Journal of Agricultural Economics, Extension and Rural Development: ISSN-2360-798X, Vol. 7(7): pp, 950-960, July, 2019.

Full Length Research Paper

Cassava-Yield Responses to Soil Properties in The Coastal Plain Soils of Bakassi Local Government Area Of Cross River State, Nigeria

M. A. Abua

Department of Geography and Environmental Science, University of Calabar, Calabar, Nigeria.

Author's E-mail: abuamoss4real@gmail.com

Accepted 19th July, 2019.

There is a close and direct relationship between soils and plants. The plants cover has always served as an indicator of soil status for primary production activities. This study focuses on cassava-yield responses to soil properties in the coastal plain soils of Bakassi Local Government Area of cross River State, Nigeria. Both transect and quadrant methods were employed for the collection of soil samples and cassava yield. Nine transects, each 400m long were established in each of the plots and a quadrant of 10 x 10m was located in every 200m interval in each of the cardinal directions and the starting point. In each of the sampling plot, soil samples were collected from two depths of 0-15cm and 15-30cm. The soils samples collected into well labeled polythene bags were brought to the laboratory for analysis. In addition, an estimated area of 10,000m^2 of cassava plot was grided into cells and 10 plots were randomly selected. At each sampling unit, an area of 100m^2 was marked out by measuring a dimension of 10 x 10m with a measuring tape. The number of cassava stands within the 100^2 area were counted and recorded. All the cassava stands in each farm were harvested and fresh tuber bulked together in a sack and then weighed with a manual weighing balance and mean weight in kg determination. Data were analyzed using descriptive statistics as well as the Pearson's moment correlation and the regression model to investigate the nature of the relationship between cassava and vegetative parameters (tuber, leaves and stem). The results revealed that cassava tuber-yield positively correlated with silt (r=0.86 P<0.01) but negatively correlated with sand (r= .0.87** P<0.01), clay (r = -0.44 P<0.01), bulk density (r = -0.85** P<0.01) and moisture content (r= -0.71** P<0.01). The results further revealed that cassava tube yield positively correlated with total nitrogen, but negatively correlated with pH, exchangeable magnesium and exchangeable potassium, estimated variables show coefficient of determination of 96%, while cassava leaves-yield negatively correlated with sand, silt, clay, bulk density, pore space and moisture content. The estimates yielded multiple regression coefficient R^2 of 0.93. Exchangeable k, Mg:k ratio, organic matter negatively correlated with cassava stem-yield but positively correlated with total nitrogen, exchangeable Ca, Na, base saturation and exchange acidity with a multiple regression coefficient (R^2) of 0.98. In order to protect the soils from deterioration in the study area, an intervention is needed for appropriate management strategy to boast cassava production.**

Keywords: Cassava-yield, Soil properties, Coastal plain sand soils, Vegetative parameters and Bakassi.

INTRODUCTION

There exists a close and direct relationship between soils and plants. That is to say, soils and plants are closely related and are associated with one another in the people's mind Areola (1983). The plant 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 observed that in the absence of animal manure and chemical fertilizers, Nigerian farmers 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 limitations on the use of either of them. Failure to realize this on the part of the people has often led to serious environmental problems.

These problems are all precipitated by the removal of the soil-plant cover by man. Forest clearance, repeated crop cultivation, over-grazing and bush burning in different parts of Nigeria frequently expose the soil to intense isolation leading to increased rate of evaporation, decomposition and oxidation of soil organic matter; while the major nutrients and trace elements are rapidly exhausted from the soil through crop removal and erosion. Abua and Ajake (2015), Areola (1978; 1983) asserts that the degradation of the soil in different parts of Nigeria has in turn impaired the sustenance of the plant cover and lowered its resource value. Plant is a renewable resource and it is its renewable nature that has been exploited by traditional agricultural system in sustaining soil productivity. However, the productivity of the plant communities in any area, can only be sustained with the full awareness of and due regard to the prevailing environmental conditions.

