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Soil Assessment and Fertility Evaluation of Selected Sites for Commercial Arable Cropping in Rivers State, Southern Nigeria

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Abstract: *Soil assessment is important and required for sustainable agricultural development. The soils of Nigerian high rainfall zone have potentials for agricultural production. However, their productivity and management is limited by inadequate investigation of the properties of the soils. Therefore, a study was carried out to assess the quality of the soils of Bonny Island for agricultural production. Seven communities in Rivers State namely: Finima, Abalamabie, Ojokolo, Iyobama, George Pepple, Rumuji and Ubeta were assessed. Soil samples were collected from three depths: 0 - 15cm, 15 - 30cm and 30 - 60cm.The soils were analysed for chemical properties and particle size distribution. The soils are moderately acidic with pH range 5.10 – 5.45 in the top soils and 5.20 – 5.55 in the sub soils with low nutrient supplying capacity. The base saturation in the top soil and sub soils are very high. The organic carbon is > 15g/kg while total nitrogen is moderately high. The dominant textural class in the top and sub soils are sand and loamy sand respectively with sand content > 900g/kg which makes the soils vulnerable to leaching. Soil management to reduce the effects of excessive water such as underground drainage to improve soil aeration, liming and proper organic matter management should be carried out to improve soil conditions and agricultural production in the study areas.*

Keywords: Fertility Evaluation, Arable Cropping, Soil Assessment, Soil Properties

INTRODUCTION

Agricultural development requires very delicate care and management as crops production, unlike many other uses of the land is highly discriminatory of the soil type. Therefore, for a successful crop production on a given piece of land, detailed information on the kinds of soil, their distribution and properties is of utmost importance (Wahba *et al.,* 2007). The aforementioned problems constitute serious soil fertility constraints and impair sustainable agricultural development as the capacity of the soil to function and sustain plant and animal lives is highly impaired (Drzewiecki, 2008). According to Moges *et al.,* (2013), factors which undermine the quality and fertility of soils include loss of vegetative cover, top soil moisture, low infiltration capacity, low water storage and retention, low soil organic matter and poor natural regeneration capacity. The challenges to soil productivity are even more so in the wetland soils where hydromorphic features and deposition of materials from freshwaters and marine sources, can present some unique features such as high sand content and water table with problems of leaching and low effective cation exchange capacity. Consequently, such soils are underutilized due to low nutrient status and capacity for agricultural development. Wetland soils are often abandoned in Nigeria due to poor drainage and low nutrient retention (Akinbola *et al.,* 2012; Ogban and Obi, 2014).

The influence of optimum soil conditions on successful agricultural production or other ventures for which the soil serves as support, cannot be over emphasized. A good understanding of soil properties and capabilities is strategic for judicious land use and planning activities for agriculture, engineering and project feasibility in land development programmes. Therefore, this study was conducted to assess the properties and fertility status of the coastal plain and beach ridge soils of Rivers state. This is aimed at assisting farmers and other land users in arriving at informed decisions on the choice of crops and appropriate practices for sustainable land management.

Materials and Methods

Location and Agroclimate

The study was carried out in selected communities of Rivers State, Southern Nigeria namely: Finima, Abalamabie, Ojokolo, George Pepple, Inyoba-Ama, Rumuji and Ubeta. The area is located in the Niger Delta region of Southern Nigeria. The map of Rivers State and the sampling locations are shown in Fig.1. The geographic co-ordinates defining the specific sites of soil sampling are presented in Table 1. Rivers State forms part of the southern Nigeria coastal zone described as Zone R (very humid/perhumid Niger Delta) of the Agro-ecological zones of Nigeria (Ojanuga, 2006). The micro-climatology indicates that the area has a mean annual rainfall of 2369mm (Fig 2A) and a mean maximum Temperature of 31^{o}C (Fig 2B). The area enjoys tropical hot monsoon climate characterized by heavy rainfall from April to October distributed in a bimodal pattern with relatively constant high humidity (Fig. 2C).

Geology and Relief

Rivers State has a relief that is generally lowland with an average elevation ranging between 0m (sea level) and 60m above sea level. The geology of the area comprises basically of Coastal plain sands, alluvial basin.

