PROPERTIES OF SOILS IN RELATION TO SOIL DEPTH, LANDUSE AND LANDSCAPE POSITION ON SOILS OF IKEDURU AREA OF IMO STATE, SOUTHEASTERN NIGERIA

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Abstract
The aim of the study was to assess the distribution of soil properties as affected by soil depth, land-uses and landscape positions in Eziama Ikeduru in Imo state, southeastern, Nigeria. Slope soilsunder three different land-uses were used for the study and soil profile pits were sited at each physiographic positions using transect technique. Soil samples were collected based on horizon differentiation and were subjected to laboratory analyses. Data generated were analyzed statistically using analysis of variance (ANOVA) and mean comparisons were made using least significant difference to determine the difference among the land-uses and landscape positions. Coefficient of variation was used to determine variation among studied horizons. Result showed no significant ($p< 0.05$) difference in sand, clay, bulk density, pH(H_2O) and TN among land-uses. The sand, silt, clay, BD, pH(H_2O), OC, and TEB recorded no significant ($p< 0.05$)difference among the landscape positions. Most soil properties had an irregular pattern of increase or decrease with soil depth. The surface horizon recorded higher level of sand and OC over the subsurface horizon. However, fallow land was the most acidic among the land-uses while, the summit is the most acidic among the landscape positions.
Keywords: Horizons, Land-uses, Landscape positions, topography, Soil depth.

Introduction

Soil is recognized as a natural body whose nature is determined by the material from which it has been developed and the environment to which it has been subjected. Soil has tremendously varied vertically and horizontally in their physical, chemical and biological properties. Lark and Wheeler (2000) stated that variation in soil properties has long been known and has been the subject of much research. Studies on the variability of soil properties have overtime been related to many factors as land-use (Langley-Turnbaugh and Keirstead, 2005; Eden *et al.*, 1991; Amusan *et al.*, 2001), slope disposition (Dowling *et al.*, 1986; Huang *et al.*, 2001) and field crops (Cox *et al.*, 1998). The variation is a gradual change in soil properties as a function of landforms, geomorphic elements, soil forming factors and soil management (Buol *et al.*, 1997). The variation of soil properties should be monitored and quantified to understand the effects of land use and management systems on soils.

Landscape position influences water velocity on a slope, variation in drainage conditions and deposition of minerals. This cause a series of changes in soil properties such as horizon differentiation, textural contrast, changes in soil depth and chemical properties (Esu *et al.*, 2008). Soil properties along a slope 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).The differences in soil properties due to slope position differ due to degree of detachment, transportation and deposition of soil materials. Understanding soil properties and their variation is important for their sustainable utilization and best management practices. The concept of slope position, which involves processes that cause properties differentiation along hillslopes and among soil horizons have improved evaluating the interaction of pedogenic and geomorphic processes (Gessler *et al.*, 2000; Esu *et al.*, 1987; Ovalles and Collins, 1986). However, Brubaker *et al.*(1993) stated that the geometry of slope such as slope angle, length, curvature influence runoff, drainage, and soil erosion causing a significant difference in soil physico-chemical properties. It is important to know that different soils occur at different positions on the landscape (Nuga *et al.*, 2006). This various positions can have effect on soil physical and chemical properties.

Land-use is a resultant interplay of available land resources with cultural, social and economic conditions of the past and present development when or more land-use types occurs on the same soil (Akamigbo and Asadu, 1983). Land-use is an integrator of several environmental attributes which influence nutrients export (Young *et al.*, 1996). When land is put to certain uses, there is an accompanying change in the intrinsic properties of the soil. The need to provide information about soils are more demanding than before because of the problem arising from misuse of soil resources resulting in soil/land degradation. Increase in agricultural activities has brought about an increase in demand on land resources. This has led to the clearing of land on steep slope and tilling of soil without proper consideration of the most suitable tillage practice. These have serious soil management implications because the more intensively cultivated upland soil deteriorates rapidly due to erosion and fertility depletion.

However, for better utilization of soil resources, soil characteristics must be known (Idoga *et al.,* 2005). In the same vein, Onweremadu (2007a) noted that the characterization of soils of any given location help in generating soil and soil related data which are useful in proper and sustained use of soil resources. There is little or no detailed information on soils of the study area, hence the need to generate soil data to improve agricultural production and environmental sustainability. However, soil depth, landscape positions in conjunction with land-use may be dominant factors that are influencing soil properties under a slope. Therefore, it is important to study not only the extent of the surface spatial variability of soil properties but also the distribution of subsurface and deep soil horizons, Iqbal *et al.* (2005). Knowledge about soil physical and chemical properties can save time and money in planning and management spatial variations of soil that, influence soil and crop management efficiencies as well as the effectiveness of soil research Wasiullah *et al.* (2010). Hence, there is need to assess soil properties distribution in relation to soil depth, land-use and landscape so as to enhance knowledge and inform proper usability/management practices on the soils of Eziama southeastern Nigeria.

Materials and Methods

Study Area

The study was conducted on a slope under different land-use type at Eziama in Ikeduru local government area of Imo state Southeastern, Nigeria. It is located on latitude 5^o 30′ N - 5^o 35′ N and longitude 7^o 05′ E - 7^o 10′ E with an altitude of 120 m. The study area has a rainforest agro-ecology characterized with 2200-2500 mm mean annual rainfall and 29 ^{o}C mean temperature (NIMET, 2014). The soil of the study area is derived from coastal plain sand (Benin Formation) (Onweremadu, 2006). Farming and hunting activities are the major socio-economic activities of the study area.

