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Sustainability of Crop Production in Relation to Landscape position and Soil properties in Isiama, Abia State.

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ABSTRACT

The research was carried out at Isiama in Umuahia North Local Government Area of Abia State, Nigeria to examine the relationship between landscape positions and some selected soil properties. The soil units studied occupied different landscape positions and were identified as the summit (EJ-1), upper (EJ-2), middle (EJ-3) and foot (EJ-4) slope classes; on 3%, 7%, 2.5% and 1% slopes respectively. One representative profile pit was established in each soil unit and described *in situ* for morphological attributes. Soil samples collected from identified horizons of the pits were analyzed for some physical and chemical properties. The study revealed variability in some of soil quality indicators (organic carbon, total nitrogen, pH, exchangeable bases, cation exchange capacity etc,) with different slope positions. The trend of the values of the soil quality indicators followed this order: EJ-2 < EJ-1 < EJ-3 <EJ-4. The thickness of A-horizon of EJ-2 was shallow (7 cm) compared with that of EJ-1 (18 cm), EJ-3 (20 cm) and EP-15 (25 cm) attributable to relative sloping nature of the unit. Soils of upland positions were bright in colour and had good drainage condition whereas; the gray colour observed in the foot-slope position was attributed to the poor drainage condition of the unit. Higher bulk density was observed under the upper slope compared to other slope positions. Therefore, the variability of soil properties across the different slope positions on the landscape would require different management practices to ensure sustainable crop production and environmental protection in the area.

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1.0 Introduction

Information on soil-slope relationship on a landscape has been relevant in pedological investigations into soil types of any geographical area. The several attempts made to relate soil properties to landscape positions for many landscapes may be partly due to the realization of the role topographic position plays in influencing runoff, soil erosion and hence soil formation (Annan-Afful *et al*., 2005; Babalola *et al*., 2007). Landscapes position influences run off, drainage and soil erosion, hence soil genesis is affected. Landscapes with different slope positions have been reported to greatly influence soil properties and pattern of crop production (Esu *et al*., 2014; Ojetade *et al*., 2014; Fasina, *et al., 2015*; Adesemuyi, *et al*., 2019).

In Nigeria, many works on relationship between landscape positions and soil properties were documented . For instance, Lawal, *et al.* (2013) deduced that nutrient status and soil properties are related to topography of the land area. Also, Osodeke, *et al.* (2005) reported differences in quantity and forms of sesquioxides as influenced by geomorphic positions. They also observed that the soils of the profiles at higher slopes were dominated by the crystalline forms of iron (Fe) and aluminum (Al) -oxides while the soils of the valley bottom were dominated by the amorphous forms of Fe and Al.

Changes in altitudinal gradients have also been reported to influence soil organic matter by controlling soil water balance, soil erosion, geologic deposition processes, species and biomass production of the native vegetation and cultivated plants (Tan *et al.,* 2004; Shazia, *et al.* 2014). Lekwa, *et al*. (2004) reiterated that soil characterization provides the basic information necessary to create functional soil classification schemes and assess soil fertility in order to unravel some unique soil problems in an ecosystem.

Understanding the dynamics and distribution of the soil properties as influenced by slope positions on a landscape is critical for assessing the effect of future land use changes on soil use and management. Therefore, the study was conducted to examine the relationship between landscape positions and some selected soil properties with the aim of generating adequate data for modeling landscape relationships and to aid both researchers and farmers in taking critical management decisions.

2.0 Materials and Methods

2.1 Study site characteristics

The study site was a selected toposequence in Isiama, Umuahia North Local Government Area of Abia State. The area is located in the low land rainforest zone of Nigeria which lies between Latitudes 5° 29' –5° 42' N and Longitudes 7° 29' –7° 33' E. The area has an average annual rainfall of 2,238 mm distributed over seven months in the rainy season (NIMET, 2020). Annual air temperatures range between 23° C and 32° C and a relative humidity of 60 - 80 % (NIMET, 2020). The vegetation of the study area is typical of the forest belt of Nigeria. The native vegetation has almost completely been replaced by secondary forest of wild oil palm trees of various densities of coverage rubber as well as woody shrubs and various grasses that form the under growth. Land use comprises mainly arable crops with varying fallow period. The fallow system is also used as a means of fertility orientation techniques. The area is underlain by one main geological formation, the coastal plain sands, comprising largely unconsolidated sands (Lekwa, 2002).

