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LAND SUITABILITY EVALUATION OF BASALTIC SOILS FOR CASSAVA PRODUCTION IN CROSS RIVER STATE, NIGERIA

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Abstract
Pedological study was conducted in soils derived from basalt parent material in Ikom, Cross River State, South-South Nigeria to assess their suitability for sustainable cassava production. A total of 500ha of land was surveyed using the rigid grid format and three mapping units were delineated based on similarities and differences observed in the morphological properties. Profile pits were dug in the identified mapping units. The Pits were sampled according to genetic horizons and taken to laboratory for analyses. From the analytical results the characteristics of the soils ranged as follows: soil texture, Sandy clay loam to Clay, pH, 4.3 to 4.4; Organic C, 11.6 to 28.0 g kg^{-1}; total N, 0.8 to 1.7g kg^{-1};available P, 6.67 to 13. 96 mg kg^{-1};CEC, 5.91 to 10.59 cmol (+) $kg^{-1}$and Base saturation, 45.91 to 75.11 %. Land Suitability classification was evaluated using the Productivity Index method which shows that the actual productivity index of the soils ranged from 53.20 to 63.04 %. This is an indication, that all the mapping units were moderately suitable for production of cassava. For the soils to be highly suitable (potential suitability) for sustainable cassava production, the fertility status of the soils needs to be improved on.

Keywords: **Cassava, Evaluation, Production, Soils and Sustainability**

Introduction

Nigeria is the largest producer of cassava in the world with an annual production rate of 59.47million metric tons (FAO, 2018). This crop provides the livelihood (food and income) for over 30 million farmers and countless processors and traders in Nigeria (Abdoulaye *et al.,* 2014). It has been observed that Nigeria is the most advanced among the African countries poised to diversify the use of cassava as a primary industrial raw material and livestock feed. According to Solomon *et al.* (2011) two factors are responsible for this comparative advantage and they include; rapid adoption of improved cassava varieties and the development of small-scale processing technologies. Though Nigeria is the highest Producer of cassava in the world and there has been substantial increase in its production in the country over the last twenty years, principally owing to an increase in the area cultivated and improvements in production efficiency through the introduction of high yielding, disease and pest resistant varieties. Despite this development, the demand of cassava in the country is highly enormous. This is as a result of the diversification of this commodity crop by the end users. There is need to breach the gap between demand of cassava and its supply, by increasing its production level. This can be done through increase in the productivity per unit area of land. According to Onyekwere et al. (2013) and FAO (2018), the global rating of Nigeria as number one producer of cassava, is not as a result of yield per unit area of land. Its yield in farmers' field is low (below 9 tons per hectare) but as a result of large expanse of land subjected to its production in the country.

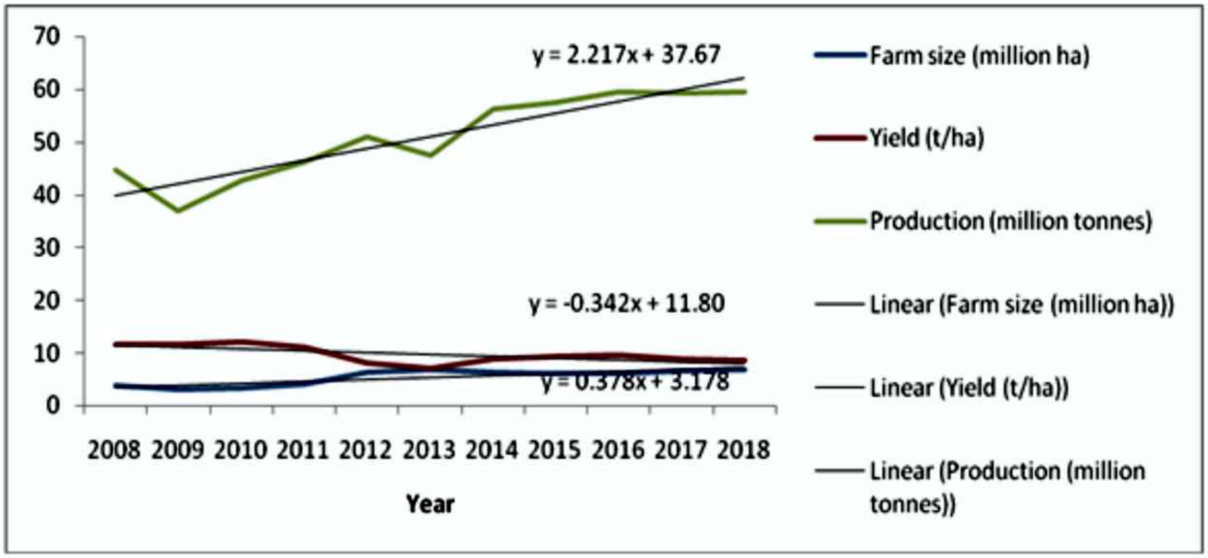

Fig. 1: Increasing Trend in Cassava Output and Farm size and Decreasing Trend in Yield
***Source: FAO,* 2018**

