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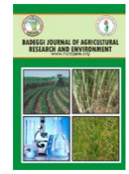

Research Article

Land Suitability Assessment for Sustainable Cassava Production in Ishiagu, South-eastern, Nigeria

Onyekwere, I. N. [1]**, Eze, P. C.**[2] **and Muogbo, P. C.** [1]
[1]National Root Crops Research Institute, Umudike, Nigeria
[2]Federal University of Technology, Minna, Nigeria
Correspondence e-mail: innonyeoma@gmail.com

Abstract
Cassava is of considerable importance to Sub-Saharan African, especially Nigeria, where it is an important source of carbohydrate. Therefore, a pedological study was conducted on the soils of Ishiagu Ebonyi State, South-eastern, Nigeria to assess their suitability for sustainable cassava production. A total of 500 hectares of land were surveyed using the rigid grid format. Three mapping units were delineated based on similarities and differences observed in the morphological properties from the augered points and profile pits were dug in the identified mapping units. The pits were sampled according to genetic horizons and taken to the laboratory for analyses. The results showed that soil texture/class ranged from sandy clay loam to clay, soil pH ranged from 4.6 to 5.2, organic carbon ranged from 0.19 to 2.68 %, total nitrogen ranged from 0.01 to 0.34 % and available phosphorus ranged from 1.40 to 5.43 mg kg^{-1}. Cation exchange capacity ranged from 6.19 to 13.70 cmol (+) kg^{-1}, base saturation ranged from 20.60 to 50.70 % and available Iron (Fe) ranged from 12.00 to 52.80 mg kg^{-1}. Land Suitability classification was evaluated by slightly modifying the Productivity Index method. The results indicated that the actual productivity index of the soils ranged from 53.20 to 59.06 %. Therefore, all the mapping units studied were moderately suitable for production of cassava.

Keywords: *Land assessment, Cassava, Characterization, Suitability, Production*

Introduction
The relative scarcity of land for agriculture requires considerable land use accuracy. Therefore, to help developers and agriculturists match the optimum use of land, land suitability evaluation plays a very important role as a part of rational cropping system (Jafarzadeh *et al*., 2010) and land use optimization for a specific use (Sys *et al*., 1991). 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 uses. Based on its attributes and potentials, every land is suitable for a 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 the first step to land use planning. This will enhance judicious and maximum utilization of any available piece of land, without jeopardizing the prospect of the future generations. There are different land suitability assessment methods, including the productivity index method, which have been adopted and also modified by some authors in Nigeria including Esu (1982), Ogunkule (1993) and Ezeaku (2000). In this method, the land utilization type is defined, and then its agronomic requirement is matched with the land qualities and soil characteristics. The suitability class is calculated, using limitation rating.

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Cassava (*Manihot esculenta*) plays a major role in the economy of Nigeria, as it supplies more than half of the calorie intake of her inhabitants (Abam *et al*., 2006). The country is the largest producer of cassava in the world, with an annual production rate of 54 million metric tons (FAO, 2016). Cassava has diverse uses; it is principally used as human food, where it provides a major source of diet and energy for the well-being of over 200 million people in Africa (Dorosh, 1988). As food it can be processed into *Garri, Fufu Farinhnade, Mandioca*, flour, chips and starch. Cassava chips, pellets and leaves are important in animal feed industry (Tewe *et al.,* 1997). Cassava starch is used in food, confectionery and textiles industries. It is a major source of cash income for a large number of household in comparison with other staple crops, thereby contributing to poverty alleviation in Africa (Onyekwere *et al.*, 2018).

The annual production rate of this important economic commodity crop in Nigeria as stated earlier is not as a result of its yield per unit area when compared to yield obtained from countries like Brazil, China and Thailand (Onyekwere *et al.*, 2018).They further observed that the production rate is due to the large expanse of land subjected to its production. Presently, it has been observed that cassava yield in farmers' field in Nigeria is less than 10 t ha^{-1} (Onyekwere *et al.*, 2018).This is as a result of some factors which include inherent poor soil fertility, pests and diseases, use of unimproved cassava varieties and weed infestation (Okeke, 1998). Among all these, the most important factor is inherent soil fertility. To have an increase in yield of cassava from farmers' field, the soil fertility needs to be managed to improve the soil resource base. Soil fertility management has resulted in increased cassava root yield in experimental fields (Onyekwere *et al.*, 2013). For soil fertility management to be meaningful for cassava production in farmers' field, the soil must be properly characterized and assessed to ascertain its suitability for production.

