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Assessment of Physicochemical Characteristics and Determination of Class of Vertisols in Mbalwaba, Hong Local Government Area of Adamawa State

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Abstract
The researched was conducted with the aimed of examining the physicochemical characteristics and identifying the class of Vertisols in Mbalwaha. Pre-field survey involved gathering information from topographic maps, interviews and meteorological data on the study area. Four locations with substantial areas of Vertisols were selected in Mbalwaha through field observation. Four profile pits were sunk, one in each of the selected areas and pedogenic samples were collected for in situ and standard laboratory analyses. Results showed that Munsell soil colour of the samples ranged from 10YR 7/2 (Light Gray) to 10YR 3/1 (Very Dark Gray). The soils were found to be clay in texture with greater than 64 % clay contents in all the pedons. Bulk density ranged from 1.25-1.61g/cm^3. Soil pH were high, Electrical Conductivity values were normal, Calcium Contents were also high and follow by Magnesium. Potassium contents were normal while sodium contents, total exachangeable acidity and exchangeable sodium percentage values were all low. Cation exchange capacity values were medium to high, effective cation exchange capacity and percentage base saturation values were all high. Organic matter, total nitrogen, and available phosphorus contents were all in traces. The class of the Vertisols was identified based on WRB system of classification as; Eutric chromusterts.

Keywords: Physicochemical Characteristics, Vertisols, Mbalwaha, Eutric Chromusterts.

Introduction

The word *Vertisols* is derived from Latin word *Vertere* meaning 'to turn' Vertisols are minerals soils that do not have a lithic, paralithic and petrocalcic horizons or duripan within 50cm depth (Brady and Weil, 1999). After the upper layer is mixed to a depth of 18cm, it must have 35% or more content of the expansive clay mineral known as montmorillonite in all horizons down to a depth of 50 cm or more. At some period in most years, Vertisols must have cracks at least 1cm wide that are open to the surface unless the soil is irrigated (Brady and Weil, 1999). Vertisols owe their origin from sediments that contain a high proportion of smectite clay or products of rock weathering, example basalt that favours the formation of smectites. Geologic materials such as mart and marine shales may also serve a parent material of Vertisols. They form on depression and level to undulating areas, mainly in tropical, semi-arid to sub-humid and Mediterranean climates with an alteration of distinct wet and dry seasons and the climax vegetation of savanna and grassland and/or woodland characteristics. Most Vertisols occur in semi-arid tropics, with an average annual rainfall of 500-1000 mm. In Nigeria, about four million (4,000,000) hectare of Vertisols occurs within the savannah ecological zones of Nigeria (Lombin and Esu, 1988).

Vertisols possesses one attribute which is the high moisture storage capacity. This attributes ensures much safer and more productive cropping; it can assist crops to survive and perhaps even to grow during prolonged dry spells, whereas failures would have resulted on soil not so well endowed.

Vertisols can also allow crops to continue to grow for several weeks after the rainy season is ended; it may therefore be possible to grow two crops in 1 year. However, despite these advantages, these soils have several disadvantages. Although the first rain infiltrates quickly to considerable depths via large cracks, subsequent infiltration and permeability are very low due to the high clay content and poor structure when wet. Drainage may be a problem and crops may become waterlogged. Poor traffic ability of the soil when wet seriously interferes with the planting operations. If crops cannot be established during the rainy season in the tropics, the high intensity of the rain on unprotected soil may cause serious erosion. Such problems are at least part of the reason why farmers in some parts of semi-arid tropics do not grow crops during the rainy season, even though the rainfall is sufficiently reliable. This has been overcome by identifying the above problems and by developing management innovations to minimize them: sowing into a dry seedbed ahead of the rains, growing crops on a raised bed to provide drainage and using furrows and waterways to conduct excess water from a watershed. The high shrink-swell potentials of these soils make them entirely problematic for any kind of highway or building construction (Yule and Ritchie, 1980).

