CHARACTERIZATION AND CLASSIFICATION OF SOME SOILS OF MINNA, NIGER STATE, NIGERIA.

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ABSTRACT
Adequate soil data is essential for productive and sustainable agricultural land use. Some soils of Chanchaga, Minna, Niger state were surveyed, characterized and classified so as to generate information for enhancing its land use capability. The study area was surveyed by the rigid grid method (100m x 100m) of soil survey. Four land units (CHA1, CHA2, CHA3, and CHA4) were established based on textural class, drainage, topography, and soil depth. Pedons were cited in each soil unit and characterized. Soil samples were collected from genetic horizons and analyzed for morphological, physical, and chemical properties. The drainage condition of the soils were generally imperfect to poor drainage, with soil colour predominantly varying from dark grayish brown to brown (under moist condition), and mainly sandy loam in texture. Sand was dominant mineral size fractions in the soils, ranging 340 g kg^{-1} to 800 g kg^{-1}. The pH of the soils were moderately acidic to alkaline in reaction, ranging from 5.75 to 6.67 and 5.85 to 7.75 in surface and sub-horizons respectively. Organic carbon ranged from 2.39 g kg^{-1} to 9.18 g kg^{-1}, and CEC ranged from 3.20 cmol kg^{-1} to 9.22 cmol kg^{-1}. The base saturation in the soils were generally high, ranging from 66.3% to 92.0%. The soils were classified as follows: CHA1- Aquic Haplustepts/Anthraquic Cambisols, CHA2 - Typic Haplustalfs/Haplic Luvisols, CHA3 - Typic Plinthusalfs/Haplic Plinthosol, and CHA4 - Lithic Ustorthents/Cambic Leptosol.

Key words: Characterization, Classification, Soil Characteristics

INTRODUCTION
Intensification of crop production on lands currently accrued to conventional farming requires a comprehensive knowledge on the soil resources as well as land attributes. Suitable and reliable soil management practice for tropical soils can be designed with the provision of information on the potentials, constraints and distribution of major soil types. Soil characterization presents a potent resource for benefits to man in this regard, essentially in the theme of food sustainability and environmental protection (Esu, 2004). It is also concerned with the determination of soil morphological properties, as well as their fitting into generally accepted soil classification system. Characterization provides the building block for understanding and appreciating the soil, and further classification of it.

Aside the explosive growth rate in population, inadequate information on soil characteristics, their responses to varying uses, could militate agricultural development in Nigeria. The classification of soils is usually based on soil properties described in terms of diagnostic horizons, identified properties and materials; which to the greatest extent could be measurable in the field. The selection of diagnostic characteristics takes into account their relationship with soil forming processes. Thus an understanding of related soil forming processes contributes to a better characterization of soils; however, not used as a distinguishing criteria. Soil characterization, classification and evaluation are the first or primary indicators for establishing soil database, as proper understanding of soil resources are indispensible for a judicious uses of land resources (Jagdish *et al.* 2009; Udoh and Lekwa, 2014). Minna being part of the Southern guinea savannah of Nigeria has a great potential for agricultural productivity. Information on the properties of the soils of Minna could better its land use capability.

METHODOLOGY
The Study Area
Satellite image of the study area is presented in fig. 1. The study area is located in Chanchaga, Minna, Southern Guinea savanna and lies within latitude 9º 31' 54.94" N and latitude 9º 31' 21.4" N, and longitude 6º 35' 53.3" E and longitude 6º 35' 55.29" E with elevation range of 209 m to 258 m above sea level. The area is mainly of flat to gently sloping plains.

Minna falls under sub-humid tropical climate, with two distinct seasons, namely dry and rainy season. Minna possess an ustic moisture condition with mean annual rainfall of 1229 mm, and an isohyperthermic temperature condition. Its temperature (about 35ºC) remains high throughout the month of March and June (Ojanuga, 2006). The vegetation of Minna is characterized by woodlands, short and tall grasses, which is inter-sparsed with tall dense trees. The major type of land use in Minna is Agriculture, with crops such as yam, maize, rice, groundnut, and melon seed as the chief cultivated crops.