The heavy, compact nature of some soils and the sandy and stony nature of much moisture-holding capacity, or the tendency to dry up on exposure, place serious limitations on the renewability of Nigeria's plant communities and the improvements that can be made to increase the productivity. For example, Iyambo and Ojo (1971) have stated that much of the 74,000km^2 of forest reserves in the Savanna areas is unsuitable for commercial tree plantation mostly on account of poor soil conditions. Failure of *Azadiracha indica* (neem) in the Sudan zone is often associated with unsuitable site conditions such as shallow lateritic soils with hard pan; heavy clay soils; or too freely drained sands.

Nevertheless, the human factor has been very important in soil-plant dynamic in Nigeria. Adejuwon (1971), has pointed out plant types in Nigeria are all anthropogenic derivatives of former climax communities as follows; (1) the forest and derived savanna communities of the humid south are derivatives of the tropical forest; (2) the Southern and Northern Guinea Savanna derived from a tropical deciduous forest which developed in a climatic region characterized by a dominance of humid over arid tropical conditions; (3) the Sudan and Sahel Savanna derived from former tropical xerophytic woodlands developed in a sub-humid to semi-arid climatic environment.

Areola (1971; 1983), concluded that such a reconstruction of past climax plant types as described above is useful for present day planning purposes because it reveals the potential productivity and resource value of the plant communities. One must not lose sight of the close relationship between soil and plant and their common fate in the face of human activities. The aim of modeling the interrelationship between crop yield, growth parameters and soil variables is to identify soil variables that significantly influence the crop production and these that could be used further in rating and assessing soils of sampled farms for crop production Gbadegesin (1990).

The need for the development of crop yield production models from plant growth/vegetative parameters has long been recognized. For example, the first attempts at analyzing crop yield in terms of growth parameters were models as far back as the beginning of the nineteenth (19th) century by Balls and Holton (1915) and Balls (1919). A few years later Engledow and Wadham (1923) investigated the yield of cereals in terms of plant characters that control yield hectare. Other studies, such as those of (Loomis & Williams, 1963; Lal & Hague,1971; Gold-Sworthly et al., 1974; Tayo, 1977; Clarke; 1978) have analyzed yields of various crops in terms of growth components. However, none of these studies has actually demonstrated the fact that crop yield could be reliably predicted or estimated using some of these vegetative components. Nevertheless, the importance of crop yield prediction from plant growth parameters cannot be over-emphasized because it ensures greater objectivity in the forecasting of crop yield, especially in advance of harvest. In many parts of the world, crop yield forecasts are generally based on farmer's records and these according to (Gbadegesin, 1986; Odjugo, 2007; Abua, 2012; 2013) are to some degree subject to vicissitude in human judgment.

This work presents a model for predicting the yield of local cultivars of cassava in the coastal area of Southern Cross River State of Nigeria. These vegetative parameters are subjected to correlation analysis with the tuber yield of the crop, with the aim of identifying the significant growth parameters influencing cassava yield.

Materials and Method

Study Area

Bakassi Local government Area is located between longitudes $8^{o}30^{1}$E and $8^{o}39^{1}$E of the Greenwich and latitudes $4^{o}30^{1}$N and $4^{o}45^{1}$N (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. The soils of Bakassi are formed from Alluvium in the quaternary period. In Bakassi, mangrove swamp