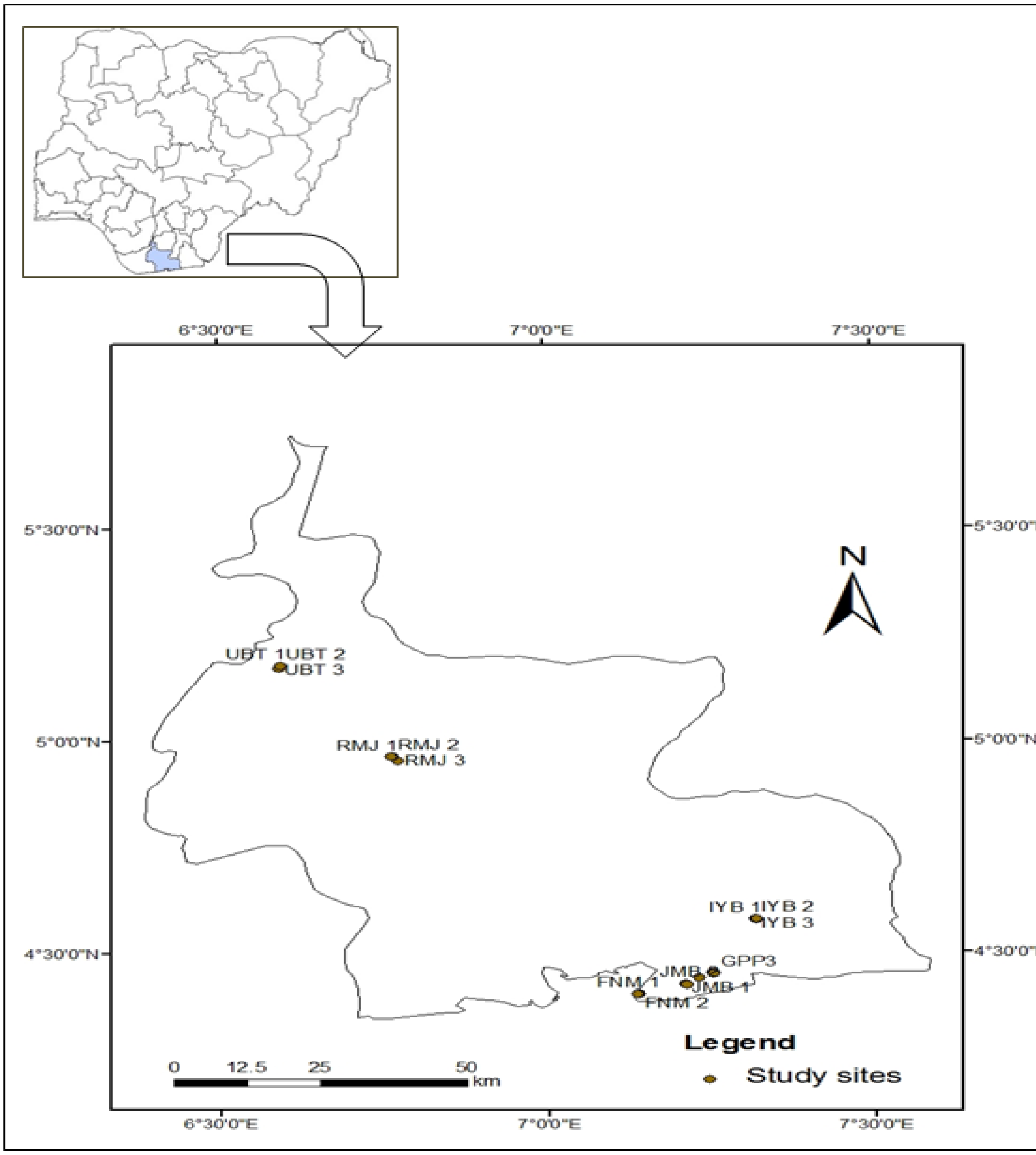
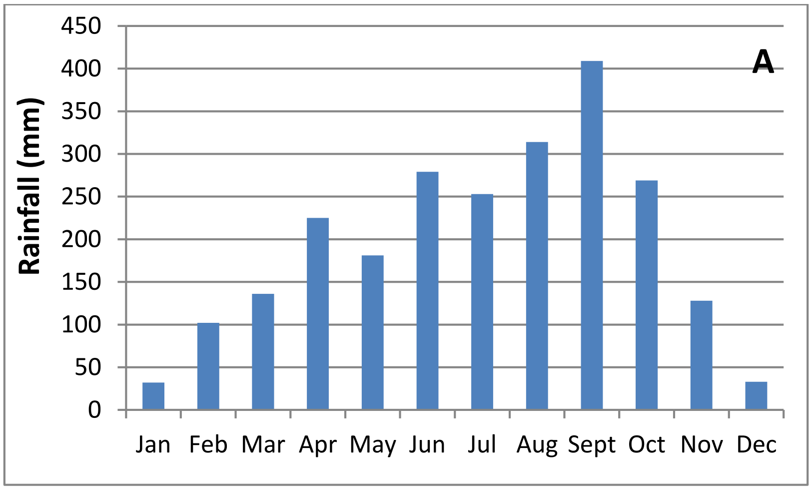