Based on the importance of cassava and its recurrent low yield in farmers' field there is need for an increase in cassava yield per unit area in Nigeria. The first step in achieving this is to characterize and assess the suitability of the available lands and also to identify soil fertility management system that will increase plant nutrients availability and restore soil resource base for yield increase. Adoption of soil management option that will guarantee high productivity depends on the nature and properties of the soil, which can be done through characterization; a pre- requite to suitability assessment. However, for cassava farmers in Ishiagu, Ebonyi State, South-eastern Nigeria to record an increase in yields, characterization and suitability assessment of the soils under cassava cultivation is necessary. Therefore, the objective of this work was to assess the physical and chemical properties of the soils in Ishiagu, Ebonyi State in the South-eastern Nigeria and further evaluate their suitability for sustainable cassava production in the area

Materials and Methods

Study area

The study area was Ishiagu, Ebonyi State, South-eastern part of Nigeria. The study area lies within Latitude 5^0 40^1 and 6^0 45^1 E and Longitude 7^0 30^1 N. The climate is characterized by distinct wet and dry seasons. The wet season lasts for about seven months (April to October), with a short break in August. On the other hand the dry season stretches mainly from November to March. The mean annual temperature ranges between 22^0C and 31^0C, mean annual rainfall ranges from 1,570 to 2,800 mm and relative humidity varying from 60 to 81 % (Table 1). The vegetation consists of derived Savannah. The underlying geology of the location consists of the tertiary Imo formation (Shale). The vast land is used for cassava production intercropped primarily with maize and *Egusi* melon.

Pedological studies

Five hundred hectares of land was demarcated with the aid of Global Positioning System (GPS). The overall micro-relief of the surveyed areas consisted of slightly undulating to gently sloping terrain of not more than 4 %, gradient, which was measured using a clinometer. A detailed soil survey using the rigid grid format was conducted, transverses were cut along a properly aligned base line at 100 m intervals. Auger borings were made at 25 cm interval to a depth of 100 cm and morphological descriptions (colour, texture, consistency and inclusions) were carried out.

Based on similarities and differences of the morphological properties, 3 different soil mapping units were delineated. Three profile pits measuring 2m x 1m x 1.00 to 1.120m, which were restricted to get to 2m depth because of impenetrable layers, were sited in each delineated soil unit, making a total of nine soil profile pits. The morphological characteristics of each profile pit 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 the bottom to avoid contamination. Samples were taken to the Laboratory for physical and chemical analysis.

All the soil samples collected were air dried, gently ground and sieved using a 2 mm sieve. Samples for the estimation of the total N and organic C were passed through a 0.5 mm 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 51.00 g of air – dried soil samples with 5 % sodium hexametaphosphate overnight using 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 by International Soil Reference and Information Centre and Food and Agricultural Organization **(**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 quantified 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 5 g 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.

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

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 the total nitrogen in the fertility index calculation.

The Productivity Index adopted for this study is given below:

Pa = H x D x Dp x T x Sp x FI ------ (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 x Om x Ce x Mr x Ap, x Tn, ---- (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 below:

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 above 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 expresses the degree of possible improvement measures needed to advance yield of arable crops grown on the soils. This was calculated thus:

$$CI = PPI/Pa \times 100 \quad \text{------------------------} \ (3)$$

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.

Suitability classification of the soils
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.

Results and Discussion

Soil characteristics
The physical land characteristic ratings of the mapping units studied are presented in Table 2 and the land requirements for cassava production are presented in Table 4. The entire mapping units studied were well drained and the effective soil depth (rooting zone) is adequate, giving the indication that there is no limitation to the production of cassava in the soils. The soil texture/class ranged from sandy loam to clay, the textural classes are conducive for the production of the crop with only slight limitation in mapping unit 3 and moderate limitation in mapping units 1 and 2. Therefore, application of organic fertilizer will improve the soil texture for sustainable cassava production. The slope rating is gently slopped ranging from 0.5 to 4 % in all the mapping units with no limitation to production of cassava. According to Fasina and Adeyanju (2006) a slope <3% favours mechanical operation. The chemical land characteristic ratings of the mapping units are presented in Table 3.The soil reaction rating of the entire mapping units studied showed that the soil pH in all the mapping units has slight limitation to the production of cassava. The total nitrogen rating of the soils indicates that all the mapping units have slight limitation to the production of cassava, apart from mapping unit 3 that has no limitation.

The available P content rating of the soils showed that all the mapping units have moderate limitation to the production of cassava (Table 3). The organic carbon rating of the soils revealed that the entire mapping units have no limitation to the production of cassava. The CEC rating of the soils showed that the entire mapping units have no limitation to the production of cassava.

The base saturation rating of the soils showed that all the mapping units have no limitation to the production of the cassava (Table 3). The soil fertility limitations can be corrected by 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 (Table 1). This is corroborated with the findings of Udoh *et al*. (2005). Based on some limitations after considering the actual and potential soil productivity indexes, and their improvement coefficient for production of cassava in the soils studied, the actual and potential suitability classification (productivity index) are as shown in Table 5.