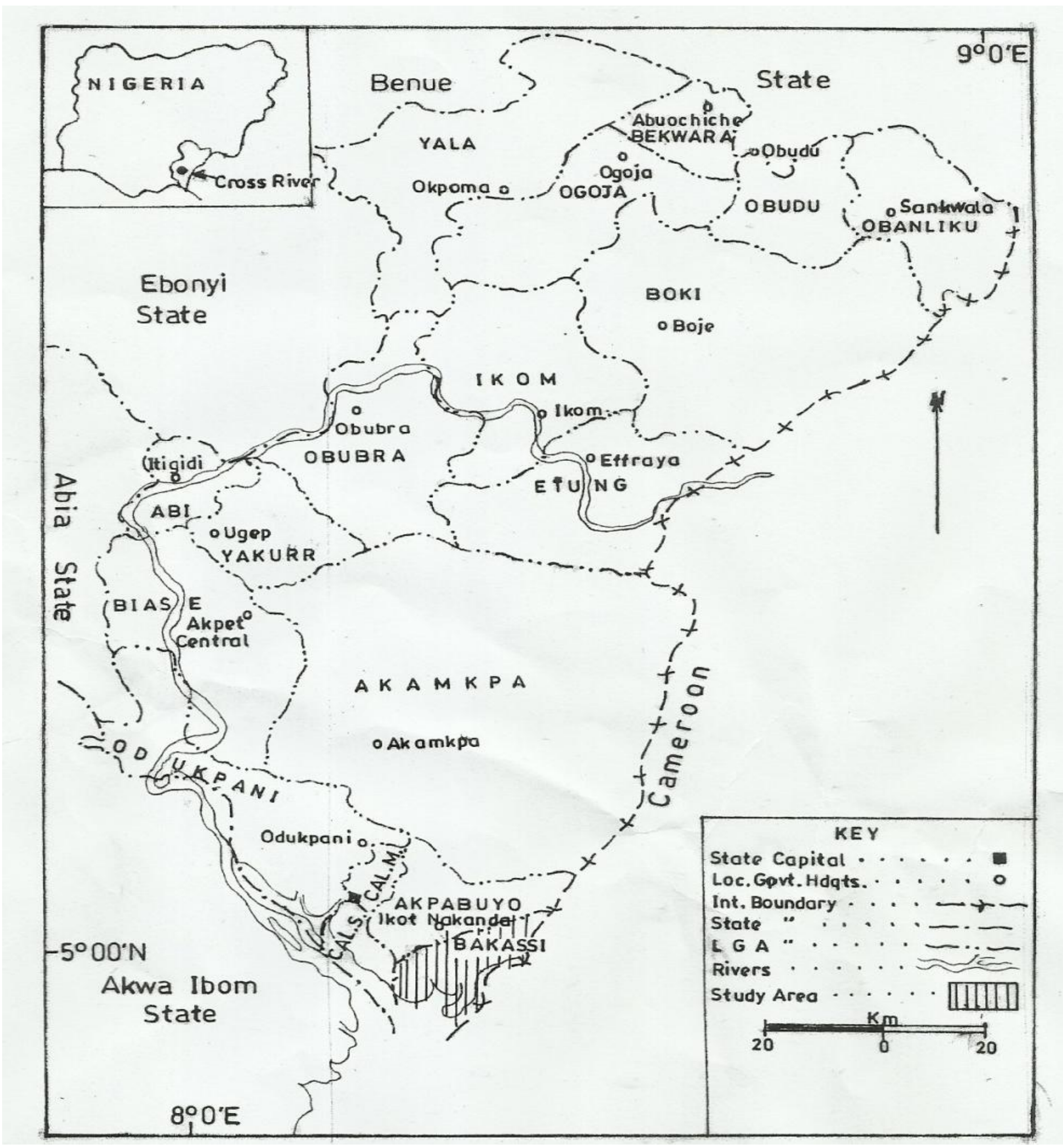

Figure 1: Cross River State

Soils dominate the sites. Such soils may contain pyretic materials (FeS_2), which undergo oxidation to Fe^{3+} and sulpheric acid (H_2804), which cause extreme acidity. The soils are characterized by "Potential Acid Sulphate Soils" and massive in terms of consistency. The soils support swamp lilies, ferns, Raphina sp. Elaesis guinensis (oil palm), timber, chromolaena odorata etc. while few areas are cultivated with cassava (monihot esculenta), red species which could be tolerant to such soil condition (Fig. 1). The climate of the area is typical of tropical humid region with a mean annual rainfall varying from 3500-4000mm (Bulktrade, 1989; Abua Essoka, 2016). The climate of the area is influenced by the direction of the south westerly wind associated with the warm humid maritime tropical airmass and the north-easterly wind related to the dry continental tropical airmass. These airmasses are separated by zone of the intertropical discontinuity which is an unstable pressure zone. The temperature in the study area is generally high ranging between 21^oc – 27^oc. The area is usually cool in the morning, warm and hot in the afternoon, and cool at night (Bulktrade, 1989; Gbadegesin et al., 2011; Abua & Ajake, 2015).

Soil Sampling Procedure

Both the transect and quadrant methods were employed for the collection of soil samples and cassava yield. Nine transects, each 400 meters long from the starting point were established in the eastern, western, northern and southern directions due to breaks in slope and creeks of land terrain. In each of the plots in the study area a quadrant of 10 by 10m was located at every 200 meters. Thus, the first quadrant was located at 0m and subsequently 200m and 400m respectively in each of the four cardinal points. This sampling method was repeatedly done in both cassava plots in the study area. The style of soil sampling was adopted because it is the most appropriate method which helps to minimize variation in soil nutrients within a plot under study.

In each of the sampling plots, soil samples were collected from two points at a depth of 0–15cm and 15-30cm because more than 70 of crop yield variability has been attributed to the nutrient concentration in the top soil of any given soil profile (Sopher & McCraken, 1973; Abua, 2012). Nonetheless, Lal and Haque (1971) showed that removing the top 2.5cm and 7.5cm at the topsoil of some western Nigeria soils, resulted in 50% and 90% reduction in crop yield.

