THE EFFECTS OF SOIL VARIATION ON CASSAVA PRODUCTION IN COASTAL AND HINTERLAND AREAS OF SOUTHERN CROSS RIVER STATE, NIGERIA: A COMPARATIVE ANALYSIS

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Abstract

This study examined the edaphological requirements of cassava in the coastal and hinterland areas of Southern Cross River State, Nigeria with the aim of identifying major soil properties determining cassava yield and drew a comparative analysis of cassava yield between the two areas. The data used in the study was based on soil samples from peasant cultivated cassava farms that are uniform in terms of cultivars, planting density, NPK fertilizer application and weeding between the 6th and 12th weeks after planting. Soil samples were collected from top soils (0-15cm) and subsoil (15-30cm) analyzed for soil properties using standard method. Ten cassava plots of 10m^2 were randomly selected from an area of 10,000m^2 for cassava yield analysis. The yield parameter was then related to the soil properties using Pearson's Moment Correlation and multiple regression as well as student's 't' test. The mean cassava yield in the hinterland (49.71ton^{-1}) was significantly higher than in the coastal area (29.11 ton^{-1}) ($P<0.05$). The soil properties that mostly influenced cassava tuber-yield in the hinterland area are calcium (r=-0.66), pore space (r=0.85) and organic matter (r=0.77) while in the coastal area, moisture content (r=-0.99),total nitrogen (r=0.98) and silt (r=0.86) are the soil properties that influenced cassava tuber-yield. The study has shown that the hinterland area is more suitable for cassava production than the coastal area due to the well drained nature of the soil. There is the need for an appropriate soil management strategy through liming and fertilizer application to boost cassava production in the coastal area.

Keywords: Soil Variation, Cassava Production, Coastal and hinterland, Cross River State.

1. INTRODUCTION

Since the beginning of the 21st century, cassava (*Manihot esculenta*) has assumed prominence as a food and industrial crop resulting in the continuous use of the soils in most parts of Cross River State for cassava production.

It is no doubt that there exists a close relationship between soils and plants. That is to say, soils and plants are closely related and are associated with one another in the peoples mind (Areola, 1983).The plants cover has always served as an indicator of soil status for the local people in their agricultural and other primary production activities.

Areola, (1978) also observes that in the absence of animal manure and chemical fertilizers, Nigerian famers have traditionally depended on the plant (bush fallow) for the restoration of soil fertility after each period of use. Hence, the impact of man's activities on either of the two elements (soil or plant), has often had repercussions on the other. The delicate balance between them necessarily places limitation on the part of the people has often led to series environmental problems.

Schumacher et al., (1999) in their study of modeling spatial variation in productivity due to tillage and water erosion observed that in undulating landscapes, water erosion induced large variability in soil productivity. Kosmas et al., (2001) reveled in their studies that spatial variability in crop yields and crop quality are linked to spatial variability in soil quality indicators. That exception to this variation is attached to changes induced by soil translocation through tillage.

Also, within-field variability in soil parameters have been reported to affect yield Cox et al., 2003; Johnson et al., 2002; Stewart et al., 2002; Kravchenko et al., 2003; Eludoyin, 2008; Abua, 2012; Abua and Essoka, 2014). In addition, Essoka and Namaku (2007) investigated variation of soil along a toposequence in a Northern Guinea Savanna Region in Nigeria. Their study showed that general pattern of particle size distribution at the downslope decreases in the coarseness of the soils as sand content decreases from crest to valley bottom respectively for forest soils. Also that the proportion of sand decreased with increased soil depth except at the valley bottom where clay distribution was rather uniform in all horizons. The studies above however, have a regional and ecological bias as none examines critically variation in crop yield in the coastal and hinterland areas. Another factor, which stimulate the researchers' interest, is that none of the studies above attempt to draw a comparative analysis of crop yield in the coastal and hinterland areas with both soils of the same sedimentary origin but of different formations, hence the thrust of this study.

2. **AIM AND OBJECTIVES**

The aim of the study is to examine a comparative analysis of cassava yield in the coastal and hinterland soils of the same parent material but of different formations. The objectives are;

- To examine the physico- chemical characteristics of soils in the area.
- To examine the relationship between soil properties and cassava yield in the study area.
- To assess the difference in crop yield between the coastal and hinterland areas and
- To suggest ways of improving the soil macro nutrients to boast cassava production in the area.

