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CLASSIFICATION OF THE OBUDU PLATEAU (CREST) AND SUB PLATEAU SOILS OF CROSS RIVER STATE, NIGERIA.

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ABSTRACT

The soils at the plateau (crest) and sub plateau of three ranges of Obudu mountains were studied using profiles. Two profiles each were dug at the Ranch, Belinge and Belegate. These six profiles were studied morphologically and physicochemically; and the result used for (USDA and FAO) classification. The plateau and sub plateau soils of the Ranch and Belinge possessed mollic A epipedons and argillic B properties with base saturation greater than 50 % by NH_4OAc to be classified as mollisols, at typic haplustolls. The mountain crest and sub plateau soils at Belegate had umbric and mollic properties respectively; argillic B properties and moderate to high base saturation to be considered as Alfisols. Further classification at the subgroup level was named Typic haplustalf for the plateau and mollic haplustalf for the sub plateau. Using the FAO classification, the soils at the Ranch and Belinge were classified as luvic phaeozems for having mollic A horizons and lacking hydromorphic properities within 100 cm of the surface. The soils at the crest of Belegete was classified as umbric Acrisol for having umbric A horizon and base saturation less than 50% by NH_4OAc part of the B- horizon. By the knowledge of the classification, these soils are a huge potential for (agro) pastoral industry since they can support a wide variety of pasture for high stocking density.

Key words: Obudu Mountains, plateau, mollisols, Alfisols.

INTRODUCTION

Out of Africa land area of 30 million km^2 covering about 20 % of the earth's surface about ten percent is found on mountains or steep lands and, out of Africa's population of about 500 million, 100 million is affected by problems of highlands. Also, half of American country possess specific mountain ecosystem (Njiro 1999). On the global scale, about ten percent of the world population lives in steep lands associated with mountains and hills.

Agricultural land use was previously limited to the low lands. This is changing in many parts of the world today and hillsides are increasingly being cultivated (Juo and Thurow, 1988; Amalu and Essoka, 1995). The reason for this could be answered by the Vietnamese and Southwestern Nigeria peasant farmers who cultivate forested hill-slopes for arable crops because of lack of flat cultivable land and increase in population (Ekanade, 1997; Jamieson *et al.*, 1998). In Midanao, Philippines, more than 33 % of the area cultivated to food crops is on steep slopes (Garity and Agustin, 1995) while 75% of staple grains consumed in Honduras is produced from steep land farms (USAID, 1980). Vietnam has only 24 % of its land for agriculture because of its mountainous nature. In peninsula Malaysia (Cameroon Highland) about 10,000 ha of steep mountainous land is used temperate vegetables, tea and floriculture while in the eastern parts the steep land is devoted to the cultivation of cocoa and pepper (Midmore *et al.,* 1996). Soils must be used to guard against erosion, landslide, nutrient mining and sedimentation downstream or other forms of soil degradation. Though attempts have constantly been made for temperate vegetables to adapt to lowland tropical environments, the greater amount of the vegetable consumed in the tropics is produced under favourable highland climates. Temperate vegetables (cabbage, tomato, pepper and leafy ones) are massively produced in the highlands of South East Asia, e.g. Bandung in Indonesia, Baguio in Philippines, Dalat in Vietnam, Cameron Highlands in Malaysia, etc. In these areas, production has persisted because it is very lucrative, and with greater vegetables being produced, more of steeper land is being opened up even with occasional government restrictions (Midmore and Poudel, 1996).

