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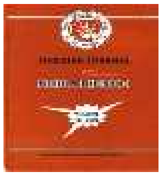

MORPHOLOGICAL AND PHYSICAL PROPERTIES OF SOILS ON BASEMENT COMPLEX IN NORTHERN GUINEA SAVANNA OF NIGERIA

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ABSTRACT

Soils developed on four basement complexes, namely Older Granites (OG), Quartzites (QZ), Mica Schists (MS) and Migmatite Gneiss (MG) were studied on crest position in Northern Guinea Savanna of Kaduna State, Nigeria with a view to examine their morphological and physical properties and suggest management options. The results indicated that parent materials significantly influenced soil depth, structures, sand subfractions, silt clay ratio, available water content of the soils. The soils were generally deep to very deep (135 – 190cm), with restriction due to parent materials and plinthite. Soil surface was sandy loam and was attributed to erosion and eluviation of clay resulting in textural variation with soil depth. The soils were mostly sub-angular blocky with platy structure dominating mica schist subsoils. Sand dominated particle size fraction of the soils and their sub fractions were significantly influenced by parent materials and pedogenic processes. Weathering intensity of the soils significantly increased in order of MS < OG < QZ < MG. Parent materials and clay content significantly varied available water content of the soils in order of MS > MG > OG > QZ. Contour ridges, cover cropping, incorporation of crop residues with farm yard manure and use of manually operated or animal powered equipment for traction on farm were management options suggested to improve soil constraints identified for sustainable use of the soils.

Keywords: Basement complex rock, morphological and physical properties, soil management

INTRODUCTION

Nature of parent material is said to profoundly influence development and characteristics of soils (Brady and Weil, 2005). In small regions of uniform climate, the nature of parent material is probably more important than any other single factor in determining characteristics and productivity of a soil (Olaitan and Lombin, 1984). Basement complex rocks are principally composed of igneous and metamorphic rocks such as granites, gneisses, migmatites, quartzites, schist and the metamorphosed derivatives of ancient sediments. Basement complex parent materials cover almost entirely the whole of Kaduna state (Osazuwa, 1994) and occupy about 50% of Nigeria's surface area (Oyawoye, 1970; Ogezi, 2002). Therefore, knowledge of the relationship between basement complex parent materials and soil formation along with their properties will help in sustainable use and management of these resources.

Most previous studies treated basement complex rocks as one unit due to the intricate nature of their complexity, yet rocks of basement complex are variable both in mineral assemblage and reactions to soil forming factors, hence likely to produce soils highly variable in morphological and physical properties. Therefore, the current study was carried out for the purpose of establishing the effect of the individual component lithologies; older granites, migmatite gneisses, mica schists and quartzites on morphological and physical characteristics and their management implication in Northern Guinea Savanna of Kaduna State, Nigeria.

MATERIALS AND METHODS

Study Location

The study areas were located in four sites situated within older granite, quartzite, mica schist and migmatite gneiss basement complexes parent material areas, within Northern Guinea Savanna Zone of Kaduna State, Nigeria. The sites lie within latitude 10°27’55.7”N to 10°43’43.2”N and longitude 06°11’14.0”E to 07°39’27.3”E (Figure 1). The mean amount of rainfall of the study areas ranged between 1,180 and 1,286 mm/annum. Mean annual evaporation record ranged between 2194 to 2822 mm/annum. Rainfalls were in excess of evaporation in the month of July to September as the peak rainfall occur in these months. The mean annual temperature ranged 25.0 and 26.4°C and the mean monthly temperature consecutively from February to October is less 5°C. Therefore, the soil temperature regime may be considered as isohyperthermic, as it is expected that the variation will be less in soil as to the atmospheric temperature.

Field Studies

Exploratory survey was used to identify suitable sites on crystal position using geological map of Kaduna State (Figure 1), ecoclimatological zones map and Topo map sheets (1:50,000). Profile pits were later sited, dug, described and soils were sampled within pedogenic horizons. The soils were sampled from three profile pits within cultivated fields on each of the four (4) parent material locations. The morphological properties observed in field were described based on procedures described in the USDA Soil Survey Manual (Soil Survey Division Staff, 1993).

Laboratory Analysis

Laboratory analysis of physical properties of the less than 2mm soil samples were carried out using standard laboratory methods described in IITA (1979) and Klute (1986). Physical properties determined include, particle size determination (IITA, 1979), bulk density (Blake and Hartge, 1986a), particle density (Blake and Hartge, 1986b), total porosity calculated, available water capacity (AWC) and water retention difference (WRD) (USDA, NRCS, 1995).