The soils samples were collected into well labeled polythene bags and were brought into laboratory for analysis. In addition, an estimated area of $10,000m^2$ (1ha) of cassava plot was grided into cells and 10 plots randomly selected. At each sampling unit an area of $100m^2$ was marked out by measuring a dimension of 10 x 10m with a measuring tape. The number of cassava stands within the $100m^2$ area were counted and recorded. All the cassava stands in each farm were harvested and fresh tuber bulked together in a sack and then weighed with a manual weighing balance and the mean weight in kg determined. The mean yield for each (plots) were evaluated. This was later converted to tone/hectare for each of the farms. The same procedure was applied to vegetative parameters of leaf weight and stem weight.

Laboratory Analysis

Soil pH was determined in both IN water INKCI, it was determined in 1:1 soil to solution ratio and in water. The pH values were read using a pH meter. Exchangeable acidity was determined by leaching the soil with IMKCI and titrating aliquots with 0.01 NaoH (Mclean, 1965). Organic carbon was determined by the Walkley and Black (1934) method. Total nitrogen was determined by the Kjeldahl method. Available phosphorus was extracted with acid fluoride using the P-1 method (Bray & Kurtz; 1945). The exchangeable bases include calcium (Ca), magnesium (mg), potassium (k) and sodium (Na). These were determined by first leaching the soil using neutral ammonium acetate determined by flame photometry and magnesium determined on atomic absorption spectrophotometer. Cation Exchange capacity was taken as the sum total of exchangeable acidity and exchangeable bases (summation method).

The texture components are the relative amount of sand, silt and clay present in the soil samples. This was determined by Bouyouces hydrometer method (Chapman, 1965).

Techniques for Data Analysis

Data were analyzed using descriptive statistics such as mean, standard deviation (S.D), Coefficient of variation (CV) as well as the pearson's product moment correlation and the multiple regression model were used to investigate the nature of the relationship between cassava yield and soil properties in the study area.

RESULT AND DISCUSSION

Soils Physico-chemical Properties of Bakassi

Physical properties of soil along the transect in 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 sampled 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 standard deviation of 69.9 and 43.9g/kg with coefficient of variability between 248.1g/kg and 133.2kg/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.