Vertisols are generally classified into four (4) soil sub-orders: torrerts, usterts, xererts and uderts (Soil Survey Staff, 1990). These four soil orders are recognized primarily based on the length of time the cracks are opened to the surface. Vertisols great groups (the sub-division of sub-orders) are determined on the basis of their chroma moist (moist soil colour) as: chromoxererts and pelluxererts; chromusterts and pellusterts; chromuderts and pelluderts. No great group was identified in the torrerts Vertisols suborder. Any chroma moist less than 1.5 at the great group level is pellu while chroma moist of 1.5 and above represents other Vertisols great groups (Eswaran and Cook, 1988).

Documented information on the genesis, properties, characteristics, management and classification of Vertisols of Adamawa State especially the Vertisols of Numan and Lamurde Local Governent Areas are available (Zata *et al.*,2013), but little or no information on this aspect are available on the Vertisols of Mbalwaha, located in Hong Local Government Area of Adamawa State. Though studies on the Vertisols might have been conducted at reconnaissance level, detailed information on the classification of these soils are unexploited leading to the under-utilization of the soils. Therefore, this research will cover some areas in the knowledge gab in the classification of Vertisols.

Materials and Methods

Location of the study area

Mbalwaha is the selected area of the researched, lies in Hong Local Government Area of Adamawa State which is located between latitudes $10^0\ 23^I$ and $10^0\ 28^I$ N and longitudes $12^0\ 48^I$ and $13^0\ 00^I$ E (Latur, 2002) (Figure 1). Hong lies at an elevation of 305-400m above sea level and situated along Yola-Maiduguri highway (Adebayo and Tukur, 1999). The climate is characterized by two seasons (dry and wet). The dry season runs from November to March and the rainy season from April to October. The amount of rainfall ranges between 700-1200mm annually with greater part falling between July and September (Adebayo, 2011). Temperature in this region is high throughout the year, because of high radiation income which is relatively evenly distributed throughout the year. April is usually the hottest month (maximum temperature being 40^oC) while December and January has the lowest temperature averaging 25^oC. The Mbalwaha Vertisols is derived from quarternary alluvium underlain by Bima sandstones and are found in nearly level plain. The geology of the area is underlain by the upper cretaceous rocks of marine sediments. The sediments are predominantly argillaceous and consist of alternating shale and limestone with sandy mudstones, siltstones and sandstones respectively. The remnants of these included materials form the major components of the resultant soils. These inclusions are either decreased or increased with depths or are uniformly distributed. The relief of the area is characterized by the gentle slopes with numerous small streams that originate from the surrounding hills that flow from the gentle slopes into the main streams (Bawden, 1972).

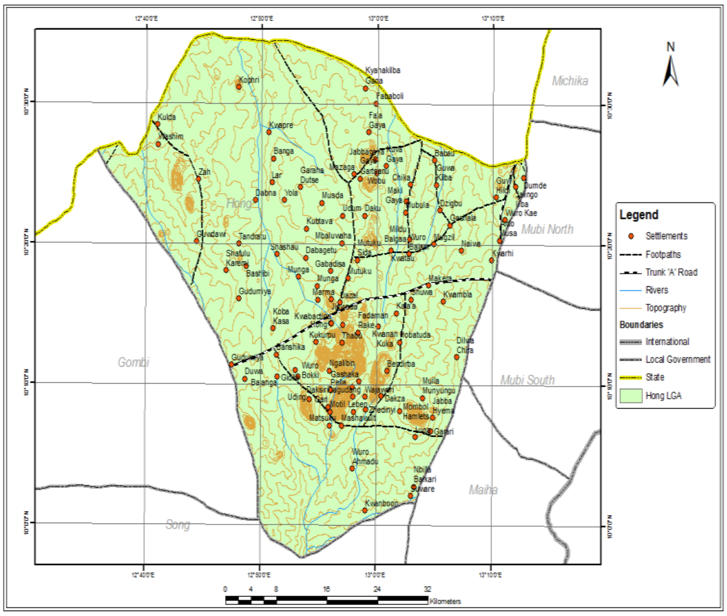

Figure 1: *Map of Hong LGA showing Mbalwaha (Source: Tsundass Envt. Consultant's; Adopted from Nigeria Boundary Commission)*

Field work and soil sampling

Pre-field survey involved gathering information from topographic maps, interviews and meteorological data on the study area was carried out. Four locations with substantial areas of Vertisols in Mbalwaha were selected through field observation. Four profile pits were sunk, one in each of the selected areas, and pedogenic samples collected according the procedures described by Dent and Young (1981). Soil samples collected from each identified horizon were taken to laboratory for analysis. Bulk density samples were taken using core samplers. Colour determination was carried out in situ using Munsell soil colour chart.

