International Journal of Research in Agricultural Sciences
Volume 1, Issue 4, ISSN (Online) : 2348 – 3997)

Soil Properties-Cassava Yield Relationship in the Coastal Ecological Zone of Southern Cross River State, South-South, Nigeria

Abua, Moses Adah and Essoka, Paulin A.
Department of Geography and Environmental Science
University of Calabar, Calabar - Nigeria

Abstract – **The prominence of cassava as a staple food and industrial crop has resulted in the continuous use of soils in the coastal areas of Cross River State for its production. Inspite of the influence of moisture regime on cassava tuberization, relatively few studies have been carried out to identify the soil properties influencing the crop yield. This study was designed to examine soil properties determining cassava yield in the Niger Delta area of Southern Cross River State – Nigeria. Soil samples were collected from nine peasant cultivated farms. Four transects, each 7.0km long were established in the eastern, western, northern and southern directions due to break in slope and creeks of the land terrain. Nine soil profiles comprising two in each direction and the starting point were selected along the transect; soil samples were collected on the identified horizons of the profile pits and were analyzed for physico-chemical properties. Ten cassava plots of 10m^2 were randomly selected from an area of 10,000m^2 for vegetative and yield parameter analysis. These parameters (leaf, stem and tuber) were correlated with soil properties using Pearson's Moment Correlation and multiple regression analysis. The soil properties (top and sub soils) were sand (33.7±19.8% and 29.00.4%), silt (28.2±7.0% and 32.9±4.4%), clay (38.08±14.78% and 38.05±12.63%), organic matter (3.8±0.6% and 2.9±0.4%), and electrical conductivity (15.4±9.3 drm-^{1} and 18.66±9.1dsm^{-1}). The mean cassava yield in the study area was (29.11 ton/ha) at (p>0.05). Moisture content (r=-0.99), total nitrogen (r = 0.98) and silt (r=0.86) had the highest association with cassava leaf, stem and tuber-yield respectively. Fifty percent, 87% and 54% of changes in cassava leaf, stem and tuber-yield were respectively influenced by the combination of soil properties while moisture content (p>0.05), total nitrogen (p>0.05) and silt (p>0.05) exerted the most influenced on cassava leaf, stem and tuber-yield in the study area. An intervention is needed for appropriate soil management strategy to boost cassava production in the area.**

Keyword – **Soil Properties, Cassava Yield, Coastal Ecological Zone, South-South Nigeria.**

I. Introduction

Soil resources constitute one of the most important elements of the natural resource base influencing both the rural and urban aspects of development of an area. The soil for ages has been a major medium for the disposal of a variety of wastes, owing to its colloidal organic matter and other related properties. In additional, whether precipitation takes beneficial or destructive routes on the earth's surface is determined by the properties of the surface horizons of the soil. Soil characteristics influence man's engineering works; for instance in the fields of mining, construction and transportation.Perhaps, the greatest significance attached to soils by most people is its productivity and use for agricultural purposes. Thus, an understanding of soil properties is an essential prerequisite for efficient land utilization, especially for improved production (Gbadegesin, Abua and Atu, 2011; Anikwe and Obi, 1999; Anikwe, 2006; Abua and Ajake, 2013).

Unfortunately, as important as this soil resource is, it has been subjected to grave abuse and misuse as a result of improper planning and land-use development. Many problems such as poor crop yield, flood damages, surface and groundwater pollution and accelerated soil erosion, have been created because of the failure to consider the capabilities and limitations of soils during the planning stages of most development projects (Abua, 2012). Eludoyin (2008) have demonstrated that variability in the yield of crops occurs mainly in relation to specific soil properties. However, the degree of explanation afforded by many of these studies is low, largely because they failed to take into account the complex interactions between the numerous soil variables used in explaining variations in crop yield. This implies that models developed in such studies are partial and inevitably have large margins of error (Briggs, 1981).

Cassava, which originated in Brazil, South America, is one of the most important food crops in West Africa. It is a root tuber and latex-producing plant which reaches a height of 1.8-3.6m, depending on the variety. The tuber is processed to garri, 'tropica'/'masoma' and cassava flour for human consumption. The leaves are cooked and eaten, especially in Sierra Leone, Liberia, Cameroon and parts of Nigeria. Sweet cassava tubers can also be eaten boiled, or boiled and beaten into 'dumboy', as in Liberia and some parts of Cameroon and Nigeria. They can also be fed or boiled to pigs, goats, horse and cattle. The main industrial use of cassava is in the manufacture of starch and alcohol (Komolafe et al., 1985; Iwena, 2007; Abua, 2002). As one of the most productive crops in the world yielding 12544-25099kg of tubers per ha on an average, and up to 30120kg under the best growing condition, because of the high yield, it exhausts the soil in which it is grown, crop rotation as well as fertilizer application is needed to ensure that good yields are maintained (Iwena, 2007; Abua, 2012).

