



CHARACTERIZATION AND CLASSIFICATION OF SOME HYDROMORPHIC VERTISOLS IN THE LAKE CHAD BASINS OF NIGERIA IN RELATION TO THEIR AGRICULTURAL LAND USE AND LIMITATIONS

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ABSTRACT

A study was conducted in the Lake Chad basin of Nigeria to characterize and classify some hydromorphic vertisols in relation to their agricultural land use and limitations. Three distinct profile pits were dug in the study locations, examined, described and soil samples collected from each pedogenetic horizon for their physico-chemical properties analysis. The soils were classified based on the criteria of USDA soil taxonomy and correlated with FAO/UNESCO system. The results showed that the soils were moderately deep (> 100 cm) depth, with a colour matrix of low chroma (< 2) in the upper soil horizons and hues of 2.5y and 5y. The textures were predominantly clayey. The pH was slightly acidic to dominantly alkaline (6.7-7.8). Organic matter; total nitrogen and available phosphorus were low with mean top soil horizon values of 13.84gkg⁻¹; 0.39 gkg⁻¹; and 6.22 mgkg⁻¹ in that order respectively. The exchangeable bases were quite high with mean top soil horizon values of 12.87 cmolkg⁻¹ for calcium, 3.83 cmolkg⁻¹ for magnesium, 0.38 cmolkg⁻¹ for potassium and 0.18 cmolkg⁻¹ for sodium respectively. The percentage base saturations were high exceeding 65% in all the top soil horizons investigated. The general results showed that the soils were low to high in nutrients. Limitations to use include sodification, low nutrient reserves resulting from low organic matter, nitrogen, and phosphorous contents. Their sustainable uses could be enhanced by judicious use of organic and inorganic fertilizers and well articulated water management program.

KEY WORDS: Characterization, classification, hydromorphic vertisols.

INTRODUCTION

According to Soil Taxonomy, the Order Vertisols include soils that are rich in expensive clays with wide and deep cracks up to the surface, and with some morphological features that denote the strong shrinking and swelling phenomena to which they have long been subjected (Soil Survey Staff, 1981). Considering this definition, hydromorphic vertisols should then, have prolonged periods of water saturation, oxygen depletion, and also a long dry period so that deep and wide cracks can develop (Comerma, 1986). In Nigeria, the soils are one of the under exploited resources that occur mainly in the Sudan and Northern Guinea Savanna areas of Lake Chad commonly referred to as Ngala and Marte Plains. They are generally dark coloured, heavy textured soils of low permeability poor internal drainage; and derived either from calcareous rocks rich in Ferro-magnesium minerals (Lithomorphic Vertisols), or in depressions enriched by constituents coming from surrounding higher land (Topographic Vertisols). The clay fractions of the soil are known to contain high proportion of the 2 : 1 lattice clay minerals mainly of montmorillonite, shrink and crack widely during the dry season, swell or expand and become very plastic and sticky when wet during the rainy season and thus making them very complicated to manage (Comerma, 1986, Mordi *et al*, 1991, and Ahmed 183). Various studies by Dudal and Mooreman (1984), Esu, (1989); Mordi *et al*, (1991) and Folorunso and Ohu (1989) have shown that the soils are rich in exchangeable bases such as calcium, and magnesium but low in organic

matter and nitrogen, available phosphorus, zinc and copper and have a pH range from 6.3-8.0 within the upper 100cm. Brammer, (1971) however, has reported less of carbonates from the upper soils of vertisols, migration of clay, silt and organic matter through cracks (flood coating) and net acidification of upper soil horizons which suggest that desaturation precedes or occur concurrently with either clay illuviation or decomposition through ferrollysis. Also, Bouma *et al*, (1984) affirmed that the most obvious and common pedogenetic processes in all hydromorphic vertisols are oxidation-reduction characterized by low chroma colours of less than 2 in the upper 50cm thereby reflecting reduction reactions. In Nigeria, the vertisols of the Lake Chad basin are agriculturally under-exploited. The study is therefore an attempt to characterize and classify the soils in relation to their agricultural land use potentials and limitations.

