**Journal of Agriculture, Environmental Resources and Management**
ISSN2245-1800(paper) ISSN 2245-2943(online)
6(7)1-800:**December.**.2024; pp100-108

www.saerem.com

# Soil Fertility Asssessment of Cross River State Cocoa Producing Areas Nigeria.

Kekong, M. A. and Attoe, E. E.

Department of Agronomy, University of Cross River State Calabar.; *Corresponding Author Email: matikekong@gmail.com

## Abstract

*Cocoa is a major agricultural export crop of Nigeria that contributes substantially to the national economy in terms of employment and foreign exchange earning. An evaluation of the soil physical and chemical properties was carried out from June, 2024 to November, 2024, in fields located across major cocoa producing areas: Akamkpa, Boki, Etung, Ikom and Obubra Local Government Areas of Cross River State. Sixty (60) representative soil samples were collected from 30 selected cocoa farms and analyzed using standard laboratory procedures. Result indicated textural classes of loamy sand, sandy loam sandy clay loam, sandy clay and clay loam soils in the cocoa farms with a mean clay 30.02 percent, silt 13.49% and sand 56.43 the result of the chemical properties of the soils show means in the ranges of pH (5.31-5.64), Ec (0.021-0.023 ds/m), OM (2.81-3.36%)TN (0.07- 0.09%), Av.P (2.82-5.92 mg/kg), exch Mg (1.47-200 cmol/kg) exchange Na (0.05-0.06 cmol/kg) ECEC (6.73-8.94 cmol/kg) BS (77.25-82.70%). The base saturation, exchangeable calcium and magnesium and total nitrogen were adequate within recommended limit. Available phosphorus, potassium, organic matter electrical conductivity and effective cation exchange capacity were below the critical level. An appropriate and guarded nutrients restorative management practice using organic and inorganic sources is recommended for increased yields and sustainable cocoa production in these study areas.*

***Key words** — soil samples, cocoa farm, soil textures, chemical properties, critical levels*

**Introduction:** Cocoa is a major agricultural export crop of Nigeria and a major employer of labour, particularly in the crop's producing areas. The crop ranks first amongst agricultural export crops in its contribution to foreign exchange earning in Nigeria (Tijani, Farinde and Agboola 2001). Nigeria is the fourth largest world producer of cocoa after Corte' ivoire, Indonesia and Ghana and the third largest exporter (Verter and Becyarora 2014). Cross River State is the second largest producer of cocoa after Ondo in Nigeria (Iremiren, Oduwole, Obatolu, Aigbekaen, Sanusi, Shittu, Emeku, Ibiremo, Aikpokpodion, Agbeniyi, Ndubuaka, Adeogun and Olaiya 2012) while production data as at 2015 indicated that Boki, Etung, Ikom, Obubra and Akamkpa are the highest cocoa producers in Cross River State (Tiku, Galadima and Iyala 2016). The Nigeria cocoa economy has not been stable. The factors responsible for this fluctuating and declining yields are climate change and its impacts on soil properties and poor soil management practices among others. Aikpokpodion (2010) observed that most soils in Nigeria under cocoa plantations are marginal to moderately suitable in fertility status. Comparative studies between uncultivated forest and cocoa plantation soils indicated lower nutrient status in cocoa plantations (Ogunlade et al., 2006) Soil has been found to be the most heterogeneous substance on earth, whose properties vary significantly within a metre square. Cacao is exceptionally demanding in its soil requirement which shows steady decline in almost all nutrients with length of cultivation (Ogunlade, Adeoye Ipimoroti, Ibiremo and Iloyanomon, 2006).

Cacao is exceptionally demanding in its soil requirement which shows steady decline in almost all nutrients with length of cultivation (Ogunlade et al.,2006). Although few studies have been carried out in Cross River State cocoa soils, which is not sufficient, the inclement weather due to climate change impacts on soil dynamics in recent years calls for periodic assessment of soils of these areas if cocoa production has to be sustained. There is paucity of soil information in some potential areas of cocoa production in Cross River State such as Obubra and Akamkpa and the existing soil data bank in areas such as Ikom, Boki and Etung are fragmented. The lack of location specificity and multiple viewpoints makes soil information unsuitable for use for local and other investors in the cocoa industry and connectivity for extension services. This study is designed to provide the background and context to Cross River State cocoa farmers and other agencies involved in cocoa production and development chain on soil potentials and management approaches for increased and sustainable yields. The productivity of plantation tree farming depends on the soil nutrients monitoring and replenishment with appropriate nutrients sources.

**Materials and Methods** : ***Study Area and Sampling Technique*** : The study was carried out at Akamkpa, Boki, Etung, Ikom and Obubra local government areas selected based on the report of Iremirenet al.,(2012). The coordinates of these areas were Akamkpa on latitude 5° 25'38.21'' N, and longitude 8° 31'6.78'' E with a land area of 4,300 $Km^2$, Boki latitude 5° 82 and 6° 40 N and longitude $8^0$ 50' and $9^0$ 00E with a land area of 2,771$Km^2$, Etung is latitude 5° 51'32''N and 6° 00N and longitude 8° 00 and 9° 00E with a land area of 815 $Km^2$, Ikom on latitude $5^0$ 57'40''N and $8^0$ 42'39''E with a land area of 1,961 $Km^2$, Obubra on latitude $5^0$44' to $6^0$17'N and longitude $8^0$11' to $8^0$33'E with a land area of 903. 22 $Km^2$ all within the rainforest belt of Nigeria. The rainfall in this cocoa growing areas is bimodal in distribution and ranges from 1200 mm – 3000 mm in density NIMET (2008).The major economic activities of these areas is farming of food and cash crops including cocoa, which is the major cash crop.

***Sampling Design and Soil Sampling :*** From each local government areas, three cocoa growing communities were randomly selected. In each cocoa growing community two farms were randomly selected making a total of 18 cocoa farms. The soil samples were taken from June to November 2024.

**Soil Sampling :** In each selected cocoa farm, two Quadrats of 50×50 m were marked. In each Quadrat, three representative core samples were collected randomly at depths of 0-25 cm and 25-50 cm using soil auger and bulked together for each depth to form a composite sample. A total of 60 (Sixty) representative soil samples were collected from 30 (Thirty) farms in Akamkpa, Boki, Etung, Ikom and Obubra. These samples were bagged and labeled in sampling bags then transported to Kaduna National Fertilizer Development Center Laboratory, Nigeria for standard laboratory analysis.

***Soil Analysis* :** Prior to physicochemical analysis, the soils were air dried under room temperature, sieved through a 2 mm mesh.

Particle size distribution (PSD): was determined by the Bouyoucos (Hydrometer) method procedure by Udo, Ibia, Ogunwale, Ano and Esu (2009). This involves the suspension of soil samples with sodium hexametaphophate (calgon). The reading on the hydrometer was taken at 40 seconds. Second reading was taken three hours later. The particle size was then calculated using the following formula:

Sand = 100- (H1 + 0.2 (T1 – 68)-2.0)2

Clay = (H2 + 0.2 (T2 (T2-68) -2.0)2

Silt= 100 – (% sand + % clay)

where:

H1 = Hydrometer first reading at 40 seconds.

