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PHYSICAL AND CHEMICAL PROPERTIES OF COCOA GROWING SOILS OF BOKI, CROSS RIVER STATE NIGERIA

[1]Kekong, M. A. and [2]Ndifon, S. O.

Department of Agronomy; Department of Forestry and Wild Life,
Cross River University of Technology, Obubra Campus
Corresponding Authors' email: matikekong @gmail.com

Abstract
Some physical and chemical properties of cocoa growing soils in six cocoa growing communities in Boki, Cross River State, Nigeria were assessed to ascertain their suitability for sustainable cocoa production. Twelve farms were randomly selected in Bunyia, Kakwagom, Ogep-Osokom, Isobendegbe, Bashua and Olum. Twenty four (24) composite representative soil samples were collected from the farms, analysed using standard laboratory procedures. Results show that the soil textural classes ranged from sandy loam to clay loam [sand (58.45%), silt (13.46%) and clay (28.09%)]. The mean values of the chemical properties include: pH (5.56), EC (0.021ds/m), OM (3.24%), TN (0.09%), Av. P (5.77 mg/kg), K (0.12 cmol/kg), exch. Mg (2.06 cmol/kg), exch. Na (0.05 cmol/kg), EA (1.61 cmol/kg), ECEC (9.00 cmol/kg) and Base saturation (81.25%). Total Nitrogen, Exchangeable Calcium, Exchangeable Magnesium and Base Saturation were adequate within and above recommended levels, while Available phosphorus, Potassium, Organic Matter, Electrical Conductivity and ECEC were below critical levels. For increased yields and sustainable cocoa production in Boki, incorporation of organic manure and other residues and application of appropriate rates of phosphorus and potassium fertilizers are therefore recommended.

Keywords: Chemical, Cocoa, Growing, Physical, Properties, and Soils

Introduction

Cocoa is a major cash crop that contributes substantially to the national economy in terms of employment and foreign exchange earnings. The crop ranks first among agricultural export crops in its contribution to foreign exchange earning in Nigeria (Tijani *et al*., 2001). About 34 billion naira is derived annually from cocoa beans export alone, besides revenue from cocoa by-products like butter, cake, liquor and powder (Akinwale, 2006). Nigeria ranks fourth in world's production of cocoa after Corte' Ivoire, Indonesia and Ghana, and third largest exporter (Verter and Becyarova, 2014). Cross River State is the second largest producer of cocoa in Nigeria after Ondo (Iremiren *et al*., 2012). Ikom, Boki and Etung Local Government Areas (LGAs) are the highest producers of cocoa in Cross River State (Tiku *et al*., 2016).

There has been a policy shift by the Nigerian Government in recent years to accord cocoa production which has been hitherto the main stay of our economy the right priority. This policy has been adopted in Cross River State by the Government on her drive in cocoa production through rehabilitation and expansion of existing Cocoa Estates and private farmers' motivation. The ongoing work on the Cross River State cocoa processing factory at Ikom LGA of the State is a booster to the cocoa value chain in the State and for price stabilization of cocoa beans. The contribution of cocoa to the economy has not been stable, part of which is poor yield. The factors responsible for the poor yield include; climate change, poor fertility management and the use of old planting materials. Soil fertility management is one of the major requirements for sustainable agricultural systems in tropical climates. Fernandez and Sanchez (1990) indicated that tropical soils are more diversified than temperate soils. In Nigeria, most soils under cocoa plantations are marginal to moderately suitable in fertility status (Aikpokpodion, 2010).

Comparable studies between uncultivated forest and cocoa growing soils show lower nutrients status in cocoa plantations (Ogunlade *et al*., 2006). This low nutrient status in cocoa plantation soils could be attributed to the high nutrient demand of cocoa trees that produce the beans exported annually, and the low or non-use of inorganic fertilizers to replenish the exported nutrients from the plantation soils. Few and generalized soil studies have been carried out in cocoa producing area of the State. The objective of this study is to evaluate some physical and chemical properties of Boki cocoa growing soils. Such localized assessment of location-specific soil information will serve as guide for recommendations of appropriate soil and fertilizer management practices for sustainable cocoa production in this area.

