CHARACTERISATION AND CLASSIFICATION OF SOILS OF TWO TOPOSEQUENCES FORMED OVER DIFFERENT PARENT MATERIALS IN IMO STATE, NIGERIA

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Abstract
A study was carried out on two toposequences underlain by two varying lithologic materials namely; Imo Clay Shale and Falsebedded Sandstones all in Imo state South-eastern Nigeria. A transect was used on each toposquence to link summit to the toeslope soils.. Two (2) profile pits were dug on each of the physiographic position (summit, midslope and toeslope) of two toposequences at an inter-pedal distance of about 100 m. Samples were collected according to FAO procedure and were prepared for routine laboratory analysis. Soil data were analyzed statistically using ANOVA and coefficient of variation. Results showed that percent organic matter(OM) content of the Falsebedded Sandstone at the summit and toeslope differed significantly at p =0.05 with that of Imo Clay Shale at the summit and toeslope. The coefficient of variation (CV) showed that sand and pH(H_2O) had low variation in all physiographic positions, low to high variation in clay, OM, effective cation exchange capacity(ECEC) and base saturation. These soils were classified according to USDA soil Taxonomy and correlated with World Reference Base. Soils of Imo Clay Shale were classified as Vertic Hapludults (Vertic Alisols) at the summit and Typic Kandiudults (Albic Luvisols) at the midlsope and toeslope. The Falsebedded Sandstone soils were classified as Arenic Kandiudalfs (Arenic Lixisols) at the summit, Typic Hapludults (Haplic Alisols) at the midslope and Arenic Hapludults (Arenic Luvisols) at the toeslope.

Keywords: Characterization, Classification, Toposequence, Topounits, Lithology

Introduction

The variation in environment give rise to variations in soils, since both the direction and the rate of the processes responsible for soil development are controlled by the environment. The distribution of individual soil series on a toposequence and the spatial distribution of the toposequence itself have considerable influence on the land-use pattern of an area. It also results in morphological changes and horizonation (Odenerho, 1980). Soil properties along a toposequence vary from summit to toeslope due to microclimate, pedogenesis and geologic processes which result to a considerable influence on the land (Nuga *et al.,* 2008). These variations along a toposequence can also be as a result of parent materials, which imply that different soil lithologies give rise to different soil formations. It is very important to understand the nature, behaviour and distributions of various soils along a toposequene and the various parent materials that constituted the soil, but this can only be possible if these soils are studied separately, characterized and classified.

Information obtained through detailed, survey and soil characterization is vital for land-use planning and soil management, because soils cannot be properly managed without proper understanding of their characteristics (Idoga *et al.,* 2005). The use of soil when not classified can lead to its mismanagement and the degradation of such soil and its environment by users, such mismanagement ranges from conventional tillage along the slope, erosion and fertility depletion. It becomes necessary therefore to classify soils of any toposequence to determine the most effective ways of conserving them and the most appropriate landuse in which the soils can be subjected. Onweremadu, (2007) noted that characterization and classification of soils of any given location help in generating soil and soil related data which are useful in sustainable use of soil resources. Therefore, it is important to characterize and classify soils in a manner that will ease communication and transfer of knowledge about such soils to farmers and other stakeholders (Nuga *et al*., 2008). Therefore, this study was aimed at characterizing and classifying soils of two different toposequences formed over different parent materials in Imo State according to USDA soil taxonomy and World Reference Base (WRB).

Materials and Methods

Study Area:

The study was carried out at two (2) different locations namely, Isiebu in Isiala Mbano Area and Ihube in Okigwe area, all in Imo State, Southeastern Nigeria. The study areas lie between latitudes $5^o 52'$ N and longitudes $7^o 22'$ E for Ihube site and $5^o 45'$ N and $7^o 10'$ E for Isiebu site. The altitudes are 232 m and 158 m, respectively.

The parent (geology) materials from which the soils of the study areas developed are Falsebedded Sandstone (Ajali formation) for Okigwe study site and Imo Clay Shale (Imo formation) for Isiala Mbano study site. The study areas are generally dominated by plains and lowlands (Ofomata, 1987).

They areas fall within the tropical rainforest zone of Southeastern Nigeria with a humid tropical rainfall range of 1500 mm to 2200 mm (Ministry of Agriculture, 2010). The average annual atmospheric temperature above 20 ^oC creates an annual relative humidity of 75 % while during the rainy season humidity reaches 90 %. The areas have a typical rainforest with sparse vegetation at Okigwe and densely vegetated rainforest at Isiala Mbano, respectively.

Field Sampling:
A reconnaissance study was carried out on the study areas. Subsequently, transect survey technique was employed in aligning soil profile pits along the toposequence. Each toposequence was divided into three physiographic land units namely summit, midslope and toeslope. Profile pits were sited according to selected physiographic land unit on each toposequence, total of six profile pits were dug, three (3) on each toposequence and one (1) on each physiographic land units. The profile pits were described and samples were collected for analysis following the guideline of FAO, (2006).