T1 = temperature first reading at 40 seconds.

H2 = Hydrometer second reading after 3 hours.

T2 = Temperature second reading after 3 hours.

1. Soil pH

This was determined in both water and 0.1 N KCL in a ratio of 1:1 soil: water and 1:2.5 soil: KCl respectively. After stirring the soil suspension for 30 minutes, the pH value was read using the glass electrode pH meter (McClean, 1982).

**Organic Matter** : This was determined by the walkley-Black method as outlined by Page, Miller, and Keeney (1982) which involves the oxidation with dichromate and tetraoxosulphate vi acid (H2 SO4). The excess was titrated against Ferrous Sulphate. The organic carbon was then calculated using the relationship:

( ) 1 2 – % . 0.3 N V V org C f W = 

where:

N = Normality of Ferous Sulphate solution.

V1 = Ml Ferrous Ammonium Sulphate for the black.

V2 = ml Ferrous Ammonium Sulphate for the sample.

W = mass of sample = farm.

f = correction factor = 1.33.

% organic matter in soil = % org.C × 1.729.

***Nitrogen in soil*** **:** Total nitrogen in soil was determined by the macro Kjeldahl method as described by Udo et al., (2009). The soil samples were digested with Tetraoxosulphate (VI) acid (H2 S04) after addition of excess caustic soda. This was distilled into a 2% Boric acid (H3BO4) and then titrated with 0.01 HCl. And the nitrogen was obtained from the relationship.

$$\%N = \frac{T\,X\,M\,X\,14}{N}\,X100$$

where:

T = Titre value.

M = Molarity of HCl.

W = Weight of soil used.

N = Normality of $H_2SO_4$.

***Available phosphorus*** : Available P was determined by Bray 1 method as outlined by Page et al., (1982). This involved mechanical shaking of the sample in an extracting solution then centrifuging the suspension at 2000 rotations per minutes for 10 minutes. Using ascorbic acid method, the percentage transmittance on the spectrophotometer at 660 nm wavelength was measured. The optical density (OD) of the standard solution was then plotted against the phosphorus ppm and the extractable P of the soil was then calculated.

***Cation Exchange capacity (CEC) and Exchangeable acidity (EA)*** : These were determined by the Kjeldahl distillation and titration method as outlined by IITA, (1979). Using ammonium acetate solution, the soil samples were leached then the soil washed with methyl alcohol and allowed to dry. The soil was then distilled in Kjeldahl operation in to a 4% Boric acid solution. The distillate was then titrated with standard solution of 0.1 N HCl.

***Exchangeable cations :*** This was determined by ammonium acetate extraction method as described by IITA, (1979). The soil samples were shaken for 2 hours then centrifuged at 2000 rpm for 5-10 minutes after decanting into a volumetric flask, ammonium acetate (30 ml) was added again and shaken for 30 minutes, centrifuged and the supernatant transferred into same volumetric flask. Atomic Absorption spectrophotometer (AAS) was used to read the cations

**Results and Discussion: Physical Properties of the Soils :**Results of particle size distribution and textural classification of soils of Akamkpa, Boki,Etung, Ikom, and Obubra are presented in Table 1. The percentage sand composition of Akamkpa cocoa growing soils taken from 0 – 25 cm and 25 – 50 cm ranged from 57.0 74 with a mean of 66.0 %. The silt fraction ranged from 11.0 – 22.0 % with a mean of 17.0% while the clay content ranged from 12.0 -23.0 % with a mean of 16.0%. The textural classification of Akamkpa cocoa growing soils is predominantly sandy clay-loam with the exception of Osomba soils which texture at the 25 – 50 cm depth was loamy sand. The sand fraction of Boki soils ranged from 40.20 - 80.00 with a mean value of 60.52% at the 0 - 50cm. The silt content of the soils ranged from 10.00% - 23.00% with a mean value of 13.20% in soil depth of 0 - 50cm. The clay content ranged from 10.00%-36.00% with a mean value for the soils of 26.28%. The value for the 0-25cm depth of the soil particles were higher than at the 25cm-50cm. The textural classes for the Boki cocoa soils were loamy sand and sandy loam for the 0-25cm depth of Bunyia soils and sandy loam and sandy clay loam for the 25-50 cm depth soils of farms in Bunyia. The textural classes of Bashua indicated the soils as sandy loam and loamy sand for the 0-25cm depth and sandy clay loam for the 25-50cm depth. The textures for Olum soils were sandy clay and clay loam.

The soils of Etung cocoa farms of Agbokim, Bendegle and Ajassor have particle size distribution range of 39.40% -70% with a mean of 52.77%. The silt content ranged from 7.80% - 1980 for the 0-50cm soil depth with a mean of 14.02% while the clay content ranged from 22.20% - 42.40% for the soil depth of 0-50 cm with a mean value of 33.13%. Textural classes of Bendeghe was sandy loam at all the 0 - 50cm depth except for one farm whose soil was sandy loam at the 025 cm. The texture for all the farms for Agbokim at all depth was clay loam. Ajassor I cocoa farms had a texture of sandy clay while farms at Ajassor II were clay loam at the 0–25 cm and sandy-clay loam at the 25–50 cm depth. Ikom soils particle size distribution showed sand ranges from 42.00%-72.20% at the 0-50cm depth with a mean of 56.01% The percentage silt content of the soils ranged from 7.80-16.00% with a mean value of 13.26%. The clay content of Ikom soils range from 18.00% - 44.00% with a mean of 30.65% the texture classes of Ikom cocoa producing soil of Okuni were predominantly sandy loan. The last Motor soil showed the soil to be clay loam with same trend in Akparabong soils that showed clay loam of depths of 25 - 50 cm. The sand fraction of Obubra cocoa producing communities soils of Iyamitet, Onyen Okpon and Ochon ranged from 36.60 - 67.30 with a mean value of 50.00% at the 0 - 50cm. The silt content of the soils ranged from 14.20% - 44.00% with a mean value of 22.00% in soil depth of 0 - 50cm. The clay content ranged from 17.70%-36.00% with a mean value for the soils of 27.85. The textural classes for the Obubra cocoa soils were Clay loam for Iyamitet and Onyen Okpon while the textural class for Ochon soils was Sandy clay loam in both top soil and sub soil 25 cm – 50 cm.