Materials and Methods

Study Area

The study was carried out in Boki LGA, Cross River State, Nigeria (Fig.1). Boki lies on latitude 6° 26′N and longitude 9° 36′E within the rainforest belt of Nigeria. The rainfall is bimodal in distribution with a density of 1200mm - 3000mm, and mean annual temperature of 25°C. Boki has a land area of 344,952km^2 with a population of 186,611 as at 2006 (NPC 2006). It is bounded in the North by Obudu, in the West by Ogoja, South by Ikom and Etung, and in the East by a contiguous territory border with Cameroon. Boki bears a National and International reputation for being a major commercial center where forest and internationally agricultural commodities such as: cocoa, timber, and palm products are sourced and supplied for international consumption. Other agricultural crops include: yam, cassava, maize, cocoyam, banana, plantain and vegetables, and non-timber forest products such as: *Gnetum africana*, Cane ropes, sponge, bush mango (Ogbono) and other minor forest products.

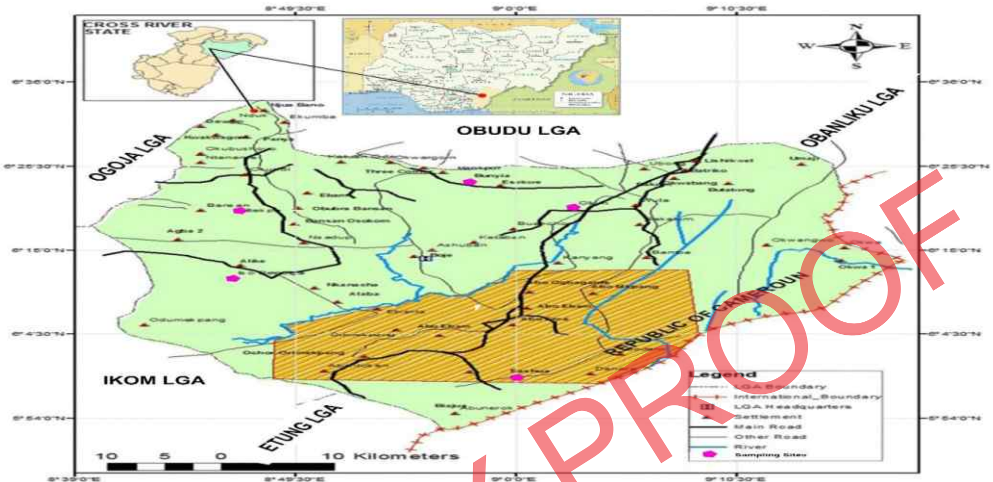

Figure 1: Map of the Study Area

Sampling Design and Soil Sampling

Six major cocoa growing communities were identified as Bunyia, Kakwagom, Ogep-Osokom, Isobendeghe, Olum and Bashua. In each community, two farms were randomly selected making a total of twelve (12) farms. The soil samples were taken from November-December 2016. In each selected Cocoa farm, two quadrats of 50m x 50m were marked. In each quadrat, three (3) representative core samples were collected randomly at depths of 0 – 25 cm and 25 – 50cm using soil auger and bulked together for each depth to form a composite sample. A total of Twenty four (24) representative composite soil samples were collected, bulked and labeled in sampling bags. These were transported to Federal University of Agriculture, Makurdi, Nigeria for standard laboratory analysis.

Soil Analysis

Prior to physical and chemical analysis, the soils were air dried under room temperature, sieved through a 2mm mesh, while those for organic matter and total nitrogen were made to pass through 0.5mm mesh.

Particle size distribution (PSD): This was determined by the Bouyoucos (Hydrometer) method procedure following Udo *et al.* (2009).

Soil pH: This was determined in both water and 0.1 N KCL in a ratio of 1:2 soil: water and 1:2.5 soil: KCl respectively. After stirring the soil suspension for 30 minutes, the pH values were read using the glass electrode pH meter (Mclean, 1982).

