LAND SUITABILITY EVALUATION OF SOILS FOR TWO CROPS ALONG A TOPOSEQUENCE IN NJIKOKA AREA OF ANAMBRA STATE, NIGERIA

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ABSTRACT

This study imployed an additive model to evaluate the suitability of selected soils for maize and cassava production in Njikoka Area, Anambra State, Nigeria. With the aid of a topographic map, three topographic units: crest, mid- and foot-slopes were selected via free survey method. Two pedons were dug in each topographic unit and described in situ following FAO guidelines. A total of 23 samples were collected from the diagnostic horizons of the six pedons for physicochemical analyses. The soils were acidic with low organic matter, total nitrogen, availabile phosphorus and exchangeable bases. The suitability evaluation showed 50% of the pedons were both moderately (S2) and marginally (S3) suitable for maize production respectively whereas 67% and 33% of the pedons were moderately (S2) and marginally (S3) suitable for cassava production, respectively.

KEYWORDS: Suitability, Cassava, Maize, Evaluation, Land Quality, Soil Properties

INTRODUCTION

Agricultural development depends not only on the availability of soil information but also on the characteristics and quality of the land. The qualities/characteristics of a land are the major determinants of its appropriate and proper use (Nuga *et al*., 2006). Agricultural land use is discriminatory, such that not all crops can be grown successfully on a particular soil type (Adeyolanu *et al*., 2017). Growing a crop on a piece of land without proper assessment of its suitability for such use leads to sub-optimal soil productivity and low yield as crop requirements are not often related to the land's potential ability (Ezeaku, 2011). Thus, the best method of ensuring optimum output from our land resources is their allocation to the use for which they are most suitable (Fasina *et al*., 2007). Developing and adopting an ideal land use plan based on the soil quality and constraints for plant growth is of immense use for achieving sustainable crop production system without degrading soil health and environmental quality (Amaresh and Rajkumar, 2014).

Land evaluation provides information on the potentials and constraints of a piece of land for a defined land-use type as well as its sustainable management with respect to crop performance as affected by the physical environment. This information is more demanding than ever because of sub-optimal crop performance, high cost of production and soil degradation problems arising from misuse of land (Atofarati *et al*., 2012). The knowledge of soil limitations arising from land evaluation aims at ameliorating such limitations before, or during cropping period (Lin *et al*., 2005). Most often, farmers treat the entire landscape as a uniform entity overlooking the differences in soil types. Soil properties and potential for crop production differ across the landscape and thus, affecting the pattern of crop production (Fasina *et al*., 2015). Therefore, soil as a main medium for crop growth needs to be evaluated before use. This is very vital at this time when precision farming is gaining wider acceptance and the relevance is particularly more now in the developing world where the use to which a land is put is very often not related to its capacity.

Despite the high agricultural development potential of Njikoka soils, there is a dearth of soil information in the area especially on terrain features; and land evaluation likely to assist farmers in crop production. Most previous soil studies in the area did not cover most of the cluster villages and besides evaluation of the suitability of these soils on diverse landforms for maize, cassava and cocoyam had not been considered. The need to generate soil information on land terrain distribution, soil potentials and constraints for their production in the study area necessitated this study, with the objective of characterizing and evaluating the suitability of soils on diverse landforms in the study area for maize and cassava production.

MATERIALS AND METHODS

Description of the Study Area

Njikoka Area, Anambra State Nigeria lies within latitudes 6° 4' 0" N and 6° 16' 0" N and longitudes 6° 56' 0" E and 7° 3' 0" E (Fig 1). It is characterized by two seasonal climatic conditions: rainy and dry seasons with most rain falling during the rainy season from March to October with its peaks in July and September; and a short break in either July ending or August known as August break. The dry season extends from November to February with harmattan occurring between the months of

December and January. The mean annual rainfall is above 1450 mm concentrated mainly in eight months of the year. It has an average temperature of 27 °C with daily minimum and maximum temperatures in ranges of 22 °C to 24 °C and 30 °C to 34 °C respectively. The relative humidity is in the range of 75 to 95% (Hydrometeorological Department, Awka, 2018). The native vegetation of area was originally rainforest characterized by very tall, big trees with thick undergrowth and numerous climbers (Ezeigwe, 2015). However, as a result of human interferences, the vegetation now consists of admixture of bush regrowth, arable crop farms and tree crops. Agriculture, hunting and cottage industries are predominant means of livelihood in the area (Orji Uzor and Obasi, 2012). The major crops along the selected toposequences include: cassava (*Manihot spp*); cocoyam (*Colocasia esculentus*); yam (*Discorea spp*); maize (*Zea mays*), plantain (*Musa spp*.), oil palm (*Elaeis guinensis*) and mango (*Mangifera indica*).

Field Study

A reconnaissance survey of the study area was carried out to complement information contained in the GIS acquired topographic map of the area (Fig. 2). The stratified simple random sampling technique based on topographic attributes of the slope was adopted in this study. The study area was delineated based on existing terrain features into crest, mid and foot slopes respectively (Fig. 2). Two profile pits of dimension 2m by 2m by 2m at 500 M interval were dug per terrain type (Figure 2), and georeferenced using a hand-held global positioning system (GPS) receiver. The pedons were described in situ following the procedures in the guidelines for soil profile description (FAO, 2014) and horizon designations of the Soil Survey Staff (2006). Soil samples were collected from each of the identified diagnostic horizons from the bottom upwards to avoid contamination.Core samples were also collected for bulk density and hydraulic conductivity determinations. A total of 23 soil samples were collected from the six pedons.