3. MATERIALS AND METHOD

STUDY AREA

The study sites are located in Akpabuyo and Bakassi representing hinterland and Coastal soils respectively in Akpabuyo and Bakassi Local Government Area of Cross River State, Nigeria. Akpabuyo Local Government Area is located on longitude $8^0$20'E and $8^0$40'E and Latitude $4^0$45'N and $5^0$10'N of the Greenwich Meridian (Fig. 1). Bakassi Local Government Area is found along the Cross River estuary located at the south-east bank of the estuary characterized by Mangrove swamps soil while Akpabuyo L.G.A. extends from the Great Kwa River along the "Atimbo" bridge head characterized by tertiary coastal plain sand of Pleistocene era while those of Bakassi are formed from alluvium in the quaternary period. Both soils are of the same geologic material of sedimentary origin.

The soils of the sampled farms are all Entisols developed from the deposition of marine organisms and fluvio-deltaic sands of the Awi formation in the early cretaceous time (probably apticen).

Soils of Akpabuyo are strongly weathered with coarse to fine sand texture ib both the surface and subsurface soils. They are characterized by low contents of orgaanic carbon, total nitrogen, exchangeable bases and high contents of available. Phospherous being soils in the humid climate environment, they are highly leacheed and therefore acidic in reaction. The soils support most arable (cassava, yam, cocoyam, vegtable among others) crops alongside tree crops such as oil palm, rubber and kolanut. Cropping in the area is intensive, particularly cassava under subsistence cropping system.

The area experience mean annual rainfall of 4021mm, raining throughout the year with peeaks from May to August (1880mm) while the lowest vaaluess (240mm) occur from December to February. Moreso, the mean number of rainy days is about 200. In sum the rainfall pattern has two peaks in June and Septembers.

Temperature in the study area is generally high with a diurnal range of 21^0c – 29^0c. Relative humidity is also high with most months of the year recording a monthly mean value of 80% except in December and January when valuees of less than 60% could be recorded.

Soil samples were collected from nine peasant cultivated cassava farms in the coastal and hinterland areas of Cross River State, Nigeria. The farms were uniform in terms of cultivars, planting density, NPK fertilizer application and weeding between the 6^{th} and 12^{th} weeks after planting. From 9 randomly selected cassava farms in each of the 16 coastal and 16 hinterland areas, soil samples were collected from top soils (0-15cm) and sub-soils (15-30cm) and analyzed using standard methods as outlined by Isodje (2003). Ten cassava plots from an estimated area of one hectare (1ha) with matured cassava plants were chosen randomly. At each sampling unit an area of $100m^2$ was marked out by measuring a dimension of 10m x 10m with a measuring tape. The number of cassava stends within the $100m^2$ area were counted and recorded. All the cassava stands in each farm were harvested and fresh tuber bulked together in sack and then weighed with a manual weighing balanace and mean weight in kg determine. The mean yield for each of the sites (plots) were evaluated.

4. Laboratory Analysis

The soil samples were air-dried grinded and sieved through a 2mm sieve. Particle size was determined by the hydrometer method (Juo, 1979). Soils reaction (pH) was determined in 1:2 soil/water rtio by use of glass electrode pH meter. Organic carbon was determined by the Walkley and Blck (1934) method while total nitrogen was by Kjeldale digestion methods. Available phosphorus was determined by the Bray No. 1 method. Exchangeable cations were extracted with IN NH_4OAC (pH:7); Calcium (Ca) and Magnesium (Mg) were determined by the

EDTA titration method while Potassium (K) abd Sodium (Na) were determined with a flame of photometer (Black et al., 1973). Exchangeable acidity (H^+ and AI^{3+}) were determined by leaching the soils with IMKCI and titrating aliquots with 0.01M NaOH. Effective Cation Exchange Capacity (CEC) was determined by ammonium ion displacement method whereby IN NH_4OAC, pH 7.0 was used as the exxtracting solution (Black et al., 1973) while base saturation was estimated by dividing the total exchangeable bases (Ca, Mg, K and Na) by the cation exchange capacity (CEC) obtained by NH_4OA6 and the result multiple by 100, given the equation thus:

$$BS = \frac{TEB}{ECEC} \times 100$$

Where

TEB = Total exchangeable bases

ECEC = Effective cation exchange capacity

BS = Base saturation

5. Procedure for Data Analysis

Both descriptie and inferential statistics were used to analyse the data. Descriptive statistics such as mean, standard deviation (S.D) and coefficient of variation (C.V) were employed. Inferential statistics such as the Pearson's Product Moment Correlaation and teh multiple regression model were used to investigate the nature of the relationship between cassava yield and soil properties in the study areas. The Pearson's product correlation formulae is given as thus:

$$= \frac{1/n\,(x - \bar{x})\,(y - \bar{y})}{(ðx)\,(ðy)} \quad \text{...} \quad \text{(equ. 1)}$$

Where:

r = correlation coefficient

x and y = the variables of interest

ð = standard deviation

y = crop yield

x = soil properties.