Laboratory Analysis:
Particle size distribution was determined by hydrometer method (Gee and Or, 2002). Bulk density was determined by core method (Grossman and Reinsch, 2002). Moisture content was determined by gravimetric method (Obi, 1990). Soil pH was determined using 1:2.5 soil – liquid ratio using a pH meter (Thomas, 1996). Organic carbon was determined by wet digestion method (Nelson and Sommers, 1982). Total nitrogen was determined by micro-Kjeldah digestion technique (Bremner, 1996). Available phosphorous was determined using Bray II method (Olsen and Sommers, 1982). Exchangeable acidity was gotten by the method described by McLean (1982). Exchangeable bases were determined by neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982).

Soil Classification:
Field and laboratory data were used to classify the soils using USDA Soil Toxonomy (Soil Survey Staff, 2010) and World Reference Base (WRB) (FAO, 2006) classification systems.

Data Analysis:
Variability among soil properties from different parent materials were analyzed using analysis of variance (ANOVA) and mean comparison were made using the least significant difference (LSD) at $P < 0.05$ (Wahua, 1999). Coefficient of variation as described by Wilding *et al.* (1994) was used to estimate the degree of variability existing among soil properties in the study sites.

Results and Discussion
The morphological characteristics of the soils in the study sites are shown in Tables 1 and 2. All the horizons of the two toposequences were well drained. The surface soils were loose at all physiographic land units except the summit and midslope of the toposequence underlain by Falsebedded Sandstone (FBS) while the subsurface horizons were mostly firm. The various toposequences have different soil colour matrix ranges. Along the toposequence underlain by the Falsebedded Sandstone, it was observed that across the horizons the soil colour ranges from red (10R $^4/_8$) to very dark reddish brown (2.5YR $^3/_3$) (moist) at the summit, dark red (10R $^3/_4$, $^3/_6$) to brownish black (10YR $^2/_3$) (moist) at the midslope and dark reddish brown (10R $^3/_3$) to very dark reddish brown (2.5YR $^2/_3$)(moist) at the toeslope. However, it was also observed that the toposequence underlain by Imo Clay Shale (ICS) , the soil colour matric ranges from dull reddish brown (2.5YR $^3/_4$) to bright reddish brown (5YR 5/6) (moist) at the summit and dull orange (2.5YR $^6/_4$) to dark brown (7.5YR ¾) (moist) at the midslope and bright reddish brown (5YR $^3/_6$) to bright brown (7.5YR $^5/_6$) (moist) at the toeslope. The drainage condition and physiographic position may have influenced the observable change in the soil colour in the topographic units which agrees with the works of Gerrard, (1981) and Esu *et al*., (2008). The parent materials and environmental factors (rainfall, humidity and temperature) may have contributed to the soil colour variation of each horizon. Also, the amount of eluviations and/or illuviations that have occurred within these toposequences may equally contribute to the soil colour matrix on each topographic unit. The red colours are due to the presence of ferrous (Fe^{2+}) compound and indicate that the soils are well aerated. According to Nuhu (1983) the brownish tinges in most of the horizons of the profile were due to the presence of organic matter which is the main colouring agent in top soil.

Table 1: Morphological Characteristics of the Soils of a Toposequence underlain by Falsebedded Sandstone

Horizon	Depth(cm)	Colour (moist)	Texture	Structure	Consistence (moist)	Drainage	Boundary	Root
				SUMMIT				
A	0 – 9	Red (10R 4/8)	SL	Granular	Friable	Well drained	cs	m1rts
E	9 – 28	Dark red (10R 3/6)	SC	SBK	Firm	Well drained	cs	f1rts
Bt_1	28 –50	Dark reddish brown (2.5YR3/6)	SC	SBK	Firm	Well drained	cs	vf1rts
Bt_2	50 – 120	Dark reddish brown (5YR3/3)	SC	SBK	Very firm	Well drained	-	vf1rts
				MIDSLOPE				
A	0 – 13	Dark red (10R 3/6)	SL	Granular	Very friable	Well drained	cs	f1rts
E	13 – 27	Dark red (10R 3/4)	SCL	SBK	Firm	Well drained	cw	vf1rts
Bt_1	27 – 63	Dark reddish brown (5YR¾)	SCL	SBK	Firm	Well drained	-	vf1rts
				TOESLOPE				
A	0 – 21	Dark reddish brown (10R 3/3)	SL	Crumb	Loose	Well drained	cs	c1rts
E	21 – 43	Dark reddish brown (5YR 3/3)	SL	Granular	Very friable	Well drained	cw	f1rts
Bt_1	43 – 80	Very dark reddish brown (2.5YR 2/4)	SL	SBK	Friable	Well drained	cw	vf1rts
Bt_2	90 – 138	Very dark reddish brown (5YR 2/3)	SCL	SBK	Very firm	Well drained	-	vf1rts