Laboratory Analyses

The soil samples were air dried, crushed and sieved using a 2 mm sieve size. Particle size distribution was determined by Bouycous hydrometer method using sodium hydroxide as a despersant (Gee and Or, 2002). Bulk density was determined using core method after oven drying the soil samples to a constant weight at temperature 105 ^{o}C for 24 hours (Grossman and Reinsch, 2002). Saturated hydraulic conductivity was measured by core method as described by Klute and Dirksen (1986). Total Porosity was calculated using the formula;

Soil total porosity (%) = 100 - (bulk density/Particle density x 100)

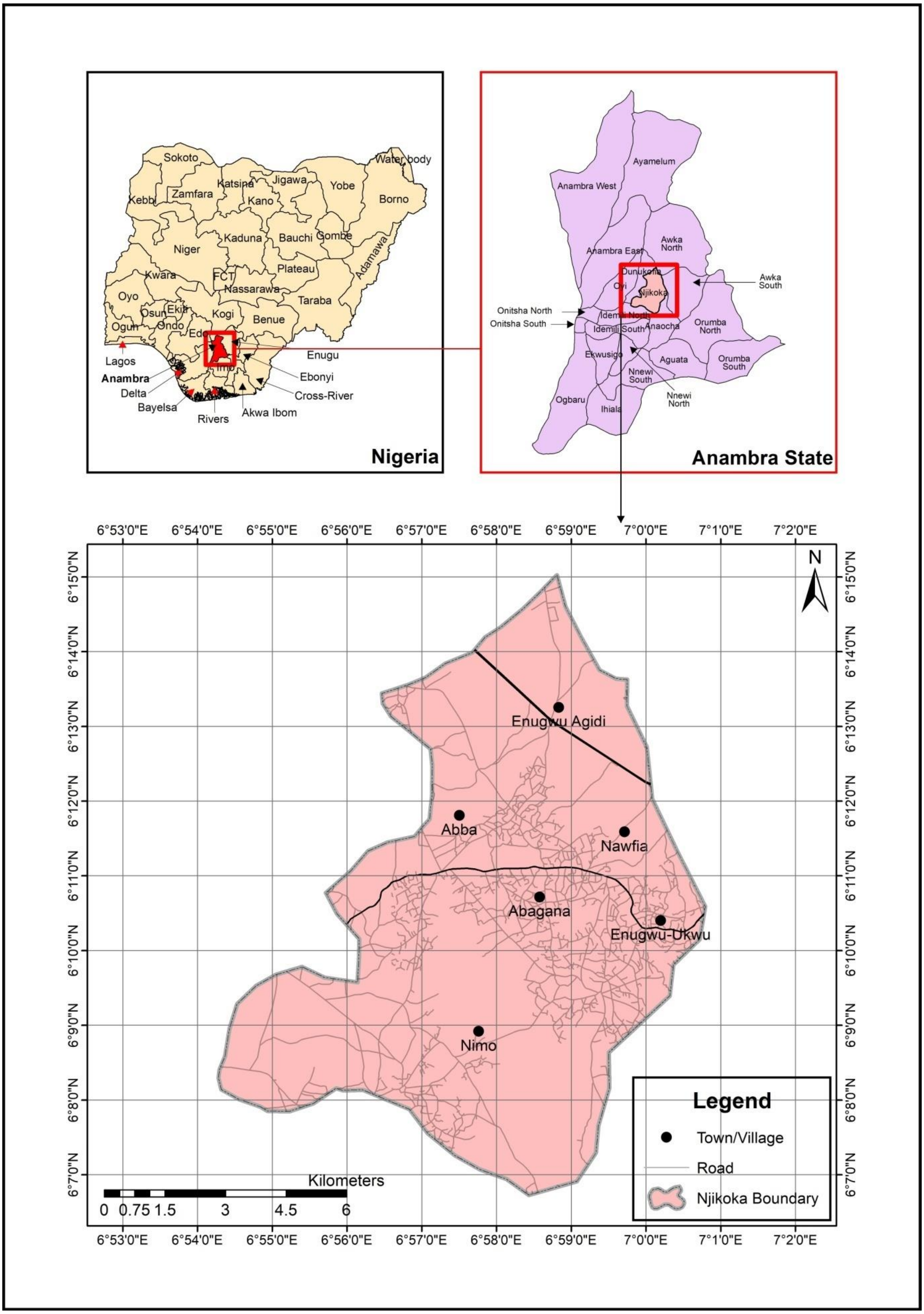

Figure 1: Map Nigeria showing Anambra State and Njikoka Area

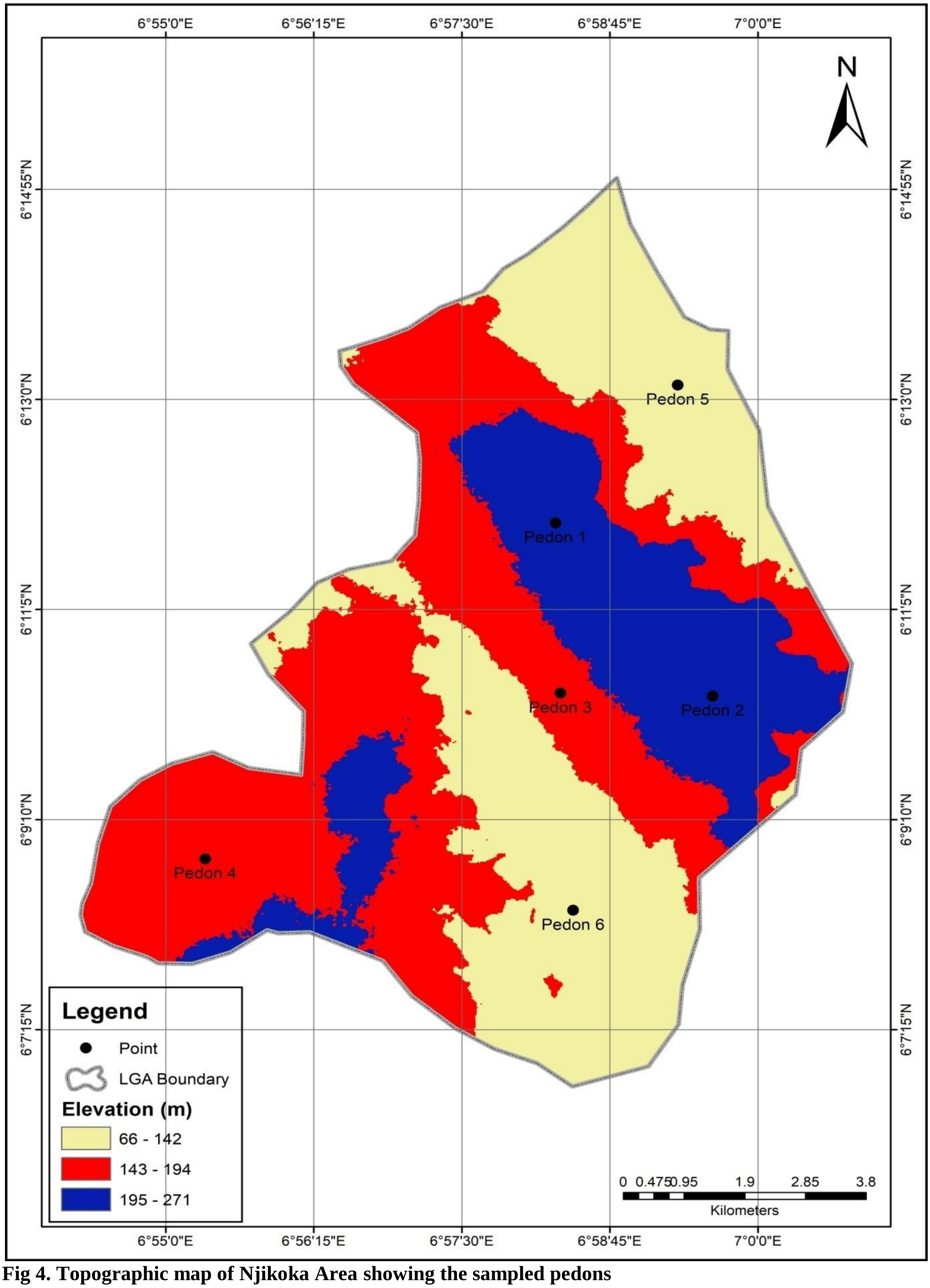

Fig 4. Topographic map of Njikoka Area showing the sampled pedons

Soil pH was determined both in water and 0.1N potassium chloride solution at the soil/liquid ratio of 1:2.5 using Beckman Zerometic pH meter (Van Reeuwijk, 1992). Organic carbon content was determined by the dichromate wet oxidation method (Jackson, 1973) and multiplied by 1.724 to obtain organic matter. Total nitrogen was determined by the Kjeldahl digestion, distillation and titration procedure as described by Bremner (1965). Available phosphorus was determined using Bray II method as described by Olsen and Sommers (1982). Cation Exchange Capacity was determined using the ammonium acetate method (Chapman, 1965). Exchangeable bases ($Ca^{2+,}$ Mg^{2+}, Na^{+} and K^{+}) were extracted using 1N ammonium acetate; calcium and magnesium were determined by titration method (Chapman, 1965) while sodium and potassium were determine using flame photometer as described by Rhoades (1982). Exchangeable hydrogen and aluminium were determined by titrimetric method using potassium chloride extract (Mclean, 1965). Exchangeable Acidity was calculated by summing the values of exchangeable aluminium and hydrogen.

$$EA = Al^{3+} + H^{+}$$

Base Saturation was calculated as thus: BS = TEB/ECEC X 100; …………………………1

where BS = base saturation; TEB = total exchangeable bases and ECEC = effective cation exchange capacity which was obtained by summation of total exchangeable bases and total exchangeable acidity.

Land Evaluation Procedure

The suitability of the soils for maize, cassava and cocoyam production was assessed using the parametric linear additive model as stated in Ezeaku and Tyav (2013):

LI = $+ B/100 + C/100 + D/100 + E/100 + F/100$ ………………...2

where LI is the Land Suitability Index (%), A is the overall lowest characteristics ratings (%) and B, C, D.…. F are the ratings for each property (%). The value of the land suitability index was used to determine the aggregate suitability class. The detailed land and soil requirements for each of the study crops (maize and cassava) were present in Tables 1 - 2.