Thus, the textures of the soils were predominantly of clay, loam fractions under study. The bulk density ranged from 1.28 to 1.97cm^3 (surface soils) and 1.10 to1.99 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.

The soil pH is strongly acidic (pH range, 2.1-4.6) in surface soils with the sub surface soils had a range of 2.0-3.9 with means of 3.5 and 3.1 respectively in the top and subsoils 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 the study location 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 7.2g/kg respectively while the corresponding values of standard deviation recorded were 1.8 and 1.2g/kg. The coefficients 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 ranged from 2 to 9mgkg^{-1} (surface soils) and 3 to 9mgkg^{-1} (surface soils) with means of 5mgkg^{-1} and 6mgkg^{-1} respectively. The standard deviations 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 and 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} (SI) = 3.20 and 3.48; CV = 33.50% and 34.84%); K (range, 0.04.21 cmol/kg^{-1}) with means of 0.30 cmol/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 Aluminium (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 0.38 cmol/kg^{-1} and 0.26 cmol/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 9.61 cmol/kg^{-1} with a mean value of 3.16 cmol/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 36.08 cmol/kg-1 and between 15.84 to 46.03 cmol/kg-1 with means of 6.76 cmol/kg-1 and 8.47 cmol/kg-1 in surface and subsurface soils respectively (Table 1). The soils had a standard deviation of 6.76 to 8.47 cmol/kg-1 and coefficient of variability between 24.19 and 27.71 cmol/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 transects in Bakassi Local Government Area, Cross River State.

			Bakassi Soils			
Parameter	**Sample type**	**Range**	**Mean**	**SD**	**CV (%)**	**Maximum permissible limit**
A) Physical						
Parameters	S	116.0-681.0	337.2	198.0	587.2	NL
(i) Sand (g/kg)	SS	94.0-652.0	290.4	152.3	525.3	NL
	S	192.0-396.0	282.0	69.9	248.1	NL
(ii) Silt (g/kg)	SS	200.0-422.0	329.1	43.9	132.2	NL
	S	127.0-561.0	380.8	147.8	147.2	NL
(iii) Clay (g/kg)	SS	148.0-552.0	380.5	126.3	126.3	NL
	S	c, l, sl	-	-	-	-
(iv) Textural class	SS	c, cl, sl, l	-	-	-	-
(g/kg)	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
(v) Pore Space (%)	S	252.8-517.0	327.1	109.6	313.2	NL
	SS	249.1-532.1	335.2	110.8	330.4	NL
(vi) Moisture contents						
(g/kg)	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	
B) Chemical	S	0.88-30.65	15.47	9.27	59.91	2-4dsm^{-1}
Parameters	SS	0.89-38-70	18.66	9.09	48.72	
(i) pH (H_20)	S	18.2-48.0	38.3	5.40	296.9	2.0**
	SS	3.4-30.8	28.5	4.81	483.0	
(ii) EC (dsm^{-1})	S	4.8-11.1	7.2	1.8	254.4	0.2%**
	SS	5.0-10.1	7.3	1.2	163.8	
(iii) Org. M (g/kg)	S	2-9	5	2.64	52.70	2.0mgkg^{-1}**
	SS	3-9	6	1.31	21.92	
(iv) Total N (g/kg)						
	S	5.06-1-20	9.54	3.20	33.50	10-20cmol/kg^{-1}**
(v) Avail P (mgkg^{-1})	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}
Exchangeable Bases	SS	7.81-26-11	16.47	5.73	34.79	
(cmol/kg^{-1})	S	0.60-0.14	0.10	0.02	21.21	0.6-1.2cmol/kg^{-1}**
(vi) Ca	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}**
(vii) Mg	SS	0.11-1.30	0.55	0.34	61.53	
(viii) K	S	0.24-0.92	0.42	0.22	54.72	4.1cmol/kg^{-1}**
	SS	0.16-0.38	0.26	0.06	22.35	
(ix) Na	S	0.18-6.54	0.27	1.88	82.82	2.1-4cmol/kg^{-1}**
	SS	0.69-9.61	3.16	2.25	71.17	
Exchange Acidity	S	16.98-36.08	27.94	6.76	24.19	
(cmol/kg^{-1})	SS	15.84-46.03	30.53	8.47	27.74	10cmol/kg^{-1}**
(x) Al	S	81-97	90	5.29	5.88	
	SS	74-97	88	6.74	7.66	60-80%
(xi) H						
	S	0.46-0.85	0.62	0.13	20.97	3.1-5.1**
(xii) ECEC (cmol/kg^{-1})	SS	0.36-1.31	0.62	0.65	35.38	
	S	90.40-303-33	157.40	157.40	41.66	1:2**
(xiii) Base saturation (%)	SS	51.71-452.50	210.49	210.49	56.88	
	S	7-17	12	12	26.42	25*
C) Fertility Indices:	SS	7-14	11	11	15.55	
(i) Ca: Mg Ratio						
(ii) Mg. K Ratio						
(iii) C. N Ratio						

