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Land suitability evaluation for maize production and taxonomic classification of soils overlying undifferentiated basement complex in Northeast Nigeria

Kefas, P. K[1], Maigida, E[1], Ezeaku, V.I[2], Ofem, K.I[3], Akwoga, J.A[1] and Ezeaku P.I.[1,2]

1. *Department of Agronomy, Taraba State University, Jalingo*
2. *Department of Soil Science, University of Nigeria, Nsukka*
3. *Department of Soil Science, University of Calabar, Nigeria*

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Corresponding Author's E-mail Address:

peter.ezeaku@unn.edu.ng .+2347066725984

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ABSTRACT

Soil characterization, classification and evaluation provide useful information for the understanding of its different facets, hence their potentials and limitations for crop production. Such information is lacking in the general area of Kona-Jalingo in Taraba State, Nigeria, hence the study to determine the macro-morphological, physical and chemical properties of the soils; classify them up to the subgroup level using USDA, and correlate them with WRB/FAO Soil Map Legend, and evaluate their suitability for maize production. Topographic units: crest, upper, middle and lower slope were identified through a free soil survey technique. Soil samples were collected and analysed using standard laboratory procedures to determine the morpho-physicochemical properties; In contrast, the direct method of land evaluation was used to ascertain the suitability of the soils for maize production. Results revealed that soil consistency ranged from sticky to plastic (wet); very friable to the firm (moist), and soft to hard (dry). The soils composed of blocky structures with the presence of mottles across the pedons except in the surface soils and sub-soils of KCP1, KUSP1 and KUSP2. Texturally, the soils were loamy sand and sandy loam. Soil depth ranged from 125cm – 200 cm; soil colour ranged from dark greyish brown to brown. Mean bulk density and total porosity value was 1.62g/cm^3 and 40.19 %, respectively. Soil pH varied from 4.3 to 7.3, while soil organic matter, total nitrogen, available phosphorus, percentage base saturation, and CEC were generally low. Ochric epipedon was observed in all pedons designated as KCP1, KUSP1, KUSP2 and KMSP2 and these belonged to the order Ultisol; KCP2 and KMSP1 fell under Inceptisol, while KLSP1 and KLSP2 were Entisol. When soil characteristics were matched with land use requirements for cultivation of maize, the results showed that the soils in the study area were marginally suitable for maize cultivation, perhaps due to low nutrient status. Adequate incorporation of organic manure; cropping across the slope to minimize nutrient loss by run-off water; embarking on afforestation program to serve as a windbreak and reduce wind effects on soil particles, were the recommended management strategies.

1.0. Introduction

Land evaluation collates and interprets essential soil resource inventories, vegetation, climate and other aspects of land to identify and make land use decisions. The evaluation of soils in respect to their supportive crop role is necessary and addresses the peculiarity and variation of soils due to their inherent nutrient status and management. Land evaluation does not determine land use but provides data through which land use decisions and options can be made. It is a vital link in the chain leading to the sustainable management of land resources; especially at such times when lands that should be used for sustainable crop production are allocated to other uses which tend to reduce agricultural lands and promote degradation (Ofem *et al*., 2016). Land evaluation for agriculture becomes more useful when it is done for a specific crop. Pedological characterization is a prerequisite for suitability evaluation and taxonomic classification in any geographical location.

Land evaluation analysis involves qualitative and quantitative expressions. Qualitative land evaluation defines categories or hierarchical system of classification (e.g. S – suitable and N – not suitable). In contrast, the quantitative system combines mathematical expressions to give a rating index on a sliding scale (Ezeaku, 2011).Some of the land evaluation methods variously applied are parametric, maximum limitation, fuzzy set theory, Neural-network models, Dynamic simulation models, Hybrid models, etc. (Ezeaku, 2003, 2005, 2006; Ezeaku and Anikwe, 2004; Ezeaku*et al*., 2013). It has been reported that "cross-fertilization" of land evaluation techniques lead to excellent scientific and practical results and also improves the accuracy and applicability of the models (Ezeaku, 2011).

Maize is the 4thworld most consumed cereal, ranked below sorghum, millet and rice (FAOSTAT, 2012) and the 3rd most crucial cereal, ranked after sorghum and millet (Juma, 2010). In Nigeria, the area planted with maize has increased from 438,000 ha in 1981 to 3,335,860 ha in 2009 with an increase in production from 720,000 to 7,338,840 tons within the same period. Grain yield had also increased from 1.6 t/ha in 1981 to 2.0 t/ha in 2009. In 2015, maize production was at 10.7 million metric tons (FAO, 2017) and 10.5 million metric tons in 2017 (Mundi index, 2018). Domestic demand of 3.5 million metric tons outstrips production level of 2.0 million metric tons (Akande, 1994). In 2017, its consumption was at 10.9 million metric tons (Girei*et al*., 2018). This has endeared intensification of production, especially in high production potential areas. Maize is versatile and can be grown in hot, cold, dry, wet and dry climatic conditions (FAOSTAT, 2011). It has been described as a crop with the capacity to thrive under different ecological conditions (Girei*et al*., 2018).Maize is used in feeding livestock as a raw material for agro-allied industries and serves as the main feedstuff for households in Nigeria (Ogunniyi, 2011).

Understanding the characteristics of the soils is vital for proper land suitability evaluation, and Taxonomic classification for the transfer of adequate technology especially as it concerns the production of maize which is most likely to improve the lives of inhabitants and ensure that appropriate decisions regarding land use options are made. The study area is an agrarian community with the paucity of information on the soils in terms of classification, and the extent to which the soils can suitably support the production of maize. The objectives of the study were to: i) characterize the soils; ii) evaluate the land for its suitability for maize production and; iii) taxonomically classify the soils following the criteria of USDA and correlate them with World Reference Base for soil resources.

2.0. Materials and Methods

2.1. Description of the study location

The study was conducted in Kona-Jalingo, Taraba State (6°30′ & 9°30′ N; 9°00′ & 12°00′ E), north-eastern Nigeria. The area is characterized by a tropical climate with distinct wet and dry seasons that last for 7 and 5 months, respectively. Mean annual rainfall ranges from 800 to over 2000 mm (Adebayo, 2012). Precipitation is lowest in January with an average of 0 mm while in August, the most precipitation falls with an average of 217 mm. Mean annual temperature is 34 °C and varies between 28.4 °C in the coldest month of December and 37 °C in the hottest month of March (NIMET, 2009). The relative humidity is generally over 80% in the morning and drops to 50 -79% in the afternoon (Iloeje, 1981). The geology of the area is mainly Undifferentiated Basement Complex with older granite as the dominant parent materials in the area. However, Precambrian granitic and migmatite gneisses with outcrops of the rocks occurring at intervals (FDARL,1990). The study area is undulating to gently undulating with scattered rock outcrops and inselbergs (Kefas,2018).