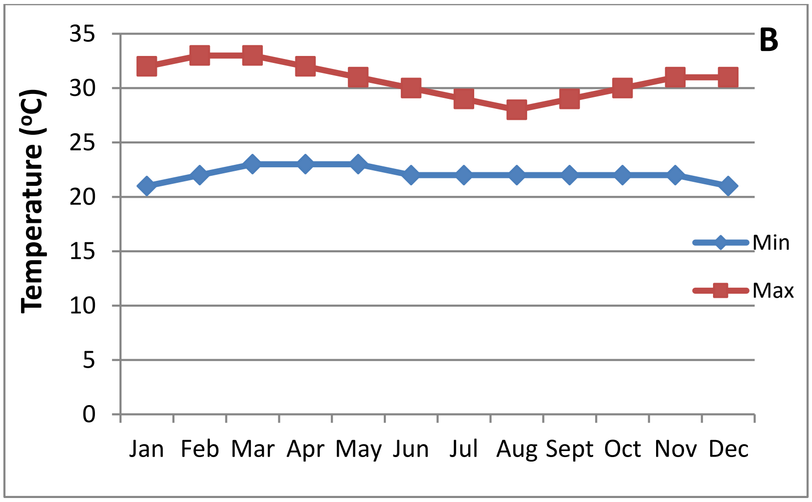
Figure 1: Map of Rivers State showing the study locations:
FNM = Finima, GPP = George Pepple, IYB = Iyobama, JMB = Jumbo Abalamabie, RMJ = Rumuji and UBT = Ubeta.

Table 1: Location of the study sites

Sampled Sites	Lat.	Long.	Eastings	Northings
	(Decimal degrees)		WGS 1984 (UTM)	
Inyoba-Ama 1	4.576	7.320	507256.4	979609.0
Inyoba-Ama 2	4.578	7.319	507431.1	979516.3
Inyoba-Ama 3	4.578	7.317	507486.8	979350.4
George Pepple 1	4.452	7.253	493420.3	972313.5
George Pepple 2	4.451	7.251	493360.2	972069.4

George Pepple 3	4.450	7.253	493253.9	972305.8
Otokolo 1	4.439	7.230	492056.6	969774.7
Otokolo 2	4.439	7.229	492010.7	969679.9
Jumbo Abalamabie 1	4.425	7.210	490435.8	967529.7
Jumbo Abalamabie 2	4.425	7.211	490437.3	967596.9
Long John Abalamabie	4.423	7.213	490193.6	967820.3
Finima 1	4.401	7.136	487693.0	959349.0
Finima 2	4.401	7.137	487686.7	959444.2
Ubeta 1	5.175	6.594	573196.0	898526.4
Ubeta 2	5.176	6.593	573279.4	898454.6
Ubeta 3	5.170	6.591	572564.3	898213.0
Rumuji 1	4.961	6.764	549527.4	917633.9
Rumuji 2	4.962	6.763	549687.1	917464.2
Rumuji 3	4.952	6.772	548526.6	918481.1