Cassava adopts to a wide range of climatic and edaphic conditions. As a crop of lowland tropics, it is grown between latitude 30^{0N} and 30^{0S} of the Equator and an of altitude of up to 2000m, though a range of 1,500 to 1,800mm was found suitable (Okigbo and Greenland, 1978). In Nigeria, a survey in the 1990s showed that cassava has grown intensively in the humid zone when it occupied 60% of the staple crop field then in the sub-humid zone (less than 20%) and the in the non-humid zone (5%) (Nweke et al., (1999). Total production of cassava in the zone depended on the respective cultiver and plants. Thus, the Food and Agriculture Organization (FAO) of the United Nations estimated the total production of cassava in Nigeria in 2002 to be approximately 34 million metric tones (from about 3.1 hectares of land) and rated the country as the world's largest producer of the crop (FAO, 2003).

In recent times, Cross River State is suffering from high rate of deforestation and forest degradation. Drivers such as conversion for large scale agriculture, uncontrolled logging, unsustainable harvest of fuel wood, overgrazing, incessant bush burning and oil exploration contribute towards the loss and degradation of more than 3500km^2 of forest annually (UNEP – WCMC, 2010). Consequently upon the above, the government of Cross River State has taken bold steps toward Reduction Emission of Deforestation and Forest Degradation (REDD+) readiness joining the UN-REDD Programme as a partner country and observer to policy board meetings in early 2010.

Furthermore, the Cross River State government involvement in REDD implies reduction in deforestation which lower timber harvests, staple food production and land conservation to agriculture. As human population of the state and study area continue to grow, while the size of farm lands as a factor of production remain constant, the implications of this is that there will arise a problem of unequal distribution (over utilization of land and other resources) resulting to lower growth in the supply of cassava, yam, rice, maize, beans, soyabeans, plantain, cattle and timber will rise their prices. It is against this background that there is need to devise a method of sustaining the crucial soil properties influencing cassava yield in order to boast cassava production in the study area.

The prominence of cassava as a staple food and industrial crop has resulted in the continuous use of the soils in the coastal area of Cross River State for its production. Inspite of the influence of moisture regime on Cassava tuberization, relatively few studies have been carried out to identify the soil properties influencing the crop yield in the area. Unfortunately, in many areas, soil and crop degradation seem to have gone too far for the process to be reserved. One must not loose sight of the close association between soil and plant and their common fate in the face of human activities. The interrelationship between crop yield, growth parameters and soil variables is to identify soil variables that significantly influence the crop production and these could be used further in rating and assessing soils of sampled farms for crop production (Gbadegesin, 1990; Abua, 2012). Hence, the thrust of this study.

The study is aimed at examining soil properties – cassava yield relationship in the coastal ecological zone of Southern Cross River State in the Niger Delta region of Nigeria.

II. Materials and Method

Study Area

The study site is located in Bakassi representing coastal soils in Bakassi Local Government Area of Cross River State – Nigeria. Bakassi Local Government Area is located between longitude $8^0 30^1$ E and $8^0 39^1$E and latitude $4^0 45^1$N and $5^0 10^1$N. 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. The soils of Bakassi are formed from Alluvium in the quaternary period of geological materials of sedimentary origin (Fig. 1). The climate of the area is typical of tropical humid region with a mean annual rainfall varying from 3500 to 4000mm (Bulktrade, 1989). Temperature in the study area and its environs is generally high ranging between 21^0C – 29^0C. Usually, high temperature are recorded in the dry season (November – March) while the lowest temperature are recorded in the rainy season (April to October). All these environmental factors influenced the growth of Cassava.

Fieldwork: Four transects were established in the eastern, western, southern and northern directions due to break in slope and creeks of the land terrain. Nine representative profiles comprising two in each direction and the starting point were selected along the transects. The profiles were dug and soil samples taken from the different horizons. The samples were stored in polythene bags and transported to the laboratory for analysis.

Laboratory Analysis: These samples were air-dried, crushed and allowed to pass through a 2mm sieve. The gravel content (materials >2mm) was determined and expressed as a percentage of the total weight of the soil. Soil samples were analyzed for soil p^H meter (McLean, 1965). Total nitrogen was determined by molybdenum blue colorimetry (Bray and Kurtz, 1945) while exchangeable cations will be extracted with IM NH40AC (pH 7.0) to determine k and Na using flame photometer and exchangeable Mg and Ca by atomic absorption spectrophotometer (Sparks, 1996). Exchangeable acidity was determined by the KCI extraction method (Mclean, 1965) and organic carbon was after dichromate wet oxidation method (Walkey and Black, 1934). Conversions between values of organic carbon and organic matter was made using Van Bemmelen factor of 1.724 on the assumption that, on average, SOM contains 57% of organic C. Cation Exchange Capacity (CEC) was calculated from the sum of all exchangeable cations, particle size distribution was determined using hydrometer method (Day, 1965).