Statistical Analysis

Descriptive statistics were used to assess soil properties. Differences in properties between soils developed on the four (4) parent materials were analysed using two way analysis of variance (ANOVA) and correlation analysis was used to determine relationship between the soil properties (SPSS Statistics 17.0).

Figure 1 Geological Map of Kaduna State indicating Project Sites ( )
Courtesy: Wadrop Engineering Incorporated and Mai & Associates. (1994).

RESULTS AND DISCUSSIONS

Soil Morphological Properties

The soils were generally deep to very deep (135 – 190cm). The soils on quartzite (QZ), mica schist (MS) and migmatite gneiss (MG) were very deep except for pedons QZ1, MS2 and MG1 that were deep (Table 1). The depth of some soils on quartzites and mica schist were restricted due to occurrence of parent materials (QZ1, MS2 and MS3) encountered between 14cm and 72cm. The depths of soils on migmatite gneiss were all restricted by the presence of plinthite within 48 - 172cm depths. These plinthite depths are within range of those reported by Osher and Buol (1998) and Yaro (2005) on soils developed on landscape position in Eastern Madre de Dios, Peru and on upper slope to crest positions on plinthite landscape at Samaru, Zaria respectively. An earlier study by several workers (Fagbami, 1981; Raji, 1995; Idoga *et al,* 2007) attributed extent of soil depth to parent material, erosion and slope of the area.

Surface horizons of the soils developed on the different parent materials were dominated by dark brown to brown colours (7.5YR 5/3 and 7.5YR 4/4 moist). The dark brown colouration in the surface horizon (Ap) was attributed to humification resulting in melanization (Raji, 1995). Strong brown (7.5YR 4/6, moist) dominated the Bt subsoil horizon indicating braunification as a significant pedogenic process occurring in these soils and was also reported by Yakubu and Ojanuga (2009) and Ande (2010).

All surface horizons of soils in this study were sandy loam with the subsoil horizons characterized by clay, sandy clay to sandy clay loam in the deeper horizons. The finer textured subsoil may be attributed to illuviation of clay (argilluviation). The lowest subsoil horizons of soils on MG were all gravelly sandy clay loam and may be attributed to plinthization as reported

Table 1: Morphological Properties of the pedons of studied areas

Horizon	Basal Depth (cm)	Colour Moist	Mottle Colour	Texture	Structure	Moist Consistence	Boundary	Other features
					SOILS ON OLDER GRANITE			
Profile – OG 1								
Ap	26	10YR 4/2	-	SL	1mskb	fi	cw	Very few thin clay cutans on ped faces
Bt1	75	7.5YR 4/6	-	C	2vcskb	fr	cw	Few thin clay cutans on pores.
Bt2	119	7.5YR 5/8	-	GSCL	2mabk	fr	ds	Very few thin clay cutans on pores;
BC	183	7.5YR 4/6	-	SCL	1mabk	fr	-	Common weathered older granitic rocks
Profile – OG 2								
Ap	17	7.5YR 4/3	-	SL	2msbk	fr	cw	Many very fine roots.
Bt1	70	10YR 3/6	-	C	3cbk	fr	gw	Many very fine roots.
Bt2	190	10YR 5/6	-	SCL	2msbk	fr	-	Few fine pores; many iron concretions.
Profile – OC 3								
Ap	23	7.5yr 3/2	-	SL	1msbk	fr	gs	Many fine roots.
Ba	57	7.5yr 4/4	5yr/5/6	CL	1vcsbk	fr	gw	Very few thin clay cutans on pores; common medium roots.
Bt1	121	7.5yr 5/6	-	CL	2vcabk	fr	di	Few medium roots.
Bt2	185	10yr 5/6	5yr 4/6	C	2msbk	fr	-	Few fine roots.
					SOILS ON QUARTZITES			
Profile – QZ 1								
Ap	14	10YR 3/2	-	GSL	1msbk	fi	gw	Few fine roots
AC	40	7.5YR 4/4	-	VGSL	1fc	fi	gi	Common fine roots; common weathered quartzites.
C1	98	7.5YR 4/6	-	EGC	2mc	fi	as	Common weathered quartzites
C2	135	75YR 4/6	-	SCL	1mc	fi	-	Encountered weathered rocks.
Profile – QZ 2								
Ap	19	7.5YR 4/4	-	SL	1msbk	fr	gs	Many fine roots
Bt1	51	7.5YR 4/6	-	SC	1msbk	fr	gw	Common fine roots
Bt2	14	7.5YR 4/6	-	C	2msbk	fr	di	Very few thin cutans on animal channels; ant channels and nests
Bt3	139	5YR 4/6	2.5YR 4/6	SC	2msbk	fr	dw	Few medium pores.
Btc	187	5YR 4/6	2.5YR 4/6	SCL	1mabk	fi	-	Common iron manganese concretion.
Profile – QZ 3								
Ap	19	75YR 4/4	-	SL	1cabk	fr	gs	Common very fine roots.
AB	40	10YR 4/4	-	SCL	2vcskb	fi	gw	Common medium roots.
Bt1	63	75YR 4/6	-	C	2msbk	fr	cs	Very few thin patch clay cutans on Pores; few very fine roots
Bt2	97	75YR 4/6	-	C	2msbk	fi	gw	Few very fine roots.
BC	167	10YR 5/6	-	SC	2msbk	fr	-	Encountered weathered quartzite rocks at 167cm.
Profile – MS 1								
Ap	18	10YR 3/2	-	SL	1msbk	fr	fs	Few thin clay cutans on pores: common medium roots.
Bt1	54	10YR 4/6	-	SCL	2msbk	fi	gw	Few moderate clay cutans on root and animal channels, common medium roots.
Bt2	177	10YR 4/6	-	SCL	1msbk	fr	-	Very few thin clay cutans on pores; many fine roots.