To maintain sustainable agriculture on the highlands, land use planning should be undertaken by investigating the soils and classification carried out at both local and regional levels (Sereke, 2002). This provides any user with information about the soil by simply giving names (classification) to different soils found in an area (Akamigbo, 2001). Studies at the Tumbang Raya mountain area showed that Xanthic Ferralsols are found on flat surface and Orthic Ferrasols on the slopes. Also, in the lowest parts, poorly drained Gleysols and Histosols occur. In the hilly region of West Java, Indonesia, where the highest altitudes of 500 m are obtained, the soils are well drained, deep and yellowish-red to brownish and strong brown clay soils (District Nitisols). The alluvial plains are moderately well to poorly drained rise to District Glycols or Gleyic Camisoles. The central Plateau soils vary widely, being either well drained, yellowish red heavy clay soils with moderate depth (District Nitisols) or moderately deep grey mottled clay soils (Gleyic Cambisols). Like many other steep lands of the world, the Obudu plateaux and hill sides have been deforested for agricultural purposes. Despite this, the Obudu plateaux have not been classified on physiographic basis to serve as a guide for sustainable use. This study was therefore, undertaken to classify these plateau soils using the USDA (Soil Survey Staff, 2003) and the World Reference Base (2006) for sustainable land use.

MATERIALS AND METHODS

Environment of the study area

The area chosen for this study was Obudu mountain plateau (crest) and sub plateau (upper slope). The Obudu plateaux lie between latitudes 5^0 40’ and 6^0 30’ N and between longitudes 8^0 18’ and 9^0 00’E (CRMLH, 2000). Obudu Mountain plateaux are found in Obanliku Local Government Area of Cross River State, Nigeria. The plateaux are about 60 km from Obudu town, and cover area of about 75 km^2 with the peak at the ranch plateau (about 1576 m above mean sea level). The Obudu Mountains are found on Precambrian basement complex (metamorphic) rocks (gneisses with migmatitic characteristics). The Obudu mountains xenoliths are pyroxene bearing gneisses. The (rock) outcrops are intensively weathered (Ekwueme, 2003). The steep sided hills which in most cases are multiple in nature are dissected by deep valleys, have slopes of 8 – 30 percent and above (Sonneveld, 2005).

The Obudu ranch plateau experiences between 1500 – 2000 mm of rain per annum and dry season from November to March (CRADP, 1992). According to Bulktrade (1989), Cross River State experiences high solar radiation throughout the year. The mean annual temperatures at the Obudu plateau do not exceed 24 ^{0}C (Bulktrade, 1989).

Food crops such as cassava, yams and cocoyam *(Colocosia antiquorum)* are widely cultivated as annual crops at the Obudu Mountains. Cocoa, oil palm and banana/plantain are also cultivated annual crops at the Obudu Mountains. Cocoa, oil palm and banana/plantain are also cultivated in the lower slopes and valley bottom. Rice is also farmed in the swampy lowlands. There is bee *(Apis mellifera)* keeping where bush regrowth is thick or forested in the valleys. The lands of the upper slopes and mountain tops are mainly used for cattle rearing.

Field and laboratory studies

Three toposequences were selected for study on three different mountain ranges. Profile 1 and 2 were dug under grassland vegetation. A profile pit was dug at the sub-Plateau (upper slope) and Plateau (crest) of each of the three mountain ranges. This made up six profile pits. Each pit was dug to a maximum depth of 2 m, except where there was an obstruction. The soil morphological characteristics of each profile pit, such as soil depth, drainage, colour, mottle, structure, consistence, concretion/ nodules, cutans, pores, roots and horizon boundary were described in the field. Core samples were collected from different horizons for determining the bulk density for other physico-chemical analyses. These latter samples were air-dried, crushed with a roller and sieved through a 2 mm sieve. The fine earth fraction was used for standard physical and chemical analyses (Klute, 2002). The analyses included size, organic carbon, total nitrogen, available phosphorus, CEC (NH_4OAc), exchangeable bases, exchangeable acidity and base saturation. Two systems of soil classification were used.