Procedure for data analysis: Different statistical tools were employed for data analysis and presentation such as descriptive and inferential statistics. Descriptive statistics such as means, range, standard deviation (SD) and coefficient of variability (CV) were used to analysis the data. The coefficient of variability (CV) is given as:

$$C.V. = \frac{\partial x}{100}$$

Where: C.V. = Coefficient of variability

∂ = Standard Deviation
X = the mean

Furthermore, Pearson's Product Moment Correlation and the step-wise multiple regression model were used to investigate the nature of the relationship between the cassava parameters and the soil properties. The essence of using the step-wise multiple regression model is to reduce the number of soil properties that mostly influence cassava yield (vegetative parameters). The Pearson's Product Moment Correlation and Multiple Regression Models are given as thus respectively:

$$r = \frac{\frac{1}{n}(x-x)(y-y)}{(\partial x)(\partial y)}$$

Where:
r = Correlation Coefficient
x and y = the variables of interest
∂ = Standard deviation
y = crop yield
x = soil properties and

$$y = a+b_1x_1+b_2x_2+b_3x_3 +\ldots + b_3x_3 +c$$

where:
y is the independence variable (soil properties)
a is the intercept
xj are the dependent variables (cassava yield)
bj are the regression coefficients and c is error term.

III. Results and Discussion

Particle Size Distribution

Physical properties of soil along the transect (Bakassi) are presented in Table 1 in relation to the transects. Sand fraction ranged from 116.0 to 681.0g/kg and 94.0 to 652.0g/kg with mean values of 337.2g/kg and 290.4g/kg respectively in surface and subsurface soils in all the soils collected from the area. The standard deviation and coefficient of variability were 198.0 and 152.5g/kg (surface and subsurface soils respectively) and 587.2g/kg and 525.3g/kg for surface and subsurface soils respectively (Table 1). Silt contents varied from 192.0 to 396.0g/kg (Surface soils) and 200.0 to 422.0g/kg (subsurface soils) with means of 282.0g/kg and 329.1g/kg in surface and subsurface soils respectively. The soils had a standard deviation of 69.9 and 43.9g/kg with coefficient of variability between 248.1g/kg and 133.2g/kg respectively in surface and subsurface soils (Table 1) in all the transects where soils were sampled. Clay fraction ranged from 127.0 to 561.0g/kg (surface soils) and between 148.0 to 552.0g/kg (subsurface soils) with mean values of 380.8g/kg and 380.5g/kg for surface and subsurface soils respectively. The standard deviation and coefficient of variability were 147.8 to 126.3g/kg and between 388.2 and 331.9g/kg in surface and subsurface soils respectively (Table 1).

Thus, the textures of the soils were predominantly of clay, loam fractions under study. The bulk density ranged from 1.28 to 1.97 cm^2 (surface soils) and between 1.10 to 1.99 $9/cm^3$ (subsurface soils) with means of 1.78 $9/cm^3$ and 1.76 $9/cm^3$ for surface and subsurface soils respectively (Table 1). Moisture contents varied from 211.0 to 421.0% (surface soils) and between 181.0 to 441.8% (subsurface soils) with means of 311.0 and 348.1g/kg in soils of the area under investigation.

Chemical Properties of Soils

1. Soil pH (Reaction)

In Bakassi, the soil pH is strongly acidic (pH range, 2.1-4.6) in surface soils while the sub surface soils had a range of 2.0-3.9 with means of 3.5 and 3.1 respectively with standard deviation of 0.78 (surface) and 0.46 (subsurface soils) while the corresponding coefficient of variation were 22.27% and 14.71% for surface and subsurface soils respectively (Table 1).

The electrical conductivity values in Bakassi varies from 0.88 to 30.65 dsm^1 (surface soils) and 0.89 to 38.70 dsm^1 (subsurface soils), while the average corresponding standard deviation recorded were 9.27 and 0.09 as well as corresponding coefficient of variability of 59.91% and 48.72% (Table 1).

Organic carbon contents ranged from 10.6 to 27.9g/kg (surface soils) and between 2.0 to 14.0g/kg (subsurface soils) with mean values of 18.3 and 6.5g/kg respectively for surface and subsurface soils (Table 1). The surface and subsurface mean values for standard deviation were 5.4 and 4.1g/kg with the corresponding coefficient of variability of 296.9 and 483.0g/kg for the experimental plots of the prescribed site in the study area.

Total nitrogen contents in Bakassi varied from 4.8 to 11.1g/kg (surface soils) and 5/0 to 10.1g/kg (subsurface soils) with means of 7.2 and 7.3g/kg respectively while the corresponding values for standard deviation recorded were 1.8 and 1.2g/kg. The coefficient of variability recorded for the prescribed experimental plot were 254.4 and 163.8g/kg respectively for surface and subsurface soils (Table 1).

The available P arranged from 2 to $9mgkg^{-1}$ (surface soils) and 3 to $9mgkg^{-1}$ (subsurface soils) with means of $5mgkg^{-1}$ and $6mgkg^{-1}$ respectively. The standard deviation for the experimental site were 2.64 and 1.31 with the corresponding coefficient of variability of 52.70% and 21.92% for the study area (Table 1).

Exchangeable bases content of the soils include calcium with a range of Ca (range, 5.04 16.87 $cmol/kg^{-1}$) with means of 9.54 $cmol/kg^{-1}$ and 9.99 $cmol/kg^{-1}$ (S1)=3.20 and 3.48; CV = 33.50% and 34.84%); K (range, 0.04.21 $cmol/kg^{-1}$) with means of $0.30cmol/kg^{-1}$ and 0.55 $cmol/kg^{-1}$ (SD=0.19 and 0.34; CV = 62.59% and 61.53%) respectively in surface and subsurface soils (Table 1). Mg ranged from 39 to 75% (surface soils) and between 36 to 74% (subsurface soils) with means of 59% and 55% and (SD = 12.61-10.32; CV = 21.39-18.76%) respectively in surface and subsurface soils in the area under investigation – Bakassi (Table 1).

