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Forms and distribution of extractable iron and aluminium in the soils of the lower slope of Bolorunduro catena, Ilorin, Nigeria

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Abstract

Forms and distribution of iron and aluminium oxides in four soil profiles representing the lower slope of a catena at Bolorunduro, Ilorin were studied.
The ranges in the values obtained for iron oxide were 179-3821, 71-693, 4-143 and 1-7 mgs/100g. of soil; while for aluminimum oxide the ranges in values were 94-434, 70-272, 5-198 and 14-72 mgs/100g. of soil in the DCB, oxalate, pyrophosphate and acetate extractants respectively. The distribution of these sesquioxides is a varibale function of the profile depth.

Positive and significant correlations were found to exist between DCB-iron and clay, DCB-aluminium and clay, pyrophosphate-iron and clay, acetate-aluminium and clay, and oxalate-iron and organic matter. Oxalate-iron was negatively correlated with clay, though the correlation was insignificant.

The mean weathering indices calculated for the soils (silt/clay, DCB-Fe/clay, DCB-Al/clay, Oxalate-Fe/clay, Oxalate-Al/clay) gave values that increased with drainage impedance.

Introduction

In the tropics and subtropics, the oxides and hydrous oxides of iron and aluminimu, in their crystalline and amorphous forms, are among the major components of soils, while small portions of iron and aluminimum are present in the form of organic complexes. Ashaye (1969) studies the relationships between clay content and Tamm's acid-oxalate extractable Fe and Al in some Nigerian soils derived from sandstone. He found that the relationships were not significant, but concluded that the amount and nature of the various form of Fe and Al oxides and organic complexes may greatly influence the physical and chemical properties of the soils. Juo et al (1974) determined iron and aluminium in selected Nigerian soils by selective extractive methods and found that the oxalate extractable Fe had greater values than the pyrophosphate extractable Fe in the Alfisol soil orders, and that this was not true for the soils that belong to the Ultisol order.

The profile distribution of the various forms of Fe and Al has been used as a criterion in interpreting soil formation in the temperate region (McKeague and Day, 1966; Blume and Schwertmann, (1969). It is well documented that the quantity and nature of the various forms of Fe and Al oxides and organic complexes greatly influence soil properties such as surface charge, swelling and aggregate formation (Sumner, 1963; Despande et al, 1968; El-Swaify and Emerson, 1975). The relationship between B-horizon colour and the kind of extractable iron has been used as a criterion for the classification of some North Carolina soils (Gamble and Daniel, 1972).

The presence of Fe and Al oxides in large quantities in soils can greatly influence chemical properties such as soil acidity and aluminium toxicity, which indirectly affect their agricultural usage (Foth, 1984).

This paper presents the forms and pedogenetic distribution of various forms of iron and aluminium in the soils of the lower slope of Bolorunduro catena, Ilorin, in the Southern Guinea Savanna of Nigeria.

Materials and methods

Genetic soil horizons of four soil profiles in the lower slope of Bolorunduro catena, Ilorin were described after the FAO guideline (FAO, 1965) and sampled. The lower slope of Bolorunduro catena consitutes the flood plain of Oyun river in the southern guinea savanna of Nigeria. Profiles 1 and 2 are well drained, profile 3 is moderately well drained while profile 4 is poorly drained. Position of profiles 1, 2, 3, and 4 are indicated as P1, P2, P3, and P4 in Figure 1. Bolorunduro is geologically situated on a granite-gneiss/banded-gneiss complex.