Table 1 *Continued*: Morphological Properties of the pedons of studied areas

Horizon	Basal Depth (cm)	Colour Moist	Mottle Colour	Texture	Structure	Moist Consistence	Boundary	Other features
Profile – MS 2								
Ap	16	10YR 5/3	-	SL	1mskb	fr	gw	Many fine roots.
Btc	37	7.5YR 4/6	5YR 5/8	SCL	1mskb	fi	gw	Few fine roots.
BC	72	10YR 5/2	7.5YR 5/8	GSLC	1mskb	fr	gi	Very few thin cutans on root channels; few Fe-Mn concretions
C	143	YR 5/2	7.5 YR 6/8	GSCL	1cp	fr	-	Few fine roots; encountered fractured rocks.
Profile – MS 3								
Ap	19	10YR 4/3	-	SL	2msbk	fr	gw	Very few moderate clay cutans on termite channels and ped faces; many fine roots.
Bt	42	7.5YR 4/6	-	CL	1mp	fi	gi	Few medium roots
C1	96	7.5YR 5/2	-	SCL	3mp	fr	di	Few very fine roots.
C2	168	10YR 5/2	-	SCL	2mp	fr	-	Few medium roots.
Profile – MG 1					**SOILS ON MIGMATITE GNEISS**			
Ap	15	7.5YR 5/4	-	SL	1mabk	fr	gs	Very few thin clay cutans on pores; few ant channels.
Bt	47	5YR 5/8	-	SCL	3msbk	fi	cw	Very few thin clay cutans on pores; common very fine roots.
Btcv1	103	2.5YR 4/8	-	SCL	2msbk	fr	as	Common iron – manganese concretions
Btcv2	147	2.5YR 4/8	-	GSCL	1fsbk	fr	-	Many iron – manganese concretions; encountered petroplinthite.
Profile – MG 2								
Ap	18	7.5YR 4/4	-	SL	1mabk	fr	cs	Many very fine roots.
AB	44	7.5YR 5/4	-	CL	1cabk	fi	gs	Few moderate humus cutans on ped faces; few very fine roots.
Bt1	78	5YR 4/6	-	C	2csbk	fr	dw	Few termite channels.
Bt2	123	5YR 5/8	-	CL	2msbk	fr	aw	Few termite channels.
BCcv	167	2.5YR 4/8	-	GSCL	2mc	fr	-	Very few thin clay cutans; many iron – manganese concretions; encountered petroplinthite.
Profile – MG 3								
Ap	25	7.5YR 4/3	-	SCL	1mabk	fr	cw	Many very fine roots.
Bt1	47	5YR 5/8	-	SCL	2csbk	fi	dw	Few very fine roots.
Bt2	89	5YR 5/8	-	C	2msbk	fr	as	Very few thin clay cutans on pores; few iron nodules
BCcv	89-162	2.5YR 4/8	2.5YR 4/8	GSCL	1msbk	fr	-	Many iron concretions; encountered petroplinthite

by Kparmwang (1993) and Yaro (2005) on lateritized basaltic soils and on plinthite landscape in Northern Guinea Savanna of Nigeria respectively.

Soils in this study were mostly medium sub-angular blocky with few fine and coarse blocky structures. The structures were mostly moderately developed with few strongly and weakly developed. Soils on mica schist were dominated by platy structure in subsoil horizons. Generally, horizonation was more pronounced between Ap and subsoil than within the subsoil horizons, and may be attributed to melanization from the humification of organic matter in Ap horizons.