The study area textural soil classes which indicated two for Akamkpa (Sandy clay loam and Loamy sand), five for Boki (Loamy sand, sandy loam, sandy clay loam, sandy clay and clay loam); Etung (sandy loam, sandy clay loam and clay loam) Ikom (four) sandy loam, sandy clay loam, sandy clay and clay loam and two textural classes for Obubra ( clay loam and sandy clay loam) is an indication of spatial variability in soil universally. This heterogeneity of soil especially, in textures in these major cocoa producing areas of Cross River State, is in line with the studies of Amajor (1989) and Chude (1998) whose findings indicated that geology of central and southern Cross River State which include Akamkpa, Boki, Etung, Ikom and Obubra, comprise majorly of sand stones, silt stone, shale-Basalt and basement complex. The clay content of the soils has earlier been observed by Floyd (1962) and Ofem and Esu (2015) who reported that red clay is found within Ikom, Etung, some parts of Boki and Obubra which are described as ferruginous tropical soils. Soil texture is a very important property of soils as it regulates moisture, nutrients, microbial activities and pollutant movement in the rhizosphere. Njukeng and Baligar (2016) asserted that preferred soil textures for cocoa plants is 30% clay, 50% sand and 20% silt.The textural classes of these soils fall within the range recommended by Anim-Kwapong and Frimpong (2004) who stated that a model profile of cocoa growing soil should be deep well drained soil over sandy clay layer. This soil textural range also were recommended by Ritung, Agus, and Hidayat (2007) to be deep soils characterized by sandy clay, clay, and silt clay textures. The clay sand ratio in all the soil textural classes is indicative of the good drainage status which prevents excess soil moisture and consequently poor aeration for enhanced microbial activities and good root development of cacao as stated by Hardy (1960) ; Smyth (1966).

**Soil pH, Electrical Conductivity (EC), Total N, Av. P, OM:** *(Table 2)* pH of Akamkpa cocoa soils of Akin, Oban and Osomba ranged from 4.6 – 5.1 with a mean of 4.8. For Boki soils, the pH ranged from 5.2-6.10 for the 0-50 cm depth for the farms in Bunyia, Bashua and Olum with a mean of 5.64. Ikom soils of Akparabong, Last motor and Okuni pH ranged from 5.00 - 5.6 with a mean of 5.31; soil pH of Etung cocoa farms in Bendeghe, Agbokim and Ajassor ranged from 4.80-7.10 with a mean of 5.39 while the pH range for Obubra cocoa producing soils ranged from 4.8 – 5.7 with a mean value of 5.3 The electrical conductivity (EC) of Akamkpa soils ranged from 0.021 – 0.041 ds/m with a mean value of 0.031; Boki soils ranged from 0. 011ds/m - 0.031 ds/m with a mean 0.022ds/m. The EC of Etung cocoa farm soils ranged from 0.013 – 0.042 ds/m with a mean of 0.024 ds/m; Ikom EC ranged from 0.016 – 0.041 ds/m with a mean of 0.028 while the electrical conductivity of Obubra cocoa gowing soils ranged from 0.016 – 0.061 ds/m with a mean of 0.031.

The organic matter content of soils of the study area for Akamkpa ranged from 2.7 - 3.6% with a mean of 3.1 %. Boki cocoa farms have OM content that ranged from 2.21 – 5.27 % with a mean of 3.36%; Ikom 2.04-3.81 with a mean of 2.96%; Etung 1.87-4.59 with a mean of 2.96% while the values for Obubra ranged from 2.1 – 3.4 % with a mean of 2.83%. Total N for Akamkpa ranged from 0.09 – 0.17 % with a mean of 0.13%. Total N for Boki ranged from 0.06 -0.12 with a mean of 0.9%, Etung Total N ranged from 0.06 – 0.12% with a mean of 0.08, Ikom 0.05-0.10 with a mean of 0.07% while total N for Obubra soils ranged from 0.05-0.16 with a mean of 0.11%. Available P for Akamkpa ranged from 2.0 – 4.8 mg/kg with a mean of 3.37 mg/kg. Available P for Boki ranged from 3.40–9.17 mg/kg with a mean of 5.08 mg/kg; 3.00-11.51 mg/kg with a mean of 5.90 mg/kg for Ikom; 1.00–5.36 mg/kg with mean of 2.82 mg/kg with of 2.82 mg/kg for Etung and a range of 6.52 – 9.0 mg/kg with a mean of 7.85 mg/kg.

**Exchangeable Bases, Exchangeable Acidity (EA) ECEC and Base Saturation (BS) (Table 3)**

The exchangeable cations content of soils in the study area showed that K in Akamkpa cocoa producing soils ranged from 0.01 – 0.12 cmol/kg with a mean of 0.11 cmol/kg. Concentration of K for Boki cocoa soils ranged from 0.09-0.17 with a mean of 0.12 cmol/kg. In Etung the K ranged from 0.09-0.14 with a mean of 0.12 cmol/kg; Ikom the range was 0.01-0.14 cmol/kg with a mean value of 10 cmol/kg while in Obubra the K ranged from 0.09 - 0.15 with a mean of 0.11 cmol/kg. Ca in Akamkpa cocoa producing areas ranged from 1.0 cmol/kg to 7.01 cmol/kg with a mean of 3.52 cmol/kg; in Boki it ranged from 4.00-6.00 cmol/kg with a mean of 5.18 cmol/kg. Ca in Etung ranged from 2.40 - 8.90 cmol/kg with a mean of 3.80 cmol/kg; Ikom cocoa producing area soils had Ca content of that ranged from 3.02-8.00 cmol/kg with a mean of 5.26 cmol/kg while Ca in Obubra soils ranged 4.00 - 6.4 cmol/kg with a mean of 5.2 cmol/kg. Mg content in Akamkpa soils ranged from 0.4 2.7 cmol/kg with a mean of 1.20 cmol/kg. In Boki soils it ranged from 1.40-2.7 cmol/kg with a mean of 2.00 cmol/kg; 1.40-3.00 cmol/kg with a mean of 1.98 in Ikom; 1.20-2.80 cmol/kg with a mean of 1.47 cmol/kg in Etung soils while the exchangeable Mg in Obubra cocoa producing soils ranged from 0.4 - 5.6 cmol/kg. Exch. Na in Akamkpa soils ranged from 0.05 – 0.09 cmol/kg with a mean of 0.08 cmol/kg; Boki was 0.03 -0.07 cmol/kg with a mean of 0.5 cmol/kg; 0.05-0.08 cmol/kg for soils of Ikom with a mean of 0.06 cmol/kg; Etung was 0.04-0.07 cmol/kg with a mean of 0.06 cmol/kg while the cocoa growing soils of Obubra had a Na content that ranged from 0.04 – 0.09cmol/kg with a mean of 0.07 cmol/kg. ECEC for Akamkpa soils ranged from 3.45 – 12.01 cmol/kg with a mean of 7.05 cmol/kg; Boki ranged from 7.78-10.62 cmol/kg with a mean of 8.97 cmol/kg; 5.96-12 .65cmol/kg with mean of 8.94 cmol/kg for Ikom; 5.09-13.05 with mean of 6.73cmol/kg in Etung soils while for Obubra soils the ECEC ranged from 6.60 – 22.41 cmol/kg with a mean of 9.59 cmol/kg. The base saturation of Akamkpa soils ranged from 50.0 88.0 % with a mean of 62.91%; for Boki it ranged from 78.02 - 83.71% with mean of 81.38 %; Etung the base saturation was 70.40–90.80 with mean of 77.25%; Ikom was 78.80 - 88.14% with mean of 82.70% and for Obubra cocoa soils the base saturation was 70.2 – 99.0% with a mean of 81.98%.