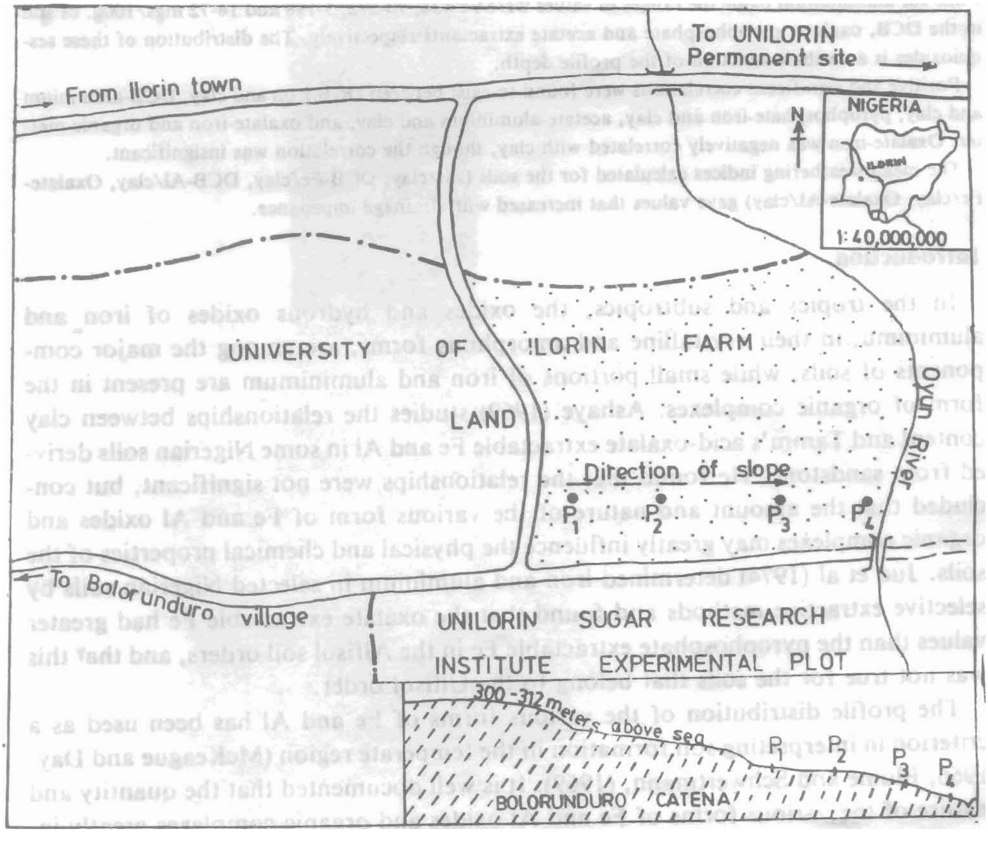

Fig 1. A schematic diagram showing relative positions of the soil profiles at the lower slope of Bolorunduro catena, Ilorin, Nigeria.

Soil samples were air-dried and passed through a 2-mm. sieve prior to analysis. Organic carbon was determined by the potassium dichromatewet oxidation method (Black, 1965). Organic matter was calculated from the organic carbon value. Soil pH was determined in water (soil: water ratio 1:2) using the direct-reading. Corning pH meter. Cation exchange capacity was determined by ammonium saturation and distillation method (Chapman, 1965). Particle-size distribution was determined by the Bouyoucos (1951) hydrometer method.

Dithionite-extractable Fe and Al were measured by the method of Mehra and Jackson (1960) using the dithionite-citrate system buffered with sodium bicarbonate. Oxalate-extractable Fe and Al were determined by the extraction method of Schwertmann (1964). Pyrophosphate-extractable Fe and Al were determined by the procedure of McKeague (1967). Ammonium acetate extractions of Fe and Al were made at pH 3.5.

Iron and aluminium in the extracting solutions were determined colorimetrically on a Bausch and Lomb Spectronic 20 - Spectrophotometer using the O-phenanthroline method for Fe (Jackson, 1969) and the Alizarin red-S method for Al (Shapiro and Brannock, 1962).

Results and discussion

Profiles 1 and 2 which are well-drained and profile 3 which is moderately well-drained have loamy sand surface with dark reddish brown (5YR 3/3 or 3/2) colour. The poorly drained profile 4 is loamy on the surface with black (10YR 2/1) colour. Profile 1 has red (2.5YR 4/6), profiles 2 and 3 have yellowish red (5YR 4/8), while profile 4 has yellowish brown (10YR 3/4) subsurface colour. The four profiles have fine granular surface structure with medium/coarse moderate subangular blocky subsurface structure. Profiles 2 and 3 are gravelly. The presence of gravels in profile 2 was recorded in two subsurface horizons (28-47cm and 145-182cm) with 32 and 45 percent gravel respectively. The only horizon of profile 3 (130-185cm) that was gravelly had 72 percent gravel.