The multiple regression model is given by:

$Y = a + b_1x_1 + b_2x_2 + bixi + e$ .... (equ. 2)

Where:

y = the independent variable (soil properties)

a is the intercept

xj is the dependent variable (crop yield)

bj are the regression coefficient and

e is the error term

Furthermore, the student 't' test was also used to compare the yield of –cassava in the hinterland (Akpabuyo) and coastal (Bakassi) study areas and is given as:

$$t = \frac{\left| X_1 \; X_2 \right|}{\sqrt{\frac{ð_1}{n_1} + \frac{ð_2}{n}}}$$

where:

$\bar{x}_1$ and $\bar{x}_2$ are the means of sample 1 and 2 respectively

$ð_1$ and $ð_2$ are the population standard deviations, n_1 and n_2 are the sample sizes.

6. RESULTS AND DISCUSSION

Physico-chemical characteristics

In the hinterland area, the soils are moderately coarse-textured in the surface while the subsurface has slight accumulation of fine clay fraction. With high sand fraction exceeding 70%, mean silt content below 15%, the soil have weak surface aggregation (FMANR, 1990). Such soil may lack adsorptive capacity for basic plant nutrients and may be susceptible to erosion menace (FPDD, 1990). In the coastal area, the sand fraction accounted for more than 50% in both top and subsoil. With silt fraction greater than 15% for both top and subsoils indicating that the soils have strong surface aggregation and may not be vulnerable to erosion hazard (FMANR, 1991; Obi, 1984; Opuwaribo, 1992).

The mean surface and subsurface values for bulk density in the hinterland (1.18mgm^{-3} and 1.42mgm^{-3}) and its corresponding pore space of 55.51% and 62.26% respectively reflect the textural classes of the study sites. Being soils with weak surface aggregation, adequately aerated and good drainage conditions, it is recommended for the cultivation of arable crops including cassava production (Donabue and Miller, 1995; Arshad et al., 1996; Abua & Essoka, 2014) while in the coastal area, the mean values for bulk density are 1.22 and 1.54mgm^{-3} for surface and subsurface soils respectively. In the hinterland area, moisture content increases with depth in both the surface and subsurface soils from 10.63 to 19.20% and 8.19 to 19.42% respectively. Such moisture levels are moderate for crops production in the ecological zone (Anikwe, 2006) while in the coastal area, moisture contents of the study site under investigation ranged from 25.28 to 51.70 with mean of 32.71 and 24.91 to 53.21 with mean of 33.52 respectively in the surface and subsurface soils (Table i). Such moisture contents are appreciable though may be lethal to some arable crops in the ecological zone (Anikwe, 2006).

The soil reaction in the hinterland is acid with means of 5.3 and 5.2 in the surface and subsurface soil respectively. The standard deviation and the coefficient of variability ranged from 0.24 to 0.18% and 4.52 to 3.46% in surface and subsurface soils respectively. Such pH condition of the soils could be attributed to high rainfall exceeding 3500mm per annum, could leach out basic cations from the soil solumn in the study area (Bulktrade, 1990; Stoorvogel et al., 2002). Such soil condition could induce phosphate fixation and reduce the ability of micro organisms to fix atmospheric nitrogen. Thus, the range of pH could influence the solubility of nutrients and biochemcial transformation with avaailability of caalcium, magnesium and phosphors (Anikwe, 2006). In the coastal area the soil pH is strongly acidic with means of 3.5 and 3.1 respectively in surface and subsurface soils, the standard deviation (SD) and the coefficient of variability (CV) of 0.78 and 0.46% and 22.27 and 14.71% respectively for surface and subsurface soils.