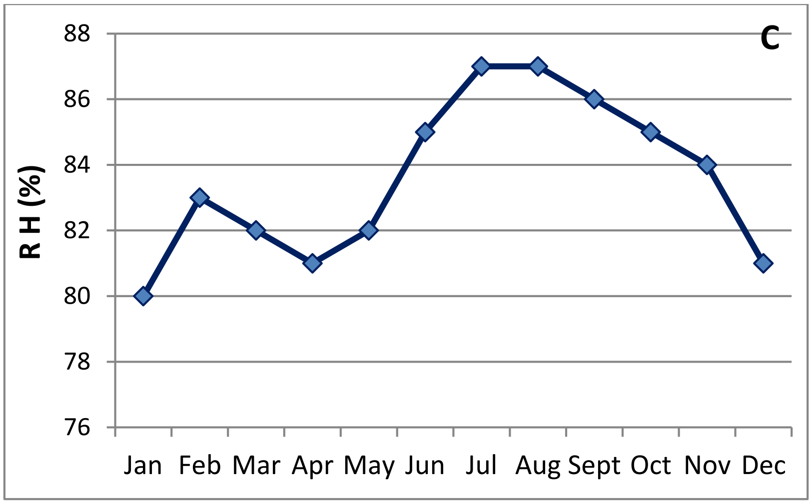


Figure 2: Pattern of agro climatic variables of Rivers State (2001-2010) A – rainfall, B – Temperature and C – Relative Humidity. Source: NIMET, Port Hacourt

The soils of the study sites were derived from these materials with beach ridges and a succession of sandy deposits forming the coast line. These give rise to well drained soils in the hinterlands or poorly drained soils depending on the height of the ridges above sea level.

Vegetation and Land use

The vegetation found in this area includes rain forest, raffia palms, and thick mangrove forests. With sandy ridges at the ocean front, a maze of interconnected rivers and creeks separate the swamps into numerous large to small parcels. These areas are subjected to diurnal flooding owing to tidal waves and river back-flows.

In the freshwater sub-zone and on the levee soils as well as older coastal plain sands and recent alluvial soils, the chief crops cultivated are cassava, plantains, yams and cocoyam typically in small plots usually less than 0.5 ha in size or even less in the back swamps. In the riverine communities where the maze of creeks and rivulets make contiguous land holding beyond 100 square meters almost impossible, small plots around homesteads are engaged in small vegetable cultivation while on the better drained uplands of Rumuji and Ubeta, other crops still in small plots are sweet potato, sugar cane and cocoyam. On recent alluvial soils that are subject to seasonal flooding, crops are usually planted as soon as the flood recedes and water table has dropped to appreciable levels, usually in December. Cropping in this area is almost continuous because of high cost of clearing bush, difficult transport system and inaccessibility. Some soils of the beach ridges are obviously unsuitable for arable crops requiring good oxidizing environment.

Soil sampling

Composite soil samples were collected with soil auger at three depths 0-15 cm, 15-30 cm and 30-45 cm (where high water table allowed) in the communities starting from Finima, Soil sampling was carried out with the guidance of the community representatives. Sampling was carried out to cover observed variations owing to natural vegetation and land use patterns. A total of 54 soil samples were collected, bagged and labelled for laboratory analysis.

Laboratory analysis

The soils were air-dried and passed through a 2mm mesh sieve.

Particle size analysis was carried out using the modified Bouyoucous hydrometer method (Gee and Or, 2002), Soil pH was determined potentiometrically in 10g of soil sample to 25ml of distilled water (ratio 1:2.5) while pH in KCl was also determined at a ratio of 1:2.5 soil to solvent and the readings were taken using the glass electrode (Methler) pH meter buffered at pH 7. Organic carbon was determined by the Walkley-Black wet oxidation method. Exchangeable bases (Ca, Mg, K, Na) were extracted with 1N NH_4OAC (pH 7). Exchangeable Ca and Mg were determined by atomic absorption spectrometer, while K and Na were determined by flame photometer. Exchangeable acidity ($A1^{3+}$, H^+) was determined by titration of soil solution with 1 N KCI. Extractable micronutrients (Mn, Zn, Cu and Fe), were leached with 0.1N HCl and were determined on the atomic absorption spectrophotometer. Base saturation was calculated as the proportion of exchange site occupied by cations while effective CEC was computed by the summation of exchangeable bases (Ca, Mg, K and Na) and exchange acidity (Al and H).