In the study area, exchange Aluminum ($A1^{3+}$) varied from 0.24 to 0.92 $cmol/kg^{-1}$ (SD = 0.22, CV = 54.72%) (surface soils) and between 0.16 to $0.38cmol/kg^{-1}$ and $0.26cmol/kg^{-1}$ respectively in surface and subsurface soils. Exchangeable hydrogen within the study area ranged from 0.18 to 6.54 $cmol/kg^{-1}$ with a standard deviation of 1.88 $cmol/kg^{-1}$ and coefficient of variability of 82.82 $cmol/kg^{-1}$ and a mean of 2.27 (surface soils) while the subsurface soils varied from 0.69 to $9.61cmol/kg^{-1}$ with a mean value of 3.16cmol/kg^{-1}, a standard deviation and coefficient of variability of 2.25 cmol/kg^{-1} and 71.17% respectively (Table 1).

The effective cation exchange capacity (ECEC) values in Bakassi ranged from 16.98 to 36.08cmol/kg^{-1} and between 15.84 to 46.03cmol/kg^{-1} with means of 6.76cmol/kg^{-1} and 8.47cmol/kg^{-1} in surface and subsurface soils respectively (Table 1). The soils had a standard deviation of 6.76 to 8.47cmol/kg^{-1} and coefficient of variability between 24.19 and 27.71cmol/kg^{-1} in surface and subsurface soils respectively in the study site (Table 1).

The base saturation values in Bakassi varied from 81 to 97% (surface soils) and between 74 to 97% (subsurface soils) with mean values of 90% (surface soils) and 88% (subsurface soils) while it had a standard deviation between 5.29 and 6.74% for surface and subsurface soils respectively with coefficient of variability between 5.88% and 7.66% for surface and subsurface soils respectively (Table 1).

Table 1: Summary results of variation in physico-chemical characteristics of soils sampled along the transects in Bakassi Local Government Area, Cross River State.

Bakassi Soils						
Parameter	Sample type	Range	Mean	SD	CV (%)	Maximum permissible limit
A) Physical Parameters						
(i) Sand (g/kg)	S	116.0-681.0	337.2	198.0	587.2	NL
	SS	94.0-652.0	290.4	152.3	525.3	NL
(ii) Silt (g/kg)	S	192.0-396.0	282.0	69.9	248.1	NL
	SS	200.0-422.0	329.1	43.9	132.2	NL
(iii) Clay (g/kg)	S	127.0-561.0	380.8	147.8	147.2	NL
	SS	148.0-552.0	380.5	126.3	126.3	NL
(iv) Textural class	S	c, l, sl	-		-	-
	SS	c, cl, sl, l	-	-	-	-
(v) Pore Space (%)	S	128.0-197.0	178.0	29.0	16.32.0	NL
	SS	110.0-199.0	176.0	29.0	1668.0	NL
(vi) Moisture contents (g/kg)	S	252.8-517.0	327.1	109.6	313.2	NL
	SS	249.1-532.1	335.2	110.8	330.4	NL
B) Chemical Parameters						
(i) pH (H_20)	S	2.1-4.6	3.5	0.78	22.27	5.1-6.5
	SS	2.0-3.9	3.1	0.46	14.71	
(ii) EC (dSm^{-1})	S	0.88-30 65	15.47	9.27	59.91	2-4dsm^{-1}
	SS	0.89-38.70	18.66	9.09	48.72	
(iii) Org. M (g/kg)	S	18.2-48.0	38.3	5.40	296.9	2.0**
	SS	3.4-30.8	28.5	4.81	483.0	
(vi) Total N (g/kg)	S	4.8-11.1	7.2	1.8	254.4	0.2%**
	SS	5.0-10.1	7.3	1.2	163.8	
(v) Avail P (mgkg^{-1})	S	2-9	5	2.64	52.70	2.0mgkg^{-1}**
	SS	3-9	6	1.31	21.92	
Exchangeable Bases (cmol/kg^{-1})	S	5.06-1-20	9.54	3.20	33.50	10-20cmol/kg^{-1}**
(vi) Ca	SS	5.04-16.87	9.99	3.48	34.84	
	S	9.04-19.21	15.30	3.56	23.26	3-8cmol/kg^{-1}**
(vii) Mg	SS	7.81-26.11	16.47	5.73	34.79	
	S	0.06-0.14	0.10	0.02	21.21	0.6-1.2cmol/kg^{-1}**
(viii) K	SS	0.04-0.21	0.10	0.01	43.01	
	S	0.12-0.61	0.30	0.19	62.59	0.7-1.2cmol/kg^{-1}**
(ix) Na	SS	0.11-1.30	0.55	0.34	61.53	
Exchange Acidity (cmol/kg^{-1})	S	0.24-0.92	0.42	0.22	54.72	4.1cmol/kg^{-1}**
(x) AI	SS	0.16-0.38	0.26	0.06	22.35	
	S	0.18-6.54	0.27	1.88	82.82	2.1-4cmol/kg^{-1}**
(xi) H	SS	0.69-9.61	3.16	2.25	71.17	
	S	16.98-36.08	27.94	6.76	24.19	
(xii) ECEC (cmol/kg^{-1})	SS	15.84-46.03	30.53	8.47	27.74	
	S	81-97	90	5.29	5.88	10cmol/kg^{-1}**
(xiii) Bsae Saturation (%)	SS	74-97	88	6.74	7.66	
						60-80%
(C) Fertility Indices:	S	0.46-0.85	0.62	0.13	20.97	3.1-5.1**
(i) Ca:Mg Ratio	SS	0.36-1.31	0.62	0.65	35.38	
	S	90.40-303-33	157.40	157.40	41.66	1:2**
(ii) Mg.K Ratio	SS	51.71-452.50	210.49	210.49	56.88	
	S	7-17	12	12	26.42	25*
(iii) C.N Ratio	SS	7-14	11	11	15.55	