Soil Sampling

A transect was used to locate and align soil profile pits in the different land-uses of the landscape at an equidistance of 100 m. Three soil profile pits were dug at three identified physiographic positions, namely summit, midslope and toeslope on each of the land-uses. Soil samples were collected from the profile pits based on the degree of horizon differentiation. Core samples were collected from each pedogenic horizon of the soil profile pits. Three samples were collected per horizon. Soil samples were air-dried at room temperature sieved using 2 mm and packaged in preparation for laboratory studies.

Laboratory Analyses

Particle size distribution was determined by Bouyoucos hydrometer method (Gee and Or, 2002). Soil pH(H_2O) was determined electrometrically using glass electrode pH meter in a solid-liquid ratio of 1:2.5 (Hendershot *et al.,* 1993). Total nitrogen was determined by micro-Kjeldahl digestion technique method (Bremner, 1996). Exchangeable bases were determined by the neutral ammonium acetate procedure buffered at pH 7.0 (Thomas, 1982). Exchangeable acidity was determined by a method described by (McLean, 1982). Total carbon was analyzed by wet digestion (Nelson and Sommers, 1982). Available phosphorous was determined by Bray ll method according to the procedure of (Olsen and Sommers, 1982). Bulk density was determined by the core method (Grossman and Reinsch, 2002). Total porosity (P_o) was obtained from bulk density (ℓp) values with assumed particle density (ℓs) 2.65 g cm^{-3} as follows, Porosity (Po) =100 – (ℓp/ℓs) ×100/1.

Statistical Analyses

Variability among soil properties from different land-uses and topographic position were analyzed using Analysis of variance (ANOVA) and mean comparism were made using the least significant difference (LSD) method at $p<0.05$ levels (Wahua, 1999). Coefficient of variation as used by Wilding *et al.* (1994) was used to estimate the degree of variability existing among soil properties of the studied pedons.

Results and Discussion

Soil depth in relation to soil properties distribution

The result (Table 1,2,3) indicated that sand fraction of the pedons had no specific trend of decrease with soil depth in all the landscape positions under the studied land-uses. It also recorded low variation (3.83 % - 7.79 %) in all the studied pedons. The low variation could be attributed to the homogeneity of the soils which resulted from similarity in parent material and climate within the study area. This is in conformity with the findings of (Onweremadu *et al.,* 2011; Ndukwu *et al.,* 2015) in soils of Southeastern Nigeria.

Table 1: Physical properties of studied soils of cassava farm land-use

Horizon	**Depth (cm)**	**Sand**	**Clay**	**Silt**	**SCR**	**TC**	**BD (g/cm^3)**	**Porosity (%)**
		→	**%**	←				
				Summit				
Ap	0-13	79	15	6	0.40	SL	0.95	64.15
AB	13-25	71	23	6	0.26	SCL	1.12	57.74
Bt_1	25-43	75	21	4	0.19	SCL	1.24	53.21
Bt_2	43-108	73	19	8	0.42	SCL	1.21	54.34
Bt_3	108-200	70	24	6	0.25	SCL	1.05	60.38
Mean		**73.60**	**20.40**	**6**	**0.30**		**1.11**	**57.96**
CV		**4.86**	**17.54**	**23.57**	**33.11**		**10.63**	**7.71**
				Midslope				
Ap	0-17	83	13	4	0.31	LS	1.03	61.13
AB	17-29	77	17	6	0.35	SL	1.12	57.74
Bt_1	29-51	79	15	6	0.40	SL	1.15	56.60
Bt_2	51-116	75	17	8	0.47	SL	1.08	59.25
Bt_3	116-200	67	23	10	0.44	SCL	1.00	62.26
Mean		**76.20**	**17**	**6.8**	**0.39**		**1.08**	**59.40**
CV		**7.79**	**22.01**	**33.53**	**16.51**		**5.75**	**3.93**
				Toeslope				
Ap	0-21	83	11	6	0.55	LS	1.24	53.21
AB	21-36	81	13	6	0.46	LS	1.18	55.47
Bt_1	36-64	77	19	4	0.21	SL	1.22	53.96
Bt_2	64-110	75	17	8	0.47	SL	1.08	59.25
Bt_3	110-200	77	15	8	0.53	SL	1.12	57.70
Mean		**78.60**	**15**	**6.4**	**0.44**		**1.17**	**55.92**
CV		**4.18**	**21.08**	**26.15**	**30.70**		**5.76**	**4.53**

SCR= silt clay ratio, TC= textural class, BD= bulk density, CV= coefficient of variation, < 15 =low variability, ≥ 15<35 = moderate variability, > 35 =high variability.