Figure 1: Satellite Image of the study area

Field Study

A Reconnaissance field survey was first carried out in the month of February and the first week of March 2017; in order to have an overview of the study site, and to generate information that could aid in the planning of the detailed field work. Detailed assessment of the area was done using rigid grid method of soil survey and carried out within the second week of March 2017 to the last week of June 2017. 60 ha land area was covered for the detailed soil survey. Traverses were cut at 100 m intervals along established baseline, and auger observations for morphological properties were at intersect traverses of 100 m interval. Soil properties such as soil colour, texture, soil depth, drainage condition, and stoniness were assessed. The out-come from the assessment delineated the area into four mapping units (namely; CHA1, CHA2, CHA3, and CHA4). Atleast two profile pits (pedons) were dug in each mapping unit except in CHA3. The pedons were described based on FAO (2006) guidelines for soil description. Bulked soil samples were collected from each identified genetic horizons and taken to the laboratory for analysis. Taxonomic classification of the soils were according to USDA Soil taxonomy (Soil Survey Staff, 2014) and WRB for Soil Resources (FAO, 2014)

Laboratory Analysis

The soil samples were air-dried and sieved with 2 mm. The following soil physical and chemical properties were determined: Particle size distribution was by determined by the Bouyoucous hydrometer method, and textural classes established from the USDA soil textural triangle; Bulk density was determined by the undisturbed soil core method (Blake and Hartge, 1986); Soil pH in water solution (soil ratio 1:1) was determined using the electrometric method; Soil organic carbon (OC) was determined by the wet dichromate method (Walkley and Black, 1934); Total nitrogen was obtained by the Macro-Kjedahl method (Bremnar and Mulvaney, 1982); Available P was determined calorimetrically after Bray-1 extraction; Exchangeable bases (Ca, Mg, Na, K) was determined using 1N NH_4OAc extractant method (Thomas, 1982), after which Ca and Mg was obtained from an Atomic Absorption Spectrometer, while Na and K obtained by the Flame Photometer; Exchangeable acidity ($Al^{3+} + H^{+}$) was determined by titremetric method after extraction with 1N KCl (Mclean, 1982); Cation exchange capacity (CEC) was obtained by the NH_4OAc displacement; and base saturation (BS) calculated as follows-

$$BS = \frac{\text{total exchangeable bases}}{CEC} X\ 100$$

RESULTS AND DISCUSSION

Morphological Characteristics

The field morphological properties of the study area are presented in table 1. The drainage pattern of the soils ranged from good drainage in surface soils to imperfect and poor drainage condition in sub and deep horizons. Redoximorphic features were evident within sub-horizons with dominant soil Hues of 10YR and 5YR. Soil colour varied predominantly from dark grayish brown (10YR 5/4) to brown (10YR 5/3) under moist condition. The soils also featured colours such as grayish brown, strong brown, reddish yellow and yellowish red. These colours features may be evidence of the presence of goethite, haematite and gibbsite minerals in the soils (Brady and Weil 1999; Aki *et al.* 2014). The structural grades of the soils varied from weak to moderate, with structural grouping varying from weak/moderate crumby to granular structure within surface horizons, and weak/moderate granular to moderate medium/coarse sub-angular structure within sub-horizons. In moist state, the soils were friable, loose and firm, while under wet condition, they exhibited slightly sticky to sticky consistence.