Table 1: Land and soil requirements for rain-fed maize production

Land Qualities	**S1(100-85)**	**S2 (85-60)**	**S3 (60-40)**	**N (<40)**
Climate (c):				
MAR (mm)	2500-1800	1800-1600	1600-500	<500
MAT (°C)	22-26	22-18/26-32	18-16/ 32+	36-30
Soil physical properties (s):				
Soil texture	SCL, L, CL	LS, SL	C	S
Depth (cm)	>75	>50	20	<20
Soil fertility (f):				
Ph	5.5-7.5	5.0-5.5/7.5-8.0	4.0-5.0/8.0-8.5	<4.0/>8.5
CEC (cmol kg^{-1})	>24	>16	<16	<10
Base saturation (%)	50-35	35-20	20-15	<15
Organic matter (g kg^{-1})	>15	8-15	5-8	<5
Av. P (mg kg^{-1})	>25	6-25	<6	Any
Wetness (w):				
Soil drainage	Well drained	Imperfectly drained	Poorly drained	Very poorly drained
Topography (t):				
Slope (%)	0-4	4-8	8-16	>16

(Adapted from Sys *et al*., 1993)
Key: S1: highly suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable; MAR: mean annual rainfall; MAT: mean annual temperature; SCL: sandy clay loam; L: loam; CL: clay loam; LS: loam sand; SL: Sandy loam; C: clay; S: sand; CEC: cation exchange capacity; Av. P: available phosphorus

Table 2: Land and soil requirements for rain-fed cassava production

Land Qualities	**S1 (100-85)**	**S2 (85-60)**	**S3 (60-40)**	**N (<40)**
Climate (c):				
MAR (mm)	1500-1100	1100-900	900-500	<500
MAT (°C)	18-30	>16	>12	Any
Soil physical properties (s):				
Soil Texture	SCL, L, CL, SC	LS, SL, SiCL	S, SiC	C
Depth (cm)	>100	100-75	75-50	<50
Soil fertility (f):				
Ph	6.1-7.3	7.4-7.8/5.1-6.0	>8.4/<4	Any
CEC (cmol kg^{-1})	>16	3-16	<3	Any
Base saturation (%)	>35	35-20	>20	Any
Organic matter (g kg^{-1})	>15	>8	>5	<3
Av. P (mg kg^{-1})	>25	6-25	<6	Any
Wetness (w):				
Soil drainage	Well drained	Imperfectly drained	Poorly drained	Very poorly drained
Topography (t):				
Slope (%)	0-5	5-12	12-20	>20

(Adapted from Sys *et al*., 1993)
Key: S1: highly suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable; MAR: mean annual rainfall; MAT: mean annual temperature; SCL: sandy clay loam; SC: sandy clay; SiCL: silty clay laom; SiC: silty clay; L: loam; CL: clay loam; LS: loam sand; SL: Sandy loam; C: clay; S: sand; CEC: cation exchange capacity; Av. P: available phosphorus

RESULTS AND DISCUSSION

Morphological Properties

The summary of the morphological properties of the soils are presented in Tables 4. All the pedons were well drained with depth of >200 excluding pedon 1. The ‘Ap’ horizons of all the pedons were dark reddish brown (10R 3/3) and reddish brown (10R 4/3) in colour underlained by red (10R 4/6, 10R 4/8 and10R 5/6) and reddish brown colours (10R 4/3, 10R 4/4 and 10R 5/4) with the exception of the pedon 1 which had reddish brown colour (10R 4/3, 10R 4/4 and 10R 5/4) throughout the entire horizons.