Organic Matter: This was determined by the walkley-Black method as outlined by Page *et al*. (1982) which involves the oxidation with dichromate and tetraoxosulphate VI acid ($H_2 So_4$).

Nitrogen in soil: Total nitrogen in soil was determined by the Macro Kjeldahls' method as described by Udo *et al.* (2009). The soil samples were digested with Tetraoxosulphate VI acid ($H_2 S0_4$) after addition of excess caustic soda. This was distilled into a 2% Boric acid (H_3BO_4) and then titrated with 0.01 Hcl.

***Available phosphorus*:** Available P was determined by Bray 1 method as outlined by page *et al*. (1982). This is mechanical shaking of the sample in an extracting solution, then centrifuging the suspension at 2000 rotations per minutes for 10 minutes. Using Ascobic acid method, the percentage transmittance on the spectrophotometer at 660 nm wave length was measured.

***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, washed with methyl alcohol and allowed to dry. The soil was then distilled in Kjeldahl operation into a 4% Boric acid solution. The distillate was 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, and 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

Results of the particle size distribution and textures presented in Table 1 show that soils of Boki cocoa farms vary in their soil separates. Sand composition of Bunyia soils ranged from 48.20 – 74.20% with a mean of 64.15%, silt 12.00 – 15.80% with a mean of 13.60%, and clay 13.00 – 36.00 % with a mean value of 22.25%. The textural classes of the soils ranged from Sandy-clay loam to Clay-loam. In Kakwagom, the percentage Sand ranged from 46.20 - 61.40% with a mean of 51.80%; Silt 14.20 – 15.80% with a mean value of 51.00% and Clay 24.40 – 38.00% with a mean of 33.20%. The soil textures ranged from Sandy-clay-loam to Sandy-clay. The soils of Ogep-Osokom farms had percentage sand that ranged from 58.20 – 72.20% with a mean of 66.20%; Silt 7.80 – 15.80% with a mean value of 10.80%, while the Clay ranged from 18.00 – 32.00% with a mean of 23.00%. The soil textures of this location ranged from Sandy-clay-loam to Sandy-loam. The soils of Isobendeghe in Boje clan had a percentage sand composition of 40.20 – 58.20 with a mean of 51.15%; Silt 5.80 – 23.80% with a mean of 15.35% and the clay ranged from 26.00 – 36.00% with a mean value of 33.50%. The textures of all the soils were Sandy-clay loam.

In Bashua of Abo clan, the percentage Sand composition of the cocoa farm soils ranged from 59.20 – 80.00% with a mean 67.80%; Silt ranged from 10.00 – 13.2% with a mean value of 11.30% and Clay from 10.00 – 27.60% with a mean of 20.75%. The cocoa farm soils in Bashua ranged from Sandy-loam to Loamy-sand. The soils of cocoa farms in Olum (Eastern Boki Clan) contained a percentage sand composition of the separates from the range of 40.20 – 58.20 with a mean of 49.60%; silt 5.80 – 23.8 with a mean value of 14.70cm, while the clay percentage range from 34.80 – 36.00% with a mean value of 35.70%. The soil textures of these cocoa farms ranged from Sandy-clay to Clay-loam.

Boki cocoa farm soils ranged from Sandy-loam to Clay-loam. Five soil textural classes of Sandy-loam, Loamy-sand, Sandy-clay-loam, Sandy-clay and Clay are common in the Boki cocoa farm soils. This variability in texture within the area is an indication of the dynamic nature of soil which is universal. The difference in textures of Boki cocoa farms soils follows the findings of Brady and Weil (2014) who noted that soil is the most heterogeneous material on earth's surface as almost every one meter square brings observable change in properties. The textures of Boki cocoa growing soils show a bearing with their parent materials which is in line with the study of Amajor (1989), whose findings indicated that geology of Central Cross River State, where Boki is located, comprised majorly of sand stone, silt, basalt and basement complex. As a factor in soil formation, parent materials give greatest imprint in the texture of the soil. Soil texture is a very important property of soils as it regulates moisture, nutrients and pollutants movement in the soil environment. The textural classes of Boki soils are within the range recommended for cocoa production by Anim-Kwapong and Frimpong (2004) who stated that a model profile of cocoa growing soil should be deep and well drained with sandy-clay layer. Ritung *et al.* (2007) recommended deep soil characterized by sandy-clay, clay and silty-clay textures.