In the hinterland area, electrical conductivity (EC) values ranged from 0.030 to 0.88dSm^{-1}(surface) and 0.011 to 0.078dSm^{-1}(subsurface). The electrical conductivity values in the surface and sub-surface soils were within the critical value of 2dSm^{-1} for sensitive crop species (FAO, 1990) and 4dSm^{-1} for identifying the soils as saline soils (Donahue, et al., 1990). This results suggest that the soils do not have salinity problem. Organic carbon had mean values of 7.95 and

7.6% for surface and subsurface soils respectively. Total nitrogen contents for surface and subsurface soils had means of 0.08% and 0.05% respectively with (SD = 0.02) in both surface and subsurface soils. Available phosphorus (means = 28mgkg^{-1} and 41mgkg^{-1}) surface and subsurface soils respectively with SD of 18.08 surface and 18mgkg^{-1} subsurface soils and (CV = 52.70% and 21.92%) surface and subsurface soils respectively. Whereas in the coastal area the EC values varies from 0.88 to 30.65dsm^{-1} (surface soils) and 38.70 dsm^{-1}(subsurface soils). The mean values of EC in th coastal area are 15.47 and 18.66 dSm^{-1} respetively for top and subsoils as such soil has salinity problem as thesse values are (>4dSm^{-1}). Organic Carbon Contents with mean values of 1.83% and 0.65 for surface and subsurface soils respectively. The soils are rated modium (moderate) in organic matter of contents as most values are below 2.0% (FPDD, 1990). According to (Donahue et al., 1990), soils of southern Nigerria have low values of organic matter which range from between 0.12 – 2.73 perrcent. The foregoing results are consistent with range of soil organic matter (8.81 – 18.28%) for surface and (9.49 – 20.9%) for subsurface. Therefore, such level of organic matter content could sustain intensive cassava production and other agronomic crops in the ecological zone. Total nitrogen had means of 0.72% and 0.73% respectively for surface and subsurface soils with SD = 0.18 surface and 0.12 for subsurface soils. The available p (means = 5mgkg^{-1} and 6mgkg^{-1}) for surface and subsurface soils respectively with SD = 0.73 =0.80, CV = 30.05, SD = 2.64 and 1.31 with the corresponding CV of 52.70% and 21.92% respectively. In the hinterland area, exchangeable bases were as follows: Ca with means of 2.44 cmolkg^{-1} and 2.33 cmolkg^{-1}, mg (means = 1.15 and 1.08 cmolkg^{-1}), k (means = 0.14 and 0.10 cmolkg^{-1}), Mg (means = 0.06 and 0.05 cmolkg^{-1}) in both the surface and subsurface soils respectively. Exchangeable bases contents of soils in the hinterland include Ca (means = 9.54 and 9.99 cmolkg^{-1}), k (means = 0.10 and 43.01), Na (means = 0.30 and 0. 55 cmolkg^{-1}) and Mg (means = 59% and 55% for surface and subsurface soils respectively. Basic cations (Na, K, Na and mg) were generally low in the soils as (ECEC) hardly exceeds 10mgkg^{-1} for productive soils (Enwezor et al., 1990). Studies by (Ande, 2011; Anikwe, 2006; Chukwu et al., 2001) also shows that coastal plain soils have low exchangeable potassium in the range of 0.02 to 0.34 cmolkg^{-1} for top and subsoils respectively. The leaching of calcium and magnessium is largely responsible for high acidity in the coastal plain soil. The indirect fertilty effect of the leaching of calcium and magnessium is the rise in the level of exchangeable aluminium which is reflected in the pH of the soil (Juo, 1981).

Base saturation in the hinterland area ranged from 39 to 75% surface and between 36 to 74% subsurface soils with means of 59% and 55% respectively (SD = 12.61 – 10.32; CV = 21.37 – 18.76%) respectively for surface and subsurface soils. The base saturation values for the coastal area varied from 81 to 97% (surface soil) and between 74 to 97 subsoils respectively while the SD = 5.29 and 6.74% and CV = 5.88% and 7.66% for surface and subsurface soils respectively. Base saturation was high (> 60%) in most soil sampled. This indicates that the soil are prolific to sustain arable crop production in the area under consideration. With such level of base saturation, basic nutrients must have occurred in available forms in the soils solution regardless of the mean cation (range: 59 – 55%) reserves in the soils.