The reddish colour of the matrix might be attributed to high iron content of the parent material and its oxidation state (Nsor, 2017). Mottles of bright yellowish brown (10YR 6/8 and 10YR 6/6) and yellowish brown (10R 5/6) were observed in some pedons. This serves as an evidence of oxidation-reduction reactions caused by seasonal rise in the water table or water logging during some periods of the year (Akamigbo *et al*., 2001; Brady and Weil, 2006). The textural characteristics of the soils by feel varied from sand to very gravelly sandy clay loam.

The structure of the soils varied from coarse single grained structure to moderately developed fine granular structure in the surface horizons and moderately developed fine granular structures to moderately developed medium angular and sub-angular blocky structure in the sub horizons. The presence of higher organic matterand root population were responsible for the granular structures (Yitbarek *et al*., 2016; Kebede *et al*., 2017) while low organic matter, low root population and higher clay content accounted for the angular or sub-angular blocky structures (Fedaku *et al*., 2018). Soil consistency varied from loose to firm (moist) and non-sticky to sticky (wet).Roots varied from very fine to coarse and few to very many in size and relative abundance respectively. The presence of the roots were indications of considerable amount of biological activities in the soils. Clay skins were observed in the sub horizons of pedons 1, 2, 4 indicating that eluviation/illuviation processes had probably taken place in the soils, hence the movement of clay down the profiles (Esu, 2010). The presence of cracks at Bt horizons of pedon 2 inferred that the soils have expanding clay minerals (Alhassan *et al*., 2012). Charcoals were found in 'B' horizons of pedon 1 and 6 depicting evidence of human settlement in the past (Esu, 2010). Stones, gravels and boulders were present in some pedons though not significant enough to hinder agricultural production. The horizon boundary varied between clear smooth, clear wavy, abrupt wavy, abrupt smooth, gradual smooth, gradual wavy and diffuse smooth.

Table 3: Morphological properties of soils

Depth (cm)	HD	Colours matix	Colours mottles	T	Structure	Consistence moist	Consistence wet	Roots	Hb	Other features
Pedon 1 (crest)										
0-25	Ap	10R 4/3 (RB)	-	LS	f ma g	fr	ns	VM vf	cs	few stones
25-88	Bt_1	10R 4/4 (RB)	-	StSCL	vf ma g	fr	ns	F vf	gs	many stones, few boulders
88-140	Bt_2	10R 5/4 (RB)	-	SCL	mod m ab	fr	ss	-	cw	thin clay skin on the ped face
140-200	BC	10R 5/4 (RB)	F vf bYB (10YR 6/8)	VgSCL	mod m ab	fr	s	-	-	Moderately thick clay skins, very many gravel
Pedon 2 (crest)										
0-35	Ap	10R 3/3 (DRB)	-	Gls	f ma g	fr	ns	M vf; F f	gw	many gravels; few stones
35-70	AB	10R 3/4 (DR)	-	VgLS	f ma g	l	ns	-	cs	very many gravels
70-160	Bt_1	10R 4/4 (RB)	F m Byb (10YR 6/6)	SL	mod m ab	fr	s	-	as	thin clay skin on the ped face, cracks
160-200	Bt_2	10R 4/6 (R)	-	SL	mod m ab	fi	s	-	-	moderately thick clay skin, cracks
Pedon 3 (Mid slope)										
0-30	Ap	10R 4/3 (RB)	-	SL	f ma g	fr	ns	M vf; F f	cs	-
30-105	B_1	10R 4/6 (R)	-	SL	mod m sab	fr	ss	F vf	gs	very few charcoal
105-200	B_2	10R 4/6 (R)	VF vf Byb (10YR 6/6)	SCL	mod m sab	fr	ss	-	-	very few charcoal
Pedon 4 (Mid slope)										
0-36	Ap	10R 3/4 (VDRB)	-	LS	f ma g	vfr	ns	M vf	cw	few stones
36-80	AB	10R 4/4 (RB)	-	LS	f m sab	fr	ns	F vf	cs	very few stones
80-145	Bt_1	10R 4/6 (R)	-	SL	mod m ab	fr	ss	-	as	thin clay skins on the ped face
145-200	Bt_2	10R 4/6 (R)	-	SL	w m ab	fr	ss	-	-	moderately thick clay skins on the ped face
Pedon 5 (Foot slope)										
0-14	Ap_1	10R 3/3 (DRB)	-	LS	f ma g	fr	ns	M vf; M f	cs	-
14-65	Ap_2	10R 4/3 (RB)	-	SL	mod m sab	fr	ns	VF C;VF m	gs	-
65-115	Bt	10R 5/6 (R)	F vf Yb (10YR	SL	mod m sab	fi	ss	-	aw	thin clay skins on the ped face

			5/8)							
115-180	C	10R 5/4 (RB)	M vf Byb (10YR 6/6)	SL	mod m sab	fi	s	-	-	Moderate thick clay skins on the ped face
					Pedon 6 (Foot slope)					
0-14	Ap_1	10R 3/2 (DRB)	-	LS	vf ma g	vfr	ns	M vf; F f	cs	very few stones
14-65	Ap_2	10R 3/3 (DRB)	-	LS	mod m sab	fr	ns	VF m	gs	very few stones
65-115	B_1	10R 3/3 (DRB)	-	LS	mod m sab	fr	ss	-	as	very few charcoal
tt115-200	B_2	10R 4/3 (RB)	-	SL	mod m sab	fr	ss	-	-	very few charcoal