Sandy loam texture dominated surface horizons, while sandy clay loam were predominant in sub-horizons. The presence of concretion and nodule inclusions indicates redoximorphic concentrations in the soils. These concentrations have developed over time under repeated reductive and oxidative reactions in saturated condition (Esu, 2010)

Table 1 Morphological properties of the Soils

Soil Unit/ Pedon	Horizon Designa Tion	Profile Depth (cm)	Soil Colour (moist)	Mottles	Textural Class	Structure	Consistency Dry	Moist	Wet	Boundary	Roots	Inclusions
CHA1												
Pedon 1	Ap	0-23	10YR 3/2 (VDGB)	10YR 5/4 (YB)	SiL	Ms	v.h	fi	st	Cw	2fmrt	-
	Bw	23-54	10YR 4/2 (DGB)	10YR 5/4 (YB)	SL	Ms	v.h	fi	s.st	-	1f rt	-
Pedon 3	Ap	0-17	10YR 3/2 (VDGB)	10YR 5/3 (B)	L	Ms	h	fi	s.st	Cw	2frt	-
	2C	17-66	10YR 4/2 (DGB)	-	SL	Sg	s	lo	n.st	-	2frt	-
CHA2												
Pedon 2	Ap	0-28	7.5YR4/4 (B)	-	SL	2m cr	s	v.fr	n.st	Aw	2mrt	-
	Bt1	28-104	5YR 4/6 (YR)	-	SL	2m sb	h	fi	s.st	Cw	1mcrt	-
	Bt2	104-166	5YR 4/6 (YR)	2.5YR3/6 (DR)	CL	2mc sb	h	fi	st	-	1mrt	Mn nodule
Pedon 7	Ap	0-17	10YR 5/2 (GB)	10YR 5/4 (YB)	SL	1m cr	lo	lo	n.st	Cs	2fmrt	-
	AB	17-32	10YR 5/2 (GB)	10YR 5/4 (YB)	SL	1m sb	s	fr	n.st	Cw	2frt	-
	Bt1	32-93	10YR 5/3 (B)	10YR 5/4 (YB)	SCL	2mc sb	h	fi	v.st	Gw	-	Mn nodule
	Bt2	93-126	10YR 5/3 (B)	10YR 5/4 (YB)	C	2mc sb	h	fi	v.st	Gw	-	-
	Bt3	126-173	10YR 5/4 (YB)	10YR 5/6 (YB)	C	2mc sb	h	fi	v.st	-	-	Mn nodule
Pedon 9	Ap	0-18	10YR 4/3 (B)	-	SL	2m gr	s	fr	n.st	Cw	2mrt	-
	AB	18-33	10YR 4/4 (B)	-	LS	2m sb	s	fr	n.st	Aw	2fmrt	Fe-Mn concretion
	Btv	33-103	7.5YR4/6	5YR 4/6	SCL	2m sb	h	fi	sl.st	Aw	1mrt	Fe-Mn concretion

			(SB)	(YR)								
	Ct	103-170	7.5YR6/6 (RY)	5YR 5/8 (YR)	L	2m sb	h	fr	St	-	1mrt	-
CHA3 Pedon 6	Ap	0-29	7.5YR4/4 (B)	-	SL	1fm gr	lo	v.fr	n.st	As	2fmrt	-
	Bt	29-85	5YR 5/6 (YR)	5YR 4/6 (YR)	SCL	2m sb	h	fi	st	Gw	1mrt	Mn nodule
	Btv	85-148	5YR 5/6 (YR)	5YR 4/6 (YR)	SCL	2m ab	h	fi	St	Gw	-	Fe-Mn concr., Mn nodule
	BC	148-185	5YR 5/6 (YR)	5YR 4/4 (YR)	CL	2mc sb	h	fi	St	-	-	Fe-Mn concretion
CHA4 Pedon 4	Ap	0-16	10YR 4/2 (DGB)	-	SL	1m gr	lo	fr	n.st	As	1frt	-
	AC	16-41	10YR 5/4 (YB)	-	SL	1m sb	lo	Fr	n.st	Cw	1frt	-
	Cr	41-143	10YR 5/2 (GB)	10YR 5/3 (B)	SL	2m gr	h	fi	n.st	-	-	-
Pedon 8	Ap	0-26	7.5YR 4/6 (SB)	-	SCL	2mc sb	h	fi	st	Cw	1frt	
	Bw1	26-105	5YR 4/6 (YR)	5YR 4/6 (YR)	SCL	2c sb	h	fi	v.st	Cw	-	Mn nodule
	Bw2	105-173	5YR 4/6 (YR)	5YR 4/6 (YR)	SCL	2m sb	h	fi	v.st	-	-	Mn nodule