Soil-cassava yield relationship

The negative and significant relationships between bulk density and mositure content in soils of the hinterland indicate that increase cassava tuberization leads to a corresponding decrease in bulk density and mositure contents. However, the negative correlation of bulk density to tuber yield indicates that the more compact the soil becomes, the lower the tuber yield of cassava. Similar result was obtained by (Gbadegesin, 1986)] who worked on soils of savanna belt of South-Western Nigeria using maize yield parameters (leaves, leaf area, number of cobs and stem height). Moreso, the negative correlation of moisture content to cassava tuber yield als suggest that decrease in mositure content could enhance tuber yield, as high moisture content would have adverse effect on tubeization.

The positive and significant correlation between soil pH and the tuber suggests the increase of cassava tuber with increase in soil pH. Implications of the relationships are that at low pH values, gave high tuber yield, occassioned by slow mineralization. Albeit pH have been reported to influence nutrient availability and biochemical transformations in soils (Udo et al., 1993). Besides, organic matter, exchangeable K, effective CEC (exception of base saturation, ca; mg, mg:k and c:n ratios) positively and significantly correlate with tuber yield, as an increase in these parameters exert a proportional increase in tuber contents while the reverse is the case for base saturation, ca:mg, mg:k and c:n ratios whose results negatively through significantly correlated with the crop yield. A number of studies have reported similar results see for instance studies by (Gbadegesin, 1986 and Odjugo, 2007) similar results relating cassava tuber in savanna belt of South-western Nigeria and some oil producing communities in Delta State and its environs.

In the coastal area, the significant and negative correlations among particle size fractions (sand, silt and clay), bulk density, moisture content and pore space with cassava tuber-yield suggest that cassava tuber-yield increase with decrease in sand, silt and clay contents, bulk density, mositure content albeit statistically significant at the one percent level. These confirmed earlier results reported by (Gbadegesin, 1986; Odjugo, 2007) of similar crop, excepting the work of (Gbadegesin, 1986) who experimented on maize grain, with satisfactory results though at different ecological and edaphic settings.

Besides, estimates also show wide variations in soils chemical and fertility status. With the exception of total nitrogen and exchangeable sodium, oil pH, organic matter, exchangeable magnesium and exchangeable potassium have strong positive correlations with cassava tuber in the study area. Thus, similar results were reported by (Odjugo, 2007; 2003) using cassava yield though at dissimilar environmentaal and ecological settings.

The pearson's correlation result indentified moisture content ($r = -0.99$), total nitrogen ($r = 0.98$) and silt ($r= 0.86$) as the soil properties that mostly influenced cassava yield in the coastal area. In the hinterland area, calcium ($r = -0.66$), pore space ($r = 0.85$) and organic matter ($r = 0.77$) showed high association with cassava yield (table ii).

Table iii shows differences between the mean annual yields of cassava produced in the hinterland and coastal areas. Result shows that the mean annual yield of cassava in the hinterland (49.71 ton^{-1}) was significantly higher than in the coastal area (29. 11 ton^{-1}) ($p< 0.05$) indicating that the difference (20.60 ton^{-1}) between the mean annual yield of cassava in the two sites was significant (tables iii and iv). The increase in the yield of cassava in the hinterland soils may be ascribed to efficient management practices vis-à-vis adaptability to local cultivars to the terrain conversely, the comparative low yields recorded in the coastal soils may be attributed to the saline nature of the soils, coupled with the high water table, albeit inherently fertile. This limitation, however, is a serious inhabiting factor to crop yield particularly tuber crops which are allergic to the area situated in a hydromorphic environment.

7. SUMMARY AND CONCLUSION

Variation in soil properties influencing cassava production were examineed using the bivariate and multiple regression statistical tools. The results showed that soil pH, total nitrogen, moisture content, bulk density and silt fraction significantly influence cassava yield particularly at the surface soil in both sites. Other soil properrties that substantivelycontributed to cassava yield include exchange acidity, effective CEC, mg:k and carbon-nitrogen ratios at both the surface and subsurface soils. Essentially, the multivariate model gave a better fit, the essence of which it increases the statistical raliability and the theoriticaal plausibility. The soil pH, organic matter contents, soil moisture negatively corrrelated with cassava yield.

The soil organic contents were high in the hinterland and moderate in the coastal area owing to liter fall accumulation in the area, with high contents of fertility parameters namely: c:n ratio, ca:mg, mg:k ratios, the soils are rich in mineral nutrients and can therefore sufficiently enhance cassava production in the ecological zone. Cassava production in the study areas is on the increase, probably on account of the presidential initiative on cassava production in the country and in view of the country's comparative advantage of production capacity, and as a major staple crop in diets of many Nigerians and Africans.