HD: horizon designation; T: texture; Hb: horizon boundary; RB; reddish brown; R: red; DRB: dark reddish brown; bYB: bright yellowish brown; YB: yellowish brown; LS: loam sand; SCL: sandy clay loam; SL; Sandy loam; vg: very gravelly; st: stony f: fine; ma: massive, g: granular; vf: very fine; m: medium; mod: moderate, ab: angular blocky; sab: sub angular blocky; fr: friable; vfr: very friable; fi: firm; ns: not sticky; ss: slightly sticky; s: sticky; vs: very sticky; VM; very many; F: few; C: coarse; M: many; cs: clear smooth; gs: gradual smooth; gw: gradual wavey; aw: abrupt wavey; -: absent

4.2. Physical Properties of the soils

Generally, the trend in particle size distribution was sand >clay >silt. The sand, silt and clay factions varied from 687 to 903 g kg^{-1}; 33 to 73 g kg^{-1} and 84.80 to 265 g kg^{-1}.The dominance of sand fraction in profiles may be attributed to high content of quartz mineral in the parent material (Lawal *et al.*, 2013; Osujieke *et al*., 2016). The texture of the soils varied from loamy sand to sandy clay loam. The values of bulk density and total porosity varied from 1.20 to 1.82 g $cm^{-3}$and 34.25 to 60.42%, respectively. Hydraulic conductivity ranged from 0.27 to 36.67 cm hr^{-1} and this wide variation might be due to variation in particle size distribution and moisture contents (Obalum *et al*., 2011, Ukabiala, 2022).

4.3. Chemical Properties of the soils

The soils were extremely acidic to slightly acidic with pH in H_2O and KCl ranging from 4.80 to 6.20 and 4.30 to 5.50, respectively. This might be attributed to continuous cultivation, application of commercial fertilizers and leaching of exchangeable bases (Brady and Weil 2002; Havlin *et al*., 2006).The values of organic matter and total nitrogen varied from 1.72 g kg^{-1} to 12.76 g kg^{-1} and 0.06 to 1.80 g kg^{-1}, respectively which might be linked to losses through runoff and crop removal.Available phosphorus ranged from 1.87 to 9.33 mg kg^{-1} were rated low as they were below the 10 mg kg^{-1} critical limit recommended for most commonly cultivated crops (Obigbesan, 2009). The low available P might be partly due the nature of the parent material and partly to the fixation of phosphorus by iron and aluminum oxides under well drained acidic condition (Nuga *et al*., 2006; Ukabiala, 2022).

Exchangeable hydrogen, aluminum and acidity varied from 0.20 cmol kg^{-1} and 6.860 cmol kg^{-1},0.00 to 8.80 cmol kg^{-1} and 1.00 to 14.80 cmol kg^{-1} respectively. The trend in dominance of the exchangeable bases at the colloid is Ca^{2+} >Mg^{2+} >K^+ >Na^{+}. Exchangeable calcium (0.20 to 2.00 cmol kg^{-1}), magnesium (0.20 to 0.60 cmol kg^{-1}), sodium (0.05 to 0.10 cmol kg^{-1}) and potassium (0.08 to 0.92 cmol kg^{-1}) were all rated low with the exception K^+ which was considered low to high based on the scale by Shehu *et al*. (2015). Total exchangeable bases ranged from 0.54 to 2.51 cmol kg^{-1}. The low values of the exchangeable bases and TEB might probably be as a result of leaching (Orji-Uzor and Obasi, 2012). The CEC values varied between 5.20 cmol kg^{-1} and 33.20 cmol kg^{-1}. The CEC toed similar trend with the clay content suggesting that clay is the major contributor to CEC in the study area. The values of base saturation varied from 15.63 to 59.18%. The wide variation in suggested the degree of leaching of the exchangeable bases (Meena *et al*., 2014).

Table 4: Physical properties of soils along Abagana toposequence

Pedons	Depth (cm)	Sand ($g\ kg^{-1}$)	Silt ($g\ kg^{-1}$)	Clay ($g\ kg^{-1}$)	TC	Bd ($g\ cm^{-3}$)	Ksat ($cm\ hr^{-1}$)	Tp (%)
1 (crest)	0-25	862	33	105	SL	1.63	14.95	38.99
	25-88	702	53	245	SCL	1.65	12.06	38.13
	88-140	687	48	265	SCL	1.70	1.80	34.42
	140-200	687	48	265	SCL	1.74	3.74	34.25
2 (crest)	0-35	842	73	85	LS	1.58	7.33	46.86
	35-70	782	73	145	LS	1.74	1.33	45.67
	70-160	782	53	165	SL	1.79	1.27	43.76
	160-200	762	33	205	SL	1.80	1.57	42.84
3 (mid)	0-30	782	53	165	SL	1.68	5.91	37.39
	30-105	762	33	205	SL	1.68	3.07	36.50
	105-200	724	33	225	SCL	1.72	1.21	36.01
4 (mid)	0-36	862	53	85	LS	1.38	18.21	46.76
	36-80	862	33	105	LS	1.61	12.67	40.56
	80-145	822	33	145	LS	1.65	11.26	36.45
	145-200	762	53	205	SL	1.73	12.88	35.43
5 (foot)	0-14	862	33	105	LS	1.20	36.67	60.42
	14-65	782	33	185	SL	1.57	28.17	41.58
	65-115	762	33	205	SL	1.57	11.29	39.48
	115-180	722	53	225	SCL	1.69	0.27	38.09
6 (foot)	0-18	822	73	105	LS	1.43	29.98	46.02
	18-60	842	33	125	LS	1.65	25.90	44.48
	60-135	822	33	145	LS	1.67	24.14	43.79
	135-200	762	33	205	SL	1.82	24.58	36.54

TC: textural class; SL: sandy loam; LS: loam sand; SCL: sandy clay loam; SCR: silt clay ratio; Bd: bulk density; Ksat: saturated hydraulic conductivity; Map: macroporosity; Mip: microporosity; Tp: total porosity; CV: coefficient of variation