Table 2: Physical properties of studied soils of fallow land-use

Horizon	Depth (cm)	Sand	Clay %	Silt	SCR	TC	BD (g/cm^3)	Porosity (%)
				Summit				
A	0-14	83	13	4	0.31	LS	1.05	60.38
AB	14-26	79	17	8	0.47	SL	1.08	59.25
Bt_1	26-49	81	15	4	0.27	SL	1.12	57.74
Bt_2	49-96	71	21	8	0.38	SCL	1.15	56.60
Bt_3	96-200	75	19	6	0.32	SL	1.06	60.00
Mean		**77.80**	**17**	**6**	**0.35**		**1.09**	**58.79**
CV		**6.19**	**18.60**	**33.33**	**22.22**		**3.85**	**2.70**
				Midslope				
A	0-19	82	12	6	0.50	LS	0.96	63.77
AB	19-31	76	18	6	0.33	SL	1.15	56.60
Bt_1	31-59	71	25	4	0.16	SCL	1.12	57.74
Bt_2	59-112	71	21	8	0.38	SCL	1.08	59.25
Bt_3	112-200	73	23	4	0.17	SCL	1.15	56.60
Mean		**74.60**	**19.80**	**5.60**	**0.31**		**1.09**	**58.79**
CV		**6.19**	**25.60**	**29.88**	**46.90**		**7.25**	**5.08**
				Toeslope				
A	0-18	81	15	4	0.27	SL	1.08	59.25
AB	18-29	77	19	4	0.21	SL	1.16	56.23
Bt_1	29-60	73	21	6	0.29	SCL	1.18	55.47
Bt_2	60-121	79	17	4	0.24	SL	1.09	58.87
Bt_3	121-200	77	15	8	0.53	SL	1.14	56.98
Mean		**77.40**	**17.40**	**5.20**	**0.31**		**1.13**	**57.36**
CV		**3.83**	**14.99**	**34.40**	**41.48**		**3.86**	**2.87**

SCR= silt clay ratio, TC= textural class, BD= bulk density, CV= coefficient of variation, < 15 =low variability, ≥ 15<35 = moderate variability, > 35 =high variability.

Table 3: Physical properties of studied soils of mixed crop land-use

Horizon	Depth (cm)	Sand	Clay %	Silt	SCR	TC	BD (g/cm^3)	Porosity (%)
				Summit				
A	0-16	79	15	6	0.40	SL	1.02	61.51
AB	16-34	73	21	6	0.29	SCL	1.12	75.74
Bt_1	34-62	71	25	4	0.16	SCL	1.15	56.60
Bt_2	62-132	69	23	8	0.35	SCL	1.08	59.25
Bt_3	132-200	67	27	6	0.22	SCL	1.10	58.49
Mean		**71.80**	**22.20**	**6**	**0.28**		**1.09**	**62.32**
CV		**6.41**	**20.74**	**23.57**	**34.01**		**4.49**	**12.37**
				Midslope				
A	0-13	79	17	4	0.24	SL	0.85	67.93
AB	13-21	71	21	8	0.38	SCL	0.95	64.15
Bt_1	21-68	73	19	8	0.42	SCL	1.15	56.60
Bt_2	68-127	71	23	6	0.26	SCL	1.02	61.51
Bt_3	127-200	67	25	8	0.32	SCL	1.10	58.49
Mean		**72.20**	**21.00**	**6.8**	**0.32**		**1.01**	**61.74**
CV		**6.07**	**15.06**	**26.31**	**23.67**		**11.76**	**7.30**
				Toeslope				
A	0-18	83	11	6	0.55	LS	0.93	64.91
AB	18-35	77	15	8	0.53	SL	1.06	60.00
Bt_1	35-71	81	13	6	0.46	LS	1.13	57.36
Bt_2	71-118	77	19	4	0.21	SL	1.19	55.09
Bt_3	118-200	71	21	8	0.38	SCL	1.17	55.85
Mean		**77.80**	**15.80**	**6.4**	**0.43**		**1.10**	**58.64**
CV		**5.92**	**26.25**	**26.15**	**32.38**		**9.6**	**6.78**

SCR= silt clay ratio, TC= textural class, BD= bulk density, CV= coefficient of variation, < 15 =low variability, ≥15<35 = moderate variability, > 35 =high variability.

Sand fraction recorded higher level (79 % - 83 %)on surface horizons over the subsurface horizon in all the studied pedons. This could be associated with sorting of soil particles by runoff activities. Clay fraction increased down the profile and had moderate variation (15.06 % - 22.20 %) in all the pedons except for the toeslope pedon of the fallow land-use where it recorded low variation (14.99 %). The moderate variation could be associated with rate of pedogenesis, clay migration (Ndukwu *et al*., 2015) and drainage pattern of the soil. However, Obi and Akinbola, (2009) had reported that increase in clay with soil depth could be attributed to clay translocation and erosion on surface horizon. The Bt horizons recorded higher level of clay fraction over other horizons which resulted from illuviation process. Silt fraction (Table 1, 2, 3) had an irregular increase pattern with soil depth in all the pedons except for the midslope pedon of the cassava farm land-use where it recorded regular increase pattern with soil depth. However, silt fraction recorded moderate variation (23.57 % - 34.40 %) in all the studied pedons. The moderate variation as recorded by silt fraction contradicts the findings of (Ahukaemere *et al.,* 2014, Osujieke *et al.,* 2016) on soils of Southeastern Nigeria where it recorded low variation.