I. Soil Taxonomy of the United States Department of Agriculture (USDA) (Soil Survey Staff, 2003), and

II. FAO-UNESCO Soil Map of the World Legend (WRB, 2006).

RESULTS AND DISCUSSION

The average depth at the plateau was 143.3 cm and sub-Plateau, 146.6 cm (Table 1). Using these mean results, it could be concluded that soils at the crest and upper slopes were deep, ranging between 100 to 150 cm topsoil colours were very dark reddish brown (5YR 2/3) and brownish black (10YR 2/3) at the Plateau and sub-Plateau (upper slope). Considering the brown to black colour of the topsoil and the well drained conditions of the subsoil horizons depicted by their reddish colours, it can be concluded that the topsoils signify high organic matter accumulation, thus, conferring high fertility to the soils (Plaster, 1992). The reddish colours of the soils are indicative that these soils are highly weathered (Olson, 1983) and the dominance of iron oxides in the pedogenic environment (Sen *et al.*,1997).

The textures of the topsoil horizons at both topographic positions of the mountains were either sandy loam or sandy clay loam. Textures of all the subsurface horizons at all topographic positions were mainly gravelly sandy clay loam. There were few occurrences of sandy clay, sand loam and clay loam textures.

The structure of the topsoil at the mountain peaks (crest) and sub-Plateau was crumb and granular. At the horizons just below the topsoil, the major structure was mostly sub angular and angular block, while it was sub angular, angular blocky and prismatic in sub-soil (B) horizons (Table 1).

Consistence of the topsoil at the mountains crest was non-sticky (wet) and friable (moist) on forested plateau, and non-sticky (wet) and firm (moist) on grassland plateaus. Horizons just below the topsoil at the crest had slightly sticky and friable Consistence. The mountains top sub-surface horizons were sticky and plastics.

Distribution of soil pores in the topsoil at the obudu mountain was many fine medium and coarse at the crest. The distribution was many, very fine, fine, medium and coarse at the upper slope (sub-Plateau). Pore distribution at the horizons below the topsoil was many, very fine and fine pores at the crest and upper slope.

Roots were found in almost all horizons at all topographic position. The distribution in the topsoil was many, very fine to coarse roots. At the horizons just below the topsoil, the distribution at all plateau and sub plateau position was common, very fine to medium roots.

The nature of transition from one horizon to another from the surface horizons for all topographic positions was abrupt and smooth. The nature of subsoil boundaries at all topographic positions was gradual and smooth

The plateau soils of Obudu were rich in organic carbon (Table 3) with all top soils having between 2.43 and 6.25%. Correspondingly, total nitrogen content of the top soil was high ranging between 0.49 and 1.68 %. However, the soils were not richly supplied in available phosphorus. Out of the sampled soils, only Belinge soil was well supplied in cation, the cation exchange capacity (by NH_4OAc) being between 9.8 and 23.6 cmol/kg. Other locations values were less than 16.0 cmol/kg. Despite this, the soils had high base saturation values except profile1 (Table 3).

Using the morphological, physical (Table 2) and chemical properties of the soil Obudu mountains plateau and sub-Plateau were classified as followed. Out of the six profiles sampled, four were classified as mollisols for possessing mollic A epipedon and argillic B poperties and percentage base saturation. Greater than 50 % by NH_4OAc in all horizons (Table3).The mollisols were profiles 3 and 5 (plateau or crest), 4 and 6 (sub plateau). Two profiles were classified as Alfisols for processing umbric A and mollic A epipedon, agrillic B horizons (Table 2) and moderate to high percentage base saturation. These soils were found at the following topographic locations; profile 1 (crest or plateau) and 2 (sub plateau).

Further classification at the sub-order level puts profiles 1 and 2 as Ustalfs for having ustic moisture regime. At the Great Group level, these profiles were classified as Haplustalfs. At the sub-group level, profile 1 was classified as Typic Haplustalf for having properties centrally representative of Alfisols. Profile 2 had mollic epipedon and was classified as Mollic Haplustalf for possessing an argillic horizon and no densic, lithic or paralithic contact within 100 cm of the soil surface. Profiles 3, 4, 5 and 6 were classified at the sub-order level as Ustolls for having ustic moisture regime. At the Great Group level, they were classified as Haplustolls and at the sub-group level as Typic Haplustols.