SL= sandy loam, SCL = sandy clay loam, LS = loamy sand, SC = sandy clay, SBK= subangular blocky, m= many, c= common, f= few, vf= very few, 1= fine, 2= medium, rts= roots, c= clear, abrupt, s= smooth, w= wavy

Table 2: Morphological Characteristics of Soils of a Toposequence underlain by Imo Clay Shale

Horizon	Depth(cm)	Colour (moist)	Texture	Structure	Consistence (moist)	Drainage	Boundary	Root
				SUMMIT				
Ap	0 – 15	Dull reddish brown (2.5YR 4/4)	SCL	Granular	Loose	Well drained	cs	f12rts
AB	15 – 34	Bright reddish brown (5YR 5/6)	SCL	SBK	Friable	Well drained	cs	f2rts
Bt_1	34 – 60	Reddish brown (2.5YR 4/6)	SCL	SBK	Firm	Well drained	cw	vf1rts
Bt_2	60 – 94	Dull reddish brown (5YR 5/4)	SCL	SBK	Firm	Well drained	cs	vf1rts
Bt_3	94 – 180	Dull reddish brown (2.5YR 4/3)	SCL	SBK	Firm	Well drained	-	vf1rts
				MIDSLOPE				
Ap	0 – 20	Dull orange (2.5YR 6/4)	LS	Crumb	Loose	Well drained	cs	f12rts
AB	20 – 34	Dull orange (5YR 6/4)	SCL	SBK	Firm	Well drained	cs	f2rts
Bt_1	34 – 70	Bright brown (7.5YR 5/6)	SCL	SBK	Firm	Well drained	cs	vf1rts
Bt_2	70 – 110	Dull reddish brown (2.5YR 4/3)	SCL	SBK	Firm	Well drained	cw	vf1rts
Bt_3	110 – 180	Dark brown (7.5YR 3/4)	SC	SBK	Very Firm	Well drained	-	vf1rts
				TOESLOPE				
Ap	0 – 23	Bright brown (2.5YR 5/6)	S	Crumb	Loose	Well drained	cs	m12rts
AB	23 – 48	Bright reddish brown (5YR 5/6)	LS	Granular	Friable	Well drained	cw	m1rts
Bt_1	48 – 63	Brown (7.5YR 4/6)	SCL	SBK	Firm	Well drained	cs	f1rts
Bt_2	63 – 150	Bright brown (7.5YR 5/6)	SC	SBK	Very firm	Well drained	-	vf1rts

S = sand, SL= sandy loam, SCL = sandy clay loam, LS = loamy sand, SC = sandy clay, SBK= subangular blocky, m= many, c= common, f= few, vf= very few, 1= fine, 2= medium, rts= roots, c= clear, abrupt, s= smooth, w= wavy

Table 3: Physical Properties of Soils of a Toposequence underlain by Falsebedded Sandstone

Hor	Depth (cm)	Sand (%)	Clay (%)	Silt (%)	Textural class	SCR	BD (g/cm^3)	TP (%)	MC (%)
					SUMMIT				
A	0 – 9	72.15	16.57	11.28	SL	0.67	1.46	44.78	5.43
E	9 – 28	52.39	39.67	7.95	SC	0.20	1.42	46.54	8.59
Bt_1	28 –50	52.72	41.67	5.61	SC	0.14	1.29	51.19	9.03
Bt_2	50 – 120	53.48	40.57	5.95	SC	0.15	1.17	55.98	10.66
	Mean	57.74	34.62	7.69		0.29	1.34	45.19	8.43
	CV (%)	16.67	34.84	33.80		88.77	2.06	2.05	26.29
					MIDSLOPE				
A	0 – 13	71.48	16.91	11.61	SL	0.69	1.33	49.81	5.01
E	13 – 27	66.39	24.67	8.95	SCL	0.36	1.24	53.08	6.98
Bt_1	27 – 63	62.57	28.33	9.28	SCL	0.33	1.11	58.24	7.07
	Mean	66.81	23.30	9.95		0.46	1.23	58.71	6.35
	CV (%)	6.69	25.02	14.58		43.42	9.02	7.77	18.32
					TOESLOPE				
A	0 – 21	73.81	14.91	10.61	SL	0.71	1.09	58.62	8.95
E	21 – 43	72.63	17.76	9.61	SL	0.54	1.06	60.13	10.39
Bt_1	43 – 80	72.39	16.67	10.95	SL	0.66	1.07	59.50	9.39
Bt_2	90 – 138	63.05	29.67	7.28	SCL	0.25	1.02	61.63	9.39
	Mean	70.47	19.75	9.61		0.54	1.06	59.97	9.53
	CV (%)	7.07	34.00	17.22		38.16	2.78	1.85	6.39

Hor= horizon, SC = Sandy clay, SL = Sandy loam, SCL = Sandy clay loam, SCR = silt clay ratio, BD= bulk density, TP = Total porosity, MC = Moisture content, CV= coefficient of variation, < 15 =low variability, >/= 15<35 = moderate variability, > 35 =high variability.

