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Characterization, Taxonomic and Fertility Capability Classification of some Soils in the Teaching and Research Farm of Taraba State University, Jalingo

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ABSTRACT

Result oriented and competitive agricultural production system requires soil characterization and land evaluation. The soils of the Teaching and Research Farm of Taraba State University were characterized, taxonomically classified and evaluated for fertility capability classification. Three mapping units were delineated using a semi-detailed survey method, and profile pits were dug in the mapping units. Soil sampling was done based on the pedogenic horizons. The soils were deep, well-drained, and brown to yellowish-brown. Soil bulk density exceeded 1.8 g/m^3 in most soils, while sand size dominated the particle size distribution. Soil reaction was slightly acid to slightly alkaline, while organic carbon and exchangeable bases were low in all the mapping units. The soils were closely fit in the order Alfisols and correlated with Lixisols. The FCC system evaluated the soils based on physical and chemical fertility constraints and limitations for general arable cropping. The strata and substrata type soils comprise sandy loam topsoil, with two of the pedons showing loamy sand strata types. Classification of the soils into various FCC units revealed that over 85 % of the soils were arable, with only one soil type as, Inceptic Haplustalf having FCC unit LR^{+++}. The major limitation of the soil was rock outcrop and very high gravel content. Most of the soils could be effectively utilized for massive maize, and groundnut production, which is the common dominant land uses in the area. Organic manuring, balanced nutrient fertilization and conservation techniques such as contour farming is recommended for soil management.

1.0. Introduction

Soil is one of the earth's life-sustaining components. It serves as physical support for crops and buildings and as a source of water and nutrients for crops, as well as a medium in which organic materials are recycled for future generations. Its filtration role ensures safe underground waters and dominates the carbon sequestrating potential of the environment.

Soil survey generates a host of soil-related information for crop production, land use planning and on-the-site farm management. Such information has been helpful in increasing crop production in sub-Saharan Africa. Reports by Malgwi and Raji (2005) indicate that about 50% of Nigeria is covered by soil survey at a scale of 1; 100,000, but only 0.58% (567.421 ha) has been covered by detailed soil survey with a non-uniform soil survey intensity across the country.

Soil characterization provides the information for our understanding of the properties of the soils we depend on to grow crops, sustain forests and grasslands as well as support homes and society structures (Ogunkunle, 2005). Its data are useful in the classification of soils and enable other scientists to remember the characteristics of similar soils in their environments, serve as a basis for a more detailed evaluation of the soil and gathers preliminary information on limitations and nutrient availability to produce capability classes (Eswaran, 1977). A soil characterization study is, therefore, a major building block for understanding the soil and environment at large (Esu, 2005). Soil classification depends on soil characterization for its data. Soil classification helps to organize knowledge, facilitate the transfer of technology and help to compare soil properties between distant locations (Esu, 2010).

he Nigerian savanna is sectioned into the Sahel, Sudan, Guinea, and Derived savanna zones (Higgins and Klinkenberg 1968; Aduayi *et al.,*2002). The soils of these regions are under continuous cultivation and rapidly lose their fertility due to a decline in organic matter, leaching of basic cations and high rates of acidification (Jones and Wild, 1975; Ogunwole, 2008; Vanlauwe and Saginga, 2004). There are also large losses of organic matter as a result of land clearing, cultivation and the use of organic materials for fuel and as roofing materials. The breakdown of the traditional land use systems (shifting cultivation and bush fallowing) has contributed to decreasing soil fertility as the soils are cultivated year-in-year-out leading to soil exhaustion (Kowal and Kassam, 1978). This study, therefore, focuses on the fertility capability (FCC) of the soils and relies on data generated via soil characterization for sustainable crop production. While the FCC is considered to be a land evaluation system by many, Rossitter (1994) believes it is a soil classification system that does not perform "ranking of soils". With thorough knowledge of FCC classes, farmers and land users can identify fertility, rooting and moisture limitations of land to specific crops and plan their activities to circumvent the drawbacks (Sanchez *et al*.,2003).