The pH range of the soils in the five main cocoa producing areas indicated that the soils were strongly, moderately to slightly acidic. The mean pH value of the soils is suitable for cacao growing and was within recommended pH of 5-8 by Ibiremo, Daniel, Iremiren and Fagbola (2011). This is also in line with the assertions of Aikpokpodion (2010), Wood and Lass (2001) that Cocoa in West Africa is widely grown on soils with either neutral or slightly acidic infertile soils. With exception of Total N (in Akamkpa, Boki and Obubra) Ca, Mg and Base Saturation, all other nutrients were below critical limits for cocoa productions. Nitrogen content in Akamkpa, Boki and Obubra soils were adequate and within the threshold for cocoa cultivation as the value was 0.09% and of N for cocoa (Egbe, Olatoye and Obatolu 1989; Aikpokpodion 2010). The higher N content of Akamkpa, Boki and Obubra cocoa soils could be attributed to the higher OM content of the farms over that of Ikom and Etung (Table 2).

The exchangeable Ca from the farms in Akamkpa, Boki, Ikom and Obubra were adequate for cocoa production as these were above 5.0 cmol/kg as recommended by Smyth, (1966) and Ibiremo et al., (2011). The deficiency of Ca in Nigerian cocoa soils in rare as concentration of Ca in these study area agree with the studies of Ipimoroti, Aikpokpodion and Akanbi (2009).The Mg content of all the cocoa farms investigated were higher than the critical level of 0.9 cmol/kg as stated by Ipimoroti et al.,(2009). The concentration of exchangeable Mg in cocoa farms soils of Akamkpa, Boki, Ikom and Obubra were above critical level and this was at variance from earlier studies by ( Obatolu and Chude, (1987) and Ipimoroti et al., (2009).. The base saturation of all the investigated soils was higher than the critical level of 60% (Ibiremo et al.,2011) for good production of cocoa. These values were reported by Kekong and Undie (2020) for Ikom, Boki and Etung. The base saturation of Akamkpa, Boki, Ikom, Etung and Obubra (Table 3) indicate promising suitability of the soils for nutrients availability as aluminium toxicity is not envisaged as Brady and Weil (2014) stated that a non-acid cation saturation ≥ 20 cmol/kg soils will not likely be the problem of Al toxicity.

OM and EC levels of the cocoa soils of Akamkpa, Boki, Etung, Ikom and Obubra were below the critical limits, as established and recommended by Obigbesan (2009; Enwezor, Udo, Usoro, Ayotade, Adekpeta, Chude, and Udegbe, (1989) for cocoa producing soils. The low EC of the soils indicates low concentration of soluble salts (Brady and Weil 2014) this Ec concentration indicated that the soils are likely to contain very little amount of soluble salts which is very conducive for cocoa production. The implication of low OM in these soils is low availability of adequate plant nutrients from native organic sources through mineralization. The low organic matter in these cocoa soils corroborates the assertions of Quaye, Doe, Attua, Yiran, Arthur, Dogbats, Konlan, Nkroma and Addo (2021) who noted that cocoa soils are low in organic carbon and require restoration. Low organic carbon in soils is low biological activities and diversity (Grover, Butterfly, Wang, Gleeson, Macdonald and Tang,2021) and consequently low mineralization. This calls for external intervention with inorganic fertilizers of N and P especially that are organic based. Hartmink, (2005) noted that larger amount of P is removed by beans, while ( Ogunlade and Aikpokpodion (2006) reported that leaf litter in cocoa plantations was not sufficient to supply P required by cocoa trees for optical yields. Available P (Table 2) in the investigated cocoa farms in the five locations were below the critical level of 10 mg/kg. The low P in the soils of Southern Nigeria was reported by Ogunlade and Aikpokpodion (2006) particularly in the cocoa farm soils of South West. This low P in the cocoa farm soils corroborates the findings of Njukeng and Baligar(2016) who reported that P is the major limiting nutrient in almost all the soils under cocoa production. The low pH, OM and clay in the soils could be attributed to the low availability of P. This status of P agrees with theassertion of Ahenkorah (1981) who earlier noted that pH,OM and clay are associated with P availability in West African soils. Hartmink (2005) noted that larger amount of P is removed by beans, while Ogunlada (2006) reported that leaf litter in cocoa plantations was not sufficient to supply P required by cocoa trees for optimal yields. The K concentration in the cocoa soils of the study area is below the critical level of 0.25 cmol/kg Ibiremo et al.,(2011). The low P and K of soils in Etung (Ajassor and Agbokim) were similar to the findings of Ajiboye, Jaiyeoba, Olaiya and Hammed,( 2015), while that of Ikom was reported by Esu, Uko, and Aki ( 2015). Although the pathways of P and K release and availability are not the same, application of these elements through inorganic fertilizers to the cocoa farms will increase yield of cocoa.

**Conclusion:** The soil textural classes of these major cocoa producing areas of Cross River State indicated suitability for cocoa production with adequate base saturation levels, Ca and Mg. These properties which are within the threshold for soil productivity is an indicator of quality cocoa beans production. But to match quality with quantity, the low levels of P, K, N, and OM requires external supplies with appropriate fertilizers to meet the high nutrients demand of cocoa trees. The thrust of the fertilizer application should be centered on phosphate availability management using organic and inorganic fertilizers in these cocoa growing areas. This will guarantee sustainable production of cocoa beans both in quantity and quality.

**Acknoledgement :** We like to express our gratitude to the Tertiary Education Tax Fund (TETFUND) Nigeria that funded this field research under the Institution Based Resaerch (IBR) of the University of Cross River State.

TABLE 1:SOIL PHYSICAL PROPERTIES OF THE STUDY AREA

| | Ikom | | | | | | Etung | | | | | | Boki | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Location | Depth cm | Sand % | Silt % | Clay % | Textural Class | Location | Depth cm | Sand | Silt | Clay | Textural Class | Location | Depth cm | Sand % | Silt % | Clay % | Textural Class |
| 1 | Aparabong I | 0-25cm | 54.00 | 9.60 | 36.40 | SC | Bendeghe I | 0-25cm | 54.00 | 17.80 | 28.20 | SCL | Bunyia I | 0-25cm | 74.20 | 12.80 | 13.00 | SL |
| 2 | | 25-50cm | 43.00 | 13.60 | 43.40 | CL | | 25-50cm | 50.00 | 19.80 | 30.20 | SCL | | 25-50cm | 72.00 | 12.00 | 16.00 | SL |
| 3 | Aparabong II | 0-25cm | 44.00 | 15.60 | 40.40 | CL | Bendeghe II | 0-25cm | 69.00 | 8.80 | 22.20 | SL SCL | Bunyia II | 0-25cm | 62.20 | 13.80 | 24.00 | SL SCL |
| 4 | | 25-50cm | 46.00 | 15.60 | 38.40 | CL | | 25-50cm | 64.00 | 7.80 | 28.20 | | | 25-50cm | 48.20 | 15.80 | 36.00 | |
| 5 | Last Motor I | 0-25cm | 58.00 | 16.00 | 26.00 | SCl | Agbokim I | 0-25cm | 54.00 | 13.80 | 32.20 | CL | Bashua I | 0-25cm | 78.00 | 12.00 | 10.00 | SL SCL |
| 6 | | 25-50cm | 54.15 | 14.24 | 31.61 | | | 25-50cm | 50.0 | 13.60 | 36.40 | CL | | 25-50cm | 59.20 | 13.20 | 27.60 | |
| 7 | Last Motor II | 0-25cm | 58.20 | 10.80 | 31.00 | CL | Agbokim II | 0-25cm | 46.00 | 13.60 | 40.40 | CL | Bashua II | 0-25cm | 80.00 | 10.00 | 10.00 | LS SCL |
| 8 | | 25-50cm | 48.00 | 15.80 | 36.00 | CL | | 25-50cm | 46.00 | 13.00 | 40.40 | CL | | 25-50cm | 64.00 | 10.00 | 26.00 | |
| 9 | Okuni I | 0-25cm | 57.00 | 16.00 | 27.00 | CL | Ajassor I | 0-25cm | 45.40 | 14.20 | 40.40 | SC | Olum I | 0-25cm | 58.20 | 5.80 | 36.00 | SC CL |
| 10 | | 25-50cm | 52.15 | 15.24 | 32.61 | CL | | 25-50cm | 38.40 | 19.20 | 42.40 | SC | | 25-50cm | 48.20 | 15.80 | 36.00 | |
| 11 | Okuni II | 0-25cm | 65.00 | 10.00 | 25.00 | CL | Ajassor II | 0-25cm | 50.20 | 17.80 | 32.00 | LSC | Olum II | 0-25cm | 51.80 | 13.40 | 34.80 | CL |
| 12 | | 25-50cm | 57.20 | 16.80 | 36.00 | CL | | 25-50cm | 52.77 | 14.02 | 33.13 | | | 25-50cm | 40.20 | 23.80 | 36.00 | CL |