2.2. Vegetation, Soils and Land use

The vegetation consists of grassland interspersed with trees and shrubs. The soils are moderately deep to deep, shallow, well-drained to poorly drained; with loamy sand

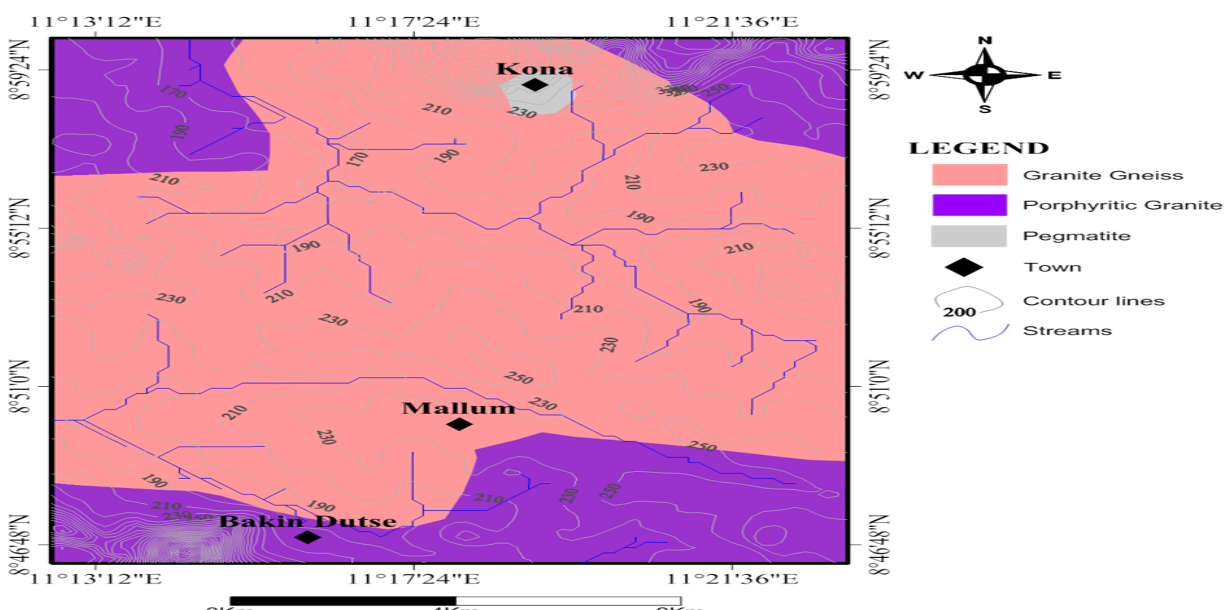

Figure I: Contoured geologic map of the Study area (A) (Source: Google map) to sandy loam surface over sandy clay loam to sandy clay subsoil (Okoye, 2014). Land use includes the cultivation of Maize (*Zea mays*), Cowpea (*Vigna unguiculata*L. Walp), Groundnut (*Arachis hypogea*), Rice (*Oryza sativa*), Guinea corn (*Sorghum bicolor*), Millet, Beniseed (*Sesamum indicum*), Bambara nut (*Voadenzia subterranea*), Yam (*Dioscorea spp*), Okra *(Albemuschus esculentus*), Cashew (*Anacardium occidentale*) and Mango (*Mangifera indica*) as well as plantations. Grassland areas support animal grazing activities.

2.3. Field and laboratory studies

The topographic map of the study area was developed in the ArcGIS 10.8 environment, and a profile graph plotted out (Kefas *et al*., 2020). Two profile pits were sunk in each elevation range to represent the crest, upper slope, middle slope, and lower slope positions using the free soil survey technique. Soil profile pits were delineated, and soil samples obtained bottom-top from pedogenic horizons. The profile pits were described following the criteria of the Soil Survey Manual (Soil survey staff, 2002). Cylindrical cores were used to vertically collect soil samples for bulk density determination while other soil samples were obtained and processed under laboratory conditions. The fine earth fraction was subjected to the determination of other physical and chemical properties. Particle size distribution was determined by the Bouyoucos hydrometer method with sodium hexametaphosphate acting as a dispersing agent. Soil pH was determined in 0.1 *N*KCl solution (1:2.5 soil: liquid) with the aid of glass electrode pH meter. Organic carbon was determined by the Walkley and Black wet oxidation method and total N by macro Kjeldahl digestion method. Bray 1 method was used to determine available phosphorus while exchangeable bases (Ca, Mg, K, and Na) were determined by neutral NH_4OAc displacement method and read through by atomic absorption spectrophotometer. Cation exchange capacity was determined by 1 *N* NH_4OAc at pH 7 while base saturation was obtained by expressing the sum of exchangeable bases as a percentage of the CEC at pH 7. Laboratory analyses were carried out as described by Udo *et al*. (2009).

2.4. Land Suitability Evaluation (LSE)

The FAO framework for soil suitability classification was used for the study, according to Sys (1985).The suitability of the soils was evaluated by a direct method where the established land characteristics (Sys, 1985) (Table 1) were cross-matched with the land characteristics obtained in the study. The outcome was cross-matched with the suitability class rates and agricultural uses, according to Ezeaku (2011) (Table 2).

3.0. **Results and Discussion**

3.1. Morphological Properties

Soil morphological properties are presented in Table 3.

Table 1: Land use requirements for maize production

Land qualities	**Land characteristic**	**Unit**	**S_1** **100 – 95**	**S_2** **94 -85**	**S_3** **84 – 40**	**N_1** **39 – 20**
Climate (C)						
Water Availability	Mean annual Rainfall	mm	1500	100 – 90	80 – 60	<50
Temperature Regime	Mean annual Temperature	^oC	32 – 18	18 – 16	16 – 14	<14
Wetness (W)						
Oxygen Availability	Soil drainage		Well Drained	Imperfectly Drained	Poorly Drained	Very Poorly Drained
Fertility (F)						
Nutrient Availability	Organic matter (0 – 15cm)	%	2 – 1.2	1.2 – 0.8	0.8 – 0.4	<0.4
	Avail. P	mg/kg	>25	6 – 25	<6	Any
	pH		5.5 – 7.5	5.0 – 5.5 or 7.5 – 8.0	4.0 – 5.0 or 8.0 – 8.5	<4.0 or >8.5
Nutrient retention	Base saturation	%	50 – 35	35 – 20	20 – 15	<15
Soil physical characteristics (s)						
Water Retention Capacity	Soil texture		SCL	LS, SL	C	S
Rooting condition	Soil depth	cm	>75	>50	>20	>20
Salinity (n)	EC	ms cm^{-1}	0 – 4	4 – 6	6 – 8	>8
Topography (t)	Slope	%	0 – 4	4 – 8	8 – 16	>16