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

Table 2: Pairwise relationship between cassava yield and physico-chemical properties of surface soils in Bakassi

	Cassava parameters		
Soil properties	**Tuber**	**Leaves**	**Stems**
Sand	0.36	-0.25	-0.15
Silt	0.86**	0.23	0.05
Clay	-0.44	0.23	0.17
Bulk Density	-0.23	0.46	0.14
Pore Space	0.23	-0.46	-0.14
Moisture	0.16	-0.99*	-0.31
Content	-0.39	-0.59**	-0.58**
pH	0.19	0.25	0.08
EC	-0.16	-0.48	0.42
Organic matter	-0.53**	-0.16	0.98**
Total Nitrogen	-0.58**	-0.47	-0.04
Avail P	0.52	0.52**	0.19
Ca	0.06	0.31	-0.05
Mg	0.10	-0.15	0.42
K	-0.003	-0.66*	-0.20
Na	0.64*	0.66*	-0.16
Exch. Acidity	0.57**	0.57**	0.03
ECEC	-0.57**	-0.46	0.34
BS	-0.13	0.45	0.44
Ca; Mg	0.62*	0.45	-0.24
Mg:K	0.32	0.32	-0.30
C:N			

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 3: Relationship between cassava yield and physico-chemical properties of subsurface soils in Bakassi.

	Cassava parameters		
Soil properties	**Tuber**	**Leaves**	**Stems**
Sand	-0.35	0.23	-0.37
Soil	0.86**	-0.23	0.67*
Clay	0.36	-0.01	6.50**
Bulk Density	-0.12	-0.32	-0.25
Pore Space	0.14	-0.34	-0.13
Moisture	0.43	-0.99*	-0.16
Content	0.39	-0.34*	-0.18
pH	0.27	0.15	0.28
EC	0.05	-0.37	0.42
Organic matter	0.25	-0.21	0.98*
Total Nitrogen	0.32	0.06	0.79*
Avail P	0.04	0.30	0.45
Ca	0.16	0.34	-0.13
Mg	-0.26	-0.06	0.28
K	-0.13	-0.29	0.04
Na	0.52**	0.54**	-0.50**
Exch. Acidity	0.31	0.51**	0.03
ECEC	0.33	-0.17	0.26
BS	0.30	0.06	0.67*
Ca; Mg	0.62*	0.51**	0.38
Mg:K	-0.08	0.60*	-0.12
C:N			

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.

Cassava tuber-yield

Cassava tuber-yield positively and significantly correlated with silt (R =.86**, P<0.01), clay (R = -0.68, P<0.05), bulk density (R = -0.85**, P<0.01), Pore space (R = .0.85**, P<0.01) and moisture content (R = -0.71**, P<0.01) (Table 4). These variables show a multiple regression coefficient of 0.90 of parameter estimates. Thus, equation iv gives a condensed relationship among the aforementioned physical parameters influencing cassava yield in the area under investigation.

$$Yth = 937.71 - 4.91Sd - 6.86s - 3.58CI - 168.46Bd - 2.88Ps - 0.75Mc + c$$
$$(\text{Intercept})\ (1.99)\ (2.88)\ (2.76)\ (60.63)\quad (1.27)\quad (0.53)$$
$$R^2 = 0.90 \qquad \text{(iv)}$$

Where:
Yth = Cassava tuber-yield (kg/ha)
Sd = Sand (%)
S = Silt (%)
CI = Clay (%)
Bd = Bulk density (M_gM^{-3})
Ps = Pore space
Mc = Moisture content (%)
Figures in parenthesis are standard errors.