The low yield being recorded in farmers' field can be attributed to inherent low fertility of the soils, which can be improved upon through fallowing. Currently, due to population increase and rural urban industrialization, the available piece of land meant for cassava production had diminished and fallow period reduced. For yield increase to be feasible there is need to resuscitate the soil resource base of the land meant for cassava production in Nigeria. The first step in achieving this is to assess the suitability of the available piece of land grown to cassava and identify soil fertility management system that will increase its yield.

Land suitability evaluation has been defined as the fitness of a given tract of land for a specified kind of use (FAO, 1984). Ibanga, (2003), had described land evaluation as the process of estimating the potentials of land for alternate kind of use. Based on its attributes and potentials, every land is suitable for particular use. Thus, land suitability is assessed, classified and presented separately for each kind of use. This implies that land suitability evaluation is necessary as a first step to land use planning. This will enhance judicious and maximum utilization of any available piece of land, without jeopardizing the prospect of future generation. The quest for better use of soils calls for their characterization as a pre-requisite to proper land suitability evaluation for various competing uses of land. As a first step to land use planning, suitability evaluation is essential to the determination of the potentials and constituents of soils to crop yield. However, for cassava farmers' in Ikom, Cross River State South-South Nigeria to record an increase from the present yield, suitability assessment of the soils under cassava cultivation is necessary. This will enable proper use and development of management technology for an increase in its production. Therefore, the objective of this study is to examine the suitability of soils derived from basalt parent material in Ikom, Cross River State under cassava cultivation, and give possible management measures for an increase in cassava productivity in the area.

Materials and Methods

Study Area

The study area is Ikom, Cross River State, South-South Nigeria. The area lies between latitude 5^0 53' N and longitude $8^0$46' to 48'E. The climate of the study area is characterized by distinct wet and dry seasons. The former, which lasts for about seven months starts immensely from April to October. The dry season stretches mainly from march through November. It can be remarked that a condition of great uniformity is experienced in the area throughout the year. The area has a mean annual temperature between 22 and 32^0C, the mean annual rainfall range from 2,490 to 2,900mm and the relative humidity vary from 60 to 74 % (Table1). The vegetation in the study area consists of tropical rain forest. The prevailing condition in the area has compelled people towards adapting farming systems that are comparatively at advantage and can adapt to their environment. The soil is derived from the igneous formation (basalt).

Pedological Studies

Based on logistics, five hundred hectares of land was demarcated with the aid of Global Positioning System (GPS). The overall micro-relief of the surveyed areas consist of slightly undulating to gently sloping terrain of not more than 4% gradient, which was determined with a clinometer. A detailed soil survey using the rigid grid format was conducted, transverses were cut along a properly aligned base line at 100m intervals, while auger borings were made at 25cm interval to a depth of 100cm and morphological descriptions (colour, texture, consistency and inclusions) were made. Based on similarities and differences of the morphological properties, 3 different soil mapping units were delineated. Three profiles pits measuring 2m x 1m by 1.30m to1.5 m, which were restricted to get to 2m depth because of impenetratable layers, sited in each delineated soil mapping unit, making a total sum of nine soil profile pits. The morphological characteristics of each of the profile pits were described, according to the guidelines for profile pit description outlined in Soil Survey Manual (Soil Survey Staff, 1993). The profile pits were cleaned and demarcated based on depths of genetic horizons. Soil samples were collected horizon by horizon starting from bottom to avoid contamination. Samples were taken to National Root Crops Research Institute (NRCRI), Umudike Soil Science Laboratory for physical and chemical analysis. All the soil samples collected were air dried, gently ground and sieved using a 2mm sieve preparatory for laboratory analysis. Samples for total N and organic C were passed through a 0.5mm sieve. For purpose of reporting, a representative profile pit was selected from the three soil profile pits in each delineated mapping unit.

Laboratory analysis

Physical Properties

Soil particle size analysis was determined after dispersing 51.00g of air-dried soil samples with 5% sodium hexametaphosphate overnight, that is the Boyoucous hydrometer method as contained in the method of soil analysis by International Soil Reference and Information Center and Food and Agricultural Organization (ISRIC and FAO, 2002).