Short hand notation for Table 1
(-) = property not determined
Colour: VDGB=very dark grayish brown, DGB=dark grayish brown, SB=strong brown, RY=reddish yellow, YR= yellowish red, YB=yellowish brown, GB=grayish brown.
Texture: SL=sandy loam, LS=loamy sand, SCL=sandy clay loam, SiL=silty loam, CL=clay loam, C=clay.
Structure: 1=weak, 2=moderate, f=fine, m=medium, c=coarse, gr=granular, Ms=massive structureless, cr=crumby, sb=sub-angular blocky, ab=angular blocky.
Consistency: h=hard, v.h= very hard, fi=firm, v.fi=very firm, fr=friable, v.fr=very friable, st=sticky, sl.st=slightly sticky, v.st=very sticky, n.st=non-sticky.
Boundary: Cs=clear smooth, Cw=clear wavy, As=abrupt smooth, Aw=abrupt wavy, Gw=gradual wavy. Roots: 1=few, 2=common, 3=many, f=fine, m=medium, c=coarse, rt =root

Soil Physical Properties

The physical properties of the soils are presented in Table 2. Sand particles are the dominant fraction in the soils. Sand particles generally decreased with depth in the soils of CHA2 and CHA3, which is prevalent in many studies because smaller size mineral particles usually increase down profile depths due to sorting, migration, and eluviation (Fasina *et al.*, 2005). However, increase in sand fractions with depth in CHA1 shows weak profile development. Sand fractions in the soils generally ranged from 340 g kg^{-1} to 800 g kg^{-1}. Silt particles were relatively high in CHA1, recording high values of 320 g kg^{-1} to 540 g kg^{-1}. CHA1 is geographically located in a depression, hence may have accumulated high amount of silt by siltation of materials washed by run-off or gravity or both from surrounding uplands. Silt particles in the soils also exhibited irregular pattern of increase and decrease down profile depth, generally varying from 120 g kg^{-1} to 540 g kg^{-1}. Clay particles showed progressive increase with soil depth in CHA2 and CHA3, indicating argillic sub-horizons. CHA1 showed no progressive increase of clay with depth. This further confirms the soils of the area to be young and weakly developed. Clay fraction in the soils recorded values of 120 g kg^{-1} to 360 g kg^{-1}. Silt-clay ratio of the soils were low to moderate, and ranged from 3.00 to 4.50 in CHA1, 0.50 to 2.67 in CHA2, 0.53 to 1.60 in CHA3, and 0.53 to 2.40 in CHA4. Bulk density values for surface soils ranged from 1.37 g cm^{-3} to 1.49 g cm^{-3} in CHA1, 1.47 g cm^{-3} to 1.60 g cm^{-3} in CHA2, and 1.45 g cm^{-3} to 1.52 g cm^{-3} in CHA4. These values are considered favorable for plant growth and fall within the range of 1.00 – 1.60 g cm^{-3} for mineral soils (Akapan-Idiok *et al.*, 2012).