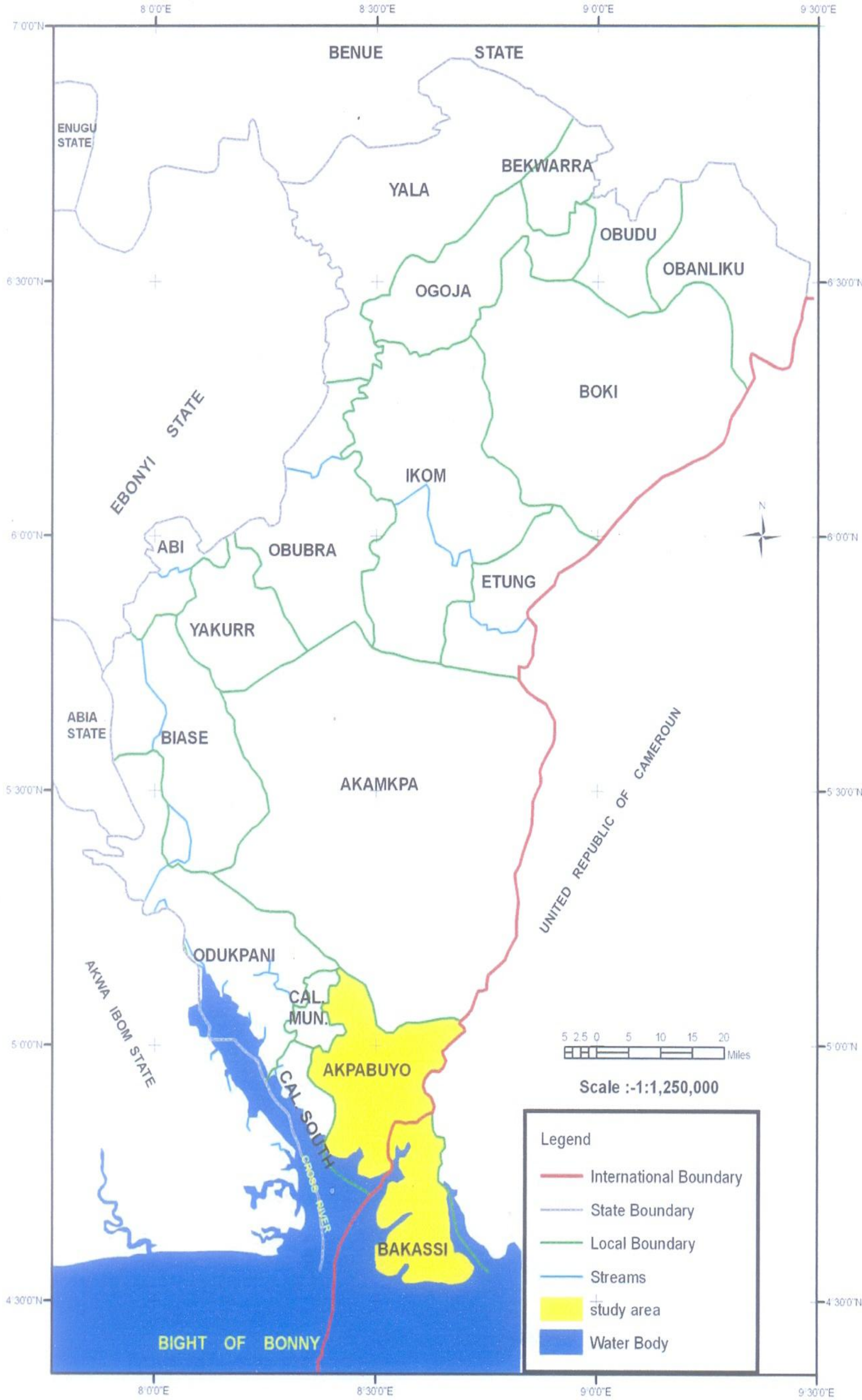

Fig. 1.: Map of Cross River State and parts of Cameroon showing study areas

Table i: Summary results showing variation in physico-chemical characteristics of soils in the Hinterland (Akpabuyo) and Coastal (Bakassi) Local Government Areas, Cross River State