Key: C=clay, SL=sandy loam, LS=loamy sandy, SCL=sandy clay loam, EC=Electrical conductivity.S_1 = highly suitable, S_2 = moderately suitable, S_3= marginally suitable, N= not suitable Modified from Sys (1985)

Table 2: Soil suitability classes, rates and potential agricultural uses

Classes	**Suitability classes**	**Rates**	**Potential agricultural uses**
Class 1 (S_1)	Highly Suitable	80-100	Excellent
Class 2 (S_2)	Moderately Suitable	50-79	Good
Class 3 (S_3)	Marginally Suitable	40-49	Fair
Class4 (N_1)	Currently Not Suitable	20-39	Poor
Class 5 (N_2)	Permanently Not Suitable	<20	Very Poor

Source:Ezeaku (2011)

Table 2: Morphological properties of thependons of the study area

Soil profile number	Horizon designation	Horizon depth (cm)	Colour matrix Dry	Moist	Colour mottles (moist/ dry)	Structure	Consistence			Boundary	Other features
							Wet	Moist	Dry		
KCP1	Ap	0-12	10Y6/1	10YR3/1		3m abk	Sssp	Fr	H	Cw	Micro-macro tubular pores, many roots
	AB	12-38	2.5Y7/1	10YR5/2		1m abk	Ssp	fi	sh	Cw	Plinthites concretions; Animal activities
	B	38-63	2.5Y8/2	10YR5/3	10YR6/8	2m abk	Sp	Fr	s	Dw	Cracks, few fine pores
	CB	63-123	10YR8	10YR5/6	10YR6/8	1m sbk	Sssp	fi	h	Gs	Few fine Pores and roots
	C	123-159	-	10YR6/8	7.6YR5/6	3m sbk	Ssp	Fr	s	Cw	Ant holes, micro pores
	CR	159-176	-	5YR3/3		2m sbk	Sp	fi	h		Micro pores, iron concretions
KCP2	Ap	0-20	10YR7/2	10YR3/1		1m sbk	Ssp	Fr	s	Gs	Animals activest and many fine roots
	Bt1	20-62	10YR6/1	10YR4/2	7.5YR5/8	3m sbk	Sp	fi	sh	Gs	Micro pores
	Bt2	62-122	2.5Y6/1	2.5 5/1	7.5YR5/8	1m sbk	Sssp	Fr	h	as	Few cracks
	BC	126-168	-	7.5YR6/6	7.5YR5/7	2m sbk	Ssp	fi	s	Dw	Presence of root and fine pores
	C	168-200	-	7.5YR7/6		3m sbk	Sssp	Fr	sh		
KUSP1	Ap	0-46	2.5YR6/2	2.5YR6/6		1m abk	Sp	Fr	s	Cw	Few moderate humus
	Bt	46-97	2.5YR5/4	2.5YR4/1		2m sbk	Sp	Fi	s	Dw	Few fine roots and pores
	C	97-145	-	2.5YR5/6	5YR5/8	2m sbk	Sp	fi	sh	Cw	Micro tubular pores ant holes
				2.5YR5/6	5YR5/8	2m sbk	Sssp	Fr	H		
KUSP2	A	0-39	10YR6/2	2.5Y4/1		3m abk	Sp	fi	s	ds	Few fine roots and microspores
	Bt	39-82	-	5Y5/1	10YR6/6	1m abk	Ssp	Fr	h	as	
	C	82-125	-	10YR6/4	10YR4/6	1m sbk	Sp	Fr	s		Micro-macro tubular pores
KMSP1	Ap	0-40	10YR7/1	10YR3/2							
					2.5YR5/6	3m abk	Sp	fi	h	Gs	Presence of ants holes ants channels, few fine roots
	Cc	40-82	7.5YR5/6	7.5YR3/3		1m abk	Ssp	Fr	sh	Gw	Pores and few fine roots
	C2	82-140	-	2.5YR4/6		2m sbk	Sp	fi	h		Presence of ants holes
KMSP2	Apg	0-37	2.5Y6/1	2.5Y4/1		1m sbk	Sssp	Fr	h	Gs	Ants channels, few fine roots
	Btg	37-66	2.5Y6/1	2.5Y5/1	7.5YR6/8	3m sbk	Ssp	fi	sh	Gs	Few fine roots
	Btg	66-120	-	2.5Y6/1		2m abk	Sp	Fr	s		Micro-macro tubular pores
KLSP1	Ap	0-23	10YR5/4	10YR3/2		3m abk	Sssp	Fr	h	Cw	Presence of cracks many microtubular pores
	Bt	23-89	10YR8/1	10YR6/1	10YR5/6	2m abk	Ssp	fi	sh	ds	Presence of micro pores
	Btg	89-100	5YR6/3	10YR6/2		1m abk	Sp	Fr	s	Gs	Presence of ants channels
	C1	100-157	2.5YR4/8	2.5YR5/8	7.5YR6/8	1m sbk	Ssp	Fr	sh	Dw	Micro-macro tubular pores
	C2	157-200	-	2.5Y7/1		3m sbk	Sssp	fi	h	Gs	micropores
KLSP2	AP	0-40	10YR6/2	10YR3/2		2m abk	Sp	fi	s	Gs	Micro-macro tubular pores, many fine roots.
	C	40-96	5YR5/4	2.5YR4/4		3m abk	Ssp	Fr	s	Cw	Few fine roots and pores
	Cv	96-168	-	10YR4/6		1m abk	Sssp	fi	sh		Micro-macro tubular pores, many fine roots

Structure: C=columnar, SBK=subangular blocky, ABK=angular blocky, P=platy

Boundary: DS=diffuse smooth, A=abrupt, W=wavy, CW=clear wavy, GS=gradual smooth

Consistence: VFR=very friable, FR= friable, LO= loose, F=firm

The soils were deep and ranged between 176 and 200 cm without significant restriction to soil depth. However, partially decomposed rocks were encountered between 14 and 72cm. These findings corroborate Idoga*et al.,* (2007) which attributed shallow soil depth to the parent material, erosion and slope of the area; on the contrary, Ogunkunle (2009) reported soils on the upper to mid-slope positions as deep soils while those on the crest were shallow and influenced by erosion process. Variation in soil colour was generally observed. Surface horizons were dominantly very dark greyish brown and brown colours (10YR 4/2 and 10YR 3/2; moist). Other notable colours within Ap horizons were dark yellowish-brown and very dark greyish brown (10YR 4/2 and 10YR 3/2; moist). Dark brown colours in the Ap horizons are attributed to humification (Raji, 1995), and decomposition of plant and animal remains. All pedons except KCP1, KUSP1 and KLSP2 showed the presence of mottles. The absence of mottles in soils is an indication of good drainage (Azuka *et al.,* 2015). The soils in the study area are either angular blocky or sub-angular blocky in structure across all physiographic units. Blocky soil structures are commonly found in the B-horizon where the clay has accumulated (Singer and Munns, 1999). When wet, most of the soils in the study area were slightly sticky or plastic; when moist, they were friable and firm, and soft to hard and very hard when dry. The presence of clay in soils results in stickiness and plasticity of soils when wet, which upon drying often becomes hard (Raji, 1995). High clay content in soils usually affects workability, which may lead to compaction. Also, hardening of soils when dry affects root development.