Table 2. Physical Properties of the Soils

Soil Unit/ Pedon	Horizon Designation	Profile depth (Cm)	Sand →	Silt kg/g	← Clay	Textural Class	Silt/Clay Ratio	Bulk density (g/cm^3)
CHA1 Pedon 1	Ap	0-23	340	540	120	SiL	4.50	1.37
	Bw	23-54	520	360	120	SL	3.00	1.36
Pedon 3	Ap	0-17	480	420	100	L	4.20	1.38
	2C	17-66	580	320	100	SL	3.20	1.50
CHA2 Pedon 2	Ap	0-28	720	200	80	SL	2.50	1.47
	Bt1	28-104	420	180	400	SL	0.45	1.53
	Bt2	104-166	440	260	300	CL	0.87	1.55
Pedon 7	Ap	0-17	780	160	60	SL	2.67	1.49
	AB	17-32	700	100	200	SL	0.50	1.61
	Bt1	32-93	580	80	340	SCL	0.24	1.80
	Bt2	93-126	420	140	440	C	0.32	1.75
	Bt3	126-173	380	200	420	C	0.57	1.40
Pedon 9	Ap	0-18	740	160	100	SL	1.60	1.60
	AB	18-33	800	120	80	LS	1.50	1.53
	Btv	33-103	500	240	260	SCL	0.92	1.55
	Ct	103-170	500	300	200	L	1.52	1.39
CHA3 Pedon 6	Ap	0-29	740	160	100	SL	1.60	1.73
	Bt	29-85	540	160	300	SCL	0.53	1.61
	Btv	85-148	500	180	320	SCL	0.56	1.57
	Ct	148-185	400	240	360	CL	0.67	1.54
CHA4 Pedon 4	Ap	0-16	660	240	100	SL	2.40	1.52
	AC	16-41	680	160	160	SL	1.00	1.50
	Cr	41-143	550	250	200	SL	1.25	1.54
Pedon 8	Ap	0-26	460	200	340	SCL	0.59	1.45
	Bw1	26-105	600	140	260	SCL	0.54	1.65
	Bw2	105-173	540	160	300	SCL	0.53	1.56

SL= Sandy Loam; SCL=Sandy Clay Loam; L=Loam; LS=Loamy Sand; SiL=Silty Loam; C=Clay; CL= Clay Loam

Soil Chemical Properties

Soil pH increased irregularly with depth in the soils, having values of 5.75 to 6.67 in surface soils, and 5.85 to 7.75 in sub-horizons. The soils are moderately acidic in surface horizons to slightly alkaline within sub-horizons. The increased pH values in sub-horizons may be as a result of the accumulation of basic cations that have washed down in solution over time from top soils into sub-layers. Organic carbon content in the soils ranged from 2.39 to 9.18 in CHA1, 2.39 to 4.49 in CHA2, 2.99 to 5.19 in CHA3, and 3.20 to 5.40 in CHA4, and were generally low (Esu, 1991). Land use activities such as livestock grazing, bush burning and the kind of arable farming in the area may have contributed to the low carbon content in the soils. Organic carbon is an essential component of soil chemical parameter for tropical soils, enhancing aggregate stability, nutrient retention and other desirable soils properties. For most Nigerian soils, optimum crop production can be achieved when critical level of carbon content stands at about 10 g kg^{-1} to 15 g kg^{-1} (Esu, 1991). Carbon values below this critical level may encourage more leaching losses of basic cations into sub-soils. Total N in all the soils units were high i.e. > 0.2 g kg^{-1}. The application mineral fertilizers by the farmer in the area may have contributed to the high N values recorded in the soils. The N values generally ranged from 0.28 g kg^{-1} to 1.15 g kg^{-1} and considered adequate for plant uptake. Distributions of available P in the soils were irregular down the profile depths and were considered low to moderate. However, notable high values of P were recorded in Pedon 1 (12.3 mg kg^{-1}) of CHA1 and Pedon 4 (16.1 mg kg^{-1}) of CHA4. Low instances of P values in the soils may be tied to low carbon content which is a major source of P in tropical soils (Sanchez, 1976). The concentration of exchangeable bases (Ca, Mg, K, Na) in soils were also irregular in distribution across profile depths. However, Ca and Mg generally increased with soil depth. As the percentage of clay fractions in the soils increased with depth, the concentration of Ca and Mg bound by them also increased (Loide, 2004). Ca values ranged from 3.51 cmol kg^{-1} to 8.56 cmol kg^{-1} in CHA1, 1.50 cmol kg^{-1} to 17.7 cmol kg^{-1} in CHA2, 2.60 cmol kg^{-1} to 9.17 cmol kg^{-1} in CHA3, and 2.19 cmol kg^{-1} to 5.79 cmol kg^{-1} in CHA4. While Mg values ranged from 0.35 cmol kg^{-1} to 2.56 cmol kg^{-1} in CHA1, 0.36 cmol kg^{-1} to 4.56 cmol kg^{-1} in CHA2, 0.28 cmol kg^{-1} to 3.05 cmol kg^{-1} in CHA3, and 0.36 cmol kg^{-1} to 1.30 cmol kg^{-1} in CHA4. Na values (0.20 cmol kg^{-1} to 0.42 cmol kg^{-1}) in the soils was low to medium but considered safe from inducing sodicity. However, surface soils of Pedon 4 (CHA4) recorded high Na value of 0.57 cmol kg^{-1}. CEC in the soils also increased with soil depth probably due to increase in clay content with depth. CEC values ranged from 3.20 cmol kg^{-1} to 6.80 cmol kg^{-1} in surface soils, and 5.70 cmol kg^{-1} to 22.6 cmol kg^{-1} in sub-horizons. The soils generally exhibited high base saturation values (66.3 % to 92.0 %). The base saturation values of the soils agrees with the results of Lawal *et al*., (2012) and Afolabi *et al.*, (2014) that the soils of Minna have high base saturation values. High base status of the soils shows that basic nutrients may occur in available form for plant uptake despite low cation reserve in the soils (Aki *et al*., 2014).