The selected properties of the soils used in this study are given in Table 1. The pH of the soils in water varies from moderately acidic to neutral (5.9 - 7.00). There is a distinct increase in clay content with profile depth except for profile 3 which had a slight drop in the last horizon. The silt distribution is irregular in the profriles. Organic matter decreased with profile depth except in profile 4. The texture of the soils which varies from loamy sand to loam in the surface, and sandy clay loam to sandy loam in the subsurface horizons has influenced drainage in the toposequence.

The ranges in the values for iron oxide were 179-3821, 71-693, 4-143 and 1-7mgs/100gms. of soil; while for aluminium oxide the values were 94-434, 70-272, 5-198 and 14-72 mgs/100mgs. of soil in the DCB, oxalate, pyrophosphate and acetate extractants respectively (Table 2). The DCB extracts the "total free" oxide forms, ammonium oxalate extracts the "amorphous" forms, pyrophosphate extracts the organic forms while "exchangeable" iron and aluminium ocides are extracted by ammonium acetate (Juo et al, 1974; Jackson, 1969). The present study gives results that are in consonance with the work of Juo et al (1974) in which the oxalate extractable iron was found to be greater in value than the pyrophosphate extractable iron. This type of situation was reported by Juo et al (1974) to be true for soils belonging to the order Alfisol and untrue for soils belonging to the order Ultisol. The four soils in the lower slope of Bolorunduro would, on the basis of th values of extractable iron, therefore place comfortably inthe order Alfisol of the soi taxonomy (Soil Survey Staff, 1975).

TABLE I: SELECTED PROPERTIES OF THE SOILS OF THE LOWER SLOPE OF BOLORUNDURO CATENA, ILORIN, NIGERIA.

Horizon	Depth in cm.	pH 1:2 ($_20$)	Organic Matter %	C.E.C. m.eq./ 100 Soil	B.S. %	Sand %	Silt %	Clay %	Texture
				PROFILE 1					
Ap	0-28	6.7	0.94	3.2	37.9	84	8.3	7.6	Loamy Sand
B_2t	28-90	5.9	0.67	6.0	37.9	57	3.3	39.6	Sandy Clay
BC	90-182	6.2	0.37	4.6	56.8	56	3.7	39.6	Sandy Clay
				PROFILE 2					
Ap	0-12	6.6	1.80	3.7	55.9	81	11.9	6.6	Loamy Sand
E	12-28	6.7	0.84	3.7	40.3	89	4.9	5.6	Sand
EB1cn	28-47	6.2	0.70	3.7	26.5	73	12.9	13.6	Loamy Sand
EB_2	47-98	6.1	0.74	11.2	19.5	81	4.9	13.6	Loamy Sand
B_2t	98-145	6.0	0.33	5.6	37.4	57	6.9	36.0	Sand Clay
B_2tcn	145-182	6.1	0.20	5.0	45.2	56	7.9	37.0	Sandy Clay
				PROFILE 3					
Ap	0-20	6.4	0.80	3.8	53.6	78	13.4	8.0	LoamySand
B_1	20-46	6.2	0.47	2.9	47.6	75	13.4	11.0	Sandy Loam
B_2t	46-130	5.8	0.23	7.8	36.0	59	5.4	35.0	Sand Clay
B_2tcn	130-185	6.0	0.10	5.3	43.5	62	9.4	28.0	S. Clay Loam
				PROFILE 4					
Ah	0-7	7.0	5.21	13.7	94.5	48	38.0	14.0	Loam
AB	7-22	6.2	2.71	5.7	69.2	64	22.0	14.0	Sandy Loam
Btw	22-44	5.9	0.77	5.9	45.0	52	28.0	20.0	Sandy Loam