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 parameter		
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 Content	0.16	-0.99*	-0.31
pH	-0.39	-0.59**	-0.58**
EC	0.19	0.25	0.08
Organic matter	-0.16	-0.48	0.42
Total Nitrogen	-0.53**	-0.16	0.98**
Avail P	-0.58**	-0.47	-0.04
Ca	0.52	0.52**	0.19
Mg	0.06	0.31	-0.05
K	0.10	-0.15	0.42
Na	-0.003	-0.66*	-0.20
Exch. Acidity	0.64*	0.66*	-0.16
ECEC	0.57**	0.57**	0.03
BS	-0.57**	-0.46	0.34
Ca; Mg	-0.13	0.45	0.44
Mg:K	0.62*	0.45	-0.24
C:N	0.32	0.32	-0.30

Notes: BD = Bulk density; PS = Pore space; MC = Moisture content; OM = Organic matter; TN = Total nitrogen; AP = Available phosphorous; ECEC = Effective cation exchange capacity; BS = Base saturation; CN = 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 parameter		
Soil properties	**Tuber**	**Leaves**	**Stems**
Sand	-0.35	0.23	-0.37
Silt	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 Content	0.43	-0.99*	-0.16
pH	0.39	-0.34*	-0.18
EC	0.27	0.15	0.28
Organic matter	0.05	-0.37	0.42
Total Nitrogen	0.25	-0.21	0.98*
Avail P	0.32	0.06	-0.79*
Ca	0.04	0.30	0.45
Mg	0.16	0.34	-0.13
K	-0.26	-0.06	0.28
Na	-0.13	-0.29	0.04
Exch. Acidity	0.52**	0.54**	-0.50**
ECEC	0.31	0.51**	0.03
BS	0.33	-0.17	0.26
Ca; Mg	0.30	0.06	0.67*
Mg:K	0.62*	0.51**	-0.38
C:N	-0.08	0.60*	-0.12

Notes: BD = Bulk density; PS = Pore space; MC = Moisture content;
OM = Organic matter; TN = Total nitrogen; AP = Available phosphorous; ECEC = Effective cation exchange capacity; BS = Base saturation; CN = 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 correlated with silt (R = 0.86**, P<0.01) but negatively correlated with sand (R = 0.87**, 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 2). These variables show a multiple regression coefficient of 0.90 of parameter estimates. Thus, equation (i) gives a condensed relationship among the aforementioned physical parameters influencing cassava yield in the area under investigation.