Soil classification

For convenience of classification, Pedon 1 (for CHA1), Pedon 2 (for CHA2), Pedon 5 (CHA3), and Pedon 4 (for CHA4) will be classified under USDA soil taxonomy and WRB. The soils of CHA1 showed no evidence of clay accumulation in sub-soils, thus qualify as Inceptisols at Order level. The soils are formed under ustic moisture regime, which qualify them as Ustepts at Suborder level and Haplustepts at Great group level, since they belong to other category of Ustepts. Under Subgroup level, the soils are classified as Aquic Haplustepts because they

Table 3. Chemical Properties of the Soils

Soil Unit/ Pedon	Horizon Designation	Profile Depth (cm)	pH (H_2O)	pH ($CaCl_2$)	OC (g/kg)	Total N (g/kg)	Avail P (mg/kg)	Ca	Mg	K	Na	Exch. Acidity	CEC	BS (%)
								←			cmol/Kg		→	
CHA1														
Pedon 1	Ap	0-23	5.85	5.45	9.18	1.15	4.38	5.12	0.55	0.07	0.25	0.80	6.90	86.8
	Bw	23-54	6.12	5.62	4.59	0.48	12.3	4.2	0.35	0.08	0.25	0.40	5.70	85.6
	*	54-84	6.62	5.89	2.39	0.42	5.95	3.82	0.64	0.10	0.32	0.40	0.60	81.3
	*	84-114	6.64	5.72	5.39	0.48	3.68	5.38	0.64	0.09	0.31	0.40	7.30	87.9
Pedon 3	Ap	0-17	6.16	5.93	7.88	0.45	3.50	5.89	0.66	0.18	0.42	0.40	8.50	84.1
	2C	17-66	6.25	5.86	6.38	0.53	3.33	4.37	0.54	0.15	0.43	0.60	6.80	80.7
	*	66-95	6.44	5.66	6.78	0.62	3.68	8.56	2.56	0.10	0.37	0.80	13.4	86.5
	*	96-126	6.37	5.82	4.39	0.28	2.98	3.51	0.54	0.13	0.47	0.60	5.70	81.6
CHA2														
Pedon 2	Ap	0-28	6.37	5.60	4.49	0.48	3.33	1.50	0.36	0.05	0.21	0.60	3.20	66.3
	Bt1	28-104	6.24	5.97	3.79	0.39	1.75	3.52	0.43	0.10	0.31	0.40	5.40	80.7
	Bt2	104-166	6.31	5.98	2.59	0.39	2.45	3.76	0.39	0.10	0.29	0.60	5.80	78.3
Pedon 7	Ap	0-17	6.50	5.38	3.99	0.39	7.70	1.75	0.38	0.09	0.21	0.80	3.60	67.5
	AB	17-32	6.15	5.29	2.39	0.45	7.18	3.44	0.46	0.10	0.29	0.80	5.70	75.3
	Bt1	32-93	7.14	6.48	3.80	0.39	3.15	7.39	2.14	0.11	0.32	0.60	11.5	86.6
	Bt2	93-126	7.68	6.98	2.59	0.45	4.20	12.6	4.56	0.09	0.45	0.10	18.8	94.1
	Bt3	126-173	7.75	6.68	3.99	0.36	4.20	17.7	3.55	0.12	0.55	0.10	22.6	97.0
Pedon 9	Ap	0-18	6.37	6.03	4.59	0.62	5.25	4.08	0.67	0.16	0.21	0.40	5.60	91.4
	AB	18-33	6.42	6.00	4.20	0.62	3.33	3.91	0.55	0.08	0.23	0.60	5.40	88.3
	Btv	33-103	6.92	6.27	1.20	0.70	2.98	6.32	0.87	0.23	0.31	0.40	8.40	92.0
	Ct	103-170	6.45	5.74	1.80	0.53	2.80	2.19	1.54	0.12	0.43	0.60	9.60	44.6
CHA3														
Pedon 6	Ap	0-29	6.22	5.54	2.99	0.48	3.68	2.68	0.28	0.25	0.24	0.40	4.10	84.1
	Bt	29-85	6.08	5.35	5.19	0.31	2.78	5.30	0.68	0.12	0.25	0.60	7.40	85.8
	Btv	85-148	6.24	5.67	4.19	0.34	3.33	6.81	1.44	0.12	0.23	0.60	9.60	89.6
	BC	148-185	6.40	5.75	4.39	0.28	3.68	9.17	3.05	0.09	0.33	0.60	14.3	88.4
CHA4														
Pedon 4	Ap	0-16	5.75	5.23	3.99	0.36	16.1	2.19	0.48	0.08	0.57	0.80	4.60	72.2
	AC	16-41	6.17	5.33	3.99	0.59	3.15	3.56	0.36	0.07	0.20	0.80	5.60	74.8
	Cr	41-143	6.50	5.51	4.39	0.31	3.85	5.79	0.56	0.10	0.37	0.60	7.80	87.4