Results

Particle size distribution

The particle size distribution and textural properties of the soils in the various communities are shown in Table 2. On the surface soils (0-15 cm depths), the range of sand for Iyiobama was 6.6 – 10.6 g/kg with a mean value of 8.60 g/kg. Highest surface soil value for sand, silt and clay were recorded in Finima (946 g/kg), Iyiobama (61 g/kg) and Rumuji (157 g/kg) respectively while the lowest values were recorded for sand (Rumuji – 811 g/kg). Ojokolo and George Pepple recorded the same values for silt (24 g/kg) while for clay; it was a value of 4.0g/kg which was recorded in Finima and Abalamabie. Texturally, the soils are generally sandy except at Rumuji where a surface soil texture of Sandy Loam was recorded

In the sub soil (15-30 cm) values with the highest values for sand and clay were recorded in Abalamabie were of 946 g/kg and 40 g/kg respectively with the highest values recorded in Finima and Abalamabie (14 g/kg) showing that the sandy nature of the soils persists at the sub soil. Lowest values for sand, silt and clay were recorded in Rumuji, Ojokolo and Finima which recorded values of 747 g/kg, 19 g/kg and 50 g/kg respectively. At the lower depth of 30-45 cm, only Rumuji had appreciable increase in clay content with 293 g/kg clay and texture of Sandy clay loam at that depth.

Chemical properties

Soil reaction at the surface soil reveals a soilpH range of 5.4 – 5.6 showing that the soils are generally acidic (Fig 3). The lowest pH values were obtained at the subsoil (15-30 cm) which marginally increased at the lower depth of 30-45cm. Total N and organic carbon were moderate at the surface (0-15 cm soils) with mean values of 1.9 and 21.4 g/kg respectively. These values decreased expectedly at lower depths. Rumuji recorded the lowest mean pH values at 5.2 while George Pepple had the highest values. Electrical conductivity had a range of 0.01 ds/m – 0.04 ds/m. Highest values for Av.P, Ca, Mg and Na were recorded in Iyiobama, Ojokolo, George Pepple / Abalamabie and Ojokolo. George Pepple still recorded the highest value for Exchangeable K (0.57 cmol/kg) for the soils of the site. Ranges for ECEC and base saturation were 4.92 cmol/kg – 6.07 cmol/kg and 79.17% - 85.86 % respectively. Fe, Mn, Cu and Zn recorded mean range values of 370 – 926.50 mg/kg, 16.3 – 65.7 mg/kg, 0.55 – 3.86 mg/kg and 1.02 – 1.37 mg/kg respectively. Highest values for Fe was recorded on Ojokolo (926.50mg/kg) while for Zn, Finima had the highest concentration. Abalamabie had the highest values for Mn(65.7 mg/kg) while for Cu, Iyobama soils had the highest concentration (3.86 mg/kg).

In the Sub soil (15-30 cm), George Pepple, Abalamabie and Finima which are all in Bonny Island recorded pH of 5.4 and these were the highest values obtained for the soils of the study area. George Pepple recorded the lowest value of electrical conductivity (0. 01 ds/m). Abalamabie and Finima had mean total nitrogen values of 13.70 g/kg and 15.50 g/kg respectively. Iyiobama, George Pepple and Ojokolo had low values which ranged from 1.70 g/kg - 1.97 g/kg. However, Iyiobama recorded the highest value for available P in the sub surface soil (52.60 mg/kg). The ranges of the mean values for Ca, Mg, K and Na were 2-2.84 cmol/kg, 0.61 – 0.90 cmol/kg, 0.31 – 0.57 cmol/kg, 0.66 – 0.90 cmol/kg. The ECEC was low (4.51 – 5.91cmol/kg) while the base saturation was high with values which ranged from 82.63 – 86.72 %. The range of Fe, Mn, Cu and Zn were 419.7 – 836.50 mg/kg, 12.21-29.10 mg/kg, 0.84 – 2.17 mg/kg, 1.06 – 1.45 mg/kg.

