv oxide compounds, thus increasing the content of soluble Fe^{2+} and Mn^{2+} as observed in (Table 4).

Conclusion

A key to enhancing and maintain intensified productive systems is proper management of soil fertility. The soils at St Gabriel Coconut plantation texture was dominated by the sand fraction which accounted for an average 889 to 914 gkg^1. The sandy nature of the soils makes the soils very susceptible to water erosion, low CEC and low buffering capacity resulting in low fertility status, multiple nutrient deficiency and nutrient imbalance. The exchangeable cations capacities were relatively very low. The values all fall below the critical limits for fertile soils, which may adversely affects optimum growth and development of the coconut palms. The values of soil fertility parameters were predominately low, indicating decline of soil physical and chemical properties due to soil degradation.

The results obtained from the soil assessment indicated that the soil pH and texture highly favour coconut cultivation, however due to poor drainage of the area and low soil fertility to raise the productivity of the soils for optimum growth, development and yield of coconut integrated nutrient management approach involving the use of organic and inorganic fertilizers, use of rock phosphates, intensive drainage and regular soil testing for balanced nutrient application is advocated.

Acknowledgements

The authors acknowledge the financial assistance given by the Akwa Ibom State Government. They also wish to express their gratitude to HJ Oil Nigeria Ltd (Engr. Johan Swart, Mr. Clyde Hepburn, Hennie du Plessis and Robin Husband) for their technical support offered during the study.

Authors' declaration

We declare that this study is an original research by our research team and we agree to publish it in the journal.

REFERENCES

Agboola, A.A. and Corey, R.B. (1976). Nutrient deficiency survey in Western Nigeria. Nigeria Agricultural Journal 2: 1-10

Association of Analytical Chemists (AOAC) (1999). Official Methods of Analysis of the Association of Analytical Chemists. 14th Ed. AOAC. Inc. Arlington, Virginia, USA.pp.53–55.

Brady NC, Weil RR (1999).The nature and properties of soils. 12th ed., Prentice -Hall, New Jersey, Pp. 178 – 189

Edem SO Ndon BA (2001). Evaluation of management properties of wetland soils of Akwa Ibom State, Nigeria, for sustainable crop production. Journal of Applied Chemistry Agriculture Research 7: 26 - 36.

FAO (2000). Fertilizer and their use. A pocket guide for Extension Officers, Fourth Edition, IFA, Rome p 70.

Gee GW Or D (2002). “Particle Size Analysis”. In: Methods of Soil Analysis,Dane, J. H. and G. C.Topp (Eds) ASA and SSSA., Madison, WI, USA. p.9-10.

Nelson DW, Sommers LE (1996). Total carbon, organic carbon and organic matter. In *Methods of Soil Analysis.* (A. L. Page, R. H. Miller and D. R. Keaney, eds). Am. Soc. of Agron.

Olaleye AO (1998). Characterization, evaluation, nutrient dynamics and rice yields on selected wetland soils in Nigeria. University of Ibadan, Ibadan Nigeria. Ph.D Thesis, pp.205.

Okusami TA (2003). A review of the soil –water requirements for optimum lowland rice production with references to Africa. In Ojanuga Okusami AG, Lekwa G TA,(Eds) Wetland soils of Nigeria: status of knowledge and potential monograph No. 2 second edition Soil Science Society of Nigeria. Pp. 143-156.

Place F, Barett CB, Freeman HA, Ramisch JJ, Vanlauwe B (2003). Prospects for Integrated Soil Fertility management using organic and inorganic inputs: Evidence from smallholder African agricultural systems’’, *Food policy*, 28:365-378

Thomas GW (1996). Exchangeable Cations, In: Methods of soil analysis- Part 2.Chemical and microbiological. 9(2):159-164.

Udo EJ, Ibia TO, Ogunwale JA, Ano AO, Esu IE (2009). Manual of soil, plant and water analysis. Sibon Books Limited, Lagos.

Radojevic M, Bashkin NV (1999). Practical environmental analysis. Royal Society of Chemistry and Thomas Graham House, Cambridge. Pp.180–430.