The soils of the Nigerian savanna are characterized as tropical ferruginous and classified as Acrisols or Alfisols (Typic Haplustalf) (Jones and Wild, 1975; Ogunwole*et al*., 2001). Akamigbo and Asadu (1983) stated that the textures of the soils are related to their parent materials which account for the similarity in particle size distribution obtained in areas with the same parent material irrespective of the land use. Igwe *et al.* (1999) also made similar observations as they reported that soils derived from different geologic formations varied in particle size distribution.

Except for the Reconnaissance Soil Survey project of the Federal Department of Agriculture and Land Resource (1990) and a few other skeletal studies, not so many studies have been carried out in the area at a detailed level. The current study evaluated the morphological, physical and chemical properties and the taxonomic and fertility capability classification of the soils for the management and sustainable production of arable crops.

2.0. Materials and Methods

2.1. Description of the study area

The study was conducted in the Teaching and Research farm of Taraba State University, Jalingo in Taraba State (6°30′, 9°30′ N; 9°00′, 12°00′ E) (Fig. 1). The farm occupies an area of thirty-seven hectares. Taraba State is located in the Northeastern part of Nigeria. The dominant vegetation in Northern Guinea Savanna, while the underlying geology is Basement Complex and dominated by Precambrian granitic and magmatic gneisses with outcrops of the rocks occurring at intervals (Ogezi, 2002).