The physical properties as shown in Tables 3, 4, and 5 showed that clay fraction ranged from 16.57 % - 41.67 % at the summit, 16.91 % - 28.33 % at the midslope and 14.91% - 29.67 % at the toeslope of the Falsebedded Sandstone. The Imo Clay Shale recorded percent clay values of 23.24 % - 28.67 % at the summit, 10.33 % - 38.57 % at the midslope and 9.67 %-45.91 % at the toeslope. The clay fraction of the soils increased with depth in all the soils. Chikezie *et al.*, (2009); Esu *et al*., (2008); Ewulo *et al*., (2002) reviewed that increased in clay content of soil with depth may be the consequence of eluviation-illuviation processes as well as contributions of the underlying geology through weathering. Analysis of variance (ANOVA) result as shown in Table 6 indicated that clay fractions in pedons at the summit and toeslope of ICS differed significantly (P=0.05) from that of FBS on the summit and toeslope, while clay content of soils under FBS on the midslope had no significant variation with that on the midslope of ICS. The significant difference between the parent materials could be as the result of their nature, humid climate, soil management practices, vegetation type and pedogenesis. Also erosion and eluviation of finer particles contributed to the sandiness of the upper horizon. Similar findings have been made of soils within this agro-ecology (Igwe *et al.,* 1995).

Bulk density values were 1.17-1.46 g/cm^3 at the summit, 1.11-1.33 g/cm^3 at the midslope and 1.02-1.09 g/cm^3 at the toeslope for soils developed from Falsebedded Sandstone while for soils derived from Imo Clay Shale values ranged from 1.18-1.52 g/cm^3 at the summit, 1.17-1.36 g/cm^3 at the midslope and 1.15-1.37 g/cm^3 at the toeslope. The mean values showed that Imo Clay Shale had the highest bulk density which could be as a result of high clay content. The bulk density of soils of the midslope and toeslope derived from ICS differed significantly ($P \leq 0.05$) from that of FBS. The variation could be as a result of nature of the parent materials, erosion effect and soil management practices, while areas with similarities could be attributed to deposited particles, type of cementing agent, and rate of runoff. However, values of bulk densities were lower than critical limits for root restriction (1.75-1.8) g/cm^3 (Soil Survey Staff, 1996).

Tables 6, 7, and 8 showed the chemical properties of the toposequences. The soil pH(H_2O) for all the toposequences were moderately acidic when compared to the rating of Singer and Munns (1999). The soils under Falsebedded Sandstone had a soil pH(H_2O) values range of 5.26- 5.92 at the summit, 5.61- 5.71 at the midslope and 5.62- 5.71 at the toeslope. Furthermore, soil pH(H_2O) values range from 5.37- 5.62 at the summit, 4.70- 5.72 at the midslope and 5.16- 6.51 at the toeslope for soils underlain by Imo Clay Shale. Perhaps, the epipedons of the varying toposequences were generally less acidic compare to the endopedons. The soil pH(H_2O) result could be attributed to leaching and erosion promoted by the high rainfall in the study areas. The result of the pH(H_2O) of soils underlain by FBS agrees with the findings of Silver *et al.* (2004) that soil pH increases from summit to toeslope. However, high pH values down the slope suggest movement of basic cations along the slope towards the toeslope, and this may account for high base saturation. The result of the ANOVA as shown on Table 10 indicated that pH(H_2O) of soils under FBS at the summit and toeslope differed significantly (p=0.05) with that of ICS at the summit and midslope respectively. The difference among toposequences could be attributed to climate, parent materials, vegetation cover and soil management practices.

Soils derived from Falsebedded Sandstone had organic matter content of 1.32-2.68 % at the summit, 1.58 - 4.37 % at the midslope and 3.03-4.94 % at the toeslope. Also, the soils formed from Imo Clay Shale recorded organic matter content of 0.93-2.45 % at the summit, 0.61 - 2.73 % at the midslope and 1.07-1.87 % at the toeslope. However, it was observed that the surface horizons recorded the highest percent organic matter at each physiographic unit in all the toposequences. This could be attributable to the deposition of organic materials on the soil surface. The OM content of soils under FBS at the summit, midslope and toeslope differ significantly (P= 0.05) with that of ICS at the summit, midslope and topslope. The variation in organic matter contents can be as a result of variation in vegetation cover of the different toposequences. Organic matter increase with physiographic position can be attributed to velocity of runoff, intensity of rainfall, hydro-morphology, slope, soil texture and vegetation type. This agrees with the reports of Feller (1993) and Igwe (2001).