Soil Physical Properties

Gravel content varied between 10 and 770 gkg^{-1} of the total soil (Table 2). Variation in parent material significantly influenced content of gravel in order of QZ > MG > MS > OG (Table 3). The variation in gravel content may be influenced by extent of weathering of parent materials and plinthization. The mean high value (130 gkg^{-1}) in migmatite gniess soil was associated with aggregation of iron oxides to form nodules (Yaro, 2005; Kparmwang, 1993) and Kparmwang (1993) related it to advanced pedogenic age.

Sand dominated the particle size fraction of the fine earth (< 2mm) portion in all the soils formed from the different parent materials. This is in harmony with previous studies in soils formed on basement complex rocks in different regions of Nigeria (Malgwi *et al,* 2000; Odunze, 2006; Fasina *et al,* 2007; Obi and Akinbola, 2009; Ande, 2010). Total sand fraction of all the soils varied between 271 and 771 gkg^{-1} and variation in parent material did not significantly influence total sand content of the soils. The sand fraction in surface (Ap) horizons were significantly higher than the subsoil horizons. When means of sand subfractions were tested statistically, all the subfractions were significantly different both between parent materials (Table 3) and between

Table 2: Particle size distribution of soils of studied areas

Pedo	Depth (cm)	Gravel (-----		Sand subfractions VCS	CS	MS	FS	Total VFS	Silt Sand	Clay	Si/V
				-----gkg^{-1}-----				-----)			
					Soils on Older Granites						
Pedon OG 1											
Ap	0-26	10	135	253	104	59	100	651	227	122	1.86
Bt1	26-75	40	193	108	41	31	18	391	187	422	0.44
Bt2	75-119	200	225	192	70	35	29	551	157	282	0.59
BC	119-183	80	238	198	82	49	44	611	147	242	0.61
Pedon OG 2											
Ap	0-17	20	111	216	138	62	64	59	247	162	1.52
Bt	17-70	30	96	131	73	38	32	371	227	402	0.56
Btc	70-190	90	238	185	78	47	43	591	167	242	0.69
Pedon OG 3											
Ap	0-23	40	57	171	111	66	89	531	327	142	2.30
Bt	23-57	30	113	126	74	47	51	411	247	342	0.72
Btc	57-121	50	68	90	62	46	65	331	287	382	0.75
Btc	128-160	40	63	79	48	32	48	271	287	442	0.65
					Soils on Quartzites						
Pedon QZ 1											
Ap	0-14	300	39	128	220	194	108	691	227	82	2.77
AC	14-40	500	47	131	219	161	91	651	207	142	1.46
C1	40-98	770	118	189	70	46	25	371	207	422	0.49
C2	98-135	160	106	126	116	110	73	531	147	322	0.46
Pedpm QZ 2											
Ap	0-19	60	34	138	286	213	99	771	147	82	1.79
Bt1	19-51	70	82	153	160	88	47	531	107	362	0.30
Bt2	51-84	50	93	120	108	60	34	414	127	462	0.27
Bt3	84-139	60	111	128	131	90	31	491	127	382	0.33
Btc	139-187	40	111	132	135	91	42	511	147	342	0.43
Pedon QZ 3											
Ap	0-19	90	48	154	254	209	84	751	147	102	1.44
AB	19-40	60	73	194	208	116	59	651	147	202	0.69
Bt1	40-63	150	128	152	97	45	29	451	127	422	0.31
Bt2	63-97	50	105	130	79	45	32	391	147	462	0.32
BC	97-167	90	125	136	91	62	36	451	167	382	0.44

Table 2 ***Continued*****: Particle size distribution of soils of studied areas**

Pedo	Depth	Gravel		**Sand subfractions**				Total VFS	Silt Sand	Clay	Si/V
				VCS	**CS**	**MS**	**FS**				
	(cm)	(-------------------------------------gkg^{-1}-----------------------------------)									
				Soils on Mica Schists							
Pedon MS 1											
Ap	0-18	30	85	134	160	123	108	611	227	162	1.40
Bt	18-54	20	82	115	109	105	79	491	207	302	0.69
Btc	54-177	30	103	115	112	103	58	491	207	302	0.69
Pedon MS 2											
Ap	0-16	40	57	126	175	186	146	691	187	122	1.53
Bt	16-37	320	113	125	103	93	77	511	207	282	0.73
BC	37-72	240	114	108	83	90	56	451	227	322	0.70
C	72-143	30	82	109	104	76	27	398	273	329	0.83
Pedon MS 3											
Ap	0-19	90	38	116	148	156	73	531	367	102	3.60
Bt1	19-42	260	107	129	88	87	80	491	267	242	1.10
Bt2	42-96	110	98	112	86	95	120	511	267	222	1.20
BC	96-168	70	84	109	100	126	72	491	287	222	1.29
				Soils on Migmatite Gneisses							
Pedon MG 1											
Ap	0-15	50	126	203	133	63	93	618	233	149	1.56
Bt	15-47	40	136	151	82	54	55	478	193	329	0.59
Btcv1	47-103	150	108	118	77	67	41	418	213	369	0.58
Btcv2	103-147	470	188	178	81	56	55	558	153	289	0.53
Pedon MG 2											
Ap	0-18	30	70	216	117	80	120	618	273	109	2.50
AB	18-44	20	89	136	86	57	70	438	213	349	0.61
Bt1	44-78	40	89	100	70	44	55	358	213	429	0.50
Bt2	78-123	30	98	122	80	44	54	398	213	389	0.55
BCcv	123-167	470	190	167	77	49	54	538	173	289	0.60
Pedon MG 3											
Ap	0-25	0	100	216	183	71	48	618	173	209	0.83
Bt1	25-47	30	90	150	134	54	43	478	173	349	0.50
Bt2	47-89	20	79	98	85	65	51	378	173	449	0.39
BCcv	89-162	340	115	137	110	84	52	498	173	329	0.53