For chemical parameters, cassava was positively and significantly correlated with total nitrogen (R = 0.61*, P<0.05), but negatively and significantly correlated with PH (R= -0.52*, P<0.05), exchangeable sodium (R= -0.78**, P<0.01), organic matter (R= -0.78**, P<0.01), exchangeable magnesium (R= -0.78**, P<0.01), and exchangeable potassium (R= -0.88**, P<0.01)) as presented in Table 4. Estimated variables show coefficient of determination (R^2) of 0.89 (see Table 4). The aforementioned variables could be presented in equation V.

$$Yth = 107.08 - 10.0pH - 8.02\ OM + 66.78\ TN - 3.19\ Ex.\ Mg + 42.46\ Ex.\ Na - 174.24\ Ex.\ K + e$$
$$(\text{Intercept})\ (16.34)\quad (6.44)\quad (86.58)\quad (24.61)\quad (95.06)$$
$$R^2 = 0.89 \qquad \text{(v)}$$

Table 4: Summary of multiple regression result with cassava tuber-yield as dependent variable in Bakassi

Independent Variables	Regression Coefficient	Standard error of coefficient	Correlation Coefficient (R)
Physical Properties			
Sand	-4.91	1.99	-0.87**
Silt	-6.86	2.88	0.86**
Clay	-3.58	2.76	-0.68*
Bulk Density	-168.46	60.63	-0.85**
Pore Space	-2.88	1.27	-0.85**
Moisture Content	-0.75	0.53	-0.71**
Multiple regression Coefficient (R^2)	0.90		
Intercept value	937.71		
Chemical properties			
pH	-10.05	16.34	-0.52*
Organic matter	-8.02	6.44	-0.78**
Total Nitrogen	66.78	86.58	0.61*
ECEC	19.49	16.45	0.57*
Exch. Acidity	0.59	0.53	0.64*
Exch. Mg	-3.19	2.59	-0.78**
Exch. Na	42.46	24.16	0.52*
Exch. C	0.59	0.51	-0.86**
Exch. K	-174.24	95.06	0 .62*
Mg:K	16.49	13.45	
Multiple regression Coefficient (R^2)	0.89		
Intercept value	107.08		

t = 5% level (95 percent); ** = 1% (99 percent)

Where Ex. Mg = Exchangeable Magnesium
Ex. Na = Exchangeable sodium
Ex. K = Exchangeable potassium
Ex. C = Exchangeable calcium
Others, as previously defined.

Figures in parenthesis as standard errors.

Cassava leaves-yield

Estimates for the cassava leaves-yield negatively and highly significantly correlated with sand, silt, clay, bulk density, pore space and moisture content (R-values = -0.98**, P<0.01) at 1% level of significance along transect two (Table 5) (equation vi). The specified parameters yielded 98% (see Table 5). Equation vi gives a clear picture of the parameter estimates (physical properties) of the variables depicted to have influenced the crop parameter (leaves).

$$Ytl = 186.78 - 1.09\,Sd - 1.35\,S - 1.14\,Cl - 21.93\,Bd - 0.66\,Ps - 0.16\,Mc + e$$
$$(Intercept)\quad (.0.52)\quad (0.076)\quad (0.073)\quad (1.597)\quad (0.033)\quad (0.014)$$
$$R^2 = 0.98 \qquad \text{(vi)}$$

The results (chemical properties) further show that cassava leaves-yield was positively and significantly correlated with Mg (R = 0.67*, P<0.05), K (R = 0.55*, P<0.05), but negatively and significantly correlated with pH (R=-0.86**, P<0.01), available P (R=-0.56*, P<0.05), and C:N ratio (R=-0.53*, P<0.05), (Table 5). The estimates yielded multiple regression relationships are presented in equation vii.

$$Yth = 18.914 - 3.84\,pH - 0.51\,Ex.\,Ca + 0.323\,Ex.\,Mg + 8.59\,Ex.\,K - 0.47\,AV.P - 0.75C{:}N + e$$
$$(Intercept)\quad (2.237)\quad (0.882)\quad (0.355)\quad (13.014)\quad (0.501)\quad (0.838) \qquad \text{(vii)}$$

Where
Ytl = Cassava leaves-yield (kg/ha)
Ex. K = Exchangeable potassium ($cmol/kg^{-1}$)
Ex. Ca = Exchangeable Calcium ($cmol/kg^{-1}$)
Av. P = Available phosphorus ($cmol/kg^{-1}$)
C:N = Carbon-nitrogen
e = Stochastic/error term

Cassava Stem-yield

The results of the analysis indicate that cassava stem was negatively correlated with send (R-0.53*, P<0.05), exchangeable K (R=-0.89*, P<0.01), Mg:K ratio (R=0.91**, P<0.01), Organic matter (R=-0.94**, P<0.01), exchangeable Mg (R=-0.92**, P<0.01), but positively and significantly correlated with total nitrogen (R=0.98**, P<0.01), exchangeable Ca (R0.88**, P<0.01), exchangeable Na (R0.94**, P<0.01), base saturation (R=0.93**, P<0.01), and exchange acidity (R=0.92**, P<0.01), (Table 5). The table further shows a multiple regression coefficient (R^2) of 0.98 with intercept value of 5.18 (see Table 5).

\- \- \- (eq viii)

Where
Ytl = Cassava stem-yield (kgha)
OM = Organic matter (%)
Sd = Sand (%)
Bs = Base saturation (%)
E = Stochastic/error term
Others, Mg:K; EA, Ex.K; Ex. Na; Ex. Mg: TN and Ex. Ca as previously defined.