| | **Akamkpa** | | | | | | **Obubra** | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Location | Depth cm | Sand % | Silt % | Clay % | Textural Class | Location | Depth cm | Sand % | Silt % | Clay % | Textural Class |
| 1 | Akin I | 0-25cm | 62.0 | 17.0 | 21.0 | SCL | IyamitetI | 0-25cm | 49.3 | 33.0 | 17.7 | CL |
| 2 | | 25-50cm | 61.0 | 16.0 | 23.0 | SCL | | 25-50cm | 48.00 | 15.00 | 36.80 | CL |
| 3 | Akin II | 0-25cm | 57.0 | 22.0 | 21.0 | SCL | Iyamitet II | 0-25cm | 36.6 | 44.0 | 19.4 | CL |
| 4 | | 25-50cm | 58.0 | 20.0 | 22.0 | | | 25-50cm | 48.00 | 15.80 | 36.00 | CL |
| 5 | Oba I | 0-25cm | 74.0 | 12.0 | 14.0 | SCL | Onyenokpon I | 0-25cm | 41.3 | 25.0 | 33.7 | CL |
| 6 | | 25-50cm | 72.0 | 11.0 | 17.0 | | | 25-50cm | 52.15 | 15.24 | 32.61 | CL |
| 7 | Oban II | 0-25cm | 65.0 | 17.0 | 16.0 | SCL | Onyenokpon II | 0-25cm | 48.2 | 32.4 | 19.4 | CL |
| 8 | | 25-50cm | 70.0 | 16.0 | 14.0 | | | 25-50cm | 57.20 | 16.80 | 36.0 | CL |
| 9 | Osomba I | 0-25cm | 71 | 18 | 11.0 | SCL | OchonI | 0-25cm | 67.3 | 15.0 | 17.7 | SCL |
| 10 | | 25-50cm | 68 | 14 | 12.0 | LS | | 25-50cm | 61.40 | 14.20 | 24.4 | SCL |
| 11 | Osomba II | 0-25cm | 68.0 | 20.0 | 12.0 | SCL | Ochon II | 0-25cm | 58.00 | 16.00 | 26.00 | SCL |
| 12 | | 25-50cm | 66.0 | 21.0 | 13.0 | SCL | | 25-50cm | 40.20 | 23.80 | 36.00 | SCL |

LS= Loamy Sand, SL=Sandy loam, SCL=Sandy Clay Loam, SC=Sandy Clay, CL=Clay Loam, LS= Loamy sand

| | Ikom | | | | | | | Etung | | | | | | Boki | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Location | Depth cm | Ph | Ec Ds/M | Om % | Total N % | Av. P Mg/Kg | Location | Ph | Ec Ds/M | Om % | Total N % | Av. P Mg/Kg | Location | Ph | Ec Ds/M | Om % | Total N % | Av. P Mg/Kg |
| 1 | Aparabong I | 0-25cm | 5.10 | 0.022 | 3.37 | 0.08 | 7.01 | Bendeghe I | 7.10 | 0.021 | 2.89 | 0.07 | 1.67 | Bunyia I | 6.00 | 0.023 | 5.57 | 0.11 | 3.80 |
| 2 | | 25-50cm | 5.30 | 0.040 | 3.81 | 0.10 | 11.51 | | 5.90 | 0.018 | 2.90 | 0.08 | 1.60 | | 5.80 | 0.021 | 2.55 | 0.08 | 4.60 |
| 3 | Aparabong II | 0-25cm | 5.10 | 0.041 | 2.72 | 0.06 | 3.50 | Bendeghe II | 5.80 | 0.013 | 4.59 | 0.12 | 4.50 | Bunyia II | 6.10 | 0.031 | 4.25 | 0.12 | 5.80 |
| 4 | | 25-50cm | 5.20 | 0.031 | 2.21 | 0.08 | 5.00 | | 6.40 | 0.014 | 4.30 | 0.11 | 5.36 | | 5.9 | 0.024 | 3.84 | 0.07 | 4.40 |
| 5 | Last Motor I | 0-25cm | 5.40 | 0.026 | 3.13 | 0.08 | 3.40 | Agbokim I | 5.00 | 0.020 | 3.64 | 0.10 | 5.50 | Bashua I | 5.30 | 0.011 | 3.33 | 0.10 | 5.00 |
| 6 | | 25-50cm | 5.20 | 0.026 | 2.79 | 0.07 | 3.40 | | 4.80 | 0.023 | 2.38 | 0.06 | 2.34 | | 5.20 | 0.022 | 2.21 | 0.08 | 3.40 |
| 7 | Last Motor II | 0-25cm | 5.70 | 0.016 | 3.23 | 0.08 | 4.84 | Agbokim II | 5.20 | 0.040 | 2.89 | 0.07 | 2.01 | Bashua II | 5.30 | 0.020 | 3.23 | 0.09 | 5.10 |
| 8 | | 25-50cm | 5.60 | 0.020 | 3.24 | 0.07 | 2.20 | | 4.90 | 0.042 | 1.87 | 0.05 | 1.17 | | 5.20 | 0.021 | 2.55 | 0.06 | 3.62 |
| 9 | Okuni I | 0-25cm | 5.55 | 0.017 | 2.98 | 0.09 | 6.40 | Ajassor I | 4.90 | 0.030 | 2.89 | 0.07 | 1.50 | Olum I | 5.70 | 0.016 | 3.23 | 0.08 | 4.84 |
| 10 | | 25-50cm | 5.20 | 0.019 | 2.84 | 0.07 | 5.80 | | 4.80 | 0.031 | 2.58 | 0.06 | 1.00 | | 5.60 | 0.020 | 3.24 | 0.07 | 5.84 |
| 11 | Okuni II | 0-25cm | 5.40 | 0.021 | 3.05 | 0.10 | 7.10 | Ajassor II | 4.90 | 0.032 | 2.61 | 0.07 | 5.00 | Olum II | 6.00 | 0.021 | 2.72 | 0.06 | 9.17 |
| 12 | | 25-50cm | 5.12 | 0.019 | 2.91 | 0.08 | 5.40 | | 5.00 | 0.030 | 2.00 | 0.06 | 2.17 | | 5.60 | 0.024 | 3.58 | 0.10 | 5.42 |
| | Mean | | 5.31 | 0.022 | 2.81 | 0.07 | 5.90 | | 5.39 | 0.026 | 2.96 | 0.08 | 2.82 | | 5.64 | 0.021 | 3.36 | 0.08 | 5.08 |