Table 2: Particle size distribution of soils in the Rivers state communities

Location	Depth	Sand	Silt	Clay	Texture
	(cm)	(g/kg)			
Inyobama	0-15	846	61	93	LS
	15-30	825	47	128	SL
	30-45	839	54	107	LS
George Pepple	0-15	898	27	75	LS
	15-30	905	21	75	LS
	30-45	898	21	81	S
Abalamabie	0-15	916	44	40	S
	15-30	946	14	40	S
	30-45	826	74	110	S
Finima	0-15	946	14	40	S
	15-30	936	14	50	S
	30-45	943	24	33	S
Ojokolo	0-15	916	24	60	S
	15-30	916	19	65	S
	30-45	868	44	88	S
Rumuji	0-15	811	34	157	SL
	15-30	747	54	199	SL
	30-45	639	67	293	SCL
Ubeta	0-15	873	54	73	LS
	15-30	827	67	106	LS
	30-45	800	47	153	SL

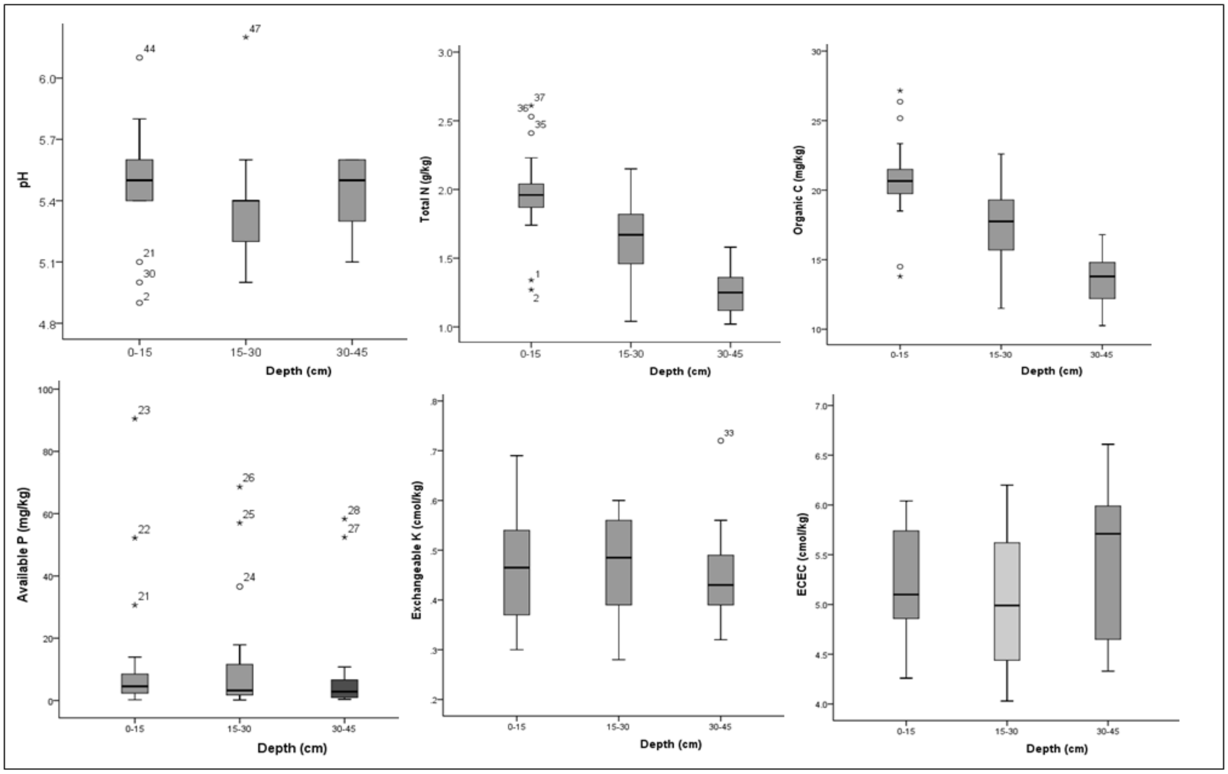


Figure 3: Box charts (with outliers outside the boxes) showing distribution of some soil chemical properties by depth in selected sites in Rivers State