surface and subsoil horizons (Table 4). The mean values of very coarse sand were statistically similar for OG and MG, though OG was significantly higher than QZ and MS which were at par. Coarse sand subfraction was similar for OG, QZ and MG, and was significantly higher than MS. Soils on quartzite was significantly higher than soils on OG, MS and MG in their medium sand sub fraction, and soils on OG, MS and MG were at par. The fine sand subfractions of QZ and MS were statistically similar and significantly greater than OG and MG which were at par. Mean values of very fine sand subfraction were not statistically different for all the soils (Figure 2).

Table 3: Ranking of means of physical properties of soils on parent materials

Parameter	Unit	Older Granites	Quartzite	Mica Schist	Migmatite Gneiss	LOS
Gravel	gkg^{-1}	52.7d	175.0a	112.7c	130.0b	*
Very coarse sand	gkg^{-1}	143.4a	87.1c	87.5c	113.7ab	**
Coarse sand	gkg^{-1}	159.0a	143.6a	118.0b	153.2a	*
Medium sand	gkg^{-1}	80.1b	155.3a	115.3b	101.2b	**
Fine sand	gkg^{-1}	46.5b	108.7a	112.7a	60.6b	**
Very fine sand	gkg^{-1}	53.0	56.4	81.5	60.8	NS
Total sand	gkg^{-1}	481.9	546.7	515.3	491.8	NS
Silt	gkg^{-1}	228.2ab	155.6c	247.5a	197.6b	**
Clay	gkg^{-1}	289.3	297.7	237.2	310.5	NS
Bulk density	Mgm^{-3}	1.6	1.5	1.5	1.5	NS
Particle density	Mgm^{-3}	2.6	2.6	2.6	2.6	NS
Total porosity	%	40.8	42.1	41.8	43.3	NS
AWC	%	6.8b	5.7b	10.1a	8.4a	*
WRD	cm	6.2	3.0	7.8	4.8	NS
Si/C	-	0.97ab	0.82b	1.25a	0.79b	*

LOS (P): NS > 0.05, * ≤ 0.05, ** ≤ 0.01

Table 4: Ranking of means of physical properties of horizons

Parameter	Unit	Surface Horizon	Subsurface Horizon	LOS
Gravel	gkg^{-1}	63.3	140.5	NS
Very coarse sand	gkg^{-1}	78.3a	116.2b	*
Coarse sand	gkg^{-1}	172.6a	134.6b	**
Medium sand	gkg^{-1}	164.1a	97.5b	**
Fine sand	gkg^{-1}	122.8a	69.9b	**
Very fine sand	gkg^{-1}	94.3a	52.1	**
Total sand	gkg^{-1}	639.4a	468.8b	**
Silt	gkg^{-1}	231.8a	194.7b	*
Clay	gkg^{-1}	128.8b	336.5a	**
Bulk density	Mgm^{-3}	1.5	1.5	NS
Particle density	Mgm^{-3}	2.6	2.6	NS
Total porosity	%	42.4	42.0	NS
Field capacity	%	12.5b	20.7a	**
Water Retention Dif.	cm	1.9b	6.5a	*
Si/C	-	1.9a	0.6b	**

LOS (P): NS > 0.05, * ≤ 0.05, ** ≤ 0.01.