Laboratory analysis

In the laboratory, soil samples were air dried and ground using wooden pestle and mortar and sieved using 2mm sieve. The particle size distribution was determined by the Buoyoucous Hydrometer Method (Jaiswal, 2003). Bulk density was determined from undisturbed soil samples in the field using core samplers (Black, 1965). pH of the soil was measured in a 1:2.5 soil-water suspension ratio and also in 0.01M $CaCl_2$ using a glass electrode pH meter (Jaiswal, 2003). Electrical Conductivity of the soil samples was measured using an EC meter (Jaiswal, 2003). Organic Carbon Content was determined using Walkley and Black (1965) method. Organic Matter was obtained by multiplying the Organic Carbon Content of the soil by a factor of 1.724 (Walkley and Black, 1965). Total nitrogen content was determined by the kjeldahl wet oxidation method (Bremnar, 1965). Available phosphorus content was determined by bicarbonate extraction method (Olsen and Dean, 1965). Exchangeable cation content was done by extracting in 1N neutral ammonium acetate (NH_4OAc). The exchangeable calcium and magnesium contents were determined by titrimetric method while the exchangeable potassium and sodium was determined by the flame photometer method (Black, 1965). Cation Exchange Capacity (CEC) of the soil was determined by neutral normal ammonium acetate displacement method while total exchangeable acidity was carried out by displacement with IN KCl (Black, 1965; Anderson and Ingram, 1993; Jaiswal, 2003). Effective Cation Exchange Capacity (ECEC) was determined by summing up the exchangeable bases and exchangeable acidity (Jaiswal, 2003). Percentage base saturation was calculated and expressed as a percentage (Black, 1965). Exchangeable sodium percentage calculated and expressed as a percentage (Black, 1965).

Soil classification

Soil classification of the study area was carried out according to the USDA soil taxonomy (Soil Survey

Staff, 1990) and FAO/UNESCO revised legend (FAO, 1988) by considering all the physical and chemical properties of soils obtained and laboratory studies.

Results and Discussion

Morphological properties

The horizons depth of all the pedons ranged are from 0-190 (Appendix 1). Required depth of 200m could not be achieved due to high water table. However, samples were collected at accessible depths as suggested by Dent and Young (1981). The horizons boundaries of all the pedons showed that, the boundaries are abrupt and smooth, abrupt and wavy, clear and smooth, clear and wavy, diffuse and wavy and gradual and wavy for all the pedons. These soils exhibit minimal horizon differentiation as a result of pedoturbation by such forces as burrowing animals. Orhan *et al.,* (2012) made a similar observation and give the same results on horizon boundaries of Vertisols. The Vertisols studied were similar characteristically in terms of colour (Appendix 1). The colours of the A-horizons were dominantly grey to dark. The colour differences were indicative of differences in drainage pattern. This finding is similar to those of Nwaka (2000) and Tekwa *et al.,* (2013) on the dark cracking soils of northern Nigeria. The structure of all the studied Vertisols samples were; strong massive granular, strong massive prismatic, strong massive angular blocky and strong massive subangular blocky (Appendix 1). This is similar to the structural report presented by Orhan *et al.,* (2012). The consistencies of all the studied Vertisols were; hard, slightly hard, firm sticky and plasticity in nature (Appendix 1). This is because Vertisols offer extremes of consistence; they are very hard when dry and very sticky and plastic when wet. Brady and Weil (1999) and Orhans *et al.,* (2012) both reported that extreme hardness when dry and stickiness and loss of traffic ability when wet. The special features observed when digging the pits were (Appendix 1); cracks, fibrous roots, roots, water table. Though, these special features observed depend on where and when the pit will be sunk.