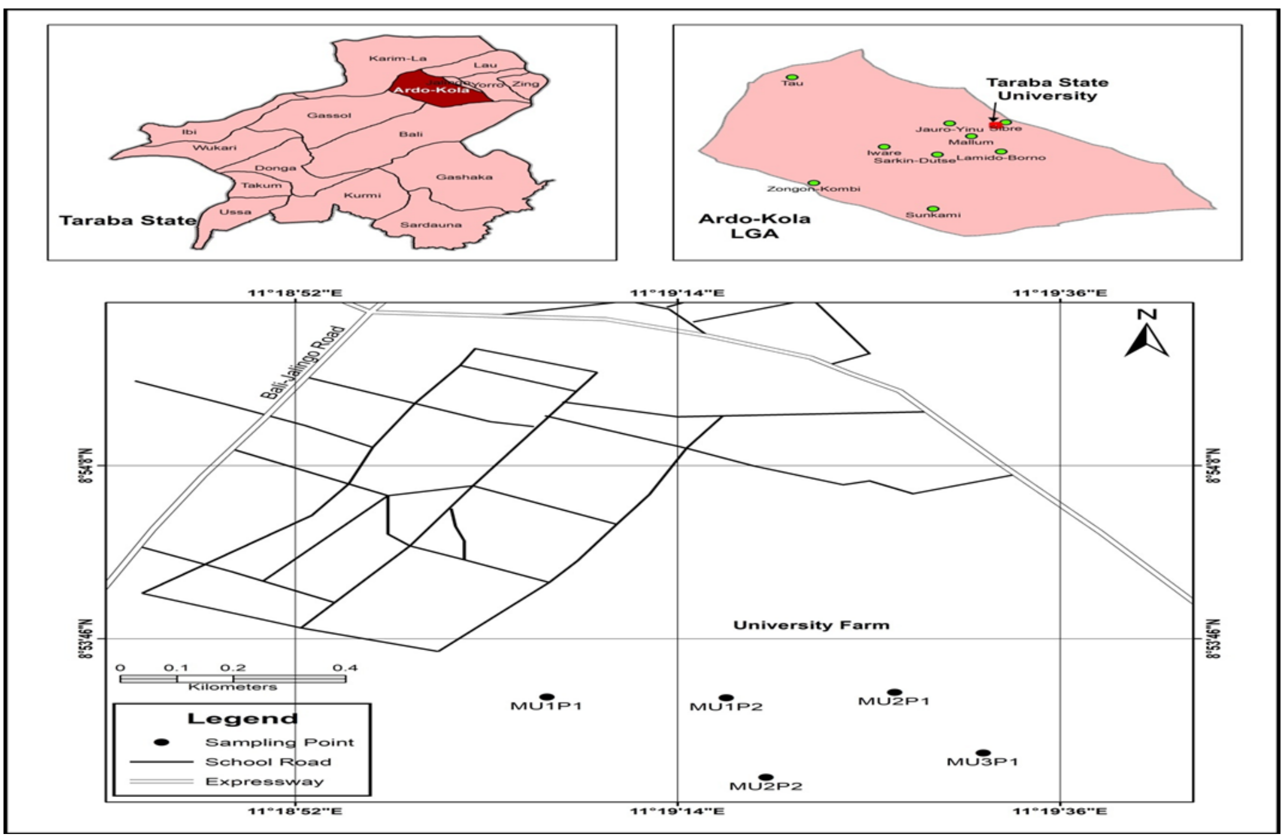

Fig. 1: Map of the study area
Source: Geography Department, Taraba State University

The area is characterized by distinct wet and dry seasons. The wet season lasts for 7 months, while the dry season lasts for 5 months. Mean annual rainfall ranges from 800 in northern Taraba State to over 2000 mm in the south (Adebayo, 2012). Precipitation is lowest in January (0 mm), with a peak value occurring in August (217 mm). Mean monthly temperature varies from 28.4 in the coolest month of December to 37^{o}C in the hottest month of March (NIMET, 2009).

2.2. Field study

A semi-detailed soil survey was conducted in the study area on a scale of 1:25,000 following the procedures of Wilding and Dress (1983). Ranging poles, pegs, machetes and GPS were used in creating transects at intervals of 100 m at right angles to the baseline. This was followed by auger borings to examine and describe the soils consistently at 100 m intervals along each traverse. Description of soil morphological properties at each observation point enabled the establishment of soil boundaries. Three soil mapping units (SMU) were MU1, MU2 and MU3 and occupying areas MU1-15ha, MU2-15ha and MU3-covers 7ha respectively were delineated, and two profile pits were excavated in each SMU. The soil profiles were described, and bulk soil samples were collected from pedogenic horizons for laboratory analysis. Soil samples were air-dried, ground and sieved. The fine earth fractions (< 2 mm) were subjected to laboratory analysis. Soil samples for bulk density, total porosity and saturated hydraulic conductivity (Ksat)were taken with cylindrical cores.

2.3. Laboratory analyses

Sodium hexametaphosphate was used to disperse the soils before particle size distribution by the Bouyoucos hydrometer method. Soil pH was determined in 1:1 soil to water and 1:2 soil to1*N* $CaCl_2$ using a glass electrode pH meter, while electrical conductivity was determined with a conductivity meter in 1:5 soil to water ratio. Organic carbon and total N were determined by the Walkley and Black wet oxidation and macro Kjeldahl digestion procedures, respectively. Bray 1 method was used to determine available phosphorus, while exchangeable bases of Ca, Mg, K, and Na were determined by the 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. All procedures areas outlined in Soil Survey Staff (2014).

2.4. Fertility capability classification (FCC)

Data obtained from field study and laboratory analyses of soil samples from the five pedons were used for the fertility capability classification. The conversion data used in evaluating the soils are as outlined by Sanchez *et al.* (1982). The system consists of three categorical levels: 'type' (texture of plough layer or top 20 cm), 'substrata type' (texture of subsoils) and 'modifiers' (soil properties or conditions that act as constraints to crop performance). Class designations from the three categorical levels are combined to form an FCC unit. The FCC units of the five pedons representing the study area are shown in Table 3.

3.0. Results and discussion

The morpho-physical properties of the soils are presented in Table 1. The soils were moderately deep (MU3P1) to deep with consolidated rock layer encountered at < 150 cm, while the Ap horizons were moderately thick, having thicknesses >15 cm. There exist a positive linear chronofunction between the thickness of horizons and soil age. Hence soil horizons increase and are more easily identified in more developed soils (SSDS, 2017; VandenBygaart and Protz, 1994). The soils may have been exposed to only moderate erosion in the savannah region. Soil horizonation indicates the presence of Bt horizon in all the pedons with transition A.B., BC and C.B. occurring before or after the argillic horizons in the horizon sequence. This indicates that the process of lessivation was active in the soils. Surface soil colour (moist) presented egreyish yellow brown, bright yellow or reddishey-grey in the surface soils with either reddish or egreyish subsurface colours. The somewhat shallow depth to consolidated rocks may have caused restricted movement of water, hence the dominant egreyish colour in the entire soil. Such colours indicate poor aeration or reduced soil condition, leached soil condition (Nsor and Ibangha, 2006) and the presence of Fe^{2+} (Ofem *et al*., 2020).