Yth = 937.71 – 4.91sd – 6.86s – 3.58Cl – 168.46Bd – 2.88Ps. 0.75Mc + c… (eq. i)
(Intercept) (1.99) (2.88) (2.76) (60.63) (1.27) (0.53)
R^2 = 0.90
Where:
Yth = Cassava tuber-yield (kg/ha)
Sd = Sand (%)
S = Silt (%)
Cl = 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 = -0.86**, P<0.01) as presented in Table 4. Estimated variables show coefficient of determination in equation ii.
Yth = 107.08 – 10.0pH – 8.02 OM+66.78 TN – 3.19 Ex. Mg + 42.46 Ex. Na – 174.24 Ex. K+e…(eq. ii)
(Intercept) (16.34) (6.44) (86.58) (24.61) (95.06)
R^2 = 0.98

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. C	42.46	24.16	0.52*
Exch. K	0.59	0.51	-0.86**
Mg. K	-174.24	95.06	0.62
Na	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 are 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 iii). The specified parameters yielded 98% (see Table 5). Equation iii gives a clear picture of the parameter estimates (physical properties) of the variables depicted to have influenced the crop parameter (leaves).

Yth = 186.78 – 1.09sd – 1.35s–1.14Cl – 21.93Bd – 0.66 Ps - 0.16 Mc + e…(eq. iii)

(Intercept) (0.52) (0.076) (0.073) (1.597) (0.033) (0.014)

$R^2 = 0.98$

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 coefficients R^2 of 0.93 with intercept value of 18.914 thus, the relationships are presented in equation iv.

Yth = 18.914 – 3.84pH – 0.51 Ex. Ca + 0.323 Ex. Mg + 8.59 Ex. K–0.47 AV.P -0.75 C:N + e…(eq. iv)

(Intercept) (2.237) (0.882) (0.355) (13.014) (0.501) (0.838)

$R^2 = 0.93$

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 sand (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 (R=0.88**, P<0.01), exchangeable Na (R=0.94**, 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).

Vtl = 5.18 – 0.65OM + 16.52TN + 0.26 EC.Ca – 0.23 Ex. Mg – 6.96 Ex, K + 2.49 Ex, Na – 0.03 Mg: K +).79 BS + 2.18 EA +e ..(eq. v)

(0.09) (3.51) (0.91) (0.01) (0.23) (0.65)

$R^2 = 0.98$

Where Ytl = cassava stem-yield (kg/ha)
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. C	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)	0.93		
Intercept value	18.914		

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

Table 6: Mean cassava yield in Bakassi Study site

Transect	Mean yield (tone/ha)
Ref. P.	23.610
BPNTI	21.060
BPNT2	36.710
BPWT1	44.340
BPWT2	31.280
BPET1	38.050
BPET2	16.490
BPST1	25.890
BPST2	24.570
Total	=262.0
Mean value	= 29.11

The results from the analysis revealed that the mean annual yield of cassava in the study area was 29.11 tonnes/ha. The cassava yield recorded in the study site may be attributed to saline nature of soils, couple with the high water table, albeit inherently fertile. This limitation, however, is a serious inhibity factor to crop yield, particularly tuber crops which does not thrive well in this area situated in a hydromorphic environment.

CONCLUSION

Cassava parameters in response to soil properties were examined using the bivariate and multiple regression statistical tools. Results showed that soil pH, total nitrogen, moisture content, bulk density and silt fraction significantly influence cassava yield particularly at the surface soil. Other soil properties that substantively contributed to cassava yield include exchange acidity, effective CEC, Mg:K and carbon-nitrogen ratio at the surface and subsurface soils. Essentially, the multivariate model gave a better fit, the essence of which it increases the statistical reliability and the theoretical plausibility. Moreso, the variegated yields in cassava tuber along different sub-transects north and south are attributed to soil nutrient and fertility status. Also, variation in leaf-yield (fresh weight) in most of the transects are enhanced by difference in edaphic and geomorphological factors. Stem yields were high in north transect due to high nutrient status.