World Reference Base Classification

The Obudu mountain plateau soils had five profiles that possessed mollic A horizons, with base saturation 50 % or more. They lacked properties diagnostic for Vertisols, Planosols, or Andosols to be classified as Phaeozems. For having argillic B and lacking hydromorphic properties within 100 cm of the surface, profiles 3 and 5 (crest or plateau), 4 and 6 (sub plateau or upper slope) were classified as Luvic Phaeozems. At the higher category, profile 2 was classified as Nitisol for having an argillic B horizon with at least 35% clay. It lacked ferric and vertic properties; and plinthite within 125 cm of the surface. At the lower category it was classified as Mollic Nitisol for having a mollic A horizon and base saturation of less than 50 % (by NH_4OAc) in at least a part of B horizon within 125 cm of the surface. Profile 1 was classified as Acrisol for having argillic B horizon with CEC (by NH_4OAc) of less than 16 cmol/kg soil and base saturation less than 50 % (by NH_4OAc) in at least some part of the horizon within 125 cm of the surface. It was further classified as Umbric Acrisol for having umbric A horizon, lacking plinthite within 125 cm of the surface and lacking hydromorphic properties within 100 cm of the surface.

From these results, it could be concluded that Mollisols followed by Alfisols are the most dominant soils found on the plateaux of Obudu mountains. Using the FAO-UNESCO soil map of the world legend, Phaeozems were the most prevalent soil types in Obudu mountain plateaux though Acrisol and Nitisol also occurred. The productivity of most soils is directly dependent on their depth. The Obudu plateaux have prime soils for possessing Mollisols (Phaeozems) as the major soils. In addition, the areas that are not Mollisols still possess mollic A horizon indicative of high productivity potential. Apart from the thick A horizons, the soils are generally deep. Good management of these soils (e.g. soil and water conservation) can guarantee high productivity of any dairy industry since they can support a wide variety of pasture for high stocking density. Where temperate crops are adopted, measures to check erosion like the use of vetiver strips must be used. From the same vetiver, mulch material could be generated to maintain the high organic matter of the A horizon. Alternatively, zero tillage could be adopted.

Table 1: Morphological properties of the Obudu plateau and sub plateau soils.