2.2 Methodology

A transect was used to link all landscape positions and observations of changes in physiographic features made for the stratification of the landscape into summit (EJ-1), upper slope (EJ-2), middle slope (EJ-3) and the foot slope (EJ-4) segments. Four profile pits were excavated, one in each of the slope segments identified (fig . 1). The pits representing EJ-1 EJ-4 were located on 3 %, 7 %, 2.5 % and 1 % slopes respectively. The soil profile pits were examined, horizonated and described *in situ* for their morphological attributes such as colour, texture, consistence, structure and slope; following the Guidelines for Field Soil Descriptions (FAO, 2006) and using the Munsell chart to identify soil colours. Disturbed and undisturbed (core) soil samples were collected from identified horizons from the bottom of the profile upward (to avoid cross contamination of the soil samples) and analyzed in the laboratory for their physical and chemical properties.

2.3 Laboratory analyzes

The soil samples taken from the identified horizons of the profile pits were air-dried, crushed and passed through a 2 mm sieve. Particle size analysis was determined according to the hydrometer method of Bouyoucous (1962). Soil pH was determined (H_2O and KCl) at 1:1 soil solution ratio using a glass electrode pH meter. Organic carbon was determined from the sieved soil samples (further passed through 0.5 mm sieves) by the dichromate wet oxidation method (Udo, *et al*., 2009). Total nitrogen was determined on samples (also passed through 0.5 mm sieve) by the regular mico-Kjeldahl method as described by Bremner (1996). Available phosphorus was extracted with Bray number II solution of HF and HCl and the P in the extract determined spectrophotometrically. Data were interpreted based on methods described by Chude, *et al*. (2011) and Hazelton and Murphy (2011).