The exchangeable base concentration showed that Sodium (Na) and potassium (K) were low compared to calcium (Ca) and Magnesium (Mg) contents. Na^+, K^+ Ca^{2+} and Mg^{2+} did follow any uniform pattern of distribution down the profiles horizons in all the physiogaphic positions of the toposequences (Tables 7-9). Higher values of Ca and Mg observed in this study could be as a result of the pedogenic processes occurring in the soils. This report agrees with the findings of Obi *et al,* (2001).

Coefficient of Variation:

The result of the coefficient of variation indicates that soil pH(H_2O) recorded low variation in all the physiographic positions. In soils derived from Falsebedded Sandstone, variation in soil pH(H_2O) decreased with physiographic position with values of 5.87 % for summit, 0.97 % for midslope and 0.78 % for toeslope respectively. The pH values of soils derived from Imo Clay Shale showed an increasing trend with physiographic positions with values of 1.88 % for summit, 7.09 % for midslope and 11.93 % for toeslope. The low variation of soil pH across all the toposequences agreed with the work of Ogunkunle, (1993); Mulla and McBratney, (2001). These results reflect the integrated effect of geology, slope (length, gradient and sequence) and to lesser extent soil management.

However, percent clay of soils of the FBS had moderate variability across the physiographic units with values 34.84 %, 25.02 % and 34.00 % for the summit, midslope and toeslope respectively. The Imo Clay Shale had low variation (8.04 %) at the summit, high variation (41.23 %) at the midslope and high variation (68.94 %) at the toeslope. The degree of variability recorded at the different physiographic units could be attributed to nature of the parent material, degree of slope, eluviation, and alluvial deposition of soil particles.

Organic matter of soils derived from FBS had a moderate variability at the summit (27.51 %) and toeslope (20.67 %) while a high variability was recorded at the midslope (46.06 %). Also, the Imo Clay Shale had a moderate variability at the summit (33.92 %) and toeslope (19.69 %) and high variation at the midslope (38.75 %). The rate of variability could be as a result of vegetation cover across the toposequences. Variation in Organic matter contents can also be as a result of leaching, runoff and movement of materials along the slopes.

The bulk density recorded a low variation across all the physiographic positions of the varying toposequences investigated. Several authors have reported the significant influence of cultivation and organic matter on bulk density (Akamigbo *et al.*, 1999; Onweremadu *et al.*, 2009). Low variation recorded at the toeslope contradicts the works of Jury, (1986); Beven *et al.* (1993) who reported that most toeslope are highly variable in same agro-ecological soil. Bulk density variation may be due to changes in organic matter distribution as well as land use pattern.

Table 4: Physical Properties of Soils of a Toposequence underlain by Imo Clay Shale

Hor	Depth (cm)	Sand (%)	Clay (%)	Silt (%)	TC	SCR	BD (g/cm^3)	TP (%)	MC (%)
				SUMMIT					
Ap	0 – 15	65.81	23.24	10.95	SCL	0.47	1.18	55.35	3.70
AB	15 – 34	64.05	25.33	10.61	SCL	0.42	1.23	53.45	4.16
Bt_1	34 – 60	62.15	28.67	8.95	SCL	0.31	1.29	51.19	4.78
Bt_2	60 – 94	60.72	27.67	11.61	SCL	0.42	1.44	45.78	5.42
Bt_3	94 – 180	63.15	26.57	10.28	SCL	0.38	1.52	42.77	6.43
	Mean	63.18	26.29	10.48		0.40	1.33	49.71	4.89
	CV (%)	3.04	8.04	9.42		14.65	10.77	10.88	21.93
				MIDSLOPE					
Ap	0 – 20	80.39	10.33	9.28	LS	0.90	1.17	55.72	1.63
AB	20 – 34	69.72	23.67	6.61	SCL	0.28	1.36	48.68	2.62
Bt_1	34 – 70	72.81	25.91	1.28	SCL	0.05	1.36	48.80	2.62
Bt_2	70 – 110	57.72	34.67	7.61	SCL	0.22	1.32	50.06	6.42
Bt_3	110 – 180	52.81	38.57	8.61	SC	0.22	1.35	49.06	7.69
	Mean	66.69	26.63	6.68		0.33	1.32	50.46	4.19
	CV (%)	16.89	41.23	47.66		97.45	6.18	6.06	63.84
				TOESLOPE					
Ap	0 – 23	81.72	9.67	3.28	SL	0.33	1.15	56.60	1.99
AB	23 – 48	73.48	14.57	11.95	LS	0.82	1.15	56.60	5.28
Bt_1	48 – 63	53.15	34.57	12.28	SCL	0.36	1.37	48.43	10.67
Bt_2	63 – 150	45.15	45.91	8.95	SC	0.19	1.29	51.19	17.21
	Mean	63.38	26.18	9.12		0.43	1.24	53.21	8.79
	CV (%)	26.95	68.94	45.73		63.37	8.79	7.72	75.77