Chemical Properties of the Soils

The chemical properties of Boki cocoa farms in Tables 2 and 3 show that the pH of Bunyia cocoa soils ranged from 5.8 to 6.10 with a mean of 5.45, while Kakwagom cocoa farm soils range of 4.90 to 6.00 with a mean of 5.45. The pH of Ogep-Osokom cocoa farm soils ranged from 5.00 – 5.60 with a mean of 5.45. For Isobendeghe, the pH ranged from 5.40 to 5.70, with a mean of 5.58. In Bashua and Olum cocoa farm soils, the pH ranged from 5.20 to 5.30 with a mean of 5.25, and 5.60 to 6.00 with mean of 5.73 respectively. The electrical conductivity (EC) of the soils in Bunyia ranged from 0.021 to 0.031ds/m with a mean of 0.025ds/m; Ogep-Osokom 0.017 to 0.021ds/m with a mean 0.019ds/m; Isobendeghe 0.016 to 0.024ds/m with a mean of 0.020ds/m. Organic matter (OM) in the cocoa farms ranged from 2.55 to 5.57% with a mean of 4.05% in Bunyia; 2.30 to 5.57% in Kakwagom with a mean of 3.41%. In Ogep-Osokom, OM ranged from 2.04 to 3.75% with a mean of 2.63%; Isobendeghe 3.13 to 3.58% with mean of 3.29%; Bashua 2.21 to 3.33% with mean of 2.83% and in Olum 2.72 to 3.58% with a mean of 3.19%. Total Nitrogen (TN) ranged from 0.07 to 0.12% (mean 0.10%) in Bunyia; 0.06 to 0.09% (mean 0.08%) in Kakwagom; 0.05 to 0.09% (mean 0.07%) in Ogep; 0.07 to 0.10% (mean 0.08%) in Isobendeghe; 0.06 to 0.10% (mean 0.08%) in Bashua and 0.06 to 0.10 with mean of 0.09 in Olum. Available Phosphorus (Av. P) in the soils ranged from 3.80 to 5.80mg/kg (mean 4.65mg/kg) in Bunyia, 1.33 to 14.67mg/kg (mean 4.88mg/kg) in Kakwagom, while in Ogep-Osokom 3.00 to 9.17mg/kg (mean 6.30mg/kg). It ranged from 2.50 to 22.01mg/kg (mean 8.10mg/kg) in Isobedeghe; 3.40 to 5.10 (mean 4.28mg/kg) for Bashua and Olum 4.84 to 9.17mg/kg (mean 6.32mg/kg).