Soil pH(H_2O) as indicated in Tables 4, 5, 6 decreased with soil depth in an irregular pattern across the studied pedons except for the pedons on the summit and midslope of mixed crop land-use. Also, pH(H_2O) recorded low variation (2.27 % - 7.53 %) across the studied pedons. The low variation could be associated to the parent material (coastal plain sand) which was earlier reported by (Onweremadu *et al.,* 2011) to contribute to the acidity of most Southeastern Nigeria soils. However, most of the surface horizons were the least acidic among the studied horizons. Organic carbon as distributed across the horizons of the studied pedons showed a regular decrease with soil depth except for pedons of summit and toeslope of the mixed crop land-use and that of midslope of the cassava farm land-use. Higher level of OC was observed in the surface horizons when compared with subsurface horizons. Organic carbon recorded high variation (38.91 % – 54.22 %)in all studied pedons except the summit pedon of mixed crop land-uses. The high variation could be associated to high level of organic materials on the surface horizons, low mineralization and low climatic activities. Also, Onweremadu, (2007b) reported that land use, landscape position, and fluvial depositions could result to high variation in pedons.

Total nitrogen had an inconsistence increase or decrease pattern across the studied pedons while, available phosphorus had an irregular decrease with soil depth in all the studied pedons. Total nitrogen and available phosphorus recorded low – high variation across the studied pedons. Such variations have been reported by (Ndukwu *et al.,* 2015) on soils under different land-uses. Effective cation exchange capacity decreased down with soil depth in an irregular trend in all the studied pedons. It recorded low – moderate variation (4.48 % - 21.59 %) across the pedons suggesting that a number of factors such as vegetation type, management history, age and microclimate may also be important in explaining variability of this soil.

Table 4: Chemical properties of studied soils of cassava farm land-use

Hori	Depth	$pH(H_2O)$	OC	TN	Av.P	Ca	Mg	Na	K	Al^{3+}	H^+	ECEC
	(cm)		→ % ←		(mg/kg)	→			cmol/kg ←			
						Summit						
Ap	0-13	5.2	1.42	0.02	0.026	0.8	0.6	0.3	0.08	2.0	1.2	4.98
AB	13-25	5.3	1.21	0.056	0.023	0.8	0.4	0.42	0.06	1.2	0.8	3.68
Bt_1	25-43	5.2	0.86	0.070	0.024	1.0	0.2	0.3	0.06	2.4	1.6	5.56
Bt_2	43-108	5.1	0.54	0.051	0.012	0.9	0.4	0.2	0.07	1.9	1.8	5.27
Bt_3	108-200	4.8	0.47	0.055	0.018	0.8	0.3	0.3	0.06	1.2	1.0	3.36
Mean		**5.12**	**0.90**	**0.052**	**0.021**	**0.86**	**0.38**	**0.30**	**0.07**	**1.74**	**1.28**	**4.57**
CV		**3.76**	**45.90**	**29.26**	**27.38**	**10.40**	**39.03**	**25.65**	**13.55**	**30.30**	**32.40**	**21.59**
						Midslope						
Ap	0-17	5.3	1.3	0.07	0.028	1.0	0.4	0.3	0.15	1.2	0.8	3.85
AB	17-29	5.4	0.06	0.051	0.011	0.8	0.2	0.25	0.13	1.2	0.8	3.38
Bt_1	29-51	5.1	0.67	0.028	0.009	0.7	0.6	0.3	0.13	2.0	1.2	4.93
Bt_2	51-116	4.9	0.50	0.042	0.026	0.8	0.6	0.22	0.11	1.5	0.6	3.83
Bt_3	116-200	5.0	0.42	0.046	0.018	0.6	0.5	0.26	0.12	1.2	0.8	3.48
Mean		**5.14**	**0.75**	**0.048**	**0.02**	**0.78**	**0.46**	**0.27**	**0.13**	**1.4**	**0.84**	**3.89**
CV		**4.03**	**46.78**	**32.19**	**46.53**	**19.02**	**36.38**	**12.91**	**11.59**	**24.60**	**26.08**	**15.80**
						Toeslope						
Ap	0-21	5.6	1.05	0.028	0.026	0.8	0.4	0.3	0.06	1.6	0.8	3.96
AB	21-36	5.4	0.86	0.014	0.01	1.0	0.2	0.34	0.06	1.2	0.8	3.6
Bt_1	36-64	5.3	0.42	0.042	0.018	0.8	0.6	0.39	0.13	1.2	1.2	4.32
Bt_2	64-110	5.4	0.46	0.028	0.018	0.9	0.4	0.34	0.08	1.3	0.9	3.92
Bt_3	110-200	5.3	0.51	0.032	0.019	0.9	0.4	0.32	0.09	1.4	1.2	4.31
Mean		**5.4**	**0.66**	**0.029**	**0.018**	**0.88**	**0.4**	**0.34**	**0.08**	**1.34**	**0.98**	**4.02**
CV		**2.27**	**42.33**	**34.93**	**31.18**	**9.51**	**35.36**	**9.90**	**34.30**	**12.49**	**20.91**	**7.50**

Hori= horizon, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, ECEC= effective cation exchange capacity, CV= coefficient of variation, < 15 =low variability, ≥ 15<35 = moderate variability, > 35 =high variability.

