LAND SUITABILITY EVALUATION OF SOILS DERIVED FROM SHALE IN SOUTH EASTERN NIGERIA, FOR SUSTAINABLE CASSAVA PRODUCTION

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ABSTRACT

Land suitability evaluation has been defined as the fitness of a given tract of land for a specified kind of use. Soils derived from shale parent material in Ishiagu, Ivo Local Government Area of Ebonyi State, Southeastern Nigeria, were evaluated for their suitability for sustainable cassava production. Detailed soil survey of the area was conducted using the rigid grid format and land suitability assessed using the productive index method. Based on the survey, three mapping units were delineated and profile pits dug and studied in each mapping unit, soil samples from pedogenetic horizons were analytically examined for particle size distribution, pH, organic carbon, total Nitrogen, available phosphorous, exchangeable cations and cation exchange capacity. The implications of the analytical data are discussed. From the suitability assessment, all the mapping units were moderately suitable for cassava production. Recommendations are given as to the options to be adopted in managing the soils and make them potentially highly suitable for sustainable cassava production.

Key words: Land suitability, evaluation, soils of shale, cassava, production

INTRODUCTION

Cassava (*Manihot esculenta*) plays a major role in the economy of Nigeria, as it supplies more than half the calorie intake of her inhabitants (Abam *et al*., 2006). The country is the largest producer in the world, with an annual production rate of 53 million metric tons (FAO, 2013). It has diversities of uses; it is principally used as human food where it provides the major source of dietary energy for well over 200 million people in Africa (Dorosh, 1988). As food it can be processed into gari, fufu, farinhnade, mandioca, flour, chips and starch (Onwueme, 1978). Cassava chips, pellets and leaves are important in animal feed industry (Hutagalung *et al*., 1973, Tewe *et al*., 1997). Onwueme (1978), reported that cassava starch is used in glucose, textiles and confectionery industries. Besides the use of cassava as food and in industry, it is also a major source of cash income for household. In this regard, it generates cash income for the largest number of household in comparison with other staple crops thereby contributing to poverty alleviation (FMANR, 1997).

The annual production rate of this important economic commodity crop by Nigeria is not as a result of its yield in farmer's field compared to yield obtained from countries like Brazil, China and Thailand, but due to large expanse of land subjected to cassava production. Presently, cassava yield in farmer's field in Nigeria is far less than 10 t ha^{-1}. This is as a result of some factors which include inherent poor soil fertility, pest and disease, use of unimproved cassava varieties and weed infestation. Among all these factors the most important is inherent poor soil fertility. In the past the issue of soil fertility was solved through shifting cultivation system or bush fallowing. Consequently, many socio-economic factors including population increase and rural urbanization have rendered bush fallowing ineffective. Fallow periods are becoming shorter and shorter and in most places continuous cultivation is practiced. This particular practice has led to continuous declining soil fertility due to the inability to replenish the soil after harvesting of crops. To get a meaningful yield of cassava from farmer's field, the soil need to be managed to improve the soil resource base. Soil fertility management has resulted to increase in cassava root yield in experimental fields. For soil fertility management to be meaningful for cassava production, the soil must be properly assessed to ascertain its suitability for the production of cassava, thereby ascertaining some remediation options (coefficient of improvement) for yield improvement.

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 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 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.

However, for cassava farmers' in Southeastern Nigeria to record an increase from the present yields, suitability evaluation of the soils under cassava cultivation is necessary, this will enable their proper use and development of technology for an increase in its yield. Therefore, the objective of this work was to assess the suitability of soils derived from shale parent material in Southeastern Nigeria under cassava cultivation and give possible management measures for an increase in cassava production.

MATERIALS AND METHODS

Study Area

The study area is Ishiagu, Ebonyi State Southeastern Nigeria. It lies within Latitude 7^0 $30'$ N and Longtitude 5^0 $40'$ and 6^0 $45'$ E. The climate is characterized by distinct wet and dry seasons. The wet season lasts for about seven months (April through October), with a short break in the month of August. On the other hand the dry season stretches mainly from November through March. Peters and Ekwe-Ozor (1982), reported that a condition of great uniformity is experienced in the area throughout the year with a mean annual temperature range between 22 and 33^0C, mean annual rainfall range of 1,570 to 2,600 mm and relative humidity varying from 61 to 79 % (Table 1). The vegetation consists of derived savanna. The underlying geology of the location consists of the tertiary Imo formation (shale).

Pedological Studies

Five hundred hectares of land which were demarcated with the aid of Global Positioning System (GPS) Receiver Garmin Ltd Kansas, USA were surveyed. The overall micro-relief of the surveyed areas consisted of slightly undulating to gently sloping terrain of not more than 4 % gradient. A detailed soil survey using the rigid grid format was conducted, transverses were cut along a properly aligned base line at 100 m intervals while auger borings were made at 25 cm interval to a depth of 100 cm and morphological descriptions (colour, texture, consistency and inclusions) were made. Based on similarities and differences of the morphological description, 3 different soil mapping units were delineated. Three profiles pits measuring 2m x 1m x 1.00 to 1.120 m, which were restricted to get to 2m depth because of impenetratable layers, were sited in each delineated soil unit, making a total sum of nine profile pits. The profile pits were cleaned and demarcated based on depths of genetic horizons, which were delineated based on differences in morphology, and sampled horizon by horizon

Table 1: Ten years meteorological data of Ishiagu (shale)