Table 5: Chemical properties of soils Abagana toposequence

Pedons	Depth (cm)	pH (H_2O)	pH (KCl)	OM (g kg^{-1})	TN (g kg^{-1})	Av. P (mg kg^{-1})	H^+ (cmol kg^{-1})	Al^{3+} (cmol kg^{-1})	EA (cmol kg^{-1})	Ca^{2+} (cmol kg^{-1})	Mg^{2+} (cmol kg^{-1})	Na^+ (cmol kg^{-1})	K^+ (cmol kg^{-1})	TEB (cmol kg^{-1})	CEC (cmol kg^{-1})	BS (%)
1(crest)	0-25	5.40	4.70	10.68	1.30	9.33	0.80	1.60	2.40	0.80	0.20	0.09	0.09	1.18	7.60	32.96
	25-88	5.30	4.60	7.41	0.80	1.87	0.20	3.80	4.00	1.40	0.40	0.10	0.09	1.99	10.08	33.22
	88-140	5.40	4.60	3.45	0.70	2.80	2.40	3.80	6.20	0.80	0.40	0.07	0.08	1.35	14.80	17.88
	140-200	5.20	4.50	3.24	0.70	1.87	1.80	3.00	4.80	1.00	0.20	0.07	0.31	1.58	17.20	27.88
2 (crest)	0-35	5.50	4.70	10.17	0.74	4.66	4.60	6.40	10.00	0.60	0.40	0.09	0.27	1.36	18.40	10.19
	35-70	5.50	4.40	9.82	0.30	4.66	4.40	4.40	10.60	1.00	0.60	0.05	0.14	1.79	23.60	14.48
	70-160	5.70	4.50	2.45	0.30	2.80	6.60	8.20	14.80	1.00	0.60	0.07	0.25	1.92	27.20	11.48
	160-200	5.70	4.50	1.72	0.30	4.66	5.60	5.60	11.20	0.80	0.60	0.04	0.16	1.60	33.20	7.81
3 (mid)	0-30	5.80	5.40	9.82	1.80	6.53	1.00	0.00	1.00	0.60	0.60	0.09	0.16	1.45	5.20	59.18
	30-105	4.90	4.50	3.62	1.00	2.80	0.80	1.40	2.20	0.20	0.20	0.07	0.09	0.56	9.20	20.29
	105-200	5.60	4.70	3.45	0.60	2.80	0.40	1.80	2.20	1.00	0.20	0.05	0.09	0.54	10.80	19.71
4 (mid)	0-36	5.30	4.50	7.41	0.70	4.66	4.00	5.60	9.60	0.20	0.60	0.10	0.28	1.18	14.00	10.95
	36-80	4.80	4.60	3.97	0.30	3.73	6.40	6.80	13.20	1.80	0.40	0.08	0.23	2.51	17.60	15.98
	80-145	6.20	4.50	3.62	0.30	1.87	4.00	4.60	8.60	0.60	0.40	0.07	0.12	1.19	20.80	12.16
	145-200	5.30	4.40	3.45	0.30	2.80	0.20	8.00	8.24	0.80	0.40	0.09	0.18	1.47	24.80	15.20
5 (foot)	0-14	6.00	5.50	9.83	1.70	6.53	2.00	0.00	2.00	0.80	0.60	0.08	0.11	1.79	10.00	47.23
	14-65	4.90	4.50	6.79	1.40	3.73	2.80	4.00	6.80	0.80	0.20	0.05	0.12	1.26	11.60	15.63
	65-115	4.80	4.30	3.45	1.30	9.33	2.80	8.80	11.60	0.60	0.40	0.05	0.21	1.46	24.40	11.18
	115-180	5.10	4.40	2.24	1.30	2.80	6.60	6.00	12.60	0.60	0.20	0.06	0.19	1.05	32.40	7.69
6 (foot)	0-18	5.40	4.50	12.76	1.10	3.73	4.00	4.60	8.60	0.60	0.20	0.06	0.39	1.25	11.60	12.69
	18-60	5.40	4.40	8.96	1.00	4.66	0.60	4.60	5.20	0.60	0.40	0.08	0.26	1.34	15.60	20.49
	60-135	5.10	4.40	2.76	0.40	2.80	5.40	4.00	9.40	1.20	0.60	0.06	0.14	2.00	16.00	12.16
	135-200	5.50	4.40	2.76	0.30	5.60	4.60	6.00	10.60	2.00	0.20	0.07	0.21	2.48	18.40	17.54

OM: organic matter; TN: total nitrogen; Av. P available phosphorus; H^+: exchangeable hydrogen; Al^{3+}: exchangeable aluminum; Ca^{2+}: exchangeable calcium; Mg^{2+}: exchangeable magnesium; Na^+: exchangeable sodium; K^+: exchangeable potassium; EA: exchangeable acidity; TEB: total exchangeable bases; CEC: cation exchange capacity; BS: base saturation; CV: coefficient of variation

4.6. Land Suitability Evaluation

The study indicated that climatic elements of rainfall and temperature are ideal for maize production and scored 70% (S2) and 95% (S1) respectively. Soil physical properties: texture and depth were moderately to highly suitable scoring 85 to 100 %. All the chemical soil characteristics except CEC and Base saturation were rated marginally to highly suitable (55 – 95%) for all the pedons (Table 6). CEC was not suitable in all the pedons except 4 and 6. Base saturation was moderately suitable to highly suitable in all the pedons but 2 and 4. Drainage and slope were rated highly suitable (95%). Aggregate suitability evaluation indicated that pedons 4, 5, and 6 were moderately suitable (S2) while pedons 1, 2 and 3 were marginally suitable (S2) for maize production.

Table 7 showed that climatic elements of rainfall and temperature are optimum for cassava production and scored 70% (S2) and 95% (S1) respectively. Soil texture and depth were moderately to highly suitable scoring 85 to 100 %. All the chemical soil characteristics but base saturation were rated marginally to highly suitable (55 – 95%) for all the pedons. Base saturation was moderately suitable to highly suitable in all the pedons with exceptions of 2 and 4. Drainage and slope were rated highly suitable (95%). Aggregate suitability evaluation showed all pedons were moderately suitable (S2) excluding pedons 2 and 4 which were marginally suitable (S3) for cassava production.

CONCLUSIONS

The soils of all the topographic units were acidic with low organic matter, total nitrogen, available P and exchangeable bases. The suitability evaluation by parametric method showed 50% of the soils were both moderately and marginally suitable for maize production whereas 67% and 33% of the soils were moderately and marginally suitable for cassava production respectively. This suggests that the differencies in soil properties across the topographic units affect the use(s) of soils. Hence, the need to evaluate soils on different topographic units for a defined use and to adopt different management practices to suit each soil type. The use of sustainable agronomic practices such as liming, bush fallowing, mulching, crop rotation, shifting cultivation, organic and inorganic fertilization could help to improve the fertility of the soils and raise the suitability of the soils for maize and cassava production.