Table 5: Chemical properties of studied soils of fallow plot

Hori	Depth (cm)	pH(H_2O)	OC %	TN	Av.P (mg/kg)	Ca	Mg	Na	K cmol/kg	Al3+	H+	ECEC
					Summit							
A	0-14	5.3	2.04	0.058	0.08	0.9	0.5	0.45	0.15	1.8	1.5	5.30
AB	14-26	5.2	1.80	0.056	0.02	0.8	0.4	0.42	0.09	1.6	1.2	4.51
Bt_1	26-49	4.8	1.05	0.056	0.03	0.4	0.3	0.42	0.06	2.6	2.4	6.18
Bt_2	49-96	4.6	0.76	0.034	0.02	0.6	0.4	0.29	0.13	2.4	1.8	5.62
Bt_3	96-200	4.7	0.56	0.029	0.02	0.6	0.5	0.20	0.10	1.8	1.1	4.38
Mean		**4.92**	**1.24**	**0.047**	**0.03**	**0.66**	**0.42**	**0.36**	**0.11**	**2.04**	**1.6**	**5.20**
CV		**6.33**	**54.22**	**29.87**	**84.98**	**29.54**	**19.92**	**30.03**	**33.09**	**21.25**	**32.78**	**14.57**
					Midslope							
A	0-19	5.4	1.24	0.031	0.028	0.8	0.6	0.50	0.10	1.6	1.6	5.20
AB	19-31	5.6	1.13	0.028	0.026	0.6	0.6	0.20	0.06	1.6	1.0	4.06
Bt_1	31-59	5.3	0.67	0.028	0.031	0.6	0.5	0.42	0.13	1.6	1.2	4.45
Bt_2	59-112	5.0	0.54	0.046	0.018	0.6	0.4	0.29	0.13	1.2	1.6	4.22
Bt_3	112-200	4.6	0.43	0.025	0.008	0.5	0.2	0.20	0.11	0.9	1.4	3.29
Mean		**5.18**	**0.80**	**0.032**	**0.02**	**0.62**	**0.46**	**0.32**	**0.11**	**1.38**	**1.36**	**4.24**
CV		**7.53**	**45.12**	**26.34**	**41.82**	**17.67**	**36.38**	**41.69**	**27.18**	**23.14**	**19.17**	**16.24**
					Toeslope							
A	0-18	5.5	1.17	0.028	0.026	0.8	0.6	0.34	0.13	1.4	1.2	4.47
AB	18-29	5.3	0.84	0.056	0.023	0.8	0.8	0.34	0.08	1.2	1.6	4.82
Bt_1	29-60	5.4	0.64	0.045	0.023	0.7	0.6	0.28	0.06	0.8	1.6	4.04
Bt_2	60-121	5.1	0.54	0.051	0.030	0.6	0.6	0.32	0.11	1.6	1.2	4.43
Bt_3	121-200	4.7	0.46	0.039	0.028	0.8	0.7	0.26	0.09	1.2	1.2	4.25
Mean		**5.2**	**0.73**	**0.044**	**0.026**	**0.74**	**0.66**	**0.31**	**0.09**	**1.24**	**1.36**	**4.40**
CV		**6.08**	**38.91**	**24.87**	**11.86**	**12.09**	**13.55**	**11.80**	**28.74**	**23.92**	**16.12**	**6.57**

Hori= horizon, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, ECEC= effective cation exchange capacity, CV= coefficient of variation, < 15 =low variability, ≥ 15<35 = moderate variability, > 35 =high variability.

Table 6: Chemical properties of studied soils of mixed crop land-use

Hori	Depth (cm)	$pH(H_2O)$	OC	TN	Av.P (mg/kg)	Ca	Mg	Na	K	Al3+	H+	ECEC
			← % →			←			cmol/kg			→
						Summit						
A	0-16	5.5	0.88	0.056	0.026	1.0	0.6	0.39	0.13	1.6	1.2	4.92
AB	16-34	5.4	0.54	0.028	0.025	1.2	0.6	0.35	0.13	1.6	1.2	5.08
Bt_1	34-62	5.2	0.63	0.056	0.019	1.1	0.4	0.39	0.06	2.4	1.6	5.95
Bt_2	62-132	5.0	0.51	0.032	0.010	1.0	0.5	0.37	0.11	1.9	1.3	5.18
Bt_3	132-200	4.7	0.53	0.029	0.012	1.1	0.4	0.35	0.08	1.3	1.2	4.43
Mean		**5.16**	**0.62**	**0.04**	**0.018**	**1.08**	**0.50**	**0.37**	**0.10**	**1.3**	**1.76**	**5.11**
CV		**6.22**	**24.84**	**36.07**	**39.68**	**7.75**	**20**	**5.41**	**30.53**	**13.32**	**23.63**	**10.76**
						Midslope						
A	0-13	5.6	0.63	0.032	0.028	0.8	0.6	0.39	0.13	1.6	1.2	4.72
AB	13-21	5.6	0.59	0.014	0.02	1.0	0.6	0.34	0.06	1.6	1.6	5.20
Bt_1	21-68	5.4	0.49	0.056	0.018	0.8	0.4	0.39	0.06	2.4	1.2	5.25
Bt_2	68-127	5.1	0.25	0.022	0.025	0.9	0.5	0.35	0.08	1.9	1.4	5.13
Bt_3	127-200	4.8	0.18	0.019	0.011	1.0	0.4	0.36	0.06	1.6	1.2	4.62
Mean		**5.3**	**0.43**	**0.03**	**0.020**	**0.9**	**0.5**	**0.37**	**0.08**	**1.32**	**1.82**	**4.98**
CV		**6.54**	**47.32**	**58.28**	**32.26**	**11.11**	**20**	**6.29**	**38.89**	**13.55**	**19.19**	**5.86**
						Toeslope						
A	0-18	5.8	1.30	0.042	0.028	1.0	0.8	0.39	0.06	1.6	0.8	4.65
AB	18-35	5.7	0.59	0.042	0.021	0.8	0.6	0.34	0.06	1.2	1.2	4.20
Bt_1	35-71	5.7	0.63	0.056	0.025	1.0	0.4	0.34	0.13	1.6	1.2	4.67
Bt_2	71-118	5.4	0.63	0.045	0.025	0.9	0.6	0.36	0.08	1.5	1.1	4.54
Bt_3	118-200	5.6	0.57	0.042	0.021	0.9	0.6	0.37	0.09	1.5	0.9	4.36
Mean		**5.64**	**0.75**	**0.045**	**0.024**	**0.92**	**0.6**	**0.36**	**0.08**	**1.04**	**1.48**	**4.48**
CV		**2.69**	**41.06**	**13.36**	**12.50**	**9.09**	**23.57**	**5.89**	**34.30**	**17.47**	**11.10**	**4.48**