3.2. Physical properties of the soils

The physical properties of the soils in the study area are shown in Table 3. From Table 3, it can be observed that the constituent soil particles vary across the pedons in all the slopes except in the lower slope (KLSP1 and KLSP2), where the clay content was the same (80 g/kg) excluding the surface soil of KLSP1 with a clay content of 100 g/kg. In general, the variation in particle size distribution is as follow: clay content (80-240 g/kg); silt (30-290 g/kg); fine sand (180-630 g/kg); and coarse sand (80-710 g/kg). The soil textural class range from sandy loam through loamy sand to sandy clay loam.

The bulk density values were found to vary between 1.34 and 1.83 g/cm^3(mean = 1.59 g/cm^3) in the surface horizons, while subsoil horizons values varied between 1.58 and 1.87 g/cm^3, with a mean value of 1.73 g/cm^3. Bulk density values of the surface horizons were observed to be lower than those of the subsoil horizons as the values increased with soil depth, especially in the Bt and BC horizons, where there is maximum clay accumulation. Higher bulk density values of subsurface horizons might likely be ascribed to surface compaction due to mechanical or animal traction, and better structural development in subsurface horizons. Similar findings have earlier been reported in the Nigerian savannah soils (Kefas *et al.,* 2018;Kefas*et al.,* 2016; Yaro, 2005;Raji, 1995; Kefas *et al.,* 2020).

The mean value of surface soil total porosity was 40.19% (range: 30.94 - 49.43%). From the result in Table 3, it can be observed that total porosity values increased with depth though irregular in some profiles. The irregular decrease in value in the lower horizons (BC and C), might be associated with poor structural development. Malgwi *et al.* (2000) made a similar report. The mean soil surface values of total porosity appear to pose no limitation to crop production as Kefas, *et al.,*(2018) report showed that total porosity of surface soils support free water movement, good aeration and ease of root penetration.

The mean values of saturated hydraulic conductivity (cm^3/hr) decreased with depth and contrasted for water holding capacity (%)(Table 3). This suggests that water transmission through the soil column was higher at the surface and more restricting at the subsurface horizons. On the other hand, the subsurface horizons retained more water relative to the surface soils.

3.3. Chemical properties

The result revealed that soil pH variedfrom5.5 to 7.5 (mean = 6.35) (Table 6). The corresponding, subsoil horizon values ranged between 6.3 and 7.5 (mean = 6.9); indicating moderately acid to neutral soil reaction. Soil pH (H_2O) mean values obtained in this study were within the range suitable for maize production. This accords earlier reports (Maniyunda, 2012; Law-Ogbomo and Nwachokor, 2010).

Soil organic carbon (SOC) content in the surface horizons ranged from 8.18 to 11.57 g/kg (mean = 9.97 g/kg), while subsurface horizon values varied between 0.40 and 7.58 (mean = 3.08) gkg^{-1}. The soils were generally low in organic carbon (OC) content, and this may be associated to continuous cultivation without fallow, bush burning, high rate of immobilization due to high temperature and crop removal for livestock feeding, fuelwood, fencing and building purposes. This accords earlier reports by Raji *et al. (*1996) and Odunze (1998) who studied some soils of northern Guinea savannah where this study was conducted. Organic carbon mediates nitrogen in the soils. A similar trend of SOC values was obtained for total nitrogen (Table 4).

Exchangeable calcium values ranged between 0.60 and 3.20 (mean = 1.90) cmol(+)kg^{-1} in the surface horizons of the soils (Table 6). For the underlying horizons, the mean values varied from 0.80 to 3.20 (mean = 2.00) cmol (+) kg^{-1}. Similar values of exchangeable Ca were rated in the medium class (Enweazor *et al.,* 1989; Esu, 1991). From the result, it can be seen that exchangeable Ca dominated other cations in the soils. The dominance of Ca (about 74%) on the exchange sites of Nigerian savannah soil were reported (Kparmwang, 1993; Raji, 1995).

There was no consistent distribution pattern of exchangeable K in the profiles. Exchangeable K was higher in the Ap horizon and decreased in trend in the immediate underlying horizons. The mean values of exchangeable K as obtained in this study were earlier rated as low to medium (Enweazor*e t al.,* 1989; Esu 1991).