Chemical Properties

The chemical properties of the soils were determined according to standard laboratory procedures as contained in the method of soil analysis ISRIC and FAO (2002). Soil pH (H_2O) was determined in 1:1 soil/ distilled water suspensions using a glass electrode. Organic carbon was determined by Walkley and Black titration method, which involved soil organic matter oxidation with potassium dichromate ($K_2Cr_2O_7$) and sulphuric acid (H_2SO_4).Total nitrogen was determined by using the modified Macro-Kjeldahl method of digestion, distillation and titration. Available phosphorus was determined using Bray P -2 extract of Bray and Kurtz method, and measured calorimetrically. Exchangeable Ca, Mg, K and Na in soil samples were extracted with I N neutral ammonia acetate (NH_4OAc), K and Na were determined by flame photometry, while Ca and Mg were by EDTA titration. The soil samples were treated with I N KCl to extract the exchangeable H^+ and Al^{3+}. The KCL extract was subsequently titrated with 0.05 N NaOH. The amount of base used was equivalent to the total acidity. Exchangeable bases were extracted using 1N potassium acetate (KOAc) saturation and neutral IN (NH_4OAC) displacement using 5g of soil sample. The displaced potassium was determined on a flame photometer, thus CEC was estimated as follows;

CEC cmol $(+)kg^{-1}$ / 100g soil = cmol $(+)kg^{-1}$ k/100g soil

Effective cation exchange capacity was calculated as the sum of the exchangeable bases and acidity. Percentage Base Saturation was calculated as the percentage of exchangeable bases divided by effective cation exchangeable capacity.

$$\frac{(K^1 + Na^1 + Ca^2 + Mg^2) \times 100}{ECEC}$$

Land Evaluation Procedure

Land suitability evaluation system adopted for the study was the Productivity Index method as defined by Riquier *et al.* (1970), which was slightly modified by taking into consideration total nitrogen in the fertility index calculation. The Productivity Index adopted for this study is given thus;

$$Pa = H \times D \times Dp \times T \times Sp \times FI \quad \ldots\ldots\ldots (1)$$

Where,
Pa = Actual productivity
H = Soil moisture based on the number of wet months
D = Drainage
Dp = Effective soil depth (rooting zone to impenetrable layer)
T = Soil texture/structure
Sp = Slope
FI = Fertility index represented as follows;

$$FI = Sr \times Om \times Ce \times Mr \times Ap, \times Tn \quad \ldots\ldots(2)$$

Where,
Sr = Soil reaction
Om = Organic matter content
Ce = Nature of clay taken as the CEC per kg clay
Mr = Mineral reserve
Ap = Available phosphorous
Tn = Total nitrogen

Values were assigned to these parameters based on their degree of limitations as shown thus:

Degree of limitations	Value (%)
None	100
Slight	95
Moderate	85
Severe	60
Very severe	>40

The result obtained from equation 2 was fitted into equation 1. The two equations stated also represented the Potential Productivity Index (PPI) and Potential Fertility Index (PFI) respectively. The potential indices were calculated after envisaged improvements such as reduction of soil acidity and fertilization. Coefficient of improvement CI, which express the degree of possible improvement measures needed to advance yield of arable crops grown on the soils. This is calculated thus;

$$CI = PPI/Pa \times 100 \quad \ldots\ldots\ldots\ldots (3)$$

The percentage rating of Potential Productivity and Actual productivity were converted to decimal place and used in equation 3, and the result was converted to percentage. According to the resulting index of productivity, the soils were assigned one of five productivity classes:

Class 1	=	Excellent	(75 - 100%)
Class 2	=	Good	(50 - 75%)
Class 3	=	Average	(25 - 50%)
Class 4	=	Poor	(0 - 25 %)

According to Van Ranst and Verdoodt (2005), these productivity classes (1 – 4) correspond to the land suitability classes of S1 (high), S2(moderate), S3(marginal), N (not suitable), and these were used for the study. The suitability classifications consist of assessing and grouping the land types in orders, classes, subclasses and units based on the crop requirement.

Results and Discussion

Suitability classification of the soils

Land suitability classification of the mapping units studied was based on the Productivity Index classification method of Riquier *et, al.* (1970), and modified by Onyekwere (2015) for rainfed cassava production. The parameters used for the land quality calculation include: slope, drainage, soil depth and texture, while materials are pH, available P, total N, cation exchange capacity, base saturation and organic carbon.