Table 5: Summary of multiple-regression result with cassava leaves-yield as dependent variable in Bakassi

Independent Variables	Regression Coefficient	Standard error of coefficient	Correlation Coefficient (R)
Physical properties			
Sand	-1.09	0.052	-0.98**
Silt	-1.35	0.076	-0.98**
Clay	-1.14	0.073	-0.98**
Bulk Density	-21.93	1.597	-0.98**
Pore Space	-0.66	0.033	-0.98**
Moisture Content	-0.16	0.014	-0.99**
Regression Coefficient (R^2)	0.98		
Intercept value	186.78		
Chemical properties			
pH	-3.84	2.237	-0.86**
Exch. Ca	-0.51	0.882	-0.70**
Exch. Mg	0.323	0.355	0.67*
Exch. K	8.59	13.014	0.55*
Available P	-0.47	0.501	-0.56*
C:N	-0.75	0.838	-0.53*

Multiple regression Coefficient (R^2) Intercept value	0.93 18.914		

* = 5% level (95 percent); ** = 1% (99 percent)

IV. Conclusion

Cassava parameter (tubers, stems and leaves) were examined and related to 18 soil parameters to statistically assess the influence of soil properties on cassava yield in the study area using the correlation and multiple regression models. The assessment of the soil/yield parameters revealed that cassava tuber-yield negatively correlated with sand (r=-0.87**, P<0.01), clay (r = -0.68, P<0.05), moisture content (r= -0.71*), Bulk density (r= -0.85*, P<0.01), pore space (r= -0.82**) but positively correlated with silt (r= 0.86**, P<0.01). The estimate shows a multiple regression coefficient of R^2 of 0.87. The multiple regression coefficient (R^2) yielded 0.50 of the estimate whereas estimates for cassava leaves-yield in the study site negatively correlated with sand, silt, clay, bulk density, pore space and moisture content with r-values of (-0.98*, P<0.01) at the 1% level of significant. Thus, the specified parameters yielded 98% coefficient of determination of the variables that contributed to cassava leaves yield in the study location. The results of the analysis further indicated that cassava stem was negatively correlated with sand (r= -0.53*, P<0.05), organic matter (r=-0.94**, P<0.01), Mg:K ratio (r=-0.91*, P<0.01), exchangeable K (r=-0.89**, P<0.01), but positively correlated with total nitrogen (r=-0.98**, P<0.01), exchangeable Mg (r=0.92**, P<0.01), exchangeable Na (r=0.94*, P<0.01), exchangeable Ca (r=0.88**, P<0.01), base saturation (r=0.93**, P<0.01) and exchangeable acidity (r=0.92**, P<0.01). The non-applicability of some of the agronomic management practices introduced by the agricultural extension services of the Agricultural Development Programme (ADP) is a limitation to improved crop performance. Therefore, an intervention is needed for appropriate soil management strategy to boost cassava production in the study site.

References

[1] Abua, M. A; Ajake, A. O. (2013): Assessment of Soil Quality Status under Different Land use in Akpabuyo Local Government Area of Cross River State – Nigeria. International Journal of Agriculture, Innovations and Research Vol. 2; No. 1, pp 137 – 140.
[2] Anikwe, M. A. N (2006): Soil Quality Assessment and monitoring: New Generation Ventures Ltd; Enugu pp. 19-31: 178-181.
[3] Anikwe, M. A. N; M. E. Obi (1999): Evaluation of an Index model for quantifying the productivity of soils in Southeastern Nigeria using maize as a test crop. Journal of Agriculture and Environment 1, 80-89.
[4] Briggs, D. J. (1981): Environmental Influences on the Yield of spring barley in England and Wales. Geoforum, 12:99-106.
[5] Bulktrade, (1989): Soils and Landuse Survey of Cross River State. CRS Ministry of Agriculture and Natural Resources. Calabar.
[6] Eludoyin, O. S. (2008): The Impact of Mono-cropping of Cassava on a forest soil in South Western Nigeria, Journal of Geographic Thought (JOGET) Vol. No. 1 and 2, pp. 73-81.
[7] Food and Agricultural Organization, FAO (2003): Production year book. FAOSTAT Data Base. htt://apps/.Fao.org. (Consulted February, 2003).
[8] Gbadegesin, A. S. and Nwagwu, U. (1990): On the suitability assessment of the forest and savanna ecological zones of South-western Nigeria for maize production. Agric Ecosystems Environ., 31-99-133. Elsevier science publisher B.V., Amsterdam Netherlands.
[9] Gbadegesin, A. S.; Abua, M. A.; Atu, J. E. (2011): Variation in Soil properties on cassava production in the coastal Area of Southern Cross River State, Nigeria. Journal of Geography and Geology. Vol. 3, No. 1, pp. 94-103.
[10] Iweng, O. A. (2007): Essential Agricultural Science for Senior Secondary Schools. Tonad Publishers Ltd. Ibafo. Pp, 21-22.
[11] Komolafe, M. F.; Adegbola, A. A.; Are, L. A. and Ashaye, T. I. (1985): Agricultural Science for West African Schools and Colleges. University Press Limited, Ibadan.
[12] Mclean, E. O. (1965): Aluminum. In: C. A. Black (ED) Methods of Soil Analysis. Arogon. No. 9 part 2. America Society of Agronomy, Madison, Isconsin. Pp 986-994.
[13] Okigbo, B. N; Greenland, D. J. (1976): Intercropping Systems in Tropical Africa. In Multiple cropping. RI Papendick, PA Sanchez PA and GB Triplett, eds. ASA special publication 27 Madison, Wisconsin, pp. 63-101.
[14] Walkley, A. and Black, I. A. (1934): An Examination of the Digestive method for determining soil organic matter and proposed modification of the chronic acid titration method. Pp, 10-18.