3.4. Soil Classification

KCP1,KUSP1, KUSP2 and KMSP2 on crest, upper slope

Table 3: Physical properties of the soils

P. No.	Hor	Depth	Clay	Silt	Sand	TC	Bulk Density	Total Porosity	Hydraulic Conductivity	H_2O holding Capacity
		Cm	g/kg				gcm^{-3}	%	cm^3/hr	%
KCP1	Ap	0–12	100	90	320	LS	1.41	39.25	6.53	17.66
	AB	12–38	80	50	340	LS	1.53	37.36	4.02	24.52
	Bt	38–63	220	290	410	SCL	1.66	37.36	3.57	29.98
	CB	63–123	180	210	420	SL	1.79	32.45	5.78	18.34
	C	123–159	120	210	320	SL	1.52	42.64	4.85	29.90
	Cvt	159–176	90	170	340	SL	1.72	35.09	2.53	19.38
KCP2	Ap	0–20	100	50	320	LS	1.78	32.83	2.02	27.07
	Bt1	20–62	80	110	440	LS	1.61	39.25	0.78	31.23
	Bt2	62–126	80	90	630	LS	1.70	35.85	0.91	26.88
	BC	126–168	80	70	300	LS	1.72	35.09	0.76	23.42
	C	168–200	120	90	340	SL	1.58	40.38	4.55	28.90
Mean Sur			100	70	320					
Mean Sub			116.7	143.3	393.3					
Range Sur			-	50-90	320					
Range Sub			80-220	50-290	300-630					
KUSP1	Ap	0–46	80	30	270	LS	1.69	36.22	3.39	28.11
	Bt	46–97	220	250	610	SCL	1.68	36.60	1.36	29.53
	C	97–145	80	30	180	LS	1.74	34.34	2.12	25.07
KUSP2	Ap	0–39	100	90	340	LS	1.53	42.26	7.07	28.24
	Bt	39–82	180	90	320	SL	1.74	34.34	1.41	25.21
	C	82–125	180	110	320	SL	1.60	39.62	3.64	19.69
Mean Sur			90	60	305					
Mean Sub			165	120	357.5					
Range Sur			80-100	30-90	270-340					
Range Sub			80-220	30-250	180-610					
KMSP1	Ap	0–40	100	30	360	LS	1.34	49.43	3.03	29.69
	CC	40–82	80	70	380	LS	1.68	36.60	6.06	24.18
	C2	82–140	120	130	300	SL				
KMSP2	Ap	0–37	140	130	360	SL	1.59	40.00	1.26	18.03
	Bt1	37–66	240	230	390	SCL	1.75	33.96	1.16	26.09
	Bt2	66–120	180	150	480	SL	1.82	31.32	1.26	21.34
Mean Sur			120	80	360					
Mean Sub			155	145	387.5					
Range Sur			100-140	30-130	360					
Range Sub			80-240	70-230	300-480					
KLSP1	Ap	0–23	100	50	300	LS	1.65	37.74	5.05	27.76
	Bt	23–89	80	70	350	LS	1.73	34.72	6.57	25.16
	Btg	89–100	80	70	480	LS	1.73	34.72	2.53	24.73
	C1	100–157	80	50	300	LS	1.81	31.70	1.45	20.62
	C2	157–200	80	70	350	LS	1.63	38.49	1.77	23.37
KLSP2	Ap	0–40	80	70	480	LS	1.83	30.94	1.67	26.79
	C	40–96	80	70	330	LS	1.87	29.43	1.45	17.76
	Cv	96–168	80	50	620	LS	1.65	37.74	3.54	22.01
Mean Sur			90	60	390					
Mean Sub			80	63.33	405					
Range Sur			80-100	50-70	300-480					
Range Sub			80-100	50-70	300-620					

and mid-slope had base saturation (NH_4OAc) values of less than 50 % at the Bt horizons as well as argillic horizons and low exchangeable basic cations and are placed in the order Ultisols. At the same time, ustic soil moisture regime in the area qualifies them in the suborder Ustults. The soil does not have a densic layer within 150 cm of the mineral soil surface and a clay decrease of 20 % from maximum clay content within 150 cm of the soil surface; it is therefore placed in the high group Haplustult and Typic Haplustult in the subgroup category. However, the presence of cambic B horizon and an ochric epipedon in KMSP1 qualified it as Inceptisols at the Order level and Ustepts at suborder level then Dystrustepts at Great-group and Typic Dystrustepts at Subgroup. Consequently, the presence of ochric epipedon and absence of argillic B horizon, as well as high water table, qualified KLSP1 andKLSP2 at the lower slope as Entisols at the order level and Aquent at suborder category and Psammaquents at the Great group and consequently Typic Psammaquents at the subgroup level. Loamy sand textural class (fine earth fraction) overlie the cambic horizon of the mid-slope.

The soils had base saturation of less than 50 % (NH_4OAc pH 7) in all horizons with argic horizons that underlie sandy loam and loamy sand textural classes (KCP1,KUSP1, KUSP2KMSP2) and correlate with Plinthosols at the Reference Soil Group. In contrast, KCP2,KMSP1, KLSP1 and KLSP2 correlate with Arenosols at the World Reference Soil Group (First Level) in the World Reference Base for Soil Resources.

3.5. Land suitability of the study area for maize cultivation

The results of cross-matching the soil characteristics as determined, with land use requirements of maize are presented in Table 8. The suitability of the soil parameters for maize cultivation range from highly suitable (S_1) to currently not suitable (N_1). The textural class of the surface soils which ranged from loamy sand to sandy loam was classified as moderately suitable (S_2) for maize cultivation. Kefas (2016) made a similar report while studying the suitability of the soils of the Teaching and Research Farm of Taraba State University for maize and groundnut cultivation.

The soil pH and rainfall were all highly suitable(S_1)except surface soils of KUSP2 that is moderately suitable (S_2). Ap horizons in KCP1 and KCP2 have high organic matter contents and are classified as highly suitable (S_1) soils and the rest marginally suitable (S_3) (Table 8). This could be associated with continuous cropping and bush burning. This is in tandem with Ezeaku (2011) finding.

Mean values of SOC and total nitrogen were generally low and thus classified as marginally suitable (N_1) for maize cultivation, while available phosphorus values were moderately suitable (S_2).

In terms of CEC content of the soils, the suitability ranges from currently not suitable (N_2) through marginal (S_3) and moderate (S_2) to high class (S_1). KCP2soil was highly suitable (S_1) CEC, while those in KCP1, KUSP2, KMSP2 and KLSP1 were moderately suitable (S_2) for maize cultivation. Soils in KMSP1, KLSP2, KCP2, KUSP1, KLSP1 have low CEC and therefore were currently not suitable for maize cultivation.

4.0. Conclusion

This study examined the morphological and physico-chemical properties of the soils in Kona- Jalingo of Taraba state for soil classification and their suitability evaluation for maize cultivation.

The results revealed variations in soil depth. Very dark greyish brown and brown colors dominated the soil. There was absence of mottles. Structurally, the soils were either angular blocky or subangular blocky, while the consistency range from soft to hard and plastic due to high clay content.

The bulk density and total porosity values of the soils range from low to high. The soils were moderately acidic, while SOC, total nitrogen and CEC values were generally low. All pedon possedochricepipedon. KCP1, KUSP1, KUSP2 and KMSP2 based on classification belong to the order Ultisols; KCP2 and KMSP1 were classified as Inceptisols; while KLSP1 and KLSP2 were Entisols. Land suitability evaluation results revealed that most of the soils were currently unsuitable, may be due to physical and chemical infertility of the soils. However, some of the soils were marginally (S_3), moderately (S_2) or highly suitable (S_1) for maize cultivation.

5.0. Recommendations.

Based on the findings of this study, the following management practices are therefore recommended for improvement of the fertility of soils in the study area; i) adequate incorporation organic manure, ii) cropping across the slope so to minimize nutrient loss through run-off water, iii) practicing afforestation to serve as wind break in order to reduce wind effects on soil particles.

References

Bray, R.H. and L.T. Kurtz. (1945). Determination of total organic and available forms of phosphorus in soils.*Soil Science* 59: 39-45.

Bremmer J.M. (1965). Total nitrogen in CA. Black Ed. Methods of Soil Analysis Part 11.American Society of Agronomy.pp 1149-1178.