	Temperature (°C)		Rainfall (mm)		Relative humidity (%)		Sunshine Hours
Year	Minimum	Maximum	Days	Amount	1500	900	
2003	23.45	31.00	150	2600.5	63	75	4.8
2004	24.00	33.00	133	1570.8	66	77	4.9
2005	23.33	32.73	129	2369.0	64	77	4.7
2006	22.88	31.20	130	2271.5	64	76	4.7
2007	22.80	31.75	132	2200.5	66	74	4.5
2008	22.00	31.87	121	1915.8	63	73	4.3
2009	22.65	32.00	139	2055.6	66	78	4.8
2010	21.75	31.45	119	2000.4	66	79	5.0
2011	22.64	32.00	132	2310.5	62	72	4.7
2012	23.50	31.00	140	2386.8	61	73	4.9

Source: Federal College of Agriculture Ishiagu Metrological unit

starting from bottom to avoid contamination. Samples were taken to the Laboratory for physicochemical analysis.

All the soil samples collected from the soil profile pits were air dried; gently ground and sieved using a 2 mm sieve preparatory for laboratory analysis. Samples for 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.

Soil Analysis

Physical Properties

Soil particle size analysis was determined after dispersing 51.00 g 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 by International Soil Reference and Information Center 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 colorometrically. Exchangeable Ca, Mg, K and Na in soil samples were extracted with I N neutral Ammonia acetate (NH_4OAc) and K and Na was determined by flame photometer while Ca and Mg was 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. 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.

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

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 total nitrogen in the fertility index calculation.

The Productivity Index adopted for this study is given below

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

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

$$FI = Sr \times Om \times Ce \times Mr \times Ap_, \times Tn_, \quad - \quad - \quad - \quad (2)$$

Where: Sr = Soil reaction
OC = Organic carbon 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 is calculated thus:

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

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.

Table 3 : Chemical Land characteristics (mean values) of the Mapping units for cassava based on 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 (%)	Base Sat Rating
1	4.9	95	21.4	100	3.50	85	1.5	95	8.16	95	42.47	100
2	4.9	95	22.1	100	3.33	85	1.3	95	7.06	95	40.70	100
3	4.6	95	26.8	100	4.00	85	2.0	100	12.45	95	35.17	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	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 Regime	Average Temperature	(°C)	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	Soil depth	(cm)	>100	100 – 75	75 – 50	< 50
Water Retension						
	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	Actualland 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

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). Land Suitability evaluation of soils 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. The entire mapping units studied were well drained, giving the indication that there is no limitation to the production of cassava in the mapping units. The effective soil depth (rooting zone) ranged from 101 to 120 cm, giving the indication that there is no limitation for cassava production. The soil texture ranged from sandy loam to clay, this shows that there is slight limitation in mapping unit 3 and moderate limitation in mapping units 1 and 2 for production. Therefore, application of organic fertilizer will improve the soil texture, for sustainable cassava production. The slope rating is gently sloping ranging from 0 to 4 % in all the mapping units which shows no limitation to production of cassava. According to Fasina and Adeyanju (2006) a slope <3% favours mechanical operation.

The chemical (mean values) land characteristic ratings of the mapping units are presented in Table 3. The soil reaction rating of the entire mapping units studied had a mean value range of 4.6 to 4.9, this shows that the soil pH in all the mapping units has slight limitation to the production of cassava. The mean total nitrogen rating of the mapping units studied ranged from 1.3 to 2.0 gkg^{-1}, indicating that all the mapping units have slight limitation to the production of cassava, apart from mapping unit 3 that has no limitation. The mean available P content rating of the mapping units studied ranged from 3.33 to 4.00 $mgkg^{-1}$, this shows that all the mapping units have moderate limitation to the production of cassava. The mean organic carbon rating of the mapping units studied ranged from 22.1 to 26.8 gkg^{-1}, this reveals that the entire mapping units have no limitation to the production of cassava. The mean CEC rating of the mapping units studied ranged from 7.06 to 12.45 $cmolkg^{-1}$, showing that the entire mapping units have no limitation to the production of cassava.

The mean base saturation rating of the mapping units studied ranged from 35.17 to 42.47 %, this shows that all the mapping units have no limitation to the production of the cassava. The soil fertility limitations can be corrected by 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 were observed to occur 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 and potential soil productivity indexes and their improvement coefficient for production of cassava in the mapping units studied their actual and potential suitability classification (productivity index) are as shown in Table 5 and land requirement for cassava is shown in Table 4.

The suitability classification of the mapping units of the soils studied for cassava production shows that the actual productivity index ranged from 53.20 to 59. 06 %, an indication 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 organic and inorganic fertilization, a potential productivity index of 77.39 % is possible thereby making the soils highly suitability for cassava production. The coefficient of improvement (CI), an indicative of cost with which the soils can be improved to a higher suitability class ranged from 1.31 to 1.45 in the mapping units studied.

However, these mapping units 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 with the use of inorganic and organic fertilizers.

CONCLUSION

The work involved pedological examination of basaltic soils of Ikom for their suitability for sustainable cassava production. From the results obtained from the study, it can be concluded as follows,

Three mapping units were delineated. The mapping units were gently sloping, well drained, the soil depth had no limitation for cassava production, with the texture having slight to moderate limitation for cassava production. The mapping units also showed slight limitation with soil pH, moderate limitation with available phosphorous and no limitation with organic carbon for cassava production. The three mapping units were then identified as being moderately suitable (S2) for cassava production.

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