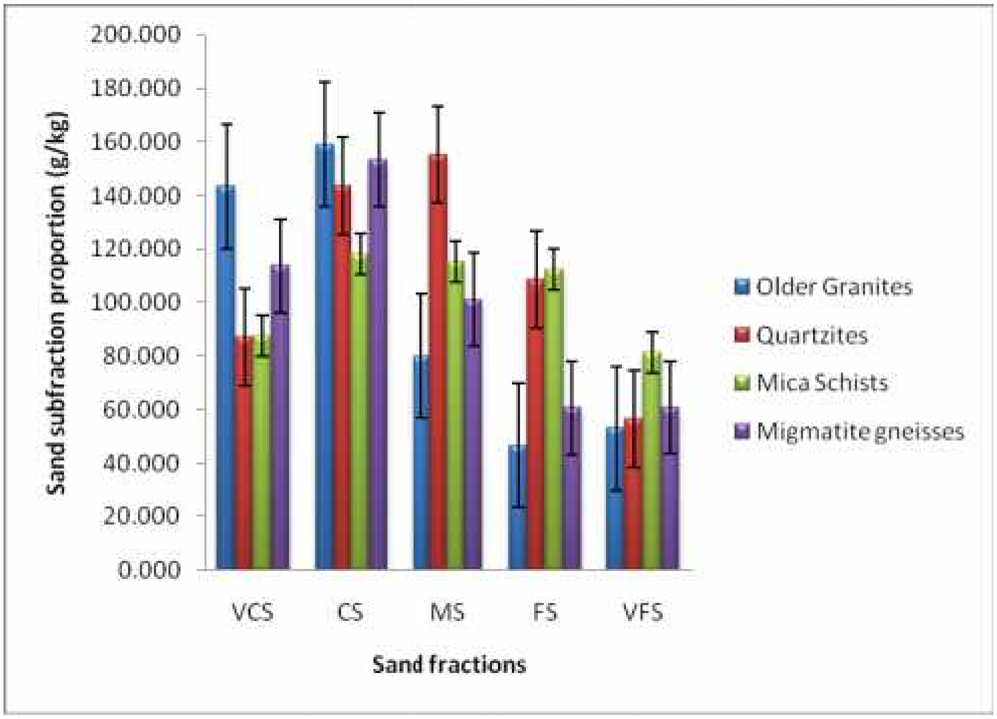

Figure 2: Histogram of proportion of fractions of sand particles in the soils of the parent materials

The nature of variation in sand subfractions was similar to trends reported by Buol *et al.*, (1980). They stated that soils formed in saprolite from mica schists tend to be silt and less coarse than those formed from granitic and gneissic saprolites. Silt particle of all the soils varied between 147 and 367 gkg^{-1}. Parent materials significantly influenced silt content ($P< 0.01$). Mean content of silt in soils on mica schist were at par with soils on older granites. However, mica schist soils were significantly higher than soils on migmatite gneiss and quartzite. Soils on older granite and migmatite gneiss were significantly higher in silt content than soils on quartzites (Table 3). Clay content of the soils ranged between 102 and 462 gkg^{-1}. The proportion of clay in surface (Ap) horizons were very significantly lower ($P<0.01$; Table 4) than subsoil horizons. The mean clay content in subsurface horizon was three times greater than the mean surface value. The increase in clay with soil depth had been attributed to clay translocation and erosion in surface horizon (Kparmwang, 1993; Raji, 1995; Obi and Akinbola, 2009). The difference in parent materials did not significantly influence clay particle of the soils.

Silt clay ratio of the soils varied between 0.27 and 3.60. Silt clay ratio was highest in Ap horizons, followed with a sharp reduction in the subsoil horizons and remains fairly constant, but increased within AC, BC and C horizons. The higher ratio in Ap horizons compared to subsoil horizons may be attributed to eluviation of clay from surface horizons and their erosion down the slope from the crestal position (Esu, 1987). The silt clay ratios in surface (Ap) horizons were significantly higher than subsoil horizons ($p < 0.01$), thus implying that the subsoil significantly weathered compared to surface horizon. The mean values of silt clay ratio of all the soils were higher than the 0.15 critical value considered to be highly or intensively weathered (Van Wambeke, 1962; Yakubu and Ojanuga, 2009), hence soils in this study were considered to be fairly to moderately weathered. Weathering intensity significantly increased in order of MS < OG < QZ < MG.

Particle density values for the soils varied between 2.56 and 2.68 Mgm^{-3} (Table 5). The mean values of these soils were within the range of 2.6 to 2.75Mgm^{-3} reported for mineral soil by Brady and Weil (2005). Difference in both parent materials and horizons did not significantly influence particle density of the soils. Bulk density of the soils was found to vary between 1.34 and 1.58 Mgm^{-3}. Total porosity ranged between 29.30 and 61.72 percent for the soils. The surface horizons were higher in total porosity compared to subsoils, though were not significantly different. Parent materials also did not significantly influence total porosity between the different soils. Bulk density, gravel, very coarse and coarse sand particles significantly influenced soil total porosity negatively (r = -0.348*, - 0.921**, - 0.543** and - 0.303* respectively), hence coarse grain material reduces porosity of the soils.