Hor= horizon, TC= textural class, SCR = silt clay ratio, BD= bulk density, TP= total porosity, MC= moisture content, CV= coefficient of variation, < 15 =low variability, >/= 15<35= moderate variability, > 35= high variability.

Table 5: Mean Values of Variation in Selected Physical Properties of Soil with Lithology and Physiography

Geomorphic unit	Sand	Clay	Silt	SCR	BD	Porosity	MC
	⟶ % ⟵				(g/cm^3)	⟶ % ⟵	
				FALSEBEDDED SANDSTONE			
Summit	57.69	34.62	7.69	0.29	1.34	49.62	8.43
Midslope	66.81	23.30	9.95	0.46	1.23	53.71	6.35
Toeslope	70.47	19.75	9.60	0.54	1.06	59.97	9.53
				IMO CLAY SHALE			
Summit	63.18	26.29	10.48	0.40	1.33	49.71	4.89
Midslope	66.69	26.63	6.68	0.33	1.32	50.46	4.91
Toeslope	63.38	26.18	9.12	0.43	1.24	53.21	8.79
G.Mean	68.24	23.83	7.64	0.38	1.19	55.20	6.19
LSD 0.05	1.69	1.04	0.97	0.07	0.08	3.17	0.73

SCR= silt clay ratio, BD= bulk density, MC= moisture content

The soils of the study locations were classified using USDA soil taxonomy (soil survey staff, 2010) and World Reference Base (FAO, 2006) soil classification systems. The study locations fall under isohyperthermic temperature and udic moisture regimes. The pedons have base saturation below 35 % which qualifies them as Ultisols except for the pedon at the summit of toposequence underlain by Falsebedded sandstone that has base saturation value above 35 % which qualifies it as an Alfisol. Considering the soil moisture regime all the pedons were classified as Udults at suborder level (Soil Survey Staff, 2010) with exception of the pedon at the summit underlain by FBS which was classified as Udalf at suborder level. The pedons at midslope and toeslope underlain by ICS and summit underlain by the FBS have kandic horizons which qualify them as Kandiudults and Kandiudalf (Soil Survey Staff, 2010). However, the rest of the pedons did not have any observable diagnostic subsurface horizons and were classified as Hapludults at suborder level (Soil Survey Staff, 2010). The toposequence underlain by the Imo Clay Shale was classified as Vertic Hapludults (Vertic Alisols) at the summit and Typic Kandiudults (Albic Luvisols) at the midlsope and toeslope. The soils of the Falsebedded Sandstone were classified as Arenic Kandiudalfs (Arenic Lixisols) at the summit, Typic Hapludults (Haplic Alisols) at the midslope and Arenic Hapludults (Arenic Luvisols) at the toeslope.

Table 6: Selected Chemical Properties of Soils of a Toposequence underlain by False bedded Sandstone