Particle size distribution is indicated by the dominance of sand-sized fraction over clay and silt, with the amount of sand exceeding 500 g/kg in all the mapping units, while silt and clay contents appeared higher in the endopedons of MU2P2. The dominance of sand content in this soilsreflect the granitic origin of the geological parent materials (Kefas et al., 2020, Kefas, 2021). Except in MU1P1, soil bulk density exceeded 1.8 g/cm^3 in all the endopedons. When the value of bulk density exceeds 1.8 g/cm^3, there is most likely to be a restriction of water and air movement in soils (Esu, 2010), hence the dominance of egreyish soil colour. In the findings of Brady and Weil (2002), sandy loam soils have a bulk density values within the range of 1.2-1.8 g/cm^3. Higher values in the study area may have

Table 1: Morphological and physical properties of the soils

Horizon	Depth	Soil colour		Particle size distr. (g/kg)			Tex.	B.D.	PD	TP	Ksat
MU1P1	Cm	Moist	Dry	Clay	Silt	Sand		g/cm3		%	cm/h
Ap	0-17	10YR4/2	10YR4/2	100	140	760	SL	1.52	2.4	36.7	2.48
Bt	17-50	10YR7/2	2.5YR6/2	120	180	700	SL	1.76	2.7	34.8	0.52
BC	50-82	2.5YR6/1	5YR5/2	100	180	720	SL	1.76	2.6	32.3	1.30
CB	82-102	7.5YR6/3	5YR4/3	80	80	840	LS	1.77	2.7	34.4	1.41
MU1P2											
Ap	0 – 15	10YR4/1	10YR3/3	60	80	860	LS	1.83	2.3	20.4	2.36
Bt1	15 – 44	7.5YR6/3	5YR6/3	80	120	800	LS	1.99	2.4	17.1	1.5
Bt2	44 – 116	5YR5/3	5YR5/3	240	240	520	SCL	1.9	2.5	24.0	2.41
Mu2 P 1											
Ap	0 – 27	10YR/6/1	7.5YR4/3	60	60	880	S	1.69	2.6	35.0	2.48
AB	27 – 47	7.5YR3/2	7.5YR4/6	60	100	840	LS	1.98	2.5	20.8	0.98
Bt	47 – 110	7.5YR6/6	5YR5/8	240	220	540	SCL	1.8	2.6	30.8	2.50
Mu2 P 2											
Ap	0 – 28	10YR7/6	10YR5/3	80	80	840	LS	1.77	2.7	34.4	5.24
Bt	28 – 60	10YR8/2	7.5YR6/3	240	300	460	L	1.89	2.3	17.8	1.07
BC	60 – 100	10YR8/2	7.5YR7/6	200	240	560	SL	1.8	2.5	28.0	1.00
Mu3 P 1											
Ap	0 – 17	2.5YR7/2	10YR3/3	100	180	720	SL	1.8	2.3	21.7	5.24
Bt	17 – 46	10YR8/2	10YR5/8	140	180	680	SL	1.96	2.6	24.6	4.96
Bt2	46 – 104	2.5YR7/2	10YR8/4	160	220	620	SL	1.85	2.6	28.8	5.1