Horizone	Depth (cm)	Colour	Mottle	Texture	Structure	Consistence	Pore	Roots	Boundary
Profile 1: Plateau 1236 msl typic Haplustalf (Umbric Acrisol)									
Ah	0-30	5YR2/3	-	GrSL	2,3 f&m Cr&gr	ns(wet), fr(moist)	M,f,m&co	Mf,m&co	Ab & s
Bt	30-70	5YR2/6	-	GrSC	2,3m&co Cr,sbk,abk	sl.s(wet), v.fr(moist)	M vf,f&m	Cvf, f,m&co	gr & s
Bt	70-130	2.5YR4/6	-	GrC	3 co abk&sbk	v.s(wet), fr(moist)	C vf&f	F vf&m	
Profile 2: Sub plateau 1220 msl Mollic Haplustalf (Mollic Nitosol)									
Ah	0-20	7.5YR2/3	-	CL	2,3 f&m Cr	sl.s(wet), fr(moist)	M vf,f,m&co	M m&co	ab&s
BA	20-54	5YR3/6	-	SCL	2,3 m&co sbk & abk	s&pl (wet), fr(moist)	M vf,f&m	C vf, f&m	gr&s
Bt1	54-90	5YR4/8	-	GrSCL	2,3 m&co sbk&abk	pl&v.s(wet), f(moist)	F vf&f	C vf, f&m	gr&s
Bt2	90-180	5YR4/8	-	GrSCL	1,2 f&m sbk,abk&p	pl & v.s(wet), fr(moist)	F vf&f	F vf,f&m	
Profile 3: Plateau 1600 msl Typic Haplustoll (Luvic Pheaozem)									
Ah	0-30	5YR2/3	-	SL	1,2 m Cr,gr,abk&sbk	ns (wet), fi(moist)	M f,m &cm	M vf&f	ab&s
Abh	30-60	5YR3/6	-	SCL	1,2 f&m abk&abk	sl. S(wet), fr(moist)	M vf&f	M vf&f	c&s
Bt	60-100	5YR3/6	-	GrSCL	2,3, m &co abk&p	s&pl(wet), fr(moist)	C vf&f	Cvf&f	c&w
Btx	100-150	2.5YR3/6	-	Gr SL	1,2 m abk, sbk&p	s(wet), fr(moist)	F vf	C vf&f	
Profile 4: Sub plateau 1572 msl typic Haplustoll (Luvic Phaeozem)									
Ah	0-40	5YR2/1	-	SCL	2 m Cr&gr	Ns(wet), fr(moist)	M vf,f&m	M vf&f	ab&s
BA	40-90	10YR3/4	-	SCL	2,3 m&co abk, sbk*p	sl.s(wet), fr(moist)	M vf&f	C vf&f	c&s
Bt	90-200	2.5YR3/6	-	SCL	2,3 m&co abk,sbk&p	pl&vs(wet), fi(moist)	Cvf&f	F vf&f	
Profile 5: Plateau 1240 msl Typic Haplustalf (Luvic Phaeozem)									
Ah	0-20	10YR2/3	-	Gr SCL	2,3 m&co Cr& gr	Ns(wet), fi(moist)	M vf,f&m	M vf,f,m&co	ab&s
Bt	20-90	7.5YR5/6	-	GrSCL	2,3 co sbk&abk	sl.s(wet), fr(moist)	C f	Mvf&f	g&s
BC t	90-150	2.5YR4/8	-	SCL	2,3,m&co sbk,abk,p	s(wet), fr(moist)	Cvf	M vf&f	
Profile 6: Sub plateau 773 msl Typic Haplustoll (Luvic Phaeozem)									
Ap	0-30	7.5YR2/2	-	GrSL	2,3 m&co abk	ns(wet), fr(moist)	M f&co	M vf,f,m&co	ab &s
Bt	30-60	5YR3/6	-	GrSC	2,3 m sbk, abk&p	sl. s(wet), fi(moist)	M vf&f	M vf,f, m&co	

Texture: Gr – Gravelly, SL – Sandy Loam, SCL – Sandy Clay Loam, SC – Sandy Clay, CL-Clay Loam, C-Clay; **Structure: (Grade)** 1 – weak, 2 – moderate, 3 – strong, (Class) f – fine, m – medium, co – coarse, (Type) Cr – crumb, gr – granular, sbk – subangular blocky, abk – angular blocky, p – prismatic; **Consistence:** ns – non-sticky, sl.s – slightly sticky, v.fr – very friable, vs – very sticky, f – frable, s&pl – sticky & plastic, pl&v.s – plastic & very sticky, fi – firm; **Pore & Roots:** vf – very fine, f – fine, m – medium, co – coarse, M – many, C – Common, F – Few; **Boundary:** ab – abrupt, s – smooth, gr – gradual, c – clear, w – wavy.

Source: *FAO (1990).*

Table 2: Some physical properties of the plateau and sub plateau soils of Obudu mountains

Profile	Horizon	Depth (cm)	Clay (%)	Silt (%)	Sand (%)	Gravel (%)	Texture
1	Ah	0-30	20	18	62	49	GrSL
	Bt	30-70	40	10	50	69	GrSC
	Bt	70-130	44	16	40	26	GrC
2	Ah	0-20	38	22	40	13	CL
	BA	20-54	30	20	50	11	SCL
	Bt2	54-90	35	17	48	45	GrSCL
	Bt2	90-180	30	22	48	28	GrSCL
3	Ah	0-30	10	20	70	9	SL
	ABh	30-60	16	24	60	5	SCL
	Bt	60-100	26	22	52	15	GrSCL
	Btx	100-150	22	16	62	73	GrSL
4	Ah	0-40	8	14	78	5	SCL
	BA	40-90	22	22	56	3	SCL
	Bt	90-200	26	14	60	7	SCL
5	Ah	0-20	28	16	56	15	GrSCL
	Bt	20-90	32	14	54	31	GrSCL
	BCt	90-150	28	16	56	13	SCL
6	Ap	0-30	16	18	66	35	GrSL
	Bt	30-60	36	16	48	36	GrSC