Table 6: Suitability evaluation of the pedons for maizeby parametric method

Land Qualities/Pedons	**1**	**3**	**5**	**2**	**4**	**6**
Climate (c):						
MAR (mm)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)
MAT (^{o}C)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Soil physical properties (s):						
Soil texture	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)
Depth (cm)	S1 (100)	S1 (100)	S1(100)	S1 (100)	S1 (100)	S1(100)
Soil fertility (f):						
Ph	S2 (70)	S1 (95)	S1(95)	S2 (70)	S2 (70)	S2 (70)
CEC (cmol kg^{-1})	N (35)	N (35)	S3 (55)	N (35)	S1(95)	S3 (55)
Base saturation (%)	S2 (70)	S1 (95)	S1 (95)	N (35)	N (35)	S2 (70)
Organic matter (g kg^{-1})	S3 (55)	S3 (55)	S3 (55)	S2 (70)	S3 (55)	S3 (55)
Av. P (mg kg^{-1})	S3 (55)	S2 (70)	S2 (70)	S3 (55)	S3 (55)	S3 (55)
Wetness (w) (soil drainage)	S1(95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Topography (t) (slope) %	S1(95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Aggregate suitability class	S3 (42)	S3 (43)	S2 (63)	S3 (43)	S2(63)	S2(63)

SI: highly suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable; A: Abagana, N: Nimo; E: Enugu-ukwu; U: upper slope; M: middle slope; L: lower slope; MAR: mean annual rainfall; MAT: mean annual temperature; CEC: cation exchange capacity; Av. P: available phosphorus

Table 7: Suitability evaluation of the soils for cassava productionby parametric method

Land Qualities/pedons	1	3	5	2	4	EL
Climate (c):						
MAR (mm)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)
MAT (^{o}C)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Soil physical properties (s):						
Soil texture	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)
Depth (cm)	S1 (100)	S1 (100)	S1 (100)	S1 (100)	S1 (100)	S1 (100)
Soil fertility (f):						
Ph	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S2 (70)
CEC (cmol kg^{-1})	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S1 (95)	S1 (95)
Base saturation (%)	S2 (70)	S1 (95)	S1 (95)	N (35)	N (35)	S2 (70)
Organic matter(g kg^{-1})	S2 (70)	S2 (70)	S2 (70)	S2 (70)	S3 (55)	S2 (70)
Avail. P (mg kg^{-1})	S2 (70)	S2 (70)	S2 (70)	S3 (55)	S3 (55)	S3 (55)
Wetness (w) (soil drainage)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Topography (t) (slope) %	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)	S1 (95)
Aggregate suitability class	S2 (77)	S2 (78)	S2 (78)	S3 (43)	S3 (43)	S2 (63)

SI: highly suitable; S2: moderately suitable; S3: marginally suitable; N: not suitable; A: Abagana, N: Nimo; E: Enugu-ukwu; U: upper slope; M: middle slope; L: lower slope; MAR: mean annual rainfall; MAT: mean annual temperature; CEC: cation exchange capacity; Av. P: available phosp

REFERENCES

Adeyolanu, O.D., Are K.S., Adelana, A.O., Denton, A.O. and Oluwatosin, G.A. (2017). Characterization, suitability evaluation and soil quality assessment of three soils of sedimentary formation for sustainable crop production. *Journal of Agriculture and Ecology Research International* 11 (2): 1 - 10

Akamigbo, F.O.R, Ezedimma, F.O.C. and Igwe, C.A. (2001). Properties and classification of some Fadama soils in Bauchi State, Nigeria. *Proceeding of the 27th Annual Conference of Soil Science Society of Nigeria* held between November 4-9th, 2001 at Calabar, Nigeria. 45-48

Alhassan, M., Mesaiyete, E. and Mustapha, A.M. (2012). Clay mineralogy of lateritic soils derived from granite basement-A case study of minna lateritic soils. *Journal of Geotechnical Engineering* 17: 1897-1903

Amaresh, D. and Rajkumar, D.S. (2014). Soil resource characterization, land capability and suitability of soils in hilly undulating terrain - A case study *International Journal of Agricultural Science and Research* 4 (6): 172 - 183

Atofarati, S.O., Ewulo, B.S and Ojeniyi, S.O. (2012). Characterization and classification of soils on two toposequence at Ile-Oluji, Ondo State, Nigeria.*International Journal of AgriScience* 2(7): 642-650

Brady, N. C., and Weil, R.R. (2002): *The Nature and properties of soils*. 4th Ed. Prentice Hall. New Jessey, U.S.A

Brady, N.C. and Weil, R.R. (2006). *Elements of the nature and properties of soils*. Prentice Hall Inc. New York, USA. 95p

Bremner, J.M. (1965). Total nitrogen in C.A. Black (Eds.). *Methods of soil analysis*. Agronomy. No 9. Part II. American society of Agronomy, Maidson, Wisconsin. USA. 1149-1178

Chapman, H.D (1965). Cation exchange capacity In: C.A. Black, L.E Ensminger and F.E. Clark (Eds.). *Methods of soil analysis*. Agronom 9. American Society of Agronomy, Maidson, Wisconsin. USA. 891-901

Esu I.E. (2010). *Soil characterization, classification and survey*. HEBN Publishers, Plc, Ibadan, Nigeria. 73-99

Ezeaku, P.I. (2011). *Methodologies for agricultural land-use planning: sustainable soil management and productivity*. Great AP Express Publishers Ltd, Nsukka. 51-98

Ezeaku, P.I. and Tyav, C. (2013). Fuzzy and parametric methods for land evaluation along Katsina-ala flood plains in central region of Nigeria: Application to rice production. *Elixir International Journal*, 61: 17033-17039

Ezeigwe, P.C. (2015). Investigation of the characteristics of the soils behind the proposed governor's lodge, Ekwueme Square Awka and the environmental hazards prevalent in the area. *Journal of Natural Science Research* 5(20): 43-51

FAO (2014). *Guidelines for soil description*. Food and Agriculture Organization of the United Nations, Rome, Italy.