Hori= horizon, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, ECEC= effective cation exchange capacity, CV= coefficient of variation, < 15 = low variability, $\geq 15<35$ = moderate variability, > 35 =high variability.

Land-use in relation to soil properties distribution

The result (Table 7) indicated that sand fraction recorded 76.13 %, 76.60 % and 73.90 % for soils under cassava farm, fallow and mixed crop land-uses, respectively. Sand fraction had no significant difference ($p<0.05$) among soils under the studied land-uses. This could be attributed topedogenesis under similar parent material and climate. These findings are in conformity with the works of (Onweremadu *et al.* 2011; Obasi *et al.*, 2015) on soils under similar agro-ecology. High sand content is an indication of high infiltration and low bulk density which encourages leaching. Clay fraction recorded no significant difference ($p< 0.05$) among the soils of the studied land-uses. Silt fraction was high in soils under cassava farm (6.40 %) and mixed crop (6.40 %) land-uses when compared with the soils under fallow (5.60 %) land-use. Silt fraction of soils under fallow land-use differed significantly ($p< 0.05$) with that under cassava farm and mixed crop land-use. The result is in concurrence with the findings of Oleghe and Chokor (2014); Maduka *et al.* (2012) on soils of Southeastern Nigeria are low in silt as a result of the physically degraded, high degree and extent of weathering and leaching they have undergone. Soil texture has an important role in the assessment of soil characteristics. The uptake capacity of soil, which is an indicator of soil fertility, depends on the textural composition of the soil. Bulk density (Table 7) recorded 1.12 gcm^{-3}, 1.11 gcm^{-3} and 1.07 gcm^{-3} for soils under cassava farm, fallow and mixed crop land-uses.

The ANOVA (Table 7) indicated that bulk density differed significantly ($p< 0.05$) among studied land-uses. The bulk density is below the critical limit (1.75 - 1.85 gcm^{-3}) for root penetration as recommended by SSS, (2006). However, Esu (2010) reported that value of bulk density less than 1.60 $gcm^{-3}$is an indication that air and water movement in the soils are optimum for plant growth. The low bulk density indicated that the soils were not compacted as reported in the work of Esu and Ojanuga (1986) on soils of southeastern Nigeria.

The pH(H_2O) (Table 8) was moderately – strongly acidic for soils across the studied land-uses. The acidic nature was determined by the ratings of Chude *et al.* (2011). pH(H_2O) of soils under mixed crop land-use differed significantly with soils under fallow land-use and had no significant difference ($p< 0.05$) with soils under cassava farm land-use. Also, there was no significant difference ($p< 0.05$) between soils under cassava farm and fallow land-uses. The moderately – strongly acidic soil reaction is characteristic of soils of southeastern Nigeria and it is the consequence of the acidic nature of the parent rocks, coupled with the influence of the leached profile under high annual rainfall condition (Eshett *et al*. 1990). Organic carbon content of soil under fallow land (0.93 %) was high when compared with those of cassava farm (0.77 %) and mixed crop (0.60 %) land-uses. Generally, OC of the studied soils under the land-uses were low according to the ratings of Landon (1991) and Enwezor (1990). Organic carbon of soils under fallow land-use differed significantly with soils under mixed crop land-use and had no significant difference with soils under cassava farm land-use. Also, OC content differed non-significantly between cassava farm land and mixed crop land-uses. The OC content availability is dependent on organic material deposit, rate of decomposition and mineralization and plant nutrient uptake. Total nitrogen recorded an increasing order of 0.038 % < 0.041 % < 0.043 % for soils under mixed crop, fallow and cassava farm land-uses, respectively. Total nitrogen content of the studied soils was low when compared with the ratings of Landon, (1991) and Chude *et al.* (2011).