10YR, 4/2 (greyish-yellow-brown), 7/2 (dull yellow-orange), 4/1 (brownishey-grey), 6/1 (brownishey-grey), 7/6 (bright yellowish), 8/2 (light gray), 3/3 (dark brown), 5/3 (dull reddish-brown), 5/8 (yellowish-brown), 8/4 (light yellowish-orange); 2.5YR, 6/1 (Reddish gray), 7/2 (reddish gray), 6/2 (grayish red), 5YR, 5/3 (dull reddish -brown), 5/2 (grayish brown), 4/3 (dull reddish-brown), 6/3 (dull orange), 5/8 (bright reddish-brown); 7.5YR, 6/3 (brown), 3/2 (brownish black), 6/6 (orange), 4/3 (brown), 4/6 (brown)7/6 (orange), been a result of traction. Such bulk density values may impair the proliferation of plant roots and the availability of nutrients to plants. Soil particle density was within the limit of 2.65 g/cm^3 for mineral soils in the tropics. Lower values in the surface soils (2.3-2.4 g/cm^3) may be a result of relatively high organic matter content. Total porosity values were within the range of 17.1-36.7 %, with lower values occurring in the subsurface soils. Exchangeable Na^+, bulk density and volume fraction of water at 30 cm of tension as well as lithology have been identified as important factors that influence porosity in tropical soils (Ofem *et al*., 2021). Saturated hydraulic conductivity (Ks) had surface soil values with a range of 2.36-5.24 cm/h and lower subsurface values ranging from 0.52 to 5.1 cm/h. On the scale of SSDS (2017), Ks is rated high to moderately high. Lower values of Ks in the subsurface soils correspond with higher values of clay and lower sand amounts in the subsurface soils. This agrees with earlier reports that Ks is higher in sandy soils than in clay soils (Ofem *et al*., 2021; SSDS, 2017).

3.1. Chemical properties of the soils

The chemical properties of the soils are presented in Table 2. Soil pH (H_2O) values indicate slightly acid to slightly alkaline soils with a range of 5.9-7.2 in the entire soil, while organic carbon ranged from 1.0 to 4.3 g/kg, with

Table 2: Chemical properties of soils of the study area

		pH						Exchangeable bases								
Horizon	Depth	H_2O	$CaCl_2$	OC	OM	N	Av. P	K	Na	Ca	Mg	E A	ECE C	ESP	BS	EC
MU1P1	Cm			g/kg			mg/kg	cmol/kg						%		dSm-1
Ap	0-17	6.5	4.5	2.4	4.1	0.34	2.06	0.13	0.11	2.2	0.59	1.0	4.03	2.73	75.19	0.34
Bt	17-50	5.9	4.6	1.7	2.9	0.24	1.54	0.14	0.19	2.4	0.65	0.8	4.18	4.55	80.86	0.28
BC	50-82	6.3	5.0	1.3	2.3	0.16	2.23	0.20	0.19	1.8	0.49	0.8	3.48	5.46	77.01	0.3
CB	82-102	6.5	5.3	1.0	1.8	0.14	3.43	0.18	0.16	5.0	1.35	0.6	7.29	2.19	91.77	0.16
MU1P2																
Ap	0 – 15	6.9	5.8	3.7	6.5	0.53	1.72	0.10	0.10	2.4	0.65	0.4	3.65	2.74	89.04	0.32
Bt1	15 – 44	6.9	5.9	1.9	3.4	0.27	5.49	0.08	0.03	3.0	0.81	0.6	4.52	0.66	86.73	0.27
Bt2	44 – 116	6.8	6.0	1.5	2.6	0.21	4.8	0.19	0.11	3.0	0.78	0.8	4.88	2.25	83.61	0.21
Mu2 P 1																
Ap	0 – 27	6.6	5.8	2.2	3.8	0.31	2.06	0.06	0.07	1.6	0.43	0.6	2.76	2.54	78.26	0.29
AB	27 – 47	6.5	5.5	2.4	4.1	0.34	2.4	0.07	0.03	3.2	0.86	0.6	4.76	0.63	87.39	0.31
Bt	47 – 110	7.2	6.3	2.0	3.5	0.29	3.09	0.19	0.07	4.8	1.3	0.6	5.66	1.24	89.40	0.22
Mu2 P 2																
Ap	0 – 28	6.9	6.0	2.6	4.6	0.37	1.54	0.13	0.06	2.6	0.7	0.6	4.09	1.47	85.33	0.5
Bt	28 – 60	6.7	5.9	2.9	5.1	0.31	2.4	0.09	0.04	3.2	0.86	0.6	4.73	0.85	87.32	0.42
BC	60 – 100	6.5	6.1	2.2	3.8	0.28	2.06	0.15	0.05	2.6	0.72	0.8	4.32	1.16	81.48	0.05
Mu3 P 1																
Ap	0 – 17	6.1	5.3	4.3	7.4	0.54	2.06	0.10	0.04	1.8	0.48	1.0	3.42	1.17	70.76	0.29
Bt	17 – 46	6.9	4.7	2.4	4.1	0.30	1.72	0.11	0.04	2.2	0.57	0.6	3.52	1.14	82.95	0.18
Bt2	46 – 87	6.3	5.2	1.8	3.2	0.26	1.72	0.20	0.10	3.4	0.92	0.8	5.42	1.85	85.24	0.22