Result of exchangeable cations and base saturation presented in Table 3 shows that Exch. K in the soils ranged from 0.11 to 0.13cmol/kg (mean 0.12 cmol/kg) for Bunyia; 0.10 to 0.15cmol/kg (mean 0.13 cmol/kg) for Kakwagom. It ranged from 0.10 to 0.14cmol/kg (mean 0.12 cmol/kg) for Ogep. Soils of Isobendeghe ranged from 0.09 to 0.12cmol/kg (mean 0.10 cmol/kg). Those of Olum ranged from 0.12-0.17cmol/kg (mean 0.15 cmol/kg). Exch Ca for the cocoa farm soils ranged from 4.80 to 5.40cmol/kg (mean 5.15 cmol/kg) for Bunyia; 4.00 to 6.40cmol/kg (mean 5.15 cmol/kg) for Kakwagom. It ranged from 5.20 to 6.00cmol/kg (mean 6.20 cmol/kg) for Ogep-Osokom soils, while in Isobendeghe it ranged from 4.40 to 600cmol/kg (mean 5.10cmol/kg) and 5.20 to 5.60cmol/kg (mean 5.40 cmol/kg) for Bashua, as the value for Olum ranged from 4.00 to 6.00cmol/kg with a mean of 5.00 cmol/kg. The soils studied showed that Exch Mg was 1.40 to 2.40cmol/kg (mean 2.00 cmol/kg) for Bunyia; 1.30 to 2.40cmol/kg (mean 1.92 cmolkg) for Kakwagom and 2.20 to 3.00cmol/kg (mean 2.52 cmol/kg) for Ogep-Osokom. The values were 1.60 to 2.70cmol/kg (mean 1.92 cmol/kg) for Isobendghe; 1.90 to 2.10cmol/kg (mean 2.00 cmol/kg) for Bashua and for Olum 1.60 to 2.70cmol/kg (means 2.03 cmol/kg). Effective Cation Exchange Capacity (ECEC) for the soils ranged from 8.37 to 9.47 cmol/kg with a mean of 8.80 cmolkg for Bunyia; 5.80 to 10.54cmol/kg (mean 8.46 cmol/kg) for Kakwagom; 9.38 to 12.65 cmol/kg with a mean of 10.55 cmol/kg for Ogep and for Isobendeghe 7.37 to 10.62cmol/kg (mean 8.62 cmol/kg). The soils of Bashua ranged from 8.83 to 9.37cmol/kg (mean 9.13 cmol/kg), while for Olum soils was 7.37 to 10.62cmol/kg (mean 8.84 cmol/kg). Content of the soils studied showed that the Base Saturation (BS) of the soils ranged from 82.27 to 83.68% (mean 83.00%) in Bunyia; 70.34 to 84.82% (mean 78.58%) in Kakwagom, while the value for Ogep-Osokom ranged from 81.88 to 88.14% (mean 84.11%). For Isobendghe, the values ranged from 78.66 to 83.71 (mean 80.67%), while Bashua was 83.00 to 83.56 (mean 83.29%) and Olum had a base saturation range of 78.02 to 83.70 (mean 80.92%).

The pH range for Boki cocoa farm soils ranged from 4.9-6.10 with a mean of 5.6 falls within moderately and slightly acidic. The mean pH value for Boki soils and the ranges for all the farms are suitable for cocoa growing as these are within the recommended pH of 5 - 8 by Ibiremo *et al.* (2011). The chemical properties of Boki cocoa farm soils with the exception of N, Ca, Mg and Base Saturation were below the critical value for cocoa growing. Although the TN range for the soils was wide, the mean for all the soils of 0.09% was within the limit for the element as recommended by Egbe *et al.* (1987) and Aikpokpodion (2010). The N in the soils could have been a product of organic matter mineralization. Hartemink (2005) had stated that N in litter of cocoa farms is higher than the N exported from cocoa beans. The exchangeable Ca content of all the cocoa farm soils were adequate for cocoa production as all their mean values were above the critical limit of 5.00cmol/kg as recommended by Smyth (1966) and Ibiremo *et al.* (2011). The concentration of Ca in Boki soils is in agreement with Ipinmoroti *et al*. (2009) who noted that Ca deficiency in Nigeria cocoa soils is rare. The exchangeable Mg concentrations in all the cocoa farm soils were higher than the critical limit of 0.9 cmol/kg as stated by Ipimoroti *et al.* (2009). The high content of Mg in Boki cocoa farm soils, however, is contrary to the earlier findings of Obatolu and Chude (1987) who reported that Nigeria cocoa soils are generally deficient in Mg. The base saturation of all the investigated soils was higher than the critical level of 60% (Ibiremo, 2011) for good cocoa production. The base saturation of these cocoa farm soils indicate promising suitability as aluminum toxicity is not envisaged in the soils. Brady and Weil (2014) stated that non-acid saturation (≥80%) will not likely be a problem of Al toxicity. Available P and exchangeable K in all the cocoa farms were below the critical limits of 10mg/kg and 0.25 cmol/kg respectively as reported by Ogunlade and Aikpokpodion (2006). The low P and K of Boki cocoa farm soils is similar to the levels of these elements in Etung cocoa farms soils of the same agro-ecological zone as reported by Ajiboye *et al*. (2015). Application of these elements through inorganic fertilizer is required to improve the yield of cocoa in Boki. The low OM and EC levels of the cocoa farm soils were below the critical limits as established and recommended by Ibiremo *et al*. (2011) for cocoa producing soils. The low EC indicate low concentration of soluble salts (Brady and Weil 2014). The implication of low OM is the low availability of adequate organic based nutrients especially P and N from native organic sources through mineralization. Hartemink (2005) observed that larger amount of P is removed by cocoa beans, while Ogunlade and Aikpokopdion (2006) reported that leaf litter in cocoa plantations was not sufficient to supply P required by cocoa trees for optimal yield. This then calls for supplemental nutrients intervention with appropriate fertilizers in Boki cocoa soils if production is to be sustained.