Table 7: Mean variation of soil properties of the studied land-uses

Land-use	Sand	Clay	Silt	SCR	BD	Po
	⟶	%	⟵		(g/cm³)	(%)
Cassava farm	76.13	17.47	6.40	0.38	1.12	59.76
Fallow land	76.60	18.07	5.60	0.32	1.11	58.32
Mixed crop	73.90	19.67	6.40	0.35	1.07	60.90
$LSD_{(0.05)}$	**3.253**	**2.79**	**1.306**	**0.0820**	**0.0605**	**2.936**

SCR= silt clay ratio, BD= bulk density

Total nitrogen (Table 8) recorded no-significant difference ($p< 0.05$) among the soils under the land-uses. This could be associated with the climatic condition of the study area which influences leaching and high mineralization. Low TN content is a common phenomenon in the soils of Southeastern Nigeria which is a result of high nitrogen losses occurring in these soils through the leaching of nitrates, as well as the rapid mineralization of organic matter under the isohyperthermic soil temperature regime (Eshett, 1987; Eshett *et al.*, 1990). Available phosphorus of soils under fallow (0.027 $mgkg^{-1}$) was high when compared with that of cassava farm (0.019 $mgkg^{-1}$) and mixed crop (0.021 $mgkg^{-1}$) land-uses. Generally, available phosphorus of the studied soils was low when compared with ratings of Enwezor (1990) and Chude *et al*. (2011). The low available phosphorus level uncounted in the study area collaborate with the findings of Eshett (1987) who remarked that most Nigerian soils have low phosphate reserves due to high P fixation. The TEB as indicated in Table 7 was high for soils under mixed crop (1.95 $cmolkg^{-1}$) land-use over other land-uses. The TEB of soils under mixed crop land-use differed significantly with that of soils under cassava farm and fallow land-uses. However, no significant difference ($p< 0.05$) was recorded between cassava farm and fallow land-uses. The difference in TEB could be attributed to leaching, runoff and plant uptake. This agreed with the finding of Uzoho *et al.* (2007) on soils of southeastern Nigeria.

Landscape position in relation to soil properties distribution

The result (Table 9) indicated that the toeslope had more sand fraction (77.93 %) when compared with the summit (74.40 %) and midslope (74.33 %). This could be associated to sand transportation and deposition at the toeslope which had been earlier reported by Brady and Weil, (1999) on soils along a slope. The ANOVA showed that sand fraction had no significant difference ($p< 0.05$) among the studied landscape positions. This could be attributed to homogeneity of the soil which resulted from the underlain parent material climate of the study area. Silt fraction had no significant difference ($p< 0.05$) among the studied landscape positions which could be associated to low silt content of most tropical soil. This is in conformity with the finding of Aweto and Enaruvbe, (2010) in tropical soils. The percent clay was 19.87 %, 19.27 % and 16.07 % for pedons on the summit, midslope and toeslope, respectively. This distribution might be due to downward movement of clay particles as a result of the action of erosion, transportation and deposition into the water body. Noma *et al.* (2011) also reported similar results. This is also in agreement with the findings of (Brady and Weil, 1999; Aweto and Enaruvbe, 2010; Udoh *et al.*, 2010). The far transportation and deposition of clay is due to its density. Clay had no significant difference ($p< 0.05$) among the landscape positions which could be attributed as homogeneity of the studied soils. This is in conformity with the findings of Ahukaemere *et al.* (2014) on soils of southeastern Nigeria. The mean comparison indicated that bulk density was high at the toeslope (1.13 gcm^{-3}) when compared with that of the summit (1.10 gcm^{-3}) and midslope (1.60 gcm^{-3}). Bulk density differed non-significantly ($p< 0.05$) among the studied landscape positions. However, the variation of bulk density among the landscape positions could be associated with tillage practice and level of organic matter and clay content despite the no significant difference recorded.

Table 8: Mean variation of soil chemical properties of the studied land-uses

Landuses	pH(H_2O)	OC	TN	Av.P	TEB	Al^{3+}	H^+	ECEC
		% →	←	(mg/kg)	→	cmol/kg	←	
Cassava farm	5.22	0.77	0.043	0.019	1.65	1.50	1.03	4.16
Fallow land	5.10	0.93	0.041	0.027	1.62	1.55	1.44	4.62
Mixed crop	5.37	0.60	0.038	0.021	1.95	1.22	1.69	4.62
$LSD_{(0.05)}$	**0.2051**	**0.2663**	**0.00947**	**0.0081**	**0.1562**	**0.2343**	**0.2437**	**0.4278**

OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEB= total exchangeable bases, ECEC= effective cation exchange capacity

Soil pH(H_2O) were acidic (5.18 – 5.40) in all the landscape positions which agreed with the works of (Ahukaemere *et al.,* 2014; Osujieke*et al.,* 2016) on tropical soils. The summit was most acidic and could be associated with washing off of the basic cations and depositing them on the other landscape positions. This is in concurrence with the work of (Sarkar *et al.,* 2001) on soils along a slope. pH(H_2O) had no significant difference among the landscape positions which is an indication that landscape had no influence on pH of soil. Organic carbon content was low according to ratings of Enwezor, (1990) and Chude *et al.* (2011). The summit (0.92 %) had high OC content over the midslope (0.66 %) and toeslope (0.71 %). The ANOVA result showed that organic carbon had no significant difference ($p< 0.05$) among the soils of the landscape positions.