TABLE 2: VALUES OF EXTRACTABLE IRON AND LUMINIUM IN THE SOILS OF THE LOWER SLOPE OF BOLORUNDORO CATENA ILORIN, NIGERIA

	Extractable Fe_2O_3				Extractable Al			
Depth in cm	D-C-B	Oxalate mg/100gms.	Pyro Soil	Acetate	D-C-B	Oxalate mg/100gms.	Pyro Soil	Acelate
				PROFILE 1				
0-28	190	100	143	1	172	87	94	17
18-90	214	179	9	2	224	94	132	39
90-182	1750	530	4	3	208	272	198	45
				PROFILE 2				
0-12	571	207	67	1	94	127	196	17
12-28	548	193	39	1	104	104	189	14
28-47	179	86	99	2	123	70	30	27
47-98	202	221	46	2	302	132	14	72
98-145	3821	71	43	1	434	123	5	63
145-182	1929	135	57	1	283	121	15	51
				PROFILE 3				
0-20	643	350	57	102	102	189	21	18
20-46	1214	114	80	7	198	76	28	-15
130-185	2357	236	52	2	321	158	6	34
				PROFILE 4				
0-7	643	564	91	1	227	120	20	32
7-22	1214	693	41	4	161	212	18	40
22-44	1517	279	100	6	170	99	14	32

TABLE 3: ACTIVE RATIOS AND MEAN SESQUIOXIDE VALUES FOR THE SOILS OF THE LOWER SLOPE OF BOLORUNDURO CETENA, ILORIN, NIGERIA.

Depth in cm.	Active Ratios		Profile Mean Fe_2O_3				Profile Mean Al_2O_3			
	Oxalate Fe DCB-Fe	Oxalate Al DCB-Al	DCB	Oxa	Pyro.	Ace. mgs/100gm	DCB soil	Oxa.	Pyro.	Ace.
					PROFILE 1					
0-28	0.53	0.93								
28—90	0.83	0.71	718	209	52	2	201	151	141	34
90-182	0.20	1.37								
					PROFILE 2					
0-12	0.36	1.35								
12-28	0.35	1.00								
28-47	0.48	0.58								
47-98	1.09	0.44	1210	152	59	1	224	113	75	41
98-145	0.02	0.28								
145-182	0.07	0.43								
					PROFILE 3					
0-20	0.54	1.85								
20-46	0.09	0.38								
46-130	0.16	0.55	1625	268	66	3	250	158	115	35
130-185	0.10	0.49								
					PROFILE 4					
0-7	0.31	0.97								
7-22	0.57	1.32	1535	512	77	4	186	117	17	35
22-44	0.18	0.08								

The distribution of the DCB and oxalate sesquioxidess in the profiles showed that there are clear evidences of eluviation of iron and aluminium in profiles 1, 3 and 4; while profile 2 gave an indication that there are truncations at depths of 28cm and 98cm along the profile (Table 2). The high values recorded for aluminium in the surface horizon of profile 4 is due to organic matter (5.21%) contribution. Ojanuga et al (1976) reported that the stratigraphic patterns in Ife and Asejire toposequences are complex and that the soils of midslopes and lower slopes formed in layered pedisediments. The layered pedisediments are usually underlain by a basal saprolitic substratum; and directly overlying the basal saprolite is the gravelly pedisediment whose materials greatly contrasted with those of the saprolite. Folster (1969) also described pedisediments in the derived savanna area of Nigeria similar to those reported by Ojanuga et al (1976) where the loamy pedisediment is not a single deposit, but consists of two or more deposits which are separated by thin stone lines. The active ratios, which are given as the rations of oxalate iron and aluminium to DCB-iron and aluminium values were found to be inconsistently distributed with profile depth in the four profiles studied (Table 3). The least active-Fe and active-Al ratios in each profile do not correspond with zones of clay maxima except in profile 4 (Table 3 and Table 1). Although clay distribution with profile depth (Table 1) does not indicate any serious truncations that can support a theory of pedisedimentation similar to that mentioned by Ojanuga et al (1976) and Folster (1969), the values of DCB-sesquioxides and active ratios do indicate that pedisedimentation has helped in the deposition of sesquioxides in at least profile 2. Profile 2 recorded 32 and 45 per-cent gravel in two horizons (28-47cm and 145-182cm) respectively, while prifle 3 recorded 72 percent gravel in one horizon (130-185cm). Profile 4 has just about 8 percent gravel in the 22-44cm horizon where digging stopped because of the water table. It is probable that Oyun river has changed course two times, each over the sur-faces where profiles 2 and 3 were sited. By the time the river cut through each of these sections, the exposed edges might have resulted in the accummulation of gravels which today had been covered up by subsequent movement of fine earth materials downslope from up-slope area. Past and recent oxidation-reduction regimes along the toposequence might have accounted for the various values of ex-tractable sesquioxides recorded for the soils at the lower slope of Bolorunduro. Daniel et al (1975) reported that the water-table history and oxidation-reduction regime of each site accounted for the amount of extractable iron in an Aquult-Udult sequence from North Carolina.