Parameter	Depth (cm)	Akpabuyo Soils Range	Mean	SD	CV (%)	Bakassi Soils Range	Mean	SD	CV (%)	Maximum Permissible limit
A) Physical Parameters:										
(i) Sand (%)	S	78.54-91.56	88.56	3.79	4.30	11.60-68.10	33.72	19.80	58.72	NL
	SS	71.84-89.84	81.98	4.98	6.04	9.40-65.20	29.04	15.25	52.53	NL
(ii) Silt (%)	S	1.88-8.87	4.63	1.96	42.33	19.20-39.60	28.20	6.99	24.81	NL
	SS	3.88-11.78	6.35	1.99	31.34	20.00-42.20	32.91	4.39	13.22	NL
(iii) Clay (%)	S	4.44-19.58	7.54	4.56	60.48	12.70-56.10	38.08	14.78	14.72	NL
	SS	6.38-18.38	11.68	3.41	29.20	14.80-55.20	38.05	12.63	12.63	NL
(iv) Textural Class	S	s, ls, sl	-	-	-	c, l, sl	-	-	-	-
	SS	sl, Is, s	-	-	-	c, cl, sl, l	-	-	-	-
(v) Pore Space (%)	S	1.00-1.30	1.18	0.12	10.21	1.28-1.97	1.78	0.29	16.32	NL
	SS	1.00-1.70	1.42	0.19	13.38	1.10-1.99	1.76	0.29	16.68	NL
(vi) Moisture Contents (%)	S	50.94-62.26	55.51	4.55	8.20	25.28-51.70	32.71	10.96	31.32	NL
	SS	35.85-62.26	46.52	7.13	15.32	24.91-53.21	33.52	11.08	33.04	NL
B) Chemical Parameters:										
(i) pH (H2O)	S	5.0-5.8	5.3	0.24	4.52	2.1-4.6	3.5	0.78	22.27	5.1-6.5
	SS	5.0-5.8	5.2	0.18	3.46	2.0-3.9	3.1	0.46	14.71	
(ii) EC (dSm-1)	S	0.030-0.088	0.054	0.021	38.98	0.88-30.65	15.47	9.27	59.91	2-4dSm-1+
	SS	0.011-0.078	0.023	0.014	59.96	0.89-38.70	18.66	9.09	48.72	
(iii) Org. M (%)	S	9.49-20.07	12.95	1.88	23.70	1.82-4.80	3.83	0.54	29.69	2.0++
	SS	8.81-18.23	9.61	1.56	20.52	0.34-3.08	2.85	0.41	48.30	
(iv) Total N (%)	S	0.05-0.11	0.08	0.02	23.75	0.48-1.11	0.72	0.18	25.44	0.2%++
	SS	0.01-0.09	0.05	0.02	36.37	0.50-1.01	0.73	0.12	16.38	
(v) Avail P (MgKg-1)	S	10-63	28	18.08	64.57	2-9	5	2.64	52.70	2.0MgKg-1+++
	SS	4-80	41	18	44	3-9	6	1.31	21.92	
Exchangeable Bases (cmol/kg-1):										
(vi) Ca	S	1.40-3.40	2.44	0.73	30.05	5.06-14.20	9.54	3.20	33.50	10-20cmol/kg-1+++
	SS	1.00-4.00	2.33	0.80	34.37	5.04-16.87	9.99	3.48	34.84	
(vii) Mg	S	0.50-2.00	1.15	0.43	37.72	9.04-19.21	15.30	3.56	23.26	3-8cmol/kg-1+++
	SS	0.40-1.80	1.08	0.32	29.86	7.81-26.11	16.47	5.73	34.79	
(viii) K	S	0.06-0.27	0.14	0.07	53.03	0.06-0.14	0.10	0.02	21.21	0.6-1.2cmol/kg-