Physical properties

The percentage sand, silt and clay contents of the studied Vertisols (Appendix 2), showed decrease in percentage silt with depth while percentage sand and clay increases with depth due to high percolation of water within the profile. When wet, the were sticky and plastic and extremely hard when dry as result the crack to at-least 1m wide and to a depth of 50 cm or more. This could be due to the presence of montmorrilonite clay (Singh *et al.,* 2004). The A, B and C horizons of the Vertisols were all clay in texture. Bawden (1972) reported that these Vertisols are derived from the same parent materials. Bulk density values ranged from 1.25-1.61g/cm^3 and increased with depth (Appendix 2), these values are in agreement with 1.50 to 1.80gcm^{-3} as reported by Folorunso *et al.,* (1988) while working on a Vertisols in Borno State.

Chemical properties

The pH values of the soils were high and increased with depth (Appendix 3), which corresponds to the increase in $CaCO_3$ and exchangeable bases, as similarly observed by Brady and Weil (1999); Orhan *et al.,* (2012) and Tekwa *et al.,* (2013). Average Electrical conductivity values (Appendix 3), were less than 1.0 dSm^{-1}, which indicates that, the Vertisols were generally not saline; a similar characteristic observed by Lombin and Esu (1988) and on the Vertisols of Nigerian savannah as well as the observation of Tekwa *et al.,* (2013) on the Vertisols of Numan. Organic matter contents of the Vertisols were low despite their dark colorations (Appendix 3), owing to low organic matter return as similarly reported by Kimer (1990) and Tekwa *et al.,* (2013). Total nitrogen contents were generally low (Appendix 3), this is because nitrogen is a volatile nutrient in the soil and is easily lost through many processes. Lombin and Esu (1998); Nwaka (2000) and Singh *et al.,* (2004) reported similarly that the total nitrogen content of Vertisols is generally low. Available phosphorus contents were also generally low (Appendix 3) due to high phosphorus fixation as a result of high pH value of the soil order as reported by Singh *et al.,* (2004). Exchangeable cations content showed that, Ca^{2+}, followed by Mg^{2+} dominated the exchange complex (Appendix 3), the amount of K^+ content in the soils were adequate to support plant growth. Lombin and Esu (1988) and Folorunso *et al.,* (1988) made a similar observation and reported similarly on the Vertisols of Northeastern Nigerian. Total exchangeable acidity contents were generally low due to low Al^{3+} and H^+ (Appendix 3). The factors contributing to high soil pH are presence of $CaCO_3$ and high contents of bases, especially calcium and magnesium in the profile. As noted by Brady (1999). Cation Exchange Capacities ranged from medium to high (Appendix 3), it is possible, that clay minerals are the major contributors of cation exchange capacity, because of the usual dominance of 2:1 crystal lattice type clay minerals, as similarly observed by Lombin and Esu (1988); Brady (1988) and Orhan *et al.,* (2012). Effective Cation Exchange Capacity are high (Appendix 3), because Vertisols are well supplied by the basic cations responsible for high pH in the soils. Egubuchua and Enujeke (2013) made a similar observation on Vertisols. Percentage Base Saturation was greater than 76% (Appendix 3). This implies that the Vertisols have high percentage of bases, due to high exchangeable cations. Exchangeable Sodium Percentage levels were less than 9% (Appendix 3), though, the exchangeable sodium percentage increased with depth, based on the results sodicity is not yet a major problem since the exchangeable sodium percentage is within the favourable limit of less than 15%.

Soil classification

This present research had revealed that all the soils studied at the four different sites exhibit deep and wide crack characteristics on drying and as well as vigorous characteristics on wetting. The clay contents of the soils were more than 30% throughout the pedon depths with some slickensides on the ped surfaces. The micro-relief gilgai was equally observed. These soils therefore, by all standards qualified to be Vertisols at order level. The studies also revealed that the moisture regime of the soils was dry ustic (Okoye *et al.,* 1983) making the soils to key out as usterts at the suborder level of generalization (USDA Soil Taxonomy). According to the Soil Survey Staff (1990), these soils could further be classified as chromusterts based on the high chroma value. At the subgroup level, the soils qualified as Eutric chromusterts for soils due to their pronounced high base saturation status. According to FAO/UNESCO revised soil legend Ikawa, (1982) now World Reference Base (WRB), the soils at Mbalwaha keyed out as Eutric Vertisols.