Brinkman R. and A.J. Smith (1973).Land evaluation for rural purposes. Publication 17.ILRI, Wageningen, Netherlands.

Dent, D. and A.Young.(1981).Soil survey and land evaluation. George Allen and Unwin, London. pp 278

Dugje, I. Y., L.O. Omoigui, F. Ekeleme, A.Y. Kamara, and H. Ajeigbe.(2009). Farmers guide to cowpea production in West Africa.IITA Ibadan, Nigeria.

Enwezor, W. O., E. J.Udo, N. J. Usoroh, K. A., Ayotede, J. A., Adepetu, V. O. Chude, and C. I. Udegbe (1989). Fertilizer use and management practices for crops in Nigeria Series, 2: 63-64.

Esu, I.E. (2005). Soil characterization and mapping for food security. A keynote address at the 29th annual con-

Table 3: Physical properties of the soils

P. No.	Hd	Depth	Soil pH H$_2$O	Soil pH KCl	EC	Org. C	TN	Avail. P	Exchangeable bases Ca	Mg	K	Na	TB	E.A	ECEC	CEC	BS
		Cm			Sm^{-1}	g/kg			cmol/kg								%
KCP1	Ap	0 – 12	6.60	5.40	0.30	14.39	1.68	6.53	1.60	1.40	0.09	0.05	3.14	1.80	4.94	10.80	29.07
	AB	12 – 38	6.30	4.80	0.13	03.70	1.12	5.60	0.80	1.20	0.05	0.02	2.07	1.00	3.07	9.20	22.50
	Bt	38 – 63	6.30	4.60	0.29	03.70	1.26	4.66	2.00	1.00	0.05	0.02	3.07	2.20	5.27	12.40	24.76
	CB	63–123	6.40	4.10	0.14	2.47	0.56	3.73	1.60	0.40	0.01	0.01	2.02	2.00	4.02	8.00	25.2
	C	123–159	7.30	6.60	0.30	1.23	0.70	3.73	1.00	1.60	0.01	0.01	2.62	1.80	4.42	8.00	32.73
		159–176	7.20	6.20	0.28	0.41	0.84	3.73	1.00	0.80	0.01	0.01	1.82	1.00	2.82	6.40	27.12
KCP2	Ap	0 – 20	5.40	4.10	0.25	17.26	1.54	4.66	1.20	1.00	0.10	0.06	2.36	1.80	4.16	9.60	24.61
	Bt1	20 – 62	5.90	4.10	0.15	10.69	0.98	5.60	2.40	1.40	0.09	0.05	3.94	1.60	5.54	28.00	14.07
	Bt2	62 – 126	6.40	4.40	0.25	4.11	0.84	3.73	2.20	2.40	0.05	0.02	4.67	1.80	6.47	16.00	29.19
	BC	126 – 168	6.60	5.10	0.208	1.64	0.28	2.80	1.20	1.80	0.01	0.01	3.02	0.80	3.82	9.60	31.42
	C	168 – 200	6.60	5.00	0.39	1.23	1.26	0.93	1.20	0.80	0.01	0.01	2.01	1.60	3.61	6.00	33.57
Mean sur			6.00	4.75	0.28	15.8	1.60	5.56	1.40	1.20	0.10	0.06	2.75	1.80	4.55	10.20	26.84
Mean sub			6.55	4.98	0.24	3.43	0.90	3.83	1.48	1.27	0.03	0.02	2.80	1.53	4.34	11.51	347.8 1
Range sur			5.40- 7.30	4.10- 5.40	0.28-0.30	14.39-17.26	1.54-1.68	4.66-6.53	1.20- 1.60	1.00- 1.40	0.09- 0.10	0.05- 0.06	2.36- 3.14	1.80- 1.00	4.16- 4.94	9.60- 10.80	24.6- 29.0
Range sub			5.90- 7.30	4.10- 6.60	0.13-0.39	1.23-10.69	0.28-1.26	0.93-5.6	0.80- 2.40	0.40- 2.40	0.01- 0.09	0.01- 0.05	2.01- 4.67	0.80- 2.20	2.82- 6.47	6.00- 28.00	14.07 - 33.57
KLSP1	Ap	0 – 23	5.40	4.60	0.25	17.67	1.40	2.80	1.80	1.20	0.10	0.06	3.16	1.60	4.76	16.80	18.83
	Bt	23 – 89	5.80	4.50	0.20	02.06	0.98	2.01	1.80	0.80	0.01	0.01	2.61	1.20	3.82	12.00	21.79
	Btg	89 – 100	7.20	4.90	0.25	0.329	0.56	1.98	1.20	0.80	0.05	0.02	2.07	0.80	2.87	8.00	25.88
	C1	100 – 157	6.60	5.00	0.17	2.39	0.98	0.93	1.20	0.80	0.01	0.01	2.02	1.40	3.42	8.40	24.04
	C2	157 – 200	6.80	4.80	0.13	0.82	0.84	0.98	1.20	1.20	0.01	0.01	2.42	1.00	3.42	9.20	25.9
KLSP2	Ap	0 – 40	6.00	5.30	0.26	7.18	0.56	3.73	1.40	0.80	0.08	0.04	2.32	1.00	3.32	6.00	38.67
	C	40 – 96	6.30	5.10	0.17	2.39	0.70	2.80	1.40	1.00	0.01	0.01	2.42	1.80	4.22	9.20	26.29
	Cv	96 – 168	7.10	5.50	0.16	1.20	0.70	2.70	1.60	1.00	0.01	0.01	2.62	1.40	4.02	7.20	27.87
Mean sur			5.70	4.90	0.25	12.40	0.90	3.26	1.60	1.00	0.09	0.05	2.741	1.30	4.04	11.40	28.75
Mean sub			6.63	4.96	0.18	2.00	0.78	1.90	1.40	0.93	0.02	0.01	2.36	1.26	3.62	7.00	25.32
Range sur			5.40- 6.00	4.60- 5.30	0.25-0.26	7.18-17.60	0.56-1.40	2.80-3.73	1.4- 01.8	0.80- 1.20	0.08- 0.1	0.04- 0.06	2.32- 3.16	100- 1.60	3.32- 4.76	6.00- 16.80	18.83 - 38.67
Range sub			5.80- 7.20	4.50- 5.50	0.13-0.25	0.80-3.20	0.56-0.98	0.98-2.80	0.20- 1.80	0.80- 1.20	0.01- 0.05	0.01- 0.02	2.01- 2.62	0.80- 1.80	2.87- 4.22	7.20- 12.00	21.79 - 27.87

Table 4, Contd.