In order to protect the soils of the study site from deterioration, an intervention is needed for appropriate soil management strategy to boast cassava production in the area.

REFERENCES

Abua, M. A. (2012). Effects of Soil Properties on Cassava (Manihot esculenta Crantz) Production in the Coastal and Hinterland Areas of Southern Cross River State, Nigeria. Ph.D thesis, Department of Geography, Faculty of Science, University of Ibadan, Nigeria. Unpublished.

Abua, M. A. (2013). Identifying soil properties influencing cassava yield in Akpabuyo Local Government Area of Southern Cross River State – Nigeria. Merit Research Journals Vol. 1, No. 3, pp. 33-41.

Abua, M. A. and Ajake, A. O. (2015). Soil-vegetation variability on a Topo-sequence in Obudu Local Government Area of Cross River State, Nigeria. Journal of Biodiversity Management and Forestry. Vol. 4, No. 3, pp. 1-7.

Abua, M. A. and Essoka, P. A. (2014): Soil Properties – Cassava yield Relationship in the Coastal Ecological Zone of the Southern Cross River State, South-South, Nigeria. International Journal of Research in Agricultural Sciences. 1:(4), 265-272.

Adejunwon, J. O. (1971). A Biogeographical Survey of the dynamics of savanna vegetation in Nigeria. Nigeria Geographical Journal, 27:244-249.

Areola, O. O. (1983). Soil and Vegetated resources in a Geography of Nigeria Development J. S. Oguntoyinbo; Areola, O. O. and M. Filani (eds). Heinemann Educational books (Nig). Limited.

Areola, O. O. (1979). Multivariate statistical analysis of soil laboratory data from Montgomeryshire, Wales, Geojournal 3:371-378.

Balls, W. L. (1919). Phil. Trans Royal Society of London Bulletin 208:157-223.

Balls, W. L. and Holton, E. S. (1915). Phil. Trans Royal Society of London Bulletin. 206:103-180; 403-408.

Bray, R. H. and Kurtz, L. J. (1945). The nature and properties of soils. 404-410, 12th ed. Prentice Hall, Upper Saddle River N. Y.

Bulktrade (1989): Soils and Landuses Survey of Cross River State. CRS Ministry of Agriculture and Natural Resources. Calabar.

Clark, J. M. (1978). The effects of leaf removal on yield components of Brassica napus, Canadian Journal of plants science 54(4), 1103-1106.

Engledow, F. I. and Wadham S. M. (1923). Fertility Status and Productivity of the "Acid Sands" of Southern Nigeria. Soil Science Society of Nigerian spectrum Publication Monograph 1:56-73.

Gbadegesin, A. S. (1986). Predicting maize yield from plants characters in the Savanna Belt of Oyo State, Nigeria. Journal of tropical Agriculture, 64(3), 109-117.

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.

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.

Goldsworthy, P. R.; Palmer, A. F. E. and Sperling, D. W. (1974). Growth of Lowland and Tropical Maize in Mexico. Journal of Agricultural Science, 83:223-230.

Iyambo, D. E and Ojo, G. C. A. 91971) "Plantation establishment techniques in the Savanna areas of Nigeria: Nigeria Journal forum, 1:(1), 16-20.

Lal, V. S. and Haque, M. F. (1971). Path analysis of yield components in Soyabean, Indian Journal of Genetics and Plants Breeding. 31:357-362.

Loomis, R. S. and Williams, W. A. (1963). Maximum crop productivity; as estimate, crop science 367-372.

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.

Odjugo, P. A. (2003): An Analysis of the effectiveness of traditional techniques of on-farm micro climate improvement of mid-western Nigeria. Ph.D thesis, Department of Geography, Faculty of Science, University of Ibadan, Nigeria. Unpublished.

Tayo, T. O. (1977). Comparative analysis of the Growth, development and yield of 3 soyabean varieties, journal of Agricultural Science, 88:151-157.

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 tiltration method. Pp, 10-18.