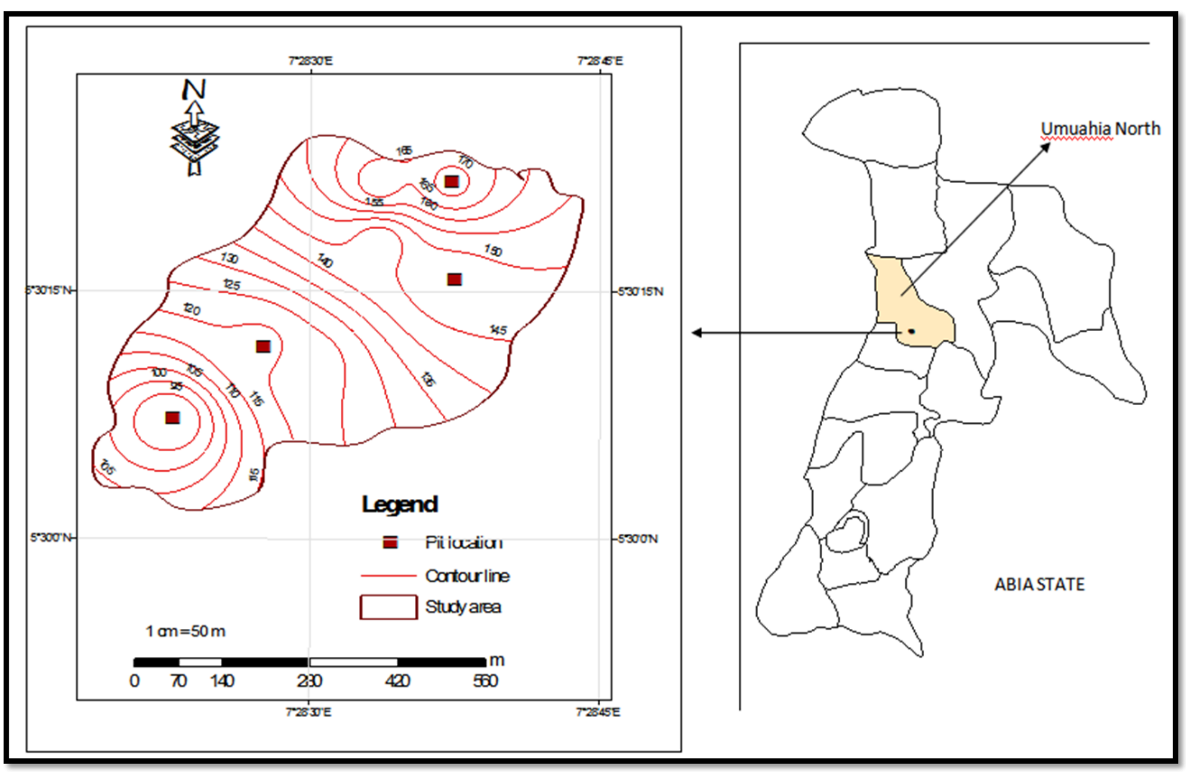

Fig. 1: Location map of the study area

3.0 Results and Discussion

3.1. Site characteristics of the landscape positions

The site characteristics of the soil units indicated differences in slope positions on the landscape. The soil units are identified as the summit (EJ-1), upper (EJ-2), middle (EJ-3) and foot (EJ-4) classes, having slopes of 3 %, 7 %, 2.5 % and 1 % respectively. The summit, upper and middle slope classes were found to be well drained, whereas the foot slope position was poorly drained. Evidence of rills and few gullies observed at the sites is an indication of the susceptibility of the soils to water erosion. Soil units EJ-2 showed signs of accelerated water erosion as evidenced by gullies on the surrounding landscape, while EJ-1 EJ-3 and EP-4 had moderate and slight water erosion, respectively. The observed well-drained condition and water erosion on EJ-1, EJ-2 and EJ-3 could be attributed their relatively higher positions on the landscape resulting to subsequent down slope movement of water, in response to gravitational force. The results are similar to topographic impact of soil quality through direct soil and water movement as well as indirect profile development documented (Shazia, *et al.* 2014).

Table 1: Site characteristics of the landscape positions.

Slope position (Pedons)	Geographic position Latitude (N)	Longitude (E)	Altitude (m)	Slope (%)	Drainage	Land use	Parent material
EJ-1	5° 30' 21.3"	7° 28' 37.2"	172	3	WD	Cassava/Oil palm	CPS
EJ-2	5° 30' 14.4"	7° 28' 37.6"	148	7	WD	Grassland	CPS
EJ-3	5° 30' 10.8"	5° 28' 27.4"	118	2.5	WD	Cassava/fallow	CPS
EJ-4	5° 30' 7.2"	5° 28' 22.8"	90	1	PD	Forest land	CPS

Key: WD = well drained, PD = poorly drained, CPS = coastal plain sands

3.2. Morphological and Physical Characteristics

Selected morphological and physical properties across the different slope positions in the study site are presented in Table 2. Variations were observed in the thicknesses of the horizons across the slops positions. For instance, the thickness of A-horizon of EJ-2 was shallow (7 cm) compared with that of EJ-1 (18 cm), EJ-3 (20 cm) and EP-15 (25 cm) (Table 2). This may be attributed to relative steepness of the slope, which is very important in influencing the rate at which water flows into or off the land. The running water may continue to erode the soils on the slope and form thinner surface layer, if unprotected. Surface layers of soils on sloping land have been reported to be less deeply weathered because the surface soil is consistently under the influence of erosion (Olatunji, *et al*., 2007). On the other hand, the increment in the thickness of A- horizon down the slope can be attributed to soil deposition at the lower landscape positions corroborating the previous findings (Mulugeta and Sheleme, 2010; Sheleme, 2011; Adesemuyi, *et al*., 2019).

The surface horizons ranged in colour from dark reddish brown (5YR 3/2) in EJ-1 and EJ-3 to grayish brown (10YR 5/2) in EJ-4. The light-colour (5YR 6/3) of EJ-2 could be attributed to low organic matter content, consequent upon the sloping effect on the rates of surface runoff and erosion. The finding is corroborated by the previous reports that thinner, light-coloured and low-organic matter soils are associated with intensely eroded landscape (Sheleme, 2011; Dinku, *et* al., 2014; Adesemuyi, *et al*., 2019). The gray colour observed in the foot-slope position (EJ-4) could be attributed to the poor drainage condition of the unit (Mulugeta and Sheleme, 2010; Lawal *et al*., 2013). B-horizons were characterized by various shades of reddish brown (5YR 4/4) and yellowish red (5YR 5/6) colours.

The surface soil was weak and crumb-structured. Absence of cracks on the surfaces of the units probably inferred that the soils have non-expanding clay minerals e.g. kaolinite in them Alhassan, *et* al. (2012). The moist consistence of the surface soil remained friable, whereas the sub-surface soils exhibited firm and sticky/plastic consistence under moist and wet conditions respectively. The overall consistence showed that the soils would be workable at appropriate moisture content. More so, the absence of very sticky and very plastic consistence, despite relatively high clay content indicated that smectite clay mineral, known to control the plasticity in the soils are