| | Akamkpa | | | | | | | Obubra | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/N | Location | Depth cm | Ph | Ec Ds/M | Om % | Total N % | Av. P Mg/Kg | Location | Depth cm | Ph | Ec Ds/M | Om % | Total N % | Av. P Mg/Kg |
| 1 | Akin I | 0-25cm | 4.9 | 0.021 | 3.5 | 0.10 | 2.0 | IyamitetI | 0-25cm | 5.7 | 0.031 | 3.2 | 0.10 | 8.37 |
| 2 | | 25-50cm | 4.6 | 0.030 | 2.8 | 0.09 | 2.0 | | 25-50cm | 4.9 | 0.028 | 2.1 | 0.08 | 6.52 |
| 3 | Akin II | 0-25cm | 5.1 | 0.026 | 3.4 | 0.11 | 4.1 | Iyamitet II | 0-25cm | 5.6 | 0.019 | 2.9 | 0.11 | 9.01 |
| 4 | | 25-50cm | 4.8 | 0.026 | 3.0 | 0.09 | 3.8 | | 25-50cm | 5.2 | 0.016 | 3.1 | 0.05 | 7.80 |
| 5 | Oba I | 0-25cm | 4.8 | 0.024 | 3.6 | 0.12 | 3.3 | Onyenokpon I | 0-25cm | 5.2 | 0.061 | 2.8 | 0.16 | 7.12 |
| 6 | | 25-50cm | 4.6 | 0.022 | 2.9 | 0.10 | 3.0 | | 25-50cm | 4.8 | 0.055 | 2.6 | 0.12 | 6.81 |
| 7 | Oban II | 0-25cm | 4.9 | 0.031 | 3.4 | 0.13 | 2.9 | Onyenokpon II | 0-25cm | 5.5 | 0.025 | 3.4 | 0.15 | 9.40 |
| 8 | | 25-50cm | 4.5 | 0.030 | 2.9 | 0.09 | 3.1 | | 25-50cm | 5.1 | 0.019 | 2.7 | 0.10 | 7.21 |
| 9 | Osomba I | 0-25cm | 5.0 | 0.041 | 3.2 | 0.15 | 4.8 | OchonI | 0-25cm | 5.6 | 0.022 | 2.9 | 0.14 | 8.10 |
| 10 | | 25-50cm | 4.6 | 0.040 | 2.9 | 0.3 | 3.6 | | 25-50cm | 5.4 | 0.020 | 2.5 | 0.09 | 6.9 |
| 11 | Osomba II | 0-25cm | 4.8 | 0.039 | 2.9 | 0.17 | 4.1 | Ochon II | 0-25cm | 5.7 | 0.042 | 2.8 | 0.08 | 9.10 |
| 12 | | 25-50cm | 4.6 | 0.031 | 2.7 | 0.15 | 3.7 | | 25-50cm | 5.4 | 0.031 | 3.0 | 0.09 | 8.50 |
| | Mean | | | | | | | | | | | | | |

TABLE 2: Chemical PROPERTIES OF THE COCOA SOILS

EC= Electrical Conductivity, OM= Organic matter, T. N= Total Nitrogen, Av. P= available Phosphorus

| Ikom | Etung | Boki |
|---|---|---|

| | | | Exhangeable Bases cmol/kg | | | | | | | Exhangeable Bases cmol/kg | | | | | | | | Exhangeable Bases cmol/kg | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| S/ N | Location | Depth cm | Ca | Mg | K | EA cmol/ kg | ECEC cmol/ kg | BASL SAT. % | Location | Ca | Mg | Na | K | EA cmol/ kg | ECEC cmol/ kg | BASL SAT. % | Location | Ca | Mg | Na | K | EA cmol/ kg | ECEC cmol/ kg | BASL SAT. % |
| 1 | Aparabong I | 0-25cm | 3.02 | 1.40 | 0.01 | 1.30 | 5.96 | 78.19 | Bendeghe I | 3.20 | 1.40 | 0.05 | 0.12 | 1.03 | 5.80 | 82.24 | Bunyia I | 0.12 | 5.40 | 1.4 | 0.05 | 1.40 | 8.37 | 82.27 |
| 2 | | 25-50cm | 6.00 | 2.00 | 0.11 | 1.20 | 9.36 | 87.18 | | 4.00 | 1.30 | 0.07 | 0.09 | 1.20 | 5.66 | 78.8 | | 0.13 | 5.10 | 2.0 | 0.04 | 1.50 | 8.77 | 82.90 |
| 3 | Aparabong II | 0-25cm | 4.00 | 1.40 | 0.13 | 1.60 | 7.30 | 78.08 | Bendeghe II | 4.40 | 1.40 | 0.06 | 0.10 | 1.30 | 7.26 | 82.09 | Bunyia II | 0.11 | 5.30 | 2.4 | 0.06 | 1.60 | 9.47 | 83.10 |
| 4 | | 25-50cm | 4.40 | 1.50 | 0.14 | 1.30 | 7.42 | 82.48 | | 8.90 | 2.80 | 0.05 | 0.10 | 1.20 | 13.05 | 90.80 | | 0.13 | 4.80 | 2.2 | 0.05 | 1.40 | 8.58 | 83.68 |
| 5 | | 0-25cm | 5.20 | 1.80 | 0.10 | 1.54 | 8.70 | 82.30 | | 2.40 | 1.20 | 0.06 | 0.13 | 1.40 | 5.09 | 72.50 | | 0.16 | 5.20 | 1.90 | 0.07 | 1.50 | 8.83 | 83.11 |
| 6 | Last Motor | 25-50cm | 5.21 | 1.60 | 0.12 | 1.50 | 8.49 | 82.33 | Agbokim I | 2.80 | 1.30 | 0.06 | 0.09 | 1.50 | 5.74 | 73.87 | Bashua I | 0.17 | 5.60 | 2.00 | 0.06 | 1.54 | 9.37 | 83.56 |
| | | | 4.67 | 1.67 | 0.12 | 1.41 | 7.89 | 81.76 | | | | | | | | | | | | | | | | |
| 7 | Last Motor II | 0-25cm | 6.00 | 2.70 | 0.12 | 1.73 | 10.62 | 83.71 | Agbokim II | 2.80 | 1.20 | 0.06 | 0.09 | 1.50 | 5.65 | 73.45 | Bashua II | 0.13 | 5.40 | 2.10 | 0.05 | 1.52 | 9.20 | 83.48 |
| 8 | | 25-50cm | 4.00 | 1.60 | 0.09 | 1.62 | 7.73 | 78.66 | | 4.00 | 1.30 | 0.07 | 0.11 | 1.60 | 7.07 | 77.37 | | 0.12 | 5.40 | 2.00 | 0.05 | 1.55 | 9.12 | 83.00 |
| 9 | Okuni I | 0-25cm | 7.01 | 2.50 | 0.11 | 1.64 | 11.01 | 87.73 | Ajassor I | 3.20 | 1.50 | 0.04 | 0.16 | 1.82 | 6.72 | 72.92 | Olum I | 0.12 | 6.00 | 2.70 | 0.07 | 1.73 | 10.62 | 83.70 |
| 10 | | 25-50cm | 5.50 | 1.53 | 0.09 | 1.66 | 9.10 | 78.90 | | 2.70 | 1.40 | 0.06 | 0.10 | 1.79 | 6.05 | 70.41 | | 0.09 | 4.00 | 1.60 | 0.06 | 1.62 | 7.37 | 78.02 |
| 11 | Okuni II | 0-25cm | 6.40 | 2.80 | 0.12 | 1.71 | 12.01 | 78.10 | Ajassor II | 3.20 | 1.40 | 0.06 | 0.13 | 1.60 | 6.38 | 75.08 | Olum II | 0.11 | 5.60 | 2.20 | 0.06 | 1.60 | 9.58 | 83.30 |
| 12 | | 25-50cm | 6.10 | 1.92 | 0.08 | 1.61 | 9.91 | 82.24 | | 4.00 | 1.50 | 0.05 | 0.14 | 1.66 | 7.35 | 77.41 | | 0.09 | 4.40 | 1.60 | 0.03 | 1.66 | 7.78 | 78.66 |
| | Mean | | 5.26 | 1.98 | 0.10 | 1.50 | 8.94 | 82.70 | Mean | 3.80 | 1.17 | 0.06 | 0.11 | 1.47 | 6.73 | 77.25 | Mean | 5.18 | 2.00 | 0.05 | 0.12 | 1.55 | 8.79 | 81.38 |