Horizon	Depth	pH H_2O	pH KCl	OC	OM	TN	C:N	Av.P	Na	K	Ca	Mg	TEB	Ca:Mg	Al^{3+}	TEA	ECEC	B sat	Al^{3+}sat
				←	%	→		(mg/kg)	←		cmol/kg		→		←	cmol/kg	→	← %	→
									SUMMIT										
A	0 – 9	5.79	5.11	1.32	2.28	0.025	52.34	16.10	0.017	0.013	0.060	0.020	0.111	2.97	0.15	0.45	0.561	19.79	26.15
E	9 – 28	5.62	4.87	1.24	2.14	0.022	56.76	16.80	0.013	0.005	0.070	0.030	0.119	2.32	0.20	0.36	0.475	24.96	42.06
Bgt_1	28 – 50	5.69	4.92	0.76	1.32	0.018	41.81	14.01	0.017	0.005	0.150	0.070	0.242	2.13	-	0.30	0.539	44.96	-
Cg	50 - 120	5.92	5.17	1.56	2.68	0.041	38.28	24.50	0.013	0.004	0.164	0.087	0.268	1.89	-	0.25	0.521	51.38	-
	Mean	5.86	5.21	1.22	2.09	0.027	47.36	17.85	0.015	0.007	0.111	0.052	0.185	2.33	0.18	0.34	0.538	37.01	34.11
	CV (%)	5.87	9.37	27.50	27.51	38.05	18.23	25.70	15.39	62.12	48.27	61.68	34.73	20.32		25.30	10.77	35.86	
									MIDSLOPE										
A	0 – 13	5.70	4.99	2.53	4.37	0.052	48.43	31.51	0.015	0.013	0.049	0.012	0.089	4.13	0.35	0.95	1.039	8.59	33.36
E	13 – 27	5.71	4.98	1.58	2.73	0.027	58.68	17.50	0.009	0.012	0.200	0.030	0.249	6.61	0.35	0.80	1.052	23.64	33.27
Bgt_1	27 - 63	5.61	4.81	0.98	1.58	0.020	47.37	14.70	0.013	0.008	0.170	0.080	0.271	2.12	0.65	0.95	1.221	22.22	53.49
	Mean	5.67	4.93	1.68	2.89	0.033	51.49	21.24	0.012	0.011	0.139	0.041	0.203	4.29	0.45	0.90	1.104	18.15	40.04
	CV (%)	0.97	2.05	46.06	46.06	50.98	10.76	42.41	24.77	24.05	57.24	51.91	46.41	28.98	38.49	9.62	7.22	45.53	30.58
									TOESLOPE										
A	0 – 21	5.68	4.92	2.86	4.94	0.045	63.17	32.13	0.014	0.009	0.156	0.033	0.212	4.78	0.85	1.15	1.362	15.57	62.65
E	21 – 43	5.64	4.89	2.43	4.19	0.038	63.45	28.00	0.011	0.009	0.131	0.029	0.179	4.40	1.15	2.85	3.033	5.92	37.81
Bgt_1	43 – 80	5.72	4.94	2.09	3.61	0.032	64.75	26.61	0.013	0.010	0.046	0.014	0.083	3.32	1.35	3.10	3.187	2.62	42.26
Cg	80 - 138	5.62	4.88	1.76	3.03	0.044	39.78	25.91	0.011	0.010	0.042	0.018	0.081	2.28	1.95	4.95	5.031	1.62	38.76
	Mean	5.67	4.91	2.29	3.94	0.039	57.79	28.16	0.012	0.009	0.094	0.024	0.139	3.69	1.33	3.01	3.153	6.43	45.37
	CV (%)	0.78	0.56	20.61	20.67	15.15	20.89	9.89	12.25	6.08	62.26	38.14	48.28	30.18	35.06	51.63	47.35	98.98	25.39

OC = organic carbon, OM = organic matter, TN = total nitrogen, Av.P = available phosphorus, TEB = total exchangeable base, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity, B. Sat = base saturation, Al^{3+}. Sat = aluminum saturation, CV= coefficient of variation, < 15 =low variability, >/= 15<35 = moderate variability, > 35 =high variability.

Table 7: Selected Chemical Properties of Soils of a Toposequence underlain by Imo Clay Shale