Pedon 8	Ap	0-26	6.67	6.03	5.40	0.56	3.85	4.89	0.54	0.10	0.25	0.10	6.80	85.0
	Bw1	26-105	5.98	5.58	3.79	0.64	2.98	5.50	0.68	0.08	0.22	0.80	7.70	84.2
	Bw2	105-173	6.25	5.74	3.20	0.42	2.98	5.61	1.30	0.07	0.21	0.60	8.60	83.6

*auger sample depth

undergo periodic saturation with water within the year. The soils of CHA2 and CHA3 exhibited argillic horizons with base saturation > 50% by NH_4OAc, thus are classified as Alfisols at Order level. The soils developed under ustic moisture, which qualifies them as Ustalfs at Suborder level. CHA2 soils fall in the category of other Ustalfs, thus qualify as Haplustalfs at Great group level, and Typic Haplustalfs at Subgroup level since the category of Haplustalfs have no identifiable association of characterization at this level. Soils of CHA3 posses plinthic materials within argillic horizons, thus are classified as Plinthustalfs at Great group level. At Sub-group level, the soils are classified as Typic Plinthusalfs because they are typical Alfisols formed under ustic moisture regime. Soils of CHA4 exhibited weak profile development with no notable textural change throughout genetic horizons, thus qualify as Entisols at Order level. The soils belong to other category of Entisols which qualify them as Orthents at Suborder level, and Ustorthents at Great group level because they are also formed under ustic moisture regime. The presence of lithic contact with rock fragments within sub-horizons qualify the soils as Lithic Ustorthents at Subgroup level. Under WRB classification, the soils are classified as follows: CHA1 - Anthraquic Cambisols, CHA2 – Haplic Luvisols, CHA3 – Haplic Plinthosol, and CHA4 – Cambic Leptosol.

CONCLUSION

The soils of the study area generally have favorable pH, high base status, but low to medium fertility. However, with adequate application of mineral fertilizers and organic inputs, the soils can be more productive.

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