MATERIALS AND METHODS

Study Area

The study was conducted in the fringes of alluvial complex of Lake Chad basin of Nigeria located at Ngala. The area lies essentially at latitude 12°20'N and longitude 14°11'E at elevation of 289 masts in the extreme North-East part of Nigeria. It is underlain by Quaternary sedimentary rocks-the Chad formation which is made up of thick beds of clay (70-125cm), aeolian and heterogeneous sands of Pleistocene age (Mordi *et al*, 2001). The mean annual rainfall ranges from 375-850 mm and the moisture control section is moist/dry during one

year for about 66 cumulative days. The mean annual air-temperature ranges from 26-30°C and this can best be described as ustic bordering on aridic soil moisture regime. Characteristically, the area has a rainy season of about 3 months and a growing season of about 80 days (Lake Chad Research Institute Annual bulletin, 2000). Major crops grown in the area are sorghum, onions, rice and maize.

Field Studies

Four profile pits were randomly dug to represent soils that occur in the selected areas covering about 2 kilometers from the Lake Chad basin within the alluvial complex. The morphological properties of each of the profiles were described following the patterns outlined in the soil survey manual (Soil Survey Staff, 1998). The properties described include soil colour, texture, structure, consistence rootlets and boundary. Soil samples were also collected from each of the pedogenetic horizons for physico-chemical analysis.

Laboratory studies

Soil samples collected from each of the pedogenetic horizons of the profiles were air-dried and ground to pass through a 2-mm sieve. Soil pH was determined in a 1.2.5 soil/water suspensions using a glass electrode pH meter. Organic carbon was determined by Bouyoucos hydrometer method using sodium Hexa meta phosphate as the dispersant (Gee and Bauder, 1986). Total nitrogen was determined by the micro-kjeldahl digestion method (Bremner, 1965); Available phosphorus was determined colorimetrically by the ascorbic acid method (Murphy and Riley, 1962). Exchangeable bases (Ca, Mg, K and Na) were determined using the 1 N neutral Ammonium Acetate (IN-NH₄OAC) buffered at pH7 (IITA, 1979). The Ca and Mg in the solution were read on an atomic absorption spectro photometer. While the K and Na were determined on a flame-emission photo-meter. The CEC

was determined by the NH₄-acetate saturation method. The exchange acidity was determined by 1 N KCl or potassium chloride method (McLean, 1965). While the ECEC was evaluated as the sum of all base forming cations plus exchange acidity (H⁺ + Al³⁺). Electric conductivity was measured in 1: 2.5 saturation extract and the percentage base saturation calculated as the sum of all base forming cations divided by the CEC, multiplied by 100.

Classification

The soils were classified based on the USDA soil classification system (Soil Survey Staff, 1998) and correlated with the FAO/UNESCO soil map of the world legend.

RESULTS & DISCUSSION

Morphological Characteristics

The results of the morphological characteristics of the representative pedons studied are shown in table 1. The soils were deep, poorly drained in most of the times, and consist mainly of clay loam at the surface horizons to predominantly clay in the subsoil horizons. The clays were of the expanding lattice type. The high clay contents and the dominance of the bivalence cations of calcium and magnesium at the exchange sites resulted in the flocculation of the soil peds. The soils had a matrix colour characterized by low chroma colours of less than 2 in the upper 50cm and hues of 2.5Y and 5Y thereby reflecting reducing conditions of the soils. Generally, the colour matrix ranged from dark reddish brown 5YR3/6, reddish brown 5YR4/6 and dull reddish brown 2.5Y5/4 across the various pedons studied. The structures were moderate to sub-angular blocky peds of friable to very friable consistence. Fine mica flakes were also common throughout the profiles.

TABLE 1: Some morphological characteristics of hydromorphic vertisols of the Lake Chad Basins of Nigeria

Pedons	Depth (cm)	Munsel Colour (moist)	Texture	Structure	Consistence	Rootlets	Boundary	Other inclusion
Pedon 1								
Ap	0-15	5YR3/6	CL	2,m, sbk	fr	Common fine roots	cw	Common fine mica flake
C ₁	15-45	5YR3/6	CL	2,c, sbk	fr	Few fine roots	cw	“
2C ₂	45-78	5YR4/6	CL	2,m, sbk	fr	“	cw	“
3C ₃	78-140	2.5YR5/4	C	2,m, sbk	vfr	“	cw	“
Pedon 2								
Ap	0-25	5YR3/6	CL	2,c, sbk	fr	Few fine roots	cw	“
C ₁	25-47	5YR4/6	CL	2,c, sbk	fr	“	cw	“
2C ₂	47-94	2.5YR5/4	C	2,m, sbk	vfr	“	cw	“
3C ₃	94-140	2.5YR5/4	C	2,m, sbk	vfr	“	cw	“
Pedon 3								
Ap	0-17	2.5YR5/4	CL	2,c, sbk	fr	Few fine roots	cw	Common fine mica flask
C ₁	17-43	2.5YR5/4	CL	2,m, sbk	fr	“	cw	“
2C ₂	43-74	2.5YR5/4	C	2,m, sbk	vfr	“	cw	“
3C ₃	74-140	2.5YR5/4	C	2,m, sbk	vfr	“	cw	“