higher values occurring in the surface soils and regularly decreasing with soil depth. When soil pH is greater than 5.5, the amount of exchangeable Al3+ in the exchange complex is not significant as to affects crop growth (Udo *et al.*, 2009) and will discourage the weathering of primary soil minerals (Tan, 1998). The slightly alkaline soil reaction may also be due to hydrolysis as H+ is consumed and O.H.$^-$ is produced, resulting in a more basic soil solution (Wild, 1993). The o, The organic carbon content of less than 15 g/kg, is low on the scale of Landon (1991) and indicates the absence of histic and mollicepipedons (Udo et al. 2009). The low organic carbon could be attributed to crop removal due to continuous cultivation over the years without recourse to replenishing lost nutrients via organic soil amendment. Poor management practices by farmers also increased organic carbon reduction as soils were exposed due to the removal of vegetative cover for domestic use or as animal feed.

Total nitrogen was less than 0.55 g/kg in the entire soil, with comparatively higher values occurring in MU3P1 and values regularly decreasing with soil depth in the entire soils. However, with values less than 1.0 g/kg in the studied soils, total N was rated low on the scale of Landon (1991). Available phosphorus was low in the soils and had a range of 1.54-5.49 mg/kg, with comparatively higher values occurring in mapping unit1 (MU1P1, MU1P2). However, values of available P were irregularly distributed with soil dept.

The soil exchange complex was dominated by exchangeable Ca, with somewhat high values occurring in MU1. Also, values of exchangeable K were low and less than 0.20 cmol/kg in the studied soils. Exchangeable acidity was less than 1.0 cmol/kg in the soils, while ECEC ranged from 2.76 in MU2P1 to 7.29 cmol/kg in MU1P1, while base saturation values exceeded 70 % in the studied soils. Effective cation exchange capacity is therefore low in the soils as values were less than 10 cmol/kg, while base saturation was high on the scale of Landon (1991). Though the individual cations were somewhat low, they were present in the soils in available forms for plant uptake (Akpan-Idiok and Ofem, 2014). Values of exchangeable Na percent were less than 15 %, while electrical conductivity was less than 1.0 dSm^{-1} which indicates that sodium and soluble salts are not threats to crop cultivation in the area. On the scale of Holland et al. (1989), exchangeable Ca and Mg were low in most of the studied soils and moderate in MU1P1 and MU2P1 (> 4.0 and 1.0 cmol/kg, respectively), while exchangeable K and Na were low. In the opinion of Ofem *et al*. (2020), high precipitation and mobility during chemical weathering are factors responsible for low exchangeable K in tropical soils.

3.2. Taxonomic classification

The studied soils had argillic B horizons within 50 cm of soil depth from the soil surface with base saturation that exceeds 35 % at this depth. The soils meet the requirement for Alfisols in the USDA Soil Taxonomy (Soil Survey Staff, 2014). Ustic soil moisture regime characterizes the study area and qualifies the soils as Ustalfs in the suborder category and as Haplustalfs in the great group. MU1P2, MU2P1 and MU2P2 have sandy or loamy sand textural classes in a layer extending from the mineral soil surface to the top of an argillic horizon at 50 cm and qualifies as ArenicHaplustalf. However, MUP1 and MU3P1 have argillic horizons that are less than 35 cm thick and do not have lithic or paralithic contact within 100 cm and qualify as IncepticHaplustalfs in the great group category.