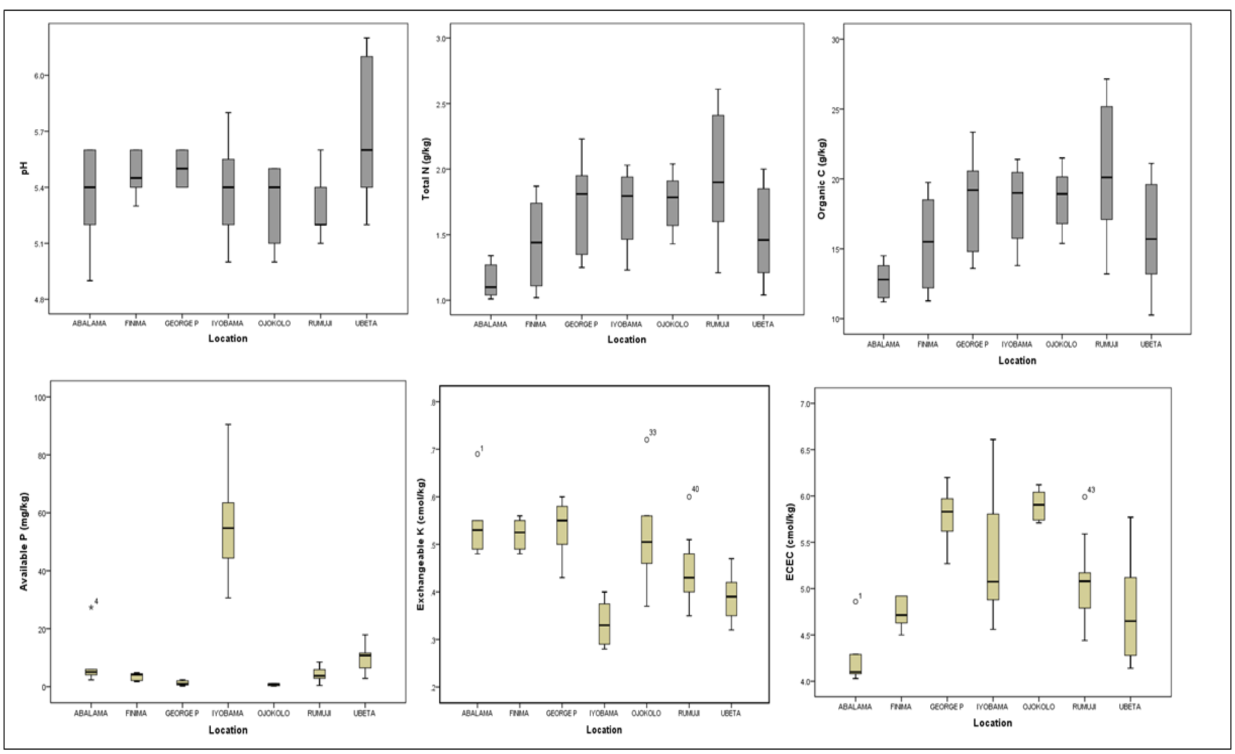


Figure 4: Box plot showing distribution of soil chemical properties by location in selected sites of Rivers State

Discussions

The clay content of the soils are generally low owing partly to the inherent sandy nature of the soil parent materials (Kamalu *et al.,* 2002).The land area can be grouped into two broad categories based on texture. Namely the sand/ loamy sand topsoil over sandy loam/ sandy clay loam with appreciable clay illuviation as found in Iyobama, Ubeta and Rumuji. The other group consists of those soils that are sandy or loamy sand overlying more sandy subsoil as found in George Pepple, Abalamabie, Ojokolo and Finima. This grouping is similar to the parent materials that gave rise to the soils, the first group being soils on Coastal plain sands while the second group is soils on more recent beach ridges and alluvial fans. Olomu and Ojo- Atere (1985) demonstrated that there is a strong link between land surface morphology and soil properties. The soils at Finima, Abalamabie, George Pepple and Ojokolo are basically sandy soils probably owing to the inherently sandy beach materials from which they were derived.