Soil Characteristics

The physical land characteristic ratings of the mapping units studied are presented in Table 2 and the land requirements for cassava production in Table 4. The entire mapping units studied were well drained, giving the indication that there is no limitation to the production of cassava in the soils. The effective soil depth (rooting zone) is adequate, with depth ranging from 101 to 155cm, giving an indication that there is no limitation for cassava production. The soil texture ranged from sandy clay loam to clay. The result shows that Mapping units 1 and 2 have severe limitation, while mapping unit 3 have slight limitation for cassava production. The textual classification of mapping unit 3 agrees with optimum criterion of light medium loam sandy soil (Onyekwere *et al*., 2009) required for unhindered anchorage, and bulking of roots and tubers, including cassava, and for easy harvest. There is need to improve the texture of mapping units 1 and 2 through application of organic fertilizer, for sustainable cassava production. The slope rating is gently sloping ranging from 0 to 4% in all the mapping units, an indication that there is no limitation to production of cassava in all the mapping units. According to Fasina and Adeyanju (2006). a slope <3% favours mechanical operation. This implies that the farmers can engage in mechanized land preparation for cassava production in all the mapping units apart from 3.

The chemical land characteristic ratings of the mapping units studied are presented in Table 3. The soil reaction of the entire mapping units studied ranged from 4.3 to 4.4, this rating shows that the soil pH has slight limitation to the production of cassava in all the mapping units. The total nitrogen ranged from 0.8 to 1.7g kg^{-1}, this rating of the soils total N indicates that all the mapping units have moderate limitation for production of cassava.

The available P content of the mapping units studied ranged from 6.67 to 13.96 mg kg^{-1}. This rating shows that mapping units 1 and 2 have no limitation for the production of cassava, while mapping unit 3 has slight limitation. The organic carbon content of the soils ranged from 11.6 to 28.0g kg^{-1}. This rating of the soils organic carbon reveals that mapping units 1 and 2 have slight limitation, while mapping unit 3 have no limitation for production of cassava. The CEC of the Mapping units studied ranged from 5.91 to 10.59cmol (+) kg^{-1}. This rating shows that the entire mapping units have slight limitation for the production of cassava. The base saturation rating of the Mapping units studied ranged from 45.91 to 75.11%. This shows that all the mapping units have no limitation fot the production of cassava. The soil fertility limitations in the mapping units studied can be corrected through the application of balance rates of nitrogen, phosphorous, and potassium fertilizers, and incorporation of harvested crop residue and other organic materials into the soil and crop rotation involving legumes.

Actual and potential soil production indexes for production of cassava

All the mapping units occurred within the zones with the ecological requirement for cassava production as was deduced from rainfall, temperature and other climatic data of the study area (Udoh *et al*., 2005). Based on some limitations after considering the actual soil productivity indexes and their improvement coefficient for production of cassava in the mapping units studied, thereby arriving at their potential productivity indexes. The actual and potential suitability classification (productivity index) of the mapping units studied is as shown in Table 5**.** The suitability classification of the mapping units of the soils studied for cassava production shows that the actual productivity index of mapping units 1 and 2 is 53.20, while that of mapping unit 3 is 63.04 %. This is an indication that all the mapping units are moderately suitable (S2) for cassava production. However, if the limitation of soil texture, soil acidity and fertility will be ameliorated through soil conservation practices, organic and inorganic fertilizer application, a potential productivity of index of 77.39 % is possible in all the Mapping units, thereby making the soils highly suitable for cassava production. The coefficient of improvement (CI), an indication of cost with which the soils can be improved to a higher suitability class is 1.45 for Mapping units 1 and 2, and 1.23 for Mapping unit 3. However, these soils possess limitations, which were low fertility, especially the primary nutrients (N, P and K), which are close to the critical level in some mapping units. This however, does not preclude its use for sustainable production of cassava, since the soil fertility and nutrient level can be greatly improved upon with the use of inorganic and organic fertilizers.

Conclusion

The work investigated pedological and suitability of basaltic soils of Ikom, Cross River State South-South Nigeria for sustainable cassava production. From the results obtained from the mapping units studied, it can be concluded that the soils are deep, strongly acidic, and moderate in total N, and moderate to high in available P. Three mapping units were identified, and are all moderately suitable (S2) for cassava production. The mapping units can be highly suitable for cassava production, if the soil fertility can be ameliorated, by application of balanced rates of N,P and K fertilizers, and incorporation of crop residue, organic manure and crop rotation involving leguminous crops.