Author's Profile

Moses Adah Abua
hails from Bayobri Ukpe in Obudu Local Government Area of Cross River State. He holds a Ph.D in Geography and Environmental Science from the University of Ibadan, Ibadan – Nigeria. He is currently lecturing at the University of Calabar, Calabar – Nigeria. He has been teaching and researching for the past fifteen years in the areas of Hydrology and Water Resources; Soils and Biographical Studies. He is happily married and blessed with four children.

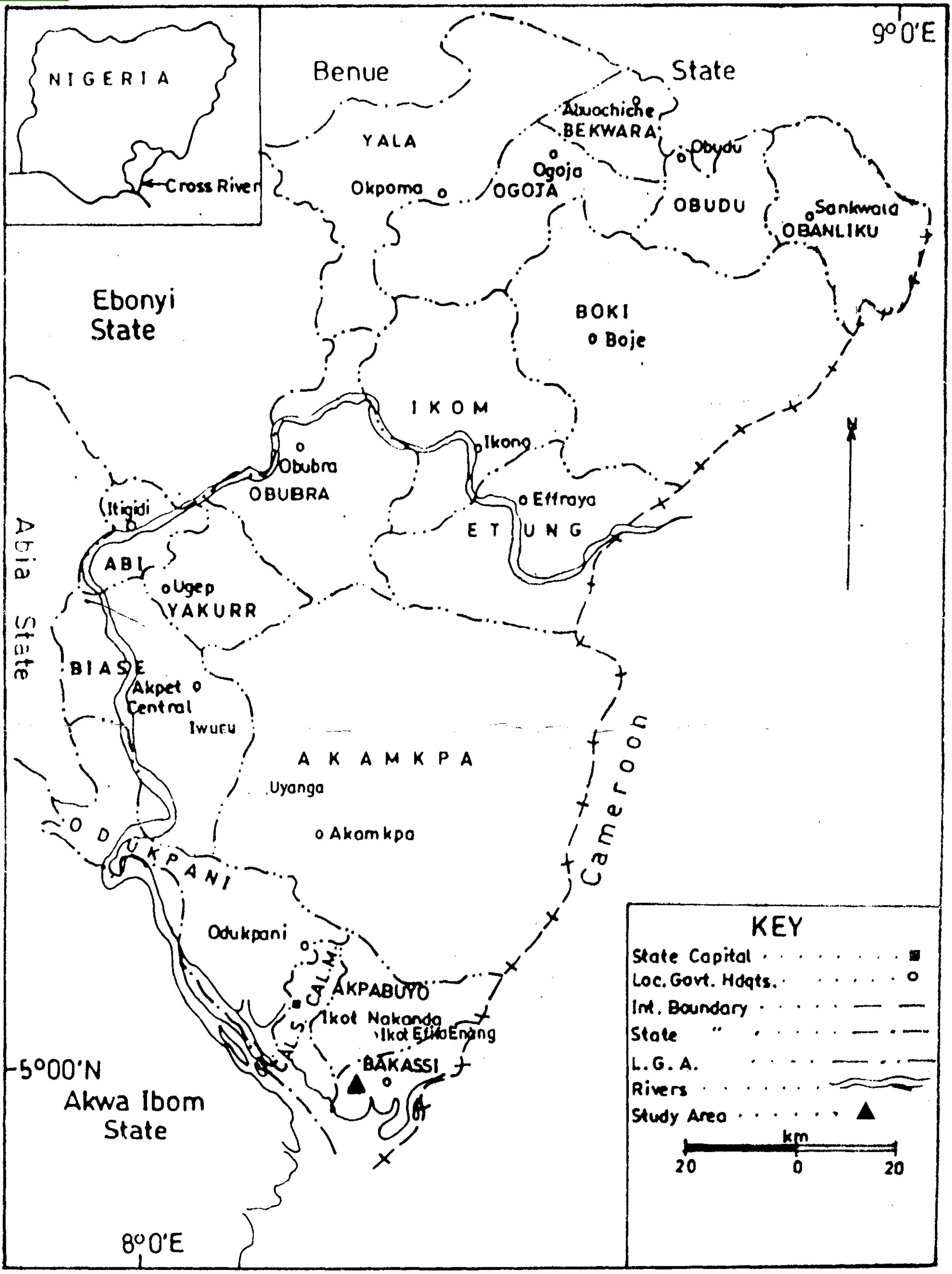

Fig.1. Map of Cross River State: The study areas