Horizon	Depth	pH H_2O	pH KCl	OC (%)	OM (%)	TN (%)	C:N	Av.P (mg/kg)	Na (cmol/kg)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)	TEB (cmol/kg)	Ca:Mg	Al^{3+} (cmol/kg)	TEA (cmol/kg)	ECEC (cmol/kg)	B sat (%)	Al^{3+}sat (%)
SUMMIT																			
Ap	0 – 15	5.62	4.95	1.42	2.45	0.028	51.00	13.54	0.013	0.015	0.362	0.052	0.442	6.97	0.80	1.10	1.542	28.68	52.11
AB	15 – 34	5.60	4.90	1.14	1.97	0.021	53.36	13.37	0.011	0.017	0.456	0.070	0.554	6.49	1.00	1.05	1.604	34.56	62.30
Bt_1	34 – 60	5.37	4.59	0.72	1.25	0.014	50.48	11.27	0.008	0.009	0.250	0.050	0.317	4.98	0.80	1.70	2.017	15.74	39.82
Bt_2	60 – 94	5.49	4.77	0.54	0.93	0.012	44.33	10.36	0.008	0.009	0.240	0.100	0.344	2.40	0.55	1.40	1.760	20.28	31.24
Bt_3	94 -180	5.46	4.80	0.79	1.37	0.018	43.23	13.09	0.013	0.012	0.124	0.056	0.205	2.23	1.45	1.70	1.980	10.72	76.18
	Mean	5.51	4.80	0.92	1.59	0.019	48.48	12.33	0.011	0..012	0.286	0.066	0.377	4.42	0.92	1.39	1.766	21.99	52.31
	CV (%)	1.88	2.89	38.33	38.21	33.92	9.05	11.56	23.68	28.85	44.28	31.64	35.45	48.36	36.58	22.52	11.32	44.11	33.92
MIDSLOPE																			
Ap	0 – 20	5.72	4.96	1.58	2.73	0.019	83.44	12.25	0.006	0.014	0.144	0.036	0.200	4.01	0.50	0.65	0.854	25.14	58.56
AB	20 – 34	5.45	4.92	0.84	1.45	0.022	38.48	16.10	0.004	0.006	0.172	0.050	0.233	3.43	1.10	2.30	2.536	9.17	43.45
Bt_1	34 – 70	5.42	4.82	0.74	1.28	0.012	63.81	10.15	0.003	0.006	0.082	0.018	0.080	4.58	2.20	3.20	3.310	3.29	66.47
Bt_2	70 -110	4.70	4.10	0.36	0.61	0.007	48.81	9.66	0.037	0.006	0.164	0.036	0.210	4.52	2.95	3.50	3.710	5.66	79.64
Bt_3	110-180	5.34	4.80	0.76	1.31	0.016	47.84	13.16	0.015	0.006	0.182	0.068	0.271	2.68	2.85	4.95	5.221	5.18	54.53
	Mean	5.33	4.72	0.86	1.47	0.015	56.48	12.26	0.006	0.008	0.149	0.042	0.199	3.85	1.92	2.92	3.126	9.69	60.51
	CV (%)	7.09	7.48	52.02	52.36	38.75	30.46	21.09	109.46	47.08	26.79	44.77	29.60	20.82	56.41	21.22	51.33	85.04	21.90
TOESLOPE																			
Ap	0 – 23	6.51	5.72	1.08	1.87	0.019	57.39	13.86	0.008	0.009	0.286	0.074	0.378	3.86	0.71	2.95	3.331	11.35	21.31
AB	23 – 48	5.16	4.67	0.98	1.69	0.023	42.50	16.73	0.006	0.009	0.118	0.022	0.156	5.38	0.79	1.70	1.860	8.41	42.84
Bt_1	48 – 63	5.22	4.84	0.96	1.66	0.020	47.75	15.40	0.006	0.013	0.292	0.048	0.359	6.03	0.79	1.90	2.259	15.91	35.26
Bt_2	63 - 150	5.20	4.72	0.62	1.07	0.014	45.93	11.20	0.008	0.006	0.270	0.050	0.335	5.37	1.45	4.04	4.375	7.66	33.22
	Mean	5.61	4.99	0.91	1.57	0.019	48.39	14.29	0.007	0.009	0.242	0.049	0.307	5.16	0.94	2.65	2.956	10.83	33.16
	CV (%)	11.93	9.89	22.01	22.96	19.69	13.25	16.61	16.49	31.05	34.31	42.82	83.42	18.00	36.94	40.72	38.33	34.54	26.63

OC = organic carbon, OM = organic matter, TN = total nitrogen, Av.P = available phosphorus, TEB = total exchangeable base, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity, B. Sat = base saturation, Al^{3+}. Sat = aluminum saturation, CV= coefficient of variation, < 15 =low variability, >/= 15<35 = moderate variability, > 35 =high variability.

TABLE 8: Mean Values of Variation in Selected Chemical Properties of Soils with Lithology and Physiography

Horizon	$pH(H_2O)$	OM	TN	C:N	Av.P	TEB	TEA	ECEC	B.Sat	Al^{3+} Sat
		→ %	←		(mg/kg)	→	cmol/kg	←	→ %	←
				FALSEBEDDED SANDSTONE						
Summit	5.76	1.91	0.022	52.91	17.00	0.229	0.34	0.569	35.27	34.11
Midslope	5.67	2.08	0.025	47.91	17.23	0.204	0.90	1.104	18.15	40.04
Toeslope	5.62	1.49	0.019	48.75	16.53	0.139	3.01	3.153	6.43	38.10
				IMO CLAY SHALE						
Summit	5.51	1.59	0.019	48.48	12.33	0.377	1.39	1.766	21.99	52.33
Midslope	5.33	1.47	0.015	56.48	12.26	0.199	2.92	3.126	9.69	60.51
Toeslope	5.61	1.57	0.019	48.29	14.29	0.307	2.65	2.956	10.83	33.16
G. mean	5.65	2.08	0.024	50.92	17.24	0.249	2.06	1.975	20.59	29.65
Lsd0.005	0.14	0.05	0.003	5.23	0.07	0.026	5.67	0.56	0.92	0.86

OM = organic matter, TN = total nitrogen, Av.P = available phosphorus, TEB = total exchangeable base, TEA = total exchangeable acidity, ECEC = effective cation exchange capacity, B. Sat = base saturation, Al^{3+}. Sat = aluminum saturation.

Conclusion

The study has shown that the soils of the studied areas were highly weathered belonging to ultisols and alfisols.. However, the studied areas invariably require different soil management practices based on on some non-soil soil factors not accounted for in the study.. The study will be a useful guide to other land user within the areas for establishment of landuse types that is most suitable for the areas.

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