Available water content (AWC) ranged between 2.5 and 22.6 percent. The mean values showed that only soils on MS have the capacity to retain enough moisture to support plant growth, as it was within 9.5 to 12.5% considered adequate for plant growth by FAO (1979). Parent materials significantly ($P < 0.05$) varied mean values of AWC between the soils in order of MS > MG > OG > QZ. Coarse sand and total sand contents were found to significantly correlate negatively with AWC (r = -0.328*, -0.383** respectively). Water retention difference (WRD) ranged between 1.17 and 33.26 percent in the soils. Mean values of WRD of subsoil horizons were significantly higher ($P < 0.05$) than surface horizons. However, there was no significant difference between the soils. Water retention difference correlated significantly but negatively with sand fractions and positively with clay (r = 0.529***). Thus implied that finer particles influence micro-pores than total porosity, hence increased retention of moisture.

Table 5: Bulk density, particle density, total porosity and water retention properties of the soils studied

Pedon	Depth (cm)	Bulk density	Particle density	Total Porosity	PC	PWP	AWC	WRD (cm)
		(-----Mgm^{-3}-----)		(-------------------%-------------------)				
				Soils on Older Granites				
Pedon OG 1								
Ap	0-26	1.58	2.58	38.76	8.6	3.7	4.9	2.01
Bt1	26-75	1.64	2.63	37.64	20.5	16.3	5.2	4.18
Bt2	75-119	1.69	2.62	35.50	20.1	13.0	7.1	5.28
BC	119-183	1.71	2.61	34.48	17.9	14.1	3.8	4.16
Pedon OG 2								
Ap	0-17	1.49	2.61	42.91	11.1	6.5	4.6	1.17
Bt	17-70	1.43	2.63	45.63	19.4	10.6	8.8	2.89
Btc	70-190	1.68	2.62	38.88	24.2	11.0	13.2	33.26
Pedon OG 3								
Ap	0-23	1.52	2.64	42.42	14.2	9.1	5.1	1.78
Bt	23-57	1.44	2.56	43.75	18.0	12.8	5.2	2.55
Btc	57-121	1.44	2.65	45.66	21.6	13.2	8.4	7.74
Btc	128-160	1.41	2.63	46.39	22.4	13.8	8.6	7.76
				Soils on Quartzites				
Pedon QZ 1								
Ap	0-14	1.56	2.56	39.06	10.8	5.7	5.1	1.11
AC	14-40	ND	2.58	Nd	10.6	5.6	ND	ND
C1	40-98	ND	2.61	ND	22.9	16.0	ND	ND
C2	98-135	1.53	2.63	41.83	25.6	18.1	7.5	4.25

ND: Not determine

Table 5 ***Continued*****: Bulk density, particle density, total porosity and water retention properties of the soils studied**