Abbreviations: Munsel: 5YR3/6= dark reddish brown; 5YR4/6= reddish brown; 2.5YR5/4= reddish brown

Texture: Cl= clay loam; c= clay

Structure: 2= moderate; c= coarse; m= medium; sbk= sub angular blocky

Consistence: fi= fine; fr= friable; vfr= very friable

TABLE 2: some particle size distribution characteristics of hydromorphic vertisols of the Lake Chad basins of Nigeria

Pedons	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Silt/Clay ratio	Textural class
Pedon 1						
Ap	0-15	36	24	40	0.60	Clay loam
C ₁	15-45	32	26	42	0.61	Clay loam
2C ₂	45-78	28	28	44	0.64	Clay loam
3C ₃	78-140	15	23	62	0.37	clay
Pedon 2						
Ap	0-25	37	31	32	0.97	Clay loam
C ₁	25-47	32	28	40	0.70	Clay loam
2C ₂	47-94	18	20	62	0.32	clay
3C ₃	94-140	12	17	71	0.24	clay
Pedon 3						
Ap	0-17	38	28	34	0.82	Clay loam
C ₁	17-43	36	25	39	0.64	Clay loam
2C ₂	43-74	21	19	60	0.32	clay
3C ₃	74-140	15	17	68	0.25	clay

Physical and Chemical Characteristics

The particle size distribution data (Table 2) showed that the soils have fine clayey particle size class (Soil Survey Staff, 1981). The irregular profile depth distribution of the clay fractions is an indication of stratification of the fluvial parent materials, while the high silt contents were as a

result of low intensity of weathering in the semi-arid environment (Moberg and Esu, 1991). The chemical data results (Table 3) showed that the pH of the soils across the pedons were slightly acidic to dominantly alkaline (6.8-7.8).

TABLE 3: Some chemical characteristics of hydromorphic vertisols of the Lake Chad basins of Nigeria

Pedons	Depth (cm)	pH (H ₂ O)	Organic matter (gkg ⁻¹)	Total N (gkg ⁻¹)	Avail. P (mgkg ⁻¹)	Exch Cations (cmolkg ⁻¹)				Exch. Acidity (H ⁺ +Al ⁺³) (cmolkg ⁻¹)	CEC (cmolkg ⁻¹)	EC Con/sec	%BS
						Ca	Mg	K	Na				
Pedon 1													
AP	0-15	6.8	14.25	0.08	6.35	12.10	3.21	0.35	0.13	1.02	22.50	0.03	70.2
2 C ₁	15-45	7.2	12.31	0.05	6.12	12.38	3.41	0.38	0.25	0.35	30.12	0.30	74.7
2C ₂	45-78	7.3	10.42	0.03	5.07	13.41	3.56	0.41	0.28	0.21	30.50	0.30	57.9
3C ₃	78-140	7.5	7.01	0.03	4.74	15.30	3.74	0.45	0.30	0.10	38.20	0.35	51.8
Pedon 2													
AP	0-25	6.7	12.10	0.07	7.10	12.76	4.10	0.38	0.18	1.04	25.31	0.02	68.8
C ₁	25-47	7.7	8.40	0.05	6.69	13.10	4.65	0.41	0.34	0.31	28.45	0.03	64.9
2C ₂	47-94	7.8	5.10	0.02	3.05	13.79	4.69	0.45	0.39	0.10	31.25	0.03	61.8
3C ₂	94-140	7.8	3.01	0.02	3.01	14.17	4.75	0.48	0.45	0.09	38.10	0.02	51.9
Pedon 3													
AP	0-17	6.7	15.17	1.02	5.21	13.74	4.17	0.42	0.18	1.00	27.10	1.70	68.3
C ₁	17-43	7.2	10.11	0.08	3.38	14.10	4.58	0.45	0.25	0.25	30.41	1.50	63.7
2C ₂	43-74	7.4	7.25	0.05	3.24	14.37	5.10	0.47	0.31	0.10	35.25	0.57	57.4
3C ₃	74-140	7.6	2.10	0.03	3.10	15.10	5.19	0.51	0.38	0.07	37.10	0.31	57.1