The suitability classification of the mapping units of the soils studied for cassava production showed that the actual productivity index ranged from 53.20 to 59. 06 %, indicating, that all the mapping units were moderately suitable (S2) for cassava production. However, if the limitation of soil texture, soil acidity and fertility will be ameliorated through soil conservation practices by organic and inorganic fertilization, a potential productivity index of 77.39 % is possible and thus the soils could be made to be 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 ranged from 1.31 to 1.45.

However, these soils possess limitation, of 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 with the use of inorganic and organic fertilizers.

Conclusion

The work involved Pedological examination of Ishiagu, South-eastern Nigeria soils and their assessment for suitability for sustainable cassava production. The results of the study revealed that the soils of the studied sites are strongly acidic, low to moderate in total N and exchangeable K and low in available P. The soil texture is favourable for production of cassava. 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, K fertilizer and incorporation of crop residue, organic manure and crop rotation involving leguminous crops .Based on the findings of this pedological work, which is a baseline study, the next level of action is to carry out a soil fertility validation study on the mapping units studied using cassava as the test crop.

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Table 1: Ten years meteorological data of Ishiagu, South-eastern Nigeria

	Temperature (^{o}C)		Rainfall (mm)		Relative humidity (%)		Sunshine Hours
Year	Minimum	Maximum	Days	Amount	1500	900	
2007	23.45	31.00	150	2600.5	63	75	4.8
2008	24.00	33.00	133	1570.8	66	77	4.9
2009	23.33	32.73	129	2369.0	64	77	4.7
2010	22.88	31.20	130	2271.5	64	76	4.7
2011	22.80	31.75	132	2200.5	66	74	4.5
2012	22.00	31.87	121	1915.8	63	73	4.3
2013	22.65	32.00	139	2055.6	66	78	4.8
2014	21.75	31.45	119	2000.4	66	79	5.0
2015	22.64	32.00	132	2310.5	62	72	4.7
2016	23.50	31.00	140	2386.8	61	73	4.9

Source: Federal College of Agriculture Ishiagu Metrological Unit

Table 2: Physical land characteristics and limitation rating of mapping units of the study area for cassava based on Mongkolsawat *et al.* (1997) rating (soil reference depth 75 cm)

Mapping unit	Slope (%)	Slope Rating	Drainage	Rating	Soil depth (cm)	Rating	Textural Class	Rating
1	2 – 4	100	Well drained	100	115	100	SCL,C	85
2	0.5 - 2	100	Well drained	100	120	100	SCL, C	85
3	0.7 - 2	100	Well drained	100	101	100	CL, C	95

Key = N = None, S = Slight, M = Moderate, SCL = Sandy Clay Loam, C = Clay, CL = Clay Loam

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

Table 3: Chemical land characteristics and limitation rating of soils derived from shale for cassava based on Mongkolsawat *et al.* (1997) rating (soil reference depth 75 cm)

Mapping unit		pH (H_2O)	Rating (%)	Organic C (gkg^{-1})	Rating (%)	Available P (mg kg^{-1})	Rating (%)	Total N (gkg^{-1})	Rating (%)	CEC (cmol (+)kg^{-1}	Rating (%)	Base Sat (%)	Rating (%)
1			95		100		85		95		95		100
	Range	4.8-5.0		21.4 - 21.4		1.40 - 5.43		0.2 – 2.8		7.85 –8.67		36.70 - 50.70	
	Mean	4.9				3.50		1.5		8.16		42.47	
2			95		100		85		95		95		100
	Range	4.7 - 5.2		22.1 - 22.1		1.75 – 5.08		0.3 – 3.1		6.19 - 7.98		36.90 - 47.20	
	Mean	4.9				3.33		1.3		7.06		40.70	
3			95		100		85		100		95		100
	Range	4.5- 4.7		26.8 - 26.8		2.63 – 5.08		0.1 – 1.4		11.03 –13.96		25.10 - 45.10	
	Mean	4.6				4.00		2.0		12.45		35.17	

Key:	N = None,	S = Slight,	M = Moderate,	S = Severe	VS = Very severe
Percentage rating	100	95	85	60	40
Degree of Limitation	None	Slight	Moderate	Severe	Very severe

Table 4: Land use requirements for cassava production

Land group quality	Land Characteristics Unit	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	Average Temperature (^oC)	18 – 30	.>16	>12	Any
Regime					
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	Soil depth (cm)	>100	100 – 75	75 – 50	< 50
Water Retention					
	Soil texture	L; SL.CL	.LS,SiCL	S,SiC	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 $^{-1}$)	>25	6 – 25	<6	Any
	pH	6.1- 7.3	7.4-7.8 or 5.1-6.0	>8.4 or <4.0	
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); Mongkolsawat *et al.*, (1997)

Table 5: Actual and potential land suitability classification of the 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
I	53.20	77.39	1.45	S2f	S1
2	53.20	77.39	1.45	S2f	S1
3	59.06	77.39	1.31	S2f	S1

f = Nutrient deficiencies