Conclusion

The textural classes of soils of Boki cocoa growing areas were found to the suitable for the growth of cocoa trees as these textures will ensure optimum movement of water and nutrients in the soils. The adequate base saturation above critical limits including Ca and Mg is an indication of the soils capacity to adsorb additional external nutrients for quality cocoa production. The low levels of P, K and OM could be supplemented with inorganic fertilizers to meet the high nutrients demand of cocoa trees. Incorporation of organic manures and other residues and application of appropriate rates of phosphorus and potassium are recommended to ensure increased yields and sustainable production of cocoa beans.

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Table 1: Particles Size Distribution and Textures of Boki Cocoa Soils

Location	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Texture
Bunyia I	0 - 25	74.20	12.80	13.00	LS
	25 - 50	72.00	12.00	16.00	SL
Bunyia II	0 - 25	62.20	13.80	24.00	SL
	25 - 50	48.20	15.80	36.00	SCL
Kakwagom I	0 – 25	61.40	14.20	24.40	SCL
	25 - 50	53.40	14.20	32.40	SCL
Kakwagom II	0 - 25	48.20	14.80	37.00	SC
	25 – 50	46.20	15.80	38.00	SC
Ogep-Osokom I	0 – 25	58.20	9.80	32.00	SCL
	25 - 50	64.20	15.80	20.00	SL
Ogep-Osokom II	0 - 25	72.20	9.80	18.00	SL
	25 - 50	70.20	7.80	22.00	SL
Isobendeghe I	0 – 25	58.20	5.80	36.00	SCL
	25 - 50	48.20	15.80	36.00	SCL
Isobendeghe II	0 - 25	58.00	16.00	26.00	SCL
	25 - 50	40.20	23.80	36.00	SCL
Bashua I	0 – 25	68.00	12.00	20.00	SL
	25 - 50	59.20	13.20	27.60	SCL
Bashua II	0 - 25	80.00	10.00	10.00	LS
	25 – 50	64.00	10.00	10.00	SCL
Olum I	0 – 25	58.20	5.80	36.00	SC
	25 - 50	48.20	15.80	36.00	CL
Olum II	0 - 25	51.80	13.40	34.80	CL
	25 – 50	40.20	23.80	36.00	CL