Pedo	Depth	Bult density	Particle density	Total Porosity	PC	PWP	AWC	WRD
	(cm)	(-----Mgm^{-3}-----)		(--------------------%--------------------)				(cm)
Pedpm QZ 2								
Ap	0-19	1.53	2.59	40.93	6.7	4.5	2.2	0.64
Bt1	19-51	1.42	2.62	45.80	17.4	12.8	4.6	2.09
Bt2	51-84	1.45	2.57	43.58	20.9	17.1	3.8	1.82
Bt3	84-139	1.52	2.61	41.76	21.1	16.7	4.4	3.68
Btc	139-187	1.64	2.56	35.94	21.1	15.7	5.4	4.25
Pedon QZ 3								
Ap	0-19	1.24	2.64	53.03	7.8	3.6	4.2	0.99
AB	19-40	1.52	2.59	41.31	11.7	9.2	2.5	0.80
Bt1	40-63	1.50	2.55	41.18	20.0	5.9	14.3	4.93
Bt2	63-97	1.38	2.64	47.73	21.5	4.4	11.1	5.21
BC	97-167	1.64	2.59	36.68	20.6	17.2	3.4	3.90
				Soils on Mica Schists				
Pedon MS 1								
Ap	0-18	1.51	2.62	42.37	16.3	8.9	6.4	1.74
Bt	18-54	1.40	2.61	46.36	20.8	13.5	7.3	3.68
Btc	54-177	1.38	2.68	49.63	21.9	12.3	9.6	9.26
Pedon MS 2								
Ap	0-16	1.43	2.56	44.14	23.0	5.1	17.9	4.10
Bt	16-37	1.70	2.59	34.36	19.9	12.4	7.5	2.68
BC	37-72	1.79	2.55	29.80	10.3	5.5	4.8	3.01
C	72-143	1.56	2.60	40.00	27.9	14.0	13.9	15.4
Pedon MS 3								
Ap	0-19	1.48	2.60	43.08	11.3	6.1	5.2	1.46
Bt1	19-42	1.66	2.63	38.78	18.5	12.0	6.5	2.41
Bt2	42-96	1.45	2.56	43.36	19.7	10.3	9.4	7.36
BC	96-168	1.34	2.56	47.66	21.9	12.3	9.6	9.26
				Soils on Migmatite Gneisses				
Pedon MG 1								
Ap	0-15	1.48	2.58	42.64	12.0	5.7	6.3	1.40
Bt	15-47	1.57	2.57	38.91	19.0	11.2	7.8	3.92
Btcv1	47-103	1.58	2.58	38.76	22.1	14.2	7.9	6.99
Btcv2	103-147	1.61	2.59	37.84	20.5	13.8	6.7	4.75
Pedon MG 2								
Ap	0-18	1.50	2.56	41.41	10.3	4.1	6.2	1.67
AB	18-44	1.58	2.56	38.76	19.4	12.2	7.2	2.96
Bt1	44-78	1.52	2.62	41.98	23.0	13.4	9.6	4.96
Bt2	78-123	1.39	2.63	47.15	19.5	13.0	6.5	4.07
BCcv	123-167	1.58	2.64	40.15	14.3	11.7	2.6	1.81
Pedon MG 3								
Ap	0-25	1.61	2.61	38.31	19.3	8.0	11.3	4.55
Bt1	25-47	1.45	2.57	43.58	25.2	11.4	13.8	4.40
Bt2	47-89	1.40	2.64	46.97	24.8	11.2	13.6	8.00
BCcv	89-162	1.48	2.63	43.73	24.7	14.7	10.0	12.28

Soil Management Option

The major morphological and physical properties constraints of these soils to sustainable crop production were identified as: soil depth restrictions caused by plinthite layer and partially decomposed parent material, erosion, weak structural development in the surface horizons, slightly high bulk densities, slightly low total porosity and low water retention. Constraints of soils identified can be managed through the following suggested options.

The soil depth restriction due to parent materials on pedons QZ1, MS2 and MS3 (between 14cm and 72cm depths) and restriction by plinthite (48 – 172cm depth) on soils on MG could be managed by construction of contour ridges and bunds to improve the soils for quality seedbed and increase rooting depth (Kang *et al.*, 1991; Odunze, 2006; Senjobi and Ogunkunle, 2011). The practice of contour ridges along with cultivation of cover crops would conserve the soils against surface runoff erosion that might expose the plinthite horizons to harden irreversibly and render the soil unsuitable for arable crop production (FAO, 2006; Fasina *et al.*, 2007; Senjobi and Ogunkunle, 2011).

The coarse textured surface horizons with gravelly sandy loam and sandy loam renders the soils susceptible to erosion. In order to use these soils for optimal crop production, ridging and incorporation of crop residues with farm yard manure should be carried out at land preparation. These would control soil erosion, crusting and improve physical conditions of crop root zones (Tarawali *et al.*, 2001; Odunze, 2006).

Most of the soils were observed to have weak structural development in the surface horizons. Mechanized land preparation will increase structural destruction, hence application of organic matter and use of simple but efficient tools operated manually or powered by animal driven for land clearing, tillage, seeding, fertilizer application and harvesting will reduce effect of mechanize structural destruction (Odunze, 2006; Ogunkunle, 2009).

The bulk densities (1.60 – 1.79 Mgm^{-3}) were considered slightly high, total pore space values of these soils were rated to be moderate and available water capacity was considered to be low. The use of heavy equipment in these soils could lead to increased bulk density and reduced pore spaces with associated consequences. Incorporation of organic matter into these soils would improve soil aeration and moisture availability for sustainable crop production (Brady and Weil, 2005; FAO, 2006; Odunze, 2006; Ogunkunle, 2009).

CONCLUSIONS

In conclusion, parent materials significantly influenced morphological and physical properties (soil depth, structures, sand subfractions, silt clay ratio, available water content) of the soils. The results indicate that the soils were generally deep to very deep (135 – 190cm), with restriction due to parent materials and plinthite. The soils were sub - angular blocky with platy structure dominating mica schist subsoils. Sand dominated particle size fraction of fine earth (< 2mm) portion in all the soils and parent material generally influenced variation in sand sub fraction and gravel content. Management options suggested to improve soil constraints identified for sustainable use of the soils; include: contour ridges, cover cropping, incorporation of crop residues with farm yard manure and use of manually operated or animal powered equipment for traction on farm.

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