| | | | Akamkpa | | | | | | | Obubra | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Exhangeable Bases cmol/kg | | | | | | | Exhangeable Bases cmol/kg | | | | | | | |
| S/N | Location | Depth cm | Ca | Mg | K | Na | EA cmol/ kg | ECEC cmol/ kg | BASL SAT. % | Location | Ca | Mg | Na | K | EA cmol/ kg | ECEC cmol/ kg | BASL SAT. % |
| 1 | Akin I | 0-25cm | 5.8 | 1.2 | 0.11 | 0.09 | 1.47 | 8.24 | 88.0 | Bendeghe I | 5.4 | 0.4 | 0.11 | 0.09 | 1.61 | 6.79 | 88.0 |
| 2 | | 25-50cm | 1.8 | 0.4 | 0.07 | 0.06 | 1.58 | 4.67 | 51.0 | | 5.0 | 2.2 | 0.12 | 0.10 | 1.58 | 10.66 | 70.0 |
| 3 | Akin II | 0-25cm | 2.3 | 0.5 | 0.09 | 0.07 | 1.61 | 4.92 | 64.23 | Bendeghe II | 5.4 | 0.4 | 0.11 | 0.08 | 1.49 | 6.79 | 88.0 |
| 4 | | 25-50cm | 1.0 | 0.5 | 0.01 | 0.06 | 1.48 | 3.45 | 47.54 | | 4.00 | 1.60 | 0.l5 | 0.05 | 1.80 | 7.60 | 76.32 |
| 5 | Oban I | 0-25cm | 2.2 | 0.8 | 0.01 | 0.08 | 1.59 | 5.18 | 61.0 | | 16.4 | 5.6 | 0.13 | 0.10 | 1.70 | 22.43 | 99.0 |
| 6 | | 25-50cm | 2.2 | 0.8 | 0.11 | 0.05 | 1.61 | 5.87 | 50.0 | Agbokim I | 6.40 | 2.40 | 0.10 | 0.04 | 1.60 | 10.54 | 84.82 |
| 7 | Oban II | 0-25cm | 2.5 | 1.5 | 0.11 | 0.09 | 1.60 | 5.44 | 77.2 | Agbokim II | 6.00 | 2.70 | 0.12 | 0.07 | 1.73 | 10.62 | 83.71 |
| 8 | | 25-50cm | 2.0 | 0.4 | 0.10 | 0.08 | 1.63 | 5.87 | 64.0 | | 4.80 | 1.60 | 0.09 | 0.06 | 1.62 | 7.37 | 78.02 |
| 9 | Osomba I | 0-25cm | 6.00 | 2.70 | 0.12 | 0.07 | 1.73 | 10.62 | 83.71 | Ajassor I | 4.40 | 0.60 | 0.10 | 0.08 | 1.58 | 6.74 | 77.00 |
| 10 | | 25-50cm | 4.00 | 1.60 | 0.09 | 0.06 | 1.62 | 7.37 | 78.66 | | 4.00 | 1.60 | 0.15 | 0.05 | 1.60 | 7.60 | 76.32 |
| 11 | Osomba II | 0-25cm | 7.01 | 2.50 | 0.11 | 0.04 | 1.64 | 11.01 | 87.73 | Ajassor II | 6.00 | 2.70 | 0.12 | 0.07 | 1.73 | 10.62 | 83.71 |
| 12 | | 25-50cm | 5.50 | 1.53 | 0.09 | 0.06 | 1.71 | 12.01 | 78.10 | | 4.00 | 1.60 | 0.09 | 0.06 | 1.62 | 7.37 | 78.90 |
| | Mean | | | | | | | | | Mean | | | | | | | |

TABLE 3:EXCHANGEABLE CATIONS OF THE COCOA SOILS
EA= Exchangeable acidity, BS= Base Saturation, ECEC= Effective Cation Exchange Capacity.

## Reference

Ahenkorah, Y. (1981) The influence of environment on growth and production of cacao tree: Soils and nutrition. Proceedings 7th International conference of cocoa research Douala, Cameroon. 167 – 176.

Aikpokpodion, P.E. (2010) Nutrients dynamics in cocoa soils, leaf and beans in Ondo State, Nigeria. Journal Agricultural Science;1(1):1-9.

Ajiboye, G, A, Jaiyeoba, J.O, Olaiya A.O and Hammed L.A. (2015) Fertility baseline study of major cocoa Growing Soils of Nigeria and Implication for cocoa production in Nigeria. Nigeria Journey of soil science VOL. 25:45-57.

Amajor, L.C. (1989) thee Eze-Aku sandstone ridge of south Eastern Nigeria. A re-interpretation of their depositional origin. Journal of Mineral Geology 23:17-26.

Anim-Kwapong, G. J. and Frimpong, E. B. (2004)Vulnerability and Adaptation Assessment Under the Netherlands Climate Change Studies Assistance Programme Phase 2 (NCCSAP2): Vulnerability of agriculture to climate change-impact of climate on cocoa production, Cocoa Research Institute of Ghana.