The alkaline nature of the soil could be attributed to the richness of calcium, calcium carbonate and gypsum in the parent materials (Agboola, 1979) and dominance of basic cations at the soil exchange sites (Egbuchua, 2007). The organic matter contents were low and ranged from 2.10-15.17gkg⁻¹. This reflects the vegetation of the semi-arid climate and cultural practice of crop residues removal for feeding livestock's in the area (Esu, 1983). Total nitrogen contents were also low (less than 1.5 gkg⁻¹). This could be attributed to low organic matter contents of the soils and continuous cultivation of the soils which is rampant in the areas as well as annual bush burning. Available phosphorus was also low and these ranged from 3.01-7.10 mgkg⁻¹. This could be attributed to high phosphorus sorption capacity or low absolute content of phosphorus of the parent materials (Egbuchua, 2007). The exchangeable cations of Ca, Mg, K and Na were significantly very high

in all the pedons studied. This could be attributed to high contents of metallic cations of the parent material, less leaching activities due to limited rainfall and mixed mineralogy that is dominated by 2: 1 clay lattice types. On the other hand, the high values of Na (0.13-0.45 cmolkg⁻¹) implied that incipient sodification is evidence in the study area due to excessive irrigation activities. The values of electrical conductivity (EC) were quite low (0.09-1.70 dsm⁻¹). This is an indication that salinization is not a significant pedogenetic process within the study area. The CEC were high in all the pedons (22.50-38.10 cmolkg⁻¹). This could be attributed to the dominance of the 2:1 clay minerals and high contents of basic cations in the exchange sites. The percentage base saturation were fairly high greater than 60% at the upper horizons. This could be attributed to the high contents of basic cations and cation exchange capacity of the soil. The high contents of CEC

and base saturation observed in this study agreed strongly with the reports of Bauden *et al.* (1972) on vertisols generally.

Classification

Based on the criteria of the USDA Soil Taxonomy (Soil Survey Staff, 1998), the vertisols meet the taxonomic requirements for placement as Vertic Ustifluents because of the presence of cracks in some parts of the year aside from their moisture regime and stratified parent material. In the FAO/UNESCO system, the soils are classified as Eutric Fluvisols.

Land Use Potentials and Limitations

The results of the physico-chemical analysis showed that the hydromorphic vertisols of the Lake Chad basin of Nigeria have strong nutrient potentials for sustainable uses. These include good soil depth of greater than 100cm, good contents of basic cations and a base saturation of more than 60% across the surface horizons in all the pedons studied. However, the major limitations to use include low organic matter content, inadequate moisture due to high aridity of the environment especially those away from river flood plains and incipient sodification arising from excessive irrigation activities.

CONCLUSIONS

The study was conducted to evaluate the physical, chemical and nutrient potentials and limitations of some hydromorphic vertisols in the Lake Chad basin of Nigeria. Results showed that the soils exhibit good soil depth of greater than 100cm, low chroma colour of less than 2 and hues of 2.5Y and 5Y respectively. The texture ranged from clay loam to dominant clays in the lower horizons and the soil pH were slightly acidic to dominantly alkaline in nature. The organic matter, total nitrogen and available phosphorus were low, while cation exchange capacity (CEC), basic cations (Ca, Mg, K and Na) and base saturation were high. The general results showed some great potentials of the soils. However, limitations such as low organic matter contents, total nitrogen, available available phosphorous, moisture deficiency and incipient sodification precluded in the study area.

RECOMMENDATIONS

For sustainable use of the hydromorphic vertisols, a guided and judicious use of organic and mineral fertilizers should be incorporated in the farming programme of the area to enhance soil nutrients available. Again, the return of harvested crop residues (crop residues management) is essential to enhance the soils productivity. Well articulated irrigation programme should be developed to cater for insufficient moisture regime of the environment due to its arid nature.

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