Soil reaction is very acidic in the study areas. This could be attributed to high precipitation and leaching of bases. Ojanuga, (2006) pointed out that low nutrients occasioned by high acidity and low buffering capacity is a major constraint in the management of the soils in this agro-ecological zone. Apart from high precipitation, most agricultural lands in this area are invariably cropped continuously. Edmeades and Ridley, (2003) observed that significant pH decreases may occur in just a few decades because of intense management practices. In highly acidic soils of this nature, iron (Fe) and aluminum (Al) oxides are likely to play a significant role in nutrient dynamics (Eriksson *et al.*, 2015).

Total organic carbon is generally moderate (mostly > 14 g/kg). Reddy *et al.,* (2000), stated that the rate of accumulation is greater than decomposition in wetlands and thus may be responsible for the moderate to high organic carbon. They have low amounts of nitrogen and phosphorus contents. The ECEC is generally low as is typical of soils of this area that are subjected to high rates of leaching resulting from the sandy texture, high rainfall and the low activity clays that are more common. High rainfall often lead to leaching out of bases (Ca+, K+, Mg2+,and Na+). Consequently, the exchange complexes are dominated by Al^{3+} and H^{+} (Brady and Weils, 1999). Excess leaching of plant nutrients and excess water in the form of seasonal floods and tidal actions inundate most of the soils and cause the soil to be properly drained. Furthermore, it causes strong acidity of soils and low nutrient supply capacity. However, the soils of Inyobama, Rumuji and Ubeta fared slightly better in nutrient accumulation probably due to higher clay content as a result of a slightly longer time the soils have been subjected to profile development.

The soils are acidic, with low CEC, low buffering capacity, multiple nutrient deficiency and possibly nutrient imbalance; coupled with high precipitation. Anjos *et al.,* (1998) and Brady, (2012), established that clay content of the soil has a positive impact on the cation exchange capacity of the soils. Soils with high acidity can be corrected with supply of lime and organic materials to neutralize the effects of high Al^{3+} and Mn^{2+} in order to supply Ca^{2+} and Mg^{2+}.

In addition to liming, fertilizer regimes that could supply the deficient nutrients will have to be applied. Acid forming fertilizers like ammonium sulphate and urea should be avoided. Also tillage practices that will conserve the soil organic matter including additions of residue mulch will enhance the conservation of the soils.

The surface soils are predominantly sandy with no appreciable amount or increase in clay content. A marginally higher clay contents is prevalent in the subsoil probably due to migration of clay to the sub soils. Fagbami and Oyekunle (1985) attributed the higher clay in the sub soils of the Delta to episodic sedimentation and clay illuviation. The consequent sandiness and high water would need adequate drainage and improvement with organic manure.

Crops and soil management strategies

Based on the climate, physical and chemical properties of the soils, the following recommendations could be made: Due to the excessive wetness of the soils at Finima, Abalamabie, Ojokolo and George Pepple communities, high water table will constrain the commercial production of most arable crops. Furthermore, the use of heavy machines for land preparation will be difficult. However, crops like coconut, Raphia and oil palms which are more adaptable to wet conditions and sandy soils could be grown on commercial quantity. In addition to these, cassava (*Manihot esculentus*) and sweet potato (*Ipomea batata*) could be grown in commercial quantities at Iyobama, Rumuji and Ubeta due to the better drainage conditions. In the fairly well drained areas, crops that can be grown on raised beds with liming and proper soil fertility management include cucumber (*Cucumis sativa*), pepper (*Piper guinensis*), okra (*Abelmuscus esculentus*), Amaranthus (*Amaranthus cruentus*) and fluted pumpkin (*Telferia occidentalis*). Generally, commercial fruit and leafy vegetable production can be practiced under protected conditions anywhere in the study area by setting up screen houses where production can be practiced with the use of growing media such as vermiculite, perlite etc. The proximity of the area to commercial centers such as Port Harcourt where there are high demands for exotic vegetables will make an all year round vegetable production under controlled agro climatic environment economically viable. If this is put in place, crops which can be grown in commercial quantity include cucumber (*Cucumis sativa*), lettuce (*Letucca sativa*), cabbage, green pepper and Tomatoes (*Lycopersicum esculentus*).

Conclusion

The soils are generally low in exchangeable bases and effective cation exchange capacity. A well-organized soil fertility management program will enhance the productivity of the soils. However, adequate drainage facilities must be put in place to solve the problem of high water table and occasional coastal flooding that may occur from time to time.

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