Gr – Gravelly, SL – Sandy Loam, SCL – Sandy Clay Loam, SC – Sandy Clay, CL – Clay Loam, C – Clay Profile 1, 3 & 5 = Plateau; profile 2, 4, & 6 = Sub-plateau.

Table 3: Some chemical properties of the plateau and sub plateau soils of Obudu mountains

Profile	Horizon	Depth (cm)	pH H_2O	O.C (%)	Total N (%)	Av. P (Mg/kg)	Na	K Cmol/kg	Mg	Ca	AE Cmol/kg	CEC NH_4Oac Cmol/kg	B.S (%)	P citric acid (mg/kg)
1	Ah	0-30	3.7	6.08	1.68	8.75	2.29	0.49	0.08	0.29	3.80	10.50	30.0	ND
	Bt	30-70	4.8	1.25	0.42	11.38	2.29	0.24	0.23	0.31	1.40	6.80	45.15	ND
	Bt	70-130	4.7	0.89	0.06	9.63	2.43	0.19	0.08	0.23	1.60	7.20	40.69	ND
2	Ah	0-20	4.2	3.40	0.81	12.25	4.57	2.00	0.05	0.27	3.40	12.30	56.02	7.5
	BA	20-54	4.3	0.95	0.07	7.38	3.14	0.61	0.26	0.28	4.20	10.50	40.85	ND
	Bt1	54-90	5.4	0.67	0.06	1.75	2.43	0.34	0.24	0.30	3.00	8.30	51.93	ND
	Bt2	90-180	5.0	0.38	0.04	1.75	2.29	2.30	0.06	0.21	3.20	8.90	90.34	ND
3	Ah	0-30	5.5	5.8	1.06	2.63	2.86	1.01	0.27	0.27	1.60	8.80	50.11	9.5
	Abh	30-60	5.7	2.4	0.46	1.75	2.29	0.40	0.08	0.27	0.40	5.60	54.29	ND
	Bt	60-100	5.6	1.56	0.14	1.75	2.57	0.43	0.08	0.28	0.40	5.20	64.52	ND
	Btx	100-150	5.8	1.10	0.09	1.75	1.86	0.26	0.23	0.26	0.40	4.60	56.74	ND
4	Ah	0-40	8.3	6.25	0.98	2.33	1.86	0.43	0.09	0.30	0.80	5.30	50.01	6.5
	BA	40-90	5.5	1.90	0.18	1.75	2.00	0.33	0.06	0.27	0.20	4.20	63.33	ND
	Bt	90-200	5.6	0.91	0.49	1.75	2.57	0.34	0.10	0.26	0.20	5.60	56.39	ND
5	Ah	0-20	5.6	2.43	0.49	1.75	14.3	2.30	1.18	0.30	1.00	22.40	80.71	7.5
	Bt	20-90	5.8	0.78	0.04	2.63	9.57	0.66	0.37	0.26	1.00	15.00	72.40	ND
	BCt	90-150	5.7	0.28	0.04	2.63	9.57	0.30	0.21	0.29	1.40	16.40	63.23	ND
6	Ap	0-30	6.1	4.56	1.46	3.20	10.85	5.57	0.77	0.29	0.40	23.60	74.07	7.5
	Bt	30-60	5.8	1.48	0.18	1.75	4.86	0.97	0.20	0.24	1.40	9.80	63.98	ND

ND – Not determined

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