The soils have an argic horizon overlain by loamy sand, sandy loam or sandy textural classes and are qualified as Lixisols in the first level of the World Reference Base for Soil Resources System (WRB, 2014). In the second level, the soils, irrespective of mapping units, qualify as HaplicLixisols (Arenic, Ochric).

3.3. Fertility capability classification of soils

The allocation of the representative pedons or mapping units into various FCC units according to Sanchez *et al.* (2003) Fertility capability classification system is shown in Table 3. MU1P1 and MU1P2 were characterized by sandy loam strata type and subtype and would require appropriate tillage before most arable crops can be planted. MU2P1 and MU2P2 have loamy sand and sandy strata types and subtypes with low organic carbon content and moderate effective cation exchange capacity. It has moderate exchangeable sodium percentage and slightly acid soil reaction It is somewhat well-drained and will require minimum tillage. However, perennial high-value crops like sugarcane can be grown on the soils.MU3P1 was characterized by Sandy and loamy strata types (topsoil and subsoils), low organic carbon, k-deficiency,<15 % ESP, moderate ECEC and acid reaction. MU3P3 was, however, characterized by shallow soils with intermittent boulders and caped sandstones. This unit is considered non-arable and could be used to build farmhouses, cattle ranches or other infrastructures. It could also be developed for recreational purposes.

Table 3: Fertility Capability Classification of the Soils

Pedon/ Type	Type	Sub Type	Condition modifiers e	m	K	d	N	H	FCC Class	Interpretation	Management options
MUIP1	SL	SL	-	-	+	+	+	+	SLkdnh	Soil profiles are characterized by sandy loam topsoil and subsoil. Low O.C. and low k reserves, moderate ECEC, dry soil, <15% ESP.acidic reaction (h)	Appropriate tillage and fertilizer application: liming: drainage and application of soil amendments: fertility management
MU1P2	LS	LS	-	-	+	+	-	-	LSkd	Loamy sand topsoil and subsoil, low O.C., k deficiency,<15%ESP moderate ECEC, acidic reaction, dry soil.	
MU2P1	S	L.S.	-	-	+	+	-	-	SLSkd	Soil profiles are characterized by sandy topsoil, low O.C., low k-reserves,<15%ESP, slightly alkaline, dry soil, and moderate ECEC.	
MU2P2	L.S.	L	-	-	+	-	-	-	LSLk	Loamy sand topsoil with loamy subsoil, low OC,K-deficiency,<15%ESP,	
MU3P1	SL	SL	-	-	+	+	-	+	SLkdh	Sandy loam topsoil and subsoil, low organic carbon, k-deficiency,<15% ESP, moderate ECEC and acidic reaction (h).	

d = dry; k = low K reserves; e = low ECEC; h = high acidic; n = sodium; m = organic carbon

4.0.Conclusion

The study was carried out ,to evaluate the morphological, physical and chemical properties and the taxonomic and fertility capability classification of the soils for the management sustainable production of arable crops. Three soil mapping units were obtained: MU1, MU2 and MU3. The soils were deep and well-drained with pronounced A, B and C horizons. Bulk density values (> 1.6 g/cm3) and egreyish soil colours present possibilities of the occurrence of densicendopedons. Soil pH was slightly acid to slightly alkaline, while organic C and total N were low except in the soils. Base saturation was rated high in the soils. Taxonomically, the soils met the requirements of Arenic Haplustalf and Inceptic Haplustalf in the USDA System and correlated with HaplicLixisols (Arenic, Ochric) in the World Reference Base for Soil Resources System. The FCC system was used to evaluate the soils based on physic -chemical fertility constraints and limitations for general arable cropping. The strata and substrata type soils are comprised mainly of sandy loam topsoil, with two of the pedons showing loamy sand strata types. Classification of the soils into various FCC units reveals that over 85 % of the soils are arable with only one soil type as Inceptic Haplustalfs with FCC unit LR^{+++} with limitations due to rock outcrop and very high gravel content. Organic manuring, balanced nutrient fertilization and conservation technique such as contour farming is recommended for the soils in the Teaching and Research Farm of Taraba State University, Jalingo.

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