S= Loamy-Sand, SL=Sandy-loam, SCL=Sandy-Clay-Loam, SC=Sandy-Clay, CL=Clay-Loam

Table 2: Chemical Properties of the Soils

Location	Depth (cm)	PH	EC (ds/m)	OM (%)	T.N (%)	Av. P (Mg/kg)
Bunyia I	0 – 25	6.00	0.023	5.57	0.11	3.80
	25 - 50	5.80	0.021	2.55	0.08	4.60
Bunyia II	0 - 25	6.10	0.031	4.25	0.12	5.80
	25 – 50	5.90	0.024	3.84	0.07	4.40
	Mean	5.95	0.025	4.05	0.10	4.65
Kakwagom I	0 – 25	5.00	0.014	3.23	0.09	1.33
	25 - 50	4.90	0.023	2.30	0.07	14.67
Kekwagom II	0 - 25	6.00	0.023	5.57	0.09	1.84
	25 – 50	5.90	0.021	2.55	0.06	1.66
	Mean	5.45	0.020	3.41	0.08	4.88
Ogep-Osokom I	0 – 25	5.00	0.016	3.23	0.08	4.84
	25 - 50	5.60	0.020	3.24	0.07	22.01
Ogep-Osokom II	0 - 25	5.60	0.026	3.13	0.08	3.40
	25 – 50	5.60	0.024	3.58	0.10	2.50
	Mean	5.58	0.022	3.29	0.08	8.10
Bashua I	0 – 25	5.30	0.011	3.33	0.10	5.00
	25 - 50	5.20	0.022	2.21	0.08	3.40
Bashua II	0 - 25	5.30	0.020	3.23	0.09	5.10
	25 – 50	5.10	0.021	2.55	0.06	3.62
	Mean	5.22	0.019	2.83	0.08	4.28
Olum I	0 – 25	5.70	0.016	3.23	0.08	4.84
	25 - 50	5.60	0.020	3.24	0.07	5.84
Olum II	0 - 25	6.00	0.021	2.72	0.06	9.17
	25 – 50	5.60	0.024	3.58	0.10	5.42
	Mean	5.73	0.020	3.19	0.08	6.32

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

Table 3: chemical properties of the soils

Location	Depth	K	Ca	Mg	Na	EA	ECEC	BS
	(cm)			Cmog/kg				%
Bunyia I	0 – 25	0.12	5.40	1.4	0.05	1.40	8.37	82.27
	25 - 50	0.13	5.10	2.0	0.04	1.50	8.77	82.90
Bunyia II	0 - 25	0.11	5.30	2.4	0.06	1.60	9.47	83.10
	25 –50	0.13	4.80	2.2	0.05	1.40	8.58	83.68
	Mean	0.12	5.15	2.00	0.05	1.48	8.80	83.00
Kakwagom I	0 – 25	0.13	4.60	1.30	0.05	1.72	5.80	70.34
	25 - 50	0.15	4.00	1.60	0.05	1.80	7.60	76.32
Kakwagom II	0 - 25	0.10	6.40	2.40	0.04	1.60	10.54	84.82
	25 –50	0.13	5.60	2.40	0.06	1.70	9.89	82.81
	Mean	0.13	5.15	1.92	0.05	1.71	8.46	78.58
Ogep-Osokom I	0 – 25	0.10	8.00	3.00	0.05	1.50	12.65	88.14
	25 - 50	0.11	5.60	2.20	0.06	1.60	9.58	83.30
Ogep-Osokom II	0 - 25	0.12	5.20	2.30	0.06	1.70	9.38	81.88
	25 –50	0.14	6.00	2.60	0.07	1.79	10.60	83.11
	Mean	0.12	6.20	2.52	0.06	1.65	10.55	84.11
Isobendeghe I	0 – 25	0.12	6.00	2.70	0.07	1.73	10.62	83.71
	25 - 50	0.09	4.80	1.60	0.06	1.62	7.37	78.02
Isobendeghe II	0 - 25	0.10	5.20	1.80	0.06	1.54	8.70	82.30
	25 –50	0.09	4.40.	1.60	0.03	1.66	7.78	78.66
	Mean	0.10	5.10	1.92	0.05	1.64	8.62	81.25
Bashua I	0 – 25	0.16	5.20	1.90	0.07	1.50	8.83	83.11
	25 - 50	0.17	5.60	2.00	0.06	1.54	9.37	83.56
Bashua II	0 - 25	0.13	5.40	2.10	0.05	1.52	9.20	83.48
	25 –50	0.12	5.40	2.00	0.05	1.55	9.12	83.00
	Mean	0.15	5.40	2.00	0.06	1.53	9.13	83.29
Olum I	0 – 25	0.12	6.00	2.70	0.07	1.73	10.62	83.71
	25 - 50	0.09	4.00	1.60	0.06	1.62	7.37	78.02
Olum II	0 - 25	0.11	5.60	2.20	0.06	1.60	9.58	83.30
	25 –50	0.09	4.40	1.60	0.03	1.66	7.78	78.66
	Mean	0.10	5.00	2.03	0.06	1.65	8.79	81.38

EA= Exchangeable acidity, BS= Base Saturation, ECEC= Effective Cation Exchange Capacity