The difference in OC among the landscape positions could be associated with the level of organic matter deposit and microclimate of the area. Soil texture has a strong influence on soils' ability to store and accrue soil organic carbon (Gili *et al*., 2010) but its distribution reflects a combination of soil physical properties, biomass inputs as well as decomposition rates which are a function of climatic conditions (Angers and Eriksen-Hamel, 2008).

Total nitrogen content was high on the summit when compared with other landscape positions which could be attributed to the rate of organic matter mineralization and erosion (runoff) on the surface horizon. The pedons of summit and toeslope have same available phosphorus (0.023 $mgkg^{-1}$) content while, the midslope recorded 0.020 $mgkg^{-1}$. The value of Av.P across the landscape positions was low when compared with the ratings (< 5 mgkg-1) of Landon, (1991). Av.P had no significant difference among studied pedons of the landscape positions which could be associated with homogeneity of the soils of the study site. This agreed with the works of (Ahukaemere *et al.,* 2014; Aweto and Iyamah, 1993) on soils across a landscape. The low level of Av.P across the landscape positions could be associated to fixation as either Al or Fe phosphate. The result indicated that the toeslope (1.82 $cmolkg^{-1}$) recorded high level of TEB when compared with that of summit (1.74 $cmolkg^{-1}$) and midslope (1.67 $cmolkg^{-1}$). The TEB at the toeslope pedon could be associated to deposition of more basic cations from the upper landscape positions. Effective cation exchange capacity had no significant difference among pedons under the landscape positions which could have resulted from forms and availability of basic and acidic cations. The ECEC was low according to the rating of Landon (1991) which could be attributed to the fact that soils in this region are strongly weathered, have little or no content of weathered materials in sand and silt fractions and have predominantly kaolinitic in their clay fractions. This finding is also in agreement with that of Korieocha *et al.* (2010) who worked on inland valley soils of Southeastern Nigeria and observed low ECEC.

Table 9: Means variation of soil properties of the studied landscape positions

Landscape Positions	Sand →	Silt % ←	Clay	BD (g/kg)	Po (%)	pH(H_2O)	OC →	TN % ←	Av.P (mg/kg)	TEB	Al^{3+} →	H^+ cmol/kg	ECEC ←
	77.8	6	17	1.09	58.79	4.92	1.24	0.047	0.03	1.55	2.04	1.6	5.19
Summit	71.8	6	22.2	1.09	62.32	5.16	0.62	0.04	0.018	2.05	1.3	1.76	5.11
	73.6	6	20.4	1.11	57.96	5.12	0.90	0.052	0.021	1.61	1.74	1.28	4.63
Mean	**74.40**	**6**	**19.87**	**1.10**	**59.69**	**5.07**	**0.92**	**0.046**	**0.023**	**1.74**	**1.69**	**1.55**	**4.98**
	74.6	5.6	19.8	1.09	58.79	5.18	0.8	0.032	0.02	1.51	1.38	1.36	4.25
Midslope	72.2	6.8	21	1.01	61.74	5.3	0.43	0.03	0.02	1.85	1.32	1.82	4.99
	76.2	6.8	17	1.08	59.4	5.14	0.75	0.048	0.02	1.64	1.40	0.84	3.88
Mean	**74.33**	**6.4**	**19.27**	**1.06**	**59.98**	**5.21**	**0.66**	**0.037**	**0.02**	**1.67**	**1.37**	**1.34**	**4.37**
	77.4	5.2	17.4	1.13	57.36	5.2	0.73	0.044	0.026	1.8	1.24	1.36	4.4
Toeslope	77.8	6.4	15.8	1.10	58.64	5.64	0.75	0.045	0.024	1.96	1.04	1.48	4.48
	78.6	6.4	15	1.17	55.92	5.4	0.66	0.029	0.018	1.7	1.34	0.98	4.02
Mean	**77.93**	**6**	**16.07**	**1.13**	**57.31**	**5.4**	**0.71**	**0.039**	**0.023**	**1.82**	**1.21**	**1.27**	**4.30**
$LSD_{(0.05)}$	**5.23**	**0.799**	**5.33**	**0.082**	**3.191**	**0.382**	**0.395**	**0.019**	**0.007**	**0.021**	**0.581**	**0.369**	**0.837**

BD= bulk density, Po= porosity, OC= organic carbon, TN= total nitrogen, Av.P= available phosphorus, TEB= total exchangeable bases, ECEC= effective cation exchange capacity

Conclusion

This study assessed the effects of soil depth, land-use and landscape position on soil properties distributions. Most soil properties had an irregular pattern of decrease or increase in most of the pedons. However, sand fraction, bulk density and pH(H_2O) recorded low variation while OC, TN and AP recorded moderate - high variations in most of the pedons. No significant differences among land-uses were found for most soil properties. Sand fraction, clay fraction, bulk density, organic carbon and AP contents recorded higher levels in soils under fallow land than those in cassava farm and mixed crop land-use. The soil under the studied land-uses was generally acidic. The summit of the landscape position recorded higher levels in clay fraction, OC, TN and ECEC over the midslope and toeslope. Also, the toeslope had higher levels in sand fraction, bulk density and TEB. However, summit is the most acidic of the landscape positions. The result will provide useful information which will help farmers and other land-users to know the nutrient status and to overcome soil constraints for further development, maintenance and sustenance of soil along the slope in Eziama and its environ in better way. It will also aid in pedotranfer technology to other areas with similar features.

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