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Table 1: Ten years (2008-2016) meteorological data of the studied area

Year	Temperature (°C)		Rainfall (mm)		Relative humidity (%)		Sunshine Hours
	Minimum	Maximum	Days	Amount	1500	900	
2008	24.60	32.00	159	2500.00	62	70	4.8
2009	24.50	31.500	146	2600.10	61	71	4.5
2009	22. 60	32.20	140	2760.20	61	70	4.6
2010	21.80	31.50	143	2720.60	60	72	4.7
2011	23.40	31.70	135	2650.60	63	74	4.4
2012	22.30	31.80	130	2490.40	62	71	4.7
2013	22.50	31.50	152	2690.90	61	70	4.8
2014	23.70	32.00	133	2700.00	60	71	4.8
2015	22.30	31.00	148	2900.00	60	70	4.7
2016	22.10	31.50	148	2800.50	60	70	4.5
Totals	158.1	221	989	1895.3	426	498	32.6
Mean	22.59	31.57	141.29	2707.57	60.86	71.14	4.66

Source: Cocoa Research Institute of Nigeria, Ikom Out-Station Metrological Unit, 2017

Table 2: Physical Land Characteristics and limitation rating of the Mapping units studied for cassava based (Mongkolsawat *et al.* 1997 rating)

Mapping unit	Slope (%)	Rating	Drainage	Rating	Soil depth (cm)	Rating	Texture	Rating
1	0 - 2	100	Well drained	100	155	100	C	60
2	0 - 4	100	Well drained	100	135	100	C	60
3	3 - 4	100	Well drained	100	101	100	SCL	95

Key = N = None, S = Slight, M = Moderate, Sv= Severe, SL = Sandy Loam, LS = Loamy Sand, SCL = Sandy Clay Loam, SC = Sandy Clay

Percentage rating	**100**	**95**	**85**	**60**	**40**
Degree of Limitation	**None**	**Slight**	**Moderate**	**Severe**	**Very severe**

Key = N = None, S = Slight, M = Moderate, Sv= Severe, SL = Sandy Loam, LS = Loamy Sand, SCL = Sandy Clay Loam, SC = Sandy Clay

Table 3: Chemical Land characteristics (mean values) and limitation rating of the mapping units studied for cassava based (Mongkolsawat *et al.* 1997 rating)

Mapping unit	pH (H_2O)	pH Rating	Organic C (gkg^{-1})	Organic C Rating	Available P (mg kg^{-1})	Available P Rating	Total N (gkg^{-1})	Total N Rating	CEC (cmol (+)kg^{-1}	CEC Rating	Base Sat (%)	Rating
1	4.3	95	16.9	95	13.93	100	0.8	85	8.22	95	68.31	100
2	4.4	95	11.6	95	13.46	100	0.9	85	9.43	95	75.11	100
3	4.4	95	28.0	100	6.67	95	1.7	85	7.31	95	45.91	100

Key : N = None , S = Slight. M = Moderate

Percentage rating	**100**	**95**	**85**	**60**	**40**
Degree of Limitation	**None**	**Slight**	**Moderate**	**Severe**	**Very severe**

Table 4: Land requirements for cassava

Land group quality	**Land Characteristics**	**S1 95 %**	**S2 85 %**	**S3 60 %**	**N1 40 %**
Climate (moisture availability)	Mean annual rainfall (mm)	1,100-1,500	900-1,100	500 – 900	<500
Temperature Regime	Average Temperature (ºC)	18 – 30	.>16	>12	any
Wetness (Oxygen Availability)	Soil Drainage	Well drained	Moderately or imperfectly drained	Poorly drained	Very poorly drained
Topography	Slope (%)	0 – 5	5 – 12	12 - 20	.> 20
Soil physical characteristics					
Rooting condition Water Retention	Soil depth (cm) Soil texture	>100 L; SL.CL	100 – 75 LS,SCL	75 – 50 S,SC	< 50 C
Fertility					
Nutrient availability	Exch K (cmol (+) kg $^{-1}$)	> 6	3– 6	<3	any
	Total nitrogen (%)	>0.2	0.2 – 0.1	<0.1	any
	Available P (mg kg $^{-1}$) PH	>25 6.1- 7.3	6 – 25 7.4-7.8 or 5.1-6.0	<6 >8.4 or <4.0	any
Nutrient retention	CEC (cmol (+) kg $^{-1}$)	>16	3-16	<3	Any
	Base saturation (%)	>35	20 - 35	< 20	Any
Salinity	Electrical conductivity mSn $^{-1}$	0 – 4	4 – 6	6 – 8	.> 8

Source: Sys *et al.* (1991) and Mongkolsawat *et al.* (1997)

Table 5: Actual and potential land suitability classification of mapping units studied for cassava production

Mapping unit	Actual productivity Index	Potential productivity Index	Coefficient of Improvement	Actual land suitability class	Potential land suitability class
1	53.20	77.39	1.45	S2f	S1
2	53.20	77.39	1.45	S2f	S1
3	63.04	77.39	1.23	S2f	S1

f = Nutrient deficiencies