Conclusion

In conclusion, the Vertisols were classified at the suborder level of generalization, and a subgroup level. This researched could further provide vital information to land users and help future researchers most especially pedologists.

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Appendix 1: Morphological Characteristics of Mblawaha Pedons

Pedons	Horizon depth (cm)	Horizon boundary	Munsell Colour Moist	Description	Dry	Description	Structure	Consistence Dry/Wet	Special features Dry/Wet
Pedon 1	0-28	as	10YR 4/1	Dark Gray	10YR 6/1	Gray	3mgr	h st pt fi	fibrous root, cracks
	28-115	aw	10YR 4/1	Dark Gray	10YR 6/1	Gray	3mabk	h st pt fi	cracks
	115-173	cw	10YR 6/1	Gray	10YR 7/2	Light Gray	3mpr	h st pt fi	water Appendix
Pedon 2	0-25	aw	10YR 4/1	Dark Gray	10YR 5/1	Gray	3mgr	sh st pt fi	fibrous roots, crack
	25-107	cw	10YR 4/1	Dark Gray	10YR 6/1	Gray	3mpr	h st pt fi	crack
	107-182	cs	10YR 6/1	Gray	10YR 7/2	Light Gray	3mpr	h st pt fi	water Appendix
Pedon 3	0-30	as	10YR 4/1	Dark Gray	10YR 6/1	Gray	3mgr	sh st pt fi	roots, crack
	30-109	cw	10YR 6/1	Gray	10YR 7/2	Light Gray	3mabk	h st pt fi	crack
	109-183	dw	10YR 5/1	Gray	10YR 7/2	Light Gray	3mpr	h st pt fi	water Appendix
Pedon 4	0-32	as	10YR 3/1	Very Dark Gray	10YR4/1	Dark Gray	3mgr	sh st pt fi	fibrous roots, crack
	32-103	aw	10YR 4/1	Dark Gray	10YR 6/1	Gray	3mpr	sh st pt fi	crack
	103-190	aw	10YR 6/1	Gray	10YR 7/2	Light Gray	3mpr	h st pt fi	water Appendix

Abbreviations: Boundary: a = abrupt; c = clear; s = smooth; w = wavy; Structure: 1 = weak; 3= strong; sg = single grain; m = massive; gr = granular; pr = prismatic; abk = angular blocky.
Consistance: h = hard; fi = firm; st = sticky; pt = plastic.

Appendix 2: Physical Properties of Mblawaha Pedons

Pedons	Depth	Particle Size Distribution			Textural class	Bulk Density
		Sand (%)	Silt (%)	Clay (%)		(gcm-3)
Pedon 1						
	0-28	10.13	19.95	69.92	Clay	1.27
	28-115	11.24	18.60	70.16	Clay	1.41
	115-173	18.46	8.72	72.82	Clay	1.61
Mean		13.28	15.76	70.96	Clay	1.43
Pedon 2						
	0-25	9.84	22.35	67.81	Clay	1.25
	25-107	11.96	17.14	70.06	Clay	1.39
	107-182	18.97	10.01	71.02	Clay	1.54
Mean		13.59	16.83	69.63	Clay	1.39
Pedon 3						
	0-30	11.47	21.72	66.81	Clay	1.43
	30-109	13.03	19.89	67.84	Clay	1.49
	109-183	19.91	11.07	69.02	Clay	1.53
Mean		14.80	17.56	67.89	Clay	1.48
Pedon 4						
	0-32	10.90	21.89	67.21	Clay	1.26
	32-103	13.38	19.19	67.33	Clay	1.34
	103-190	17.68	12.14	70.18	Clay	1.55
Mean		13.99	17.74	68.24	Clay	1.38
Overall mean		13.92	16.97	69.18	Clay	1.42