P. No.	Hd	Depth	Soil pH H_2O	Soil pH KCl	EC	Org. C	TN	Avail. P	Exchangeable bases Ca	Exchangeable bases Mg	Exchangeable bases K	Exchangeable bases Na	TEB	E.A	ECEC	CEC	BS
		Cm			Sm^{-1}	g/kg			cmol/kg								%
C	Ap	0 – 46	6.5	5.6	0.3	2.44	0.42	5.6	1.6	0.4	0.01	0.01	2.01	1.2	3.21	10	20.13
	Bt	46 – 97	5.8	4.3	0.16	5.29	0.42	3.73	7.4	2.6	0.06	0.02	10.08	3.6	13.68	16.8	60
	C	97 – 145	6.3	5.1	0.15	0.81	0.56	7.46	1.2	1.2	0.01	0.01	2.41	3	5.41	15.2	15.83
KUSP2	Ap	0 – 39	5.9	4.2	0.2	8.95	0.42	3.73	8.8	1.6	0.07	0.04	10.51	2.8	13.31	12.4	84.76
	Bt	39 – 82	6.2	4.4	0.16	3.66	0.84	5.6	0.6	3.6	0.05	0.02	4.27	1.4	5.67	18	23.72
	C	82 – 125	6.3	5.2	0.11	0.81	0.28	5.6	1.2	1.8	0.01	0.01	3.01	1.4	4.41	8	37.58
Mean sur			6.2	4.9	0.25	5.69	0.42	6.53	5.2	1	0.04	0.02	11.51	3.4	14.91	11.2	52.44
Mean sub			6.15	4.75	0.14	2.64	0.52	5.59	2.55	2.3	0.03	0.01	4.94	2.35	7.292	14.5	34.28
Range sur			5.90-6.50	4.20-5.60	0.20-0.30	2.40-8.90	0.42-0.42	3.73-5.60	1.60-8.80	0.40-1.60	0.01-0.07	0.004-0.04	2.01-10.5	1.20-2.80	3.2-13.3	10.00-12.40	20.13-84.8
Range sub			5.80-6.30	4.30-5.20	0.11-0.16	0.81-5.30	0.28-0.84	3.73-7.46	0.60-7.40	1.20-3.60	0.01-0.06	0.001-0.02	2.41-10.08	1.40-3.60	4.41-13.68	8.00-18.00	15.83-60
KMSP1	Ap	0 – 40	5.6	4.3	0.16	0.225	0.28	1.01	7.8	0.4	0.01	0.01	8.22	2.2	10.42	9.6	85.6
	CC	40 – 82	6.3	5.1	0.17	0.075	0.28	0.89	6.6	1.4	0.01	0.001	8.01	1.4	9.41	9.4	85.17
	C2	82 – 140	7.5	6.8	0.1	0.038	0.28	0.93	1.2	1	0.01	0.002	2.21	1.2	3.41	8	85.12
KMSP2	Ap	0 – 37	5.7	4.4	0.35	1.013	0.84	3.73	1.6	1	0.09	0.05	2.74	1.6	4.34	20	13.7
	Bt1	37 – 66	6.3	5.1	0.2	0.6	0.42	1.87	3.4	1.2	0.07	0.03	4.7	1.6	6.3	26.4	17.8
	Bt2	66 – 120	5.5	4.8	0.18	0.326	0.7	1.87	2.4	1.4	0.05	0.02	3.87	1.4	5.27	12.8	30.23
Mean sur			8.5	4.35	0.43	1.125	0.98	2.37	5.5	0.7	0.01	0.05	6.85	2.7	9.55	14.8	56.5
Mean sub			6.4	5.45	0.16	0.259	0.42	1.39	3.4	1.25	0.03	0.01	4.7	1.4	6.09	14.15	54.58
Range sur			5.60-5.70	4.30-4.40	0.16-0.35	0.225-1.013	0.28-0.84	1.01-3.73	1.60-7.80	0.00-1.00	0.01-0.09	0.01-0.05	274-8.22	1.60-2.20	4.34-10.42	9.60-20.00	13.7-85.6
Range sub			5.50-7.50	4.80-6.80	0.10-0.20	0.032-0.6	0.28 – 0.70	0.89-1.87	1.20-6.60	1.00-1.40	0.01-0.07	0.001-0.03	2.21-8.01	1.40-1.60	3.41-9.41	8.00-26.40	17.8-85.17

ference of soil science society of Nigeria held at University of Nigeria, Nsukka, from 6th to10th December, 2004.

Esu I.E (1999). Classification of soils formed from different parent materials in Nigeria, in proceeding of the 29th annual conference of the soil science society of Nigeria.

Ezeaku, P. I.,C. Tyav, C.L. A. Asadu, D. Gabriels (2013). Application of spatially based models to evaluation for rice production along Katsina-Ala flood plains in central region of Nigeria. Proceedings of the 3rdworkshop of the ICTP Soil Physics Associates ICTP, Trieste, Italy, March, 2013. Pg 39 -53.

Ezeaku, P.I. (2011). Methodologies for Agricultural Land-use Planning - sustainable soil management and productivity. Great AP Express Publishers Ltd, Nsukka, Nigeria. Pp69.

Ezeaku, P.I. (2006). Application of statistical methods in parametric land evaluation of cereal cropping system in two soil types in Nigeria. J. of Science of Agriculture, Food Technology and the Environment, 6:46-52

Ezeaku P. I. and M. A. N. Anikwe (2004).Application of two land evaluation systems for rainfed maize cultivation in a typichaplustult in south-eastern Nigeria. Journal of Science, and Technology,10: 58 -64.

Ezeaku, P.I. (2003). Determination of the efficacy of parametric and limitation methods of land evaluation for suitability classification of some soils of south-eastern Nigeria. Savanna J. Sci. & Agriculture 2: 91-102

FAO, (2017). GIEWS - Global Information and Early Warning System: Country briefs,

Nigeria. http://www.fao.org/giews/countrybrief/country.jsp?code=NGA

FAOSTAT (2012).Top maize production. Retrieved June 20, 2012 from www.faostat.fao.org

Food and Agricultural Organization (FAO) (2006).Guidelines for soil description.4thEdition.Food and Agricultural Organization of the United Nations. www.fao.org

Federal Department of Agricultural and Land Resources (1990).Lagos Nigeria. In: Gardiner, D. T. and R.W. Miller.(2004). Soils in our environment, 10th Edition. Pearson Education, Inc. Upper Saddle River, New Jersey. Pp 53-59

Gee, G.W. and Or, D. (2002): Particle size analysis. In: Dane, J.H. and G.C. Top, (eds). Methods of soil analysis (Part 4), Physical Methods, Soil Sci. Soc. An. Book Series No. 5.ASA and SSSA maidson. WI. pp 255-293

Girei, A.A, Saingbe, N. D., Ohen, S. B. & Umar, K. O. (2018).Economics of Small-Scale Maize Production in Toto Local Government Area, Nasarawa State, Nigeria. *Agrosearch: 18 (1): 90 – 104*

Idoga, S and D. E. Azagaku, A.J. Adewumi, and B. Orefade, (2012).Heavy metal assessment of selected soils in owo township, South-western Nigeria. Science Focus, 17(3):255-268.