	SS	0.04-0.23	0.10	0.06	55.74	0.04-0.21	0.10	0.04	43.01	1+++
(ix) Na	S	0.04-0.07	0.06	0.11	18.63	0.12-0.61	0.30	0.19	62.59	0.7-1.2cmol/kg-
	SS	0.03-0.08	0.05	0.02	31.29	0.11-1.30	0.55	0.34	61.53	1+++
Exchange Acidity (cmol/kg-1):										
(x) Al3+	S	1.05-2.81	1.69	0.53	31.41	0.24-0.92	0.42	0.22	54.72	4.1cmol/kg-1+++
	SS	0.60-2.85	1.65	0.59	36.03	0.16-0.38	0.26	0.06	22.35	
(xi) H	S	0.30-3.[illegible]	1.14	0.88	77.19	0.18-6.54	0.27	1.88	82.82	2.1-4cmol/kg-
	SS	0.45-1.90	1.14	0.42	36.84	0.69-9.61	3.16	2.25	71.17	1+++
(xii) ECEC (cmol/kg-1):	S	4.54-9.03	6.41	1.52	23.68	16.98-36.08	27.94	6.76	24.19	-
	SS	3.98-9.11	6.33	1.26	19.85	15.84-46.03	30.53	8.47	27.74	
(xiii) Base Saturation (%)	S	39-75	59	12.61	21.37	81-97	90	5.29	5.88	10cmol/kg-1+++
	SS	36-74	55	10.32	18.76	74-97	88	6.74	7.66	
C) Fertility Indices:										60-80%+++
(i) Ca:Mg Ratio	S	1.50-2.86	2.25	0.48	21.16	0.46-0.85	0.62	0.13	20.97	3:1-5:1**
	SS	1.25-2.86	2.15	0.37	17.14	0.36-1.31	0.62	0.65	35.38	
(ii) Mg:K Ratio	S	2.61-22.22	10.20	6.77	66.36	90.40-303-33	157.40	157.40	41.66	1:2**
	SS	1.74-28.00	13.94	6.87	49.28	51.71-452.50	210.49	210.49	56.58	
(iii) C:N Ratio	S	17-25	22	2.78	12.64	7-17	12	12	26.42	25*
	SS	12-25	18	3.92	21.75	7-14	11	11	15.55	

Notes:
S = Surface soils; SS = Subsurface soils; S_1 = Sand; Ls = Loamy sand; sl = Sandy loam + = Miller and Donahue (1995); ++ = FPDD (1990); +++ = Holland *et al* (1989)
ECEC = Effective cation exchange capacity * = Paul and Clark (1989); ** = Landon (1991)
EC = Electrical conductivity NL = No limit

TABLE ii: Results of the correlation analysis relating cassava yield and physico-chemical properties of soils in the study area.

Soil Properties	**Cassava-yield**	
	Coastal	Hinterland
Sand	-0.35	0.10
Silt	0.86*	-0.86*
Clay	0.36	-0.22
BD	-0.12	-0.26
PS	0.14	0.85*
MC	-0.99*	0.32
pH	0.39	-0.34
EC	0.27	-0.45
OM	0.05	0.77*
TN	0.98*	-0.11
AP	0.32	0.20
Ca	0.04	-0.66**
Mg	0.16	0.20
K	-0.26	0.56**
Na	-0.13	0.04
Exch. Acidity	0.52**	0.63**
ECEC	0.31	-0.11
BS	0.33	-0.21
Ca:Mg	0.30	-0.34
Mg:K	0.62*	0.12
C:N	-0.08	0.34

Notes: BD = Bulk density; PS = Pore space; MC = Moisture content; OM = Organic matter; TN= Total Nitrogen; AP = Available phosphorus; ECEC= Effective cation exchange capacity; BS = Base saturation; C:N = Carbon-nitrogen ratio; Ca:Mg = Calcium-Magnesium ratio; Mg:K = Magnesium-Potassium ratio; *= Significant at 5% level; **= Significant at 10% level

Table iii: Comparative Mean Annual Cassava Yield in the coastal andhinterland areas(t-test) (tone/ha).

Descriptive parameters	*Hinterland site*	*Coastal site*
Mean	49.71344444	29.11111111
Variance	414.6974313	82.45528611
Observations	9	9
Pearson Correlation	-0.466121865	
Hypothesized Mean Difference	0	
Df	8	
t Start	2.388633434	
P(T<=t) one-tail	0.021974734	
t Critical one-tail	1.8595488033	
P(T<=t) two-tail	0.043949468	
t Critical two-tail	2.306114133	

Table iv: Comparative Mean Yield in Bakassi and Akpabuyo Sites

Plot/farm	Coastal Site (Tons/ha)	Hinterland Site (tons/ha)
Plot 1	23.610	47.800
Plot 2	21.060	66.120
Plot 3	36.710	23.495
Plot 4	44.340	15.542
Plot 5	31.280	68.422
Plot 6	38.050	74.630
Plot 7	16.490	60.640
Plot 8	25.890	39.820
Plot 9	24.570	50.952
	$\overline{X}$ = 29.11 tons/ha	$\overline{X}$ = 49.71 tons/ha

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