http://www.fao.org/docrep/019/a0541e/a0541e.pdf

Fasina, A. S.; Omolayo, F. O.; Ajayi, O. S. and Falodun, A. A. (2007). Influence of land use on soil properties of three mapping units in Southwestern Nigeria: Implications for sustainable soil management. *Research Journal of Applied Sciences* 2 (8): 879 - 883

Fasina, A.S., Raji, A., Oluwatosin, G.A., Omoju, O.J. and Oluwadare, D.A. (2015). Properties, genesis, classification, capability and sustainable management of soils from South-Western Nigeria. *International Journal of Soil Science*10: 142-152

Fekadu, A., Kibebew, K.A, Bobe, B.A. and, Asmare, M.B. (2018). Characterization and classification of soils of Yikalo Subwatershed in Lay Gayint District, Northwestern Highlands of Ethiopia Endalkachew. *Eurasian Journal of Soil Science*7(2): 151-166

Gee, G.W. and Or, D. (2002). Particle size analysis. In: Dane, J.H., Topp, G.C. (Eds). Methods of soil analysisPart 4, Physical Methods.*Soil Science Society of AmericaBook series*; No 5 ASA and SSSA Madison WI. 255-295

Grossman, R.B. and Reinsch, J.G. (2002). Bulk Density and linear extensibility in methods of soil analysis part 4. Physical Methods. *Book Series*. No. 5. ASA and SSA Madison, WI. 201-228

Havlin, J.L., Beaton, J.D., Tisdale, S and Nelson, W.L., (2006). *Soil fertility and fertilizers. An introduction to nutrient management*. 7th ed. Prentice Hall of India private limited, New Delhi.110001. 633p

Hydrometeorological Department, Awka, (2018). Weather Report

Kebede, M., Shimbir, T., Kasa, G., Abera, D. and Girma, T., (2017). Description, characterization and classification of the major soils in Jinka Agricultural Research Center, South Western Ethiopia. *Journal of Soil Science and Environmental Management* 8(3): 61-69

Klute, A. and Dirksen, C. (1986). Hydraulic conductivity and diffusivity: Laboratory methods. In Klute, A. (Eds). *Methods of soil analysis part 1: Physical and mineralogical methods*. 2nd edition. Agronomy 9, America Society of Agronomy, Madison, WI. 199-224

Lawal, B.A., Ojanuga, A.G., Tsado, P.A. and Mohammed, A. (2013). Characterization, classification and agricultural potentials of soils on a toposequence in Southern Guinea Savanna of Nigeria. *International Journal of Agricultural and Biosystems Engineering*7(5): 330-334

Lin, Y.S., Chen, Y.G., Chen, Z.S., and Hsieh, M.L. (2005). Soil morphological variations on the Taoyuan Terrace, Northwestern Taiwan: Roles of topography and groundwater. *Geomorphology* 69: 138-151

McLean, E.O. (1965). Aluminum. Pp 978-998. In: C.A. Black (Eds.). *Methods of soil analysis*. Agronomy. No 9. Part II. American society of Agronomy, Maidson, Wisconsin. USA

Meena, R.S., Natarajan, A., Thayalan, S., Hegde, R., Niranjana, K.V., Naidu, L.G.K. and Sarkar, D. (2014). Characterization and classification of lowland soils of Chikkarsinkere Hobli, Maddur taluk, Mandya district of Karnataka. *Agropedology* 24 (1): 95 - 101

Nuga, B.O., Eluwa, N.C., Abimbola, G.E. and Wokocha, C.C. (2006). Characterization and classification of soils along a toposequence in Ikwano Local Government Area of Abia State, Nigeria. *Agricultural Journal* 1(2): 192 -197

Obalum, S.E., Nwite, J.C., Oppong, J., Igwe, C.A. and Wakastuki T. (2011). Variations in selected soil physical properties with land forms and slopes within an inland valley ecosystem in Ashanti Region of Ghana. *Soil and water research* 6 (2): 73-82

Obigbesan, G. O. (2009). Impact of Liebig's research on the development of agriculture in Africa. *Proceedings 33rd Conference of the Soil Science Society of Nigeria*held at Ado-Ekiti. 51p

Olsen, S.R. and Sommers, L.E. (1982). Phosphorous In: *Method of soil analysis*. Page, A.L., Miller, R.H. and Keeney, D.R. (Eds). Madison, WI. American Society of Agronomy: 1572p

Orji Uzor, E.N. and Obasi, S.N. (2012). Properties and classification of erosion prone soils of Ukpo, Nnewi South L.G.A, Anambra State, Nigeria. *International Journal of Agricultural Sciences and Rural Development* 15(2): 1079 - 1084

Osujieke, D.N., Onweremadu, E.U., Ahukaemere, C.M. and Ndukwu, B.N. (2016). Classification of soils of a toposequence underlain by coastal plain sand in Southeast Nigeria. *Nigerian Journal of Soil and Environmental Research* 14: 256-263

Rhoades J.D. (1982). Cation exchange capacity. In Page A L. (Eds.). *Methods of soil analysis* part II. 2nd edition Agronomy Monogor.9.ASA, Madison, WI. 149-157

Shehu, B.M, Jubrin, J.M. and Samndi A.M. (2015). Fertility status of selected soils in the sudan savanna biome of Northern Nigeria. *International Journal of soil science* 10(2): 74-83. www.academicjournals.com

Soil Survey Staff (2006). *Soil survey manual*. USDA Handbook No. 18. Government Printing Office, Washington DC. 279p

Sys, C, Van Ranst, E, Debaveye, I J, and Beernaert F. (1993). *Land evaluation. part III: crop requirements*. General Administration for Development Cooperation, Agricultural Publication No. 7, Brussels-Belgium.

Ukabiala M.E. (2022). Characterization, classification and suitability evaluation of some soils in the floodplains of River Niger, Kogi East, Nigeria for rice, maize, cassava and oil palm production. *Agro-Science*, **21 (2),** 33-44. DOI: https://dx.doi.org/10.4314/as.v21i2.4

Van Reeuwijk, L.P. (1992). *Procedures for soil analysis*. 3rd edition. International Soil Reference and Information Centre (ISRIC), Wageningen, the Netherlands. 34p

Yitbarek, T., Heluf G., Kibebew K. and Shelem B. (2013). Impact of land use on selected physiochemical properties of the soils of Abobo Area, Wertern Ethiopia. *Agricultural*, *Forsetry and Fisheries* 2(5): 177-183