Iloeje, N.P. (1981). A new geography of Nigeria. New revised edition. Longman. Nig. Ltd Ikeja.

Jackson (1985).Soil chemical analysis; Advance course (6th printing), Published by the Author. Department of Soil Science, University of Wisconsonmadison (USA).

Jaiswal. P.C.(2003). Soil, Plant and Water Analysis. Kalyani Publishers, Ludhiana, New Delhi, Norda Hyderabab India. pp 1-339.

Juma, C. (2010). The new harvest: Agricultural innovation in Africa. Oxford University Press.Pp.56.

Juo, A.S. and A. Lal (1979). Nutrient Profile in a Tropical Alfisol Under Conventional and No-Till Systems. Soil Science, 127:168-173.

Kefas, P.K. (2016),Charactreization,Classification and Suitability Evaluation of Soils Research Farm of Taraba State University for the cultivation of maize, Cassava and groundnut. Unpublished M.Sc. Thesis of the University of Nigeria, Nsukka

Kefas, P. K., Ali, S., Ofem, K. I., Umeugokwe, C. P. (2020). Genesis and Classification of Soils

along a Toposequence in the Teaching and Research Farm of Taraba State University, Jalingo, Nigeria. Global Journal of Agricultural Sciences, 19: 33-43

Klute A. and Dirksen C. (1986). Hydraulic conductivity and diffusivity: Laboratory methods 687-784. In: Methods of soil analysis (Part 1). Physical and Mineralogical Methods (2nd Edition).Agron.Monogr.9.ASA and SSSA. Madison, W.I.

Lekwa, M.U., B.O Anene, and G. Lekwa (2004). Chemical and morphological soil characteristics in drainage toposequence in southeastern Nigeria. In: Ojeniyi, S.O., A.O. Ano, D.O Asawalam, and G.O. Chukwudi.(Ed). Land degradation, agricultural productivity and rural poverty, environmental implication. Proceedings of the 28th Annual Institute, Umudike, Abia State. Nov.2003. 4th- 7th. pp 316-322.

Msanya, B.M., J.A. Munishi, N. Amuri, E. Semu, L. Mhoro, and Z. Maley, (2016).” Morphology, Genesis, physicochemical properties, classification and potential of soils, derived from volcanic parent materials in selected districts of Mbeya Region, Tanzania, International Journal of Plant and Soil Science*;* 10 (4): 1-19

Nath, T.N. (2014). Soil texture and organic matter content and its influences on soil water holding capacity of some selected tea growing soils in Sivasagar. District of Assam, India. *International Journal of Chemistry Science*: 12(4). Pp 1419-1429. ISSN. 0972-768X

Nelson D.W., and L.E.Sommers (1982).Total carbon, total organic carbon and organic matter. Pp. 539-580. In: Miller, (ed). Methods of soil analysis, Part 2, 2nd Edition, *Agronomy Monograph*, 27, ASA, Madison, W. I.

Nigeria Meteorological Agency (Nimet) (2009). Weather report: Nimet, Yola international Airport.

Ogunniyi, L.T. (2011). Household Consumption of Cassava Products in Oyo State. *Global Journal of Science Frontier Research*. 11 (6): 38–44.

Ogunkunle, A.O. (1993). Soil in Land Suitability Evaluation: An example with oil palm in Nigeria. Soil Use and Management, 9(1):35-40.

Ogunkunle, A.O. (2009). Soil survey and sustainable land management. Proceedings of the 29th annual conference of the Soil Science Society of Nigeria.

Okoye E.O.U (2014). Soil survey and crop production. TitsBits. Madol press Ltd. Pp 120Nichols, K.A., S.F. Wright, M.A. Liebig, and J.L. Pikul (2004). Functional significance of glomalin to soil fertility. Proceedings from the Great Plains Soil Fertility Conference. Denver, CO, March 2-4, 2004.

Raji, B.A. (1995). Pedogenesis of ancient dune soils in Sokoto sedimentary basin, north-west, Nigeria. *Unpublished PhD. Thesis*. Dept. of Soil Science, ABU, Zaria.

Raymond, W.M. and L.D. Donahue (1995). Soils in our environment. 7th Edition, Prentice Hall, Englewood Cliffs, NJ07632. Pp127.

Sharu, M.B., M. Yakubu, S.S. Noma, and A.I. Tsafe, (2013)."classification of soils on an agricultural landscape in dingyadi district, Sokoto State, Nigeria". *Nigerian Journal of Basic and Applied Science*. 21 (2) : 137-147.

Soil Survey Staff (1975).Soil survey manual. United State Department of Agriculture. Washington DC.

Soil Survey Staff (1999). Soil quality information sheet: Soil quality indicators aggregate stability. National soil survey centre in collaboration with NRCS, USDA and the National soil tilth laboratory. ARS.USDA.

Singer, M.J. and D.N. Munns, (1999). Soils; An Introduction. 4th Ed. Prentice-Hall. Inc. Upper Saddle River, New Jersey. Pp. 27-29, 48-49.

Soil Survey Staff (2014). Soil taxonomy: A basic system of soil classification for making and interpreting soil survey. Agric. Handbook 432, USDA, Washington DC. Pp 869

Tsegaye K. (2011). Soil fertility characterization along the toposequence of Enewari areas in the Northern Shewa, Ethiopia. Published Msc Thesis, Haramaya University

Udoh, B. T., H. B. Henry, and U. S. Akpan (2011).Suitability evaluation of alluvial soils for rice (*Oryzasativa*) and cocoa (*Theobroma cacao*) cultivation in an acid sands area of South-eastern Nigeria. Journal of Innovative Research in Engineering and Science, 2(3). ISSN: 2141-8225

Udoh B. T., and A. O Ogunkunle (2012). land suitability evaluation for maize (*Zea mays*) cultivation in humid tropical area of south eastern of Nigeria (AkwaIbom). Nigeria Journal of Soil Science, Vol 22 (1), 2012: 1-10.

Ukut, A.N., U.S. Akpan, and B.T. Udoh (2014)."Characterization and classification of soils in steep sided hills and sharp-crested ridges of Akwa-Ibom State, Nigeria". *Net Journal of Agricultural Science,*2 (2) : 50-57.