The mean sesquioxide values in the four profiles were given for iron oxide as 1204.8, 259.0 62.7 and 2.5mgs/100gms of soil; while for aluminium oxide the values were 213.75, 149.75, 62.0 and 36.0 mgs/100gms of soil in the DCB, oxalate, pyrophosphate and acetate extractants respectively (Table 3). The expression of ox-alate, pyrophosphate and acetate as percentages of DCB-extractable sesquioxides were 21.53, 5.2 and 0.20 for iron; while the percentages were 64.78, 27.85 and 15.79 for aluminium. It is obvious that the dithionite-citrate-bicarbonate (DCB) extracted greater sesquioxides from the soils than either the oxalate, pyrophosphate or the acetate. Ogunwale and Ashaye (1975) showed that sandstone-derived soils of Iperu, Nigeria had higher DCB-sesquioxides values than oxalate.

The mean weathering indices calculated for the soils were silt/clay, DCB-Fe/clay, oxalate-Fe/clay and oxalate-Al/clay ratios (Table 4). These four weathering indices gave values that increased with drainage impedance; that is the poorer the drainage in the profile the higher the mean weathering index.

Correlation coefficient (r) values were calculated for the sesquioxides and clay, and for the sesquioxides and organic matter (Table 5). Positive and significant correlations were found to exist between DCB-extractable iron and clay, pyrophosphate-extractable iron and clay, DCB-aluminium and clay, acetate aluminium and clay, and oxalate-iron and organic matter. Oxalate-iron was negatively correlated with clay, though the correlation was insignificant. The positive correlation coefficient (r) values between DCB-sesquioxides and clay suggest a strong possibility of the co-migration of the sesquioxides with clay in the soils.

TABLE 4: MEAN PROFILE WEATHERING INDICES IN THE SOILS OF THE LOWER SLOPE OF BOLORUNDORO CATENA, ILORIN.

Index Profile		Silt / Clay	DCB-Fe / Clay	Oxalate-Fe / Clay	Oxalate-Al / Clay
W.D.	Profile 1	0.18	0.02	0.007	0.005
	Profile 2	0.44	0.09	0.008	0.006
M.W.D	Profile 3	0.51	0.08	0.013	0.008
P.D	Profile 4	1.84	0.10	0.032	0.011

W.D = Well drained
M.W.D = Moderately Well drained
P.D. = Poorly drained.

TABLE 5: CORRELATION COEFFICIENT (R) VALUES FOR EXTRACTABLE SESQUIOXIDES-CLAY AND SESQUIOXIDES-ORGANIC MATTER.

	Clay	Organic Matter
DCB-Fe_2O_3	0.52**	-0.03
DCB-Al_2O_3	0.60***	-0.21
Oxalate-Fe_2O_3	-0.08	0.61***
Oxalate-Al_2O_3	0.27	0.33
Pyrophosphate-Fe_2O_3	0.51**	0.22
Pyrophosphate-Al_2O_3	-0.01	-0.04
Acetate-Fe_2O_3	-0.01	-0.16
Acetate-Al_2O_3	0.60***	-0.17

*** Significant at 1% level
** Significant at 5% level

Conclusion

The sesquioxides in the soils of the lower slope of a catena at Bolorunduro, Ilorin were studied. The amorphous forms of sesquioxides had greater values than the organic forms, indicative of the Alfisol order.

The values of DCB-sesquioxides and active ratios do indicate that pedisedimentation has helped in the deposition of sesquioxides in at least profile 2. Oxidation-reduction regimes along the slope have accounted generally for the values obtained for extractable sesquioxides in the soils of the lower slope of Bolorunduro catena.

The profile mean weathering indices calculated for the soils increased with drainage impedance. The mean weathering indices employed in this study could help in determining relative drainage of soil profiles.

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