Brady, N.C. and Weil, R.R. (2014) Nature and properties of soils (13th Edition) Pearson Educational Publishers, New Delhi India.

Chude, V.O. (1998) Understanding Nigeria Soils and their Fertility Management for Sustainable Agriculture. Inaugural Lecture delivered at ABU, Zaria on Thursday Nov. 26. 1998 Inaugural lecture series 13.

Egbe, N. E., Olatoye, S. and Obatolu C. (1989). Impact of rate and types of fertilizers on productivity and nutrient cycling in tree crop plantation ecosystem. Paper submitted for MAB Workshop, Abuja.

Enwezor, W. O.,Udo, E. J., Usoro, N. J., Ayotade, K.. A., Adekpeta, J. A., Chude, V. O. and Udegbe, C. I. (1989) Fertilizer use and management Practices for Crops in Nigeria. Series No. 2. Fertilizer Procurement and Distribution Division, Federal Ministry of Agriculture, Water Resources and Rural Development, Lagos, Nigeria 163Pp.

Esu, I. E., Uko, U. and Aki, E. E. (2015) Morphological, Physicochemical and Mineralogical Properties of Soils Developed from Basalt at Ikom, Cross River State, Nigeria. Nigeria Journal of Soil Soil Science Vol. 25: 168 – 180

Floyd, B. (1969). Eastern Nigeria a Geographical Macmillian company limited London pp 67-110.

Grover, S. P., Butterfly, C. R., Wang, X., Gleeson, D. B., Macdonald, L. M. and Tang, C. (2021) Liming and priming : the long-term impact of pH amelioration o mineralisation may negate carbon sequestration gains Soil Secur., 3, 100007, 10.1016/j.soisec.2021.100007

Hardy F. (1960). Cacao Manual. Inter-American Institute of Agricultural Science, Turrialba, Costa Rica. 134pp.

Hartemink, A.E. (2005) Nutrient Stocks, Nutients cycling and soil changes in cocoa ecosystems- a review. Advances in Agronomy 86: 227 –253.

Ibiremo, O.S., Daniel, M.A., Iremiren, G.O. and Fagbola O. (2011) Soil fertility evaluation for Cocoa production in South-eastern Adamawa State, Nigeria. World Journal of Agricultural Science 7(2)218-223.

IITA (1979) Selected methods for soil and plant analysis. International Institutes for Tropical Agriculture, Ibadan Nigeria. Manual series No. 1. Institute and World Agroforestry centre, Boyor Indonesia 42pp.

Ipinmoroti, R. R., Aikpokpodion, P. E. and Akanbi, O. (2009) Nutritional assessment of Cocoa plots for Soil fertility management on some Cocoa farms in Nigeria. 16th International Cocoa Conference, Indonesia.

Iremiren, G.O., Oduwole, O., Obatolu, B.O., Aigbekaen, E., Sanusi, R.A., Shittu T.R., Emeku L. E., Iberemo, O.S., Aikpokpodion, P., Agbeniyi, S.O., Ndubuaka, T.C.N., Adeogun, S. and Olaiya, A. (2012). Cocoa production survey in Nigeria. Report of cocoa Research Institute of Nigeria (CRIN) ISBN: 9789785065664, 84pp.

Kekong, M .A. and Undie, U. L.(2020) ) Soil Fertility Evaluation of Major Cocoa Producing Areas of Cross River State, Nigeria. European Journal of Agriculture and Food Sciences, VOL. 2. No. 6. 1- 6

McClean, E. O. (1982), Soil pH and Lime requirement. In: Page D. C. (eds) Methods of Soils Analysis part 2. Chemical and soil microbial properties. Agronomy series No. 9 ASA, SSSA, Madison. Page, A. L., R. H. Miller, and D. R. Keeney (1982). Methods of soil Analysis part 2. Chemical and microbiological properties. American Society of Agronomy, Madison 55 pp

NIMET (2008) Weather Report: Nigeria Meteorological Agency, Ikom, Cross River State.

Njukeng, N. J. and Baligar V.C. (2016) Soil Physical and Chemical Properties of Cacao Farms In South Western Region of Cameroon. International Journal of Plant and Soil Science 11 (6): 1 – 10

Obatolu, C. R. and Chude, V. O. (1987). Soils and Nutritional requirement of cocoa in Nigeria, Review of Soils and Fertilizer Use Research in South Western Nigeria. Lagos: FPDD/FMAWR &RD

Obigbesan, G. O. (2009) Ratings for soil fertility classes in Nigeria. Personal communication. 24Pp.

Ofem, K. I. and Esu, I. E. (2015) Pedological Study of Soils Developed on Schist in Biase Local Government Area, Cross River State, Nigeria. Nigeria Journal of Soil Science 25: 181 – 193

Ogunlade, M.O. and Aikpokpodion. P.O. (2006) Available phosphorus and some micronutrient contents of cocoa soils in three cocoa growing ecological zones of Nigeria. Proceedings of 15 the International Research Conference, Costa Rica; 2006

Page, A. L., R. H. Miller, and D. R. Keeney (1982). Methods of soil Analysis part 2. Chemical and microbiological properties. American plantation ecosystem. Paper submitted for MAB Workshop, Abuja.

properties. Agronomy series No. 9 ASA, SSSA, Madison.

Page, A. L., R. H. Miller, and D. R. Keeney (1982). Methods of soil Analysis part 2. Chemical and microbiological properties. American Society of Agronomy, Madison 55 pp.

Quaye, A. K., Doe, E. K., Attua, E. M., Yiran, G., Arthur, A., Dogbats, J. A., Konlan, S.,

Nkroma, Y. D. and Addo, D. (2021) Geospatial distribution of soil organic carbon and soil pH within the cocoa agroecological zones of Ghana Geoderma, 386 (2021),114921, 10.1016/j.

Ritung, S. W; Agus, F. and Hidayat H. (2007) land suitability Evaluation with a case map of Aceh Barat District. Indonesian soil Research

Smyth, A.J. (1966). The Selection of Soils for Cocoa, Soils Bulletin; No 5, Rome: FAO

Tijani, A.A., Farinde A. and Agboola A. A. (2001). Measuring the impact of Extension on Cocoa Production in Ondo State, Nigeria. *Moore Journal of Agricultural Research, 2: 186-190*

Tiku, N.E. Galadima, M. and Iyala, D. (2006) Scale efficiency of Cocoa production in Cross River State. *Federal University Wukari Trends in Science and Technology Journal Vol. 1 (2)417-422*

Udo, E. J., T. O. Ibia, J. O. Ogunwale, A. O. Ano and I. Esu (2009), Manual of Soil, Plant and Water Analysis, 183pp., Sibon Books Ltd. Lagos.

Verter, N. and Becyarova, V. (2014) Analysis of Some Drivers of Cocoa Export in Nigeria in the Era of Trade Liberalization. Agris On-line Papers in Economics and Informatics 6(4): 208-218.

Wood, G.A.R. and Lass, R.A. (2001) Cocoa, 4th Edition. Blackwell Science Oxford.