Appendix 3: Chemical Properties of Mblawaha Vertisols

Pedon (Depth in cm)	pH (H_2O)	pH ($CaCl_2$)	EC (dSm^{-1})	O.C (gKg^{-1})	O.M (gKg^{-1})	AV.P ($mgKg^{-1}$)	Total N. (%)	Exch. Cations ($cmol(+)Kg^{-1}$) Ca^{2+}	Mg^{2+}	K^+	Na^+	Exch. Acidity ($cmol(+)Kg^{-1}$) Al^{3+}	H^+	CEC ($cmol(+)Kg^{-1}$)	ECEC ($cmol(+)Kg^{-1}$)	PBS (%)	ESP (%)
Pedon 1																	
0-28	6.8	6.5	0.41	0.57	0.99	0.23	0.16	5.10	4.70	0.30	1.10	2.40	1.01	13.60	14.61	76.71	8.28
28-115	7.3	6.7	0.60	0.41	0.71	0.22	0.15	5.60	5.30	0.31	1.21	2.44	0.83	14.77	15.60	79.03	7.76
115-173	7.6	6.7	0.58	0.39	0.67	0.12	0.10	4.50	4.40	0.21	0.96	1.83	0.61	11.90	12.51	80.50	7.38
MEAN	7.2	6.6	0.53	0.46	0.79	0.19	0.14	5.07	4.80	0.27	1.00	2.22	0.82	13.42	14.24	78.75	7.81
Pedon 2																	
0-25	6.8	6.6	0.38	0.49	0.85	0.24	0.13	5.20	4.50	0.28	0.90	2.10	0.59	12.98	13.37	81.37	6.73
25-107	7.1	6.8	0.49	0.52	0.90	0.23	0.11	6.11	4.90	0.32	1.10	2.62	0.71	15.05	15.76	78.87	7.00
107-182	7.6	7.1	0.61	0.36	0.62	0.23	0.09	7.40	4.50	0.31	1.11	2.10	0.81	15.42	16.23	82.07	6.84
MEAN	7.2	6.8	0.49	0.46	0.79	0.24	0.11	6.24	4.63	0.30	1.13	1.04	0.70	14.48	15.12	80.77	6.86
Pedon 3																	
0-30	7.3	6.8	0.52	0.53	0.92	0.21	0.15	4.54	4.50	0.31	1.20	2.10	1.06	12.65	13.71	76.95	8.76
30-109	7.5	7.2	0.61	0.46	0.80	0.18	0.13	5.13	4.66	0.26	1.18	2.81	0.91	14.04	14.95	75.12	7.89
109-183	7.8	7.1	0.71	0.31	0.54	0.16	0.08	5.10	4.58	0.24	1.22	2.64	0.74	13.78	14.52	76.72	8.40
MEAN	7.5	7.0	0.61	0.43	0.75	0.18	0.12	4.92	4.58	0.27	1.20	2.51	0.90	13.49	14.39	76.26	8.35
Pedon 4																	
0-32	6.8	6.5	0.45	0.51	0.88	0.28	0.15	6.40	5.10	0.27	1.13	2.81	0.96	15.71	16.67	77.38	6.78
32-103	7.6	7.2	0.49	0.52	0.90	0.21	0.14	6.60	5.50	0.29	0.90	2.72	0.81	16.01	16.82	79.01	5.35
103-190	7.5	7.4	0.60	0.38	0.75	0.19	0.11	5.80	5.20	0.20	1.20	2.61	0.76	15.01	15.77	78.63	7.61
MEAN	7.3	7.0	0.51	0.47	0.81	0.23	0.13	6.26	5.27	0.25	1.08	2.71	0.84	15.57	16.42	78.44	6.58
AVERAGE MEAN	7.3	6.9	0.54	0.46	0.76	0.21	0.13	5.62	5.38	0.27	1.10	2.12	0.82	14.24	14.70	78.56	7.40

Abbreviation: EC = Electrical conductivity; O.C = Organic carbon; O.M = Organic matter; Av.P = Available phosphorus; Exch. cations = Excangeable cations; Ca = Calcium; Mg = Magnesium; Na = Sodium; K=Potassium; Exch. Acidity=Exchangeable; Al = Aluminium; H = Hydrogen; CEC = Cation exchange capacity; ECEC = Effective cation exchange capacity; PBS = Percentage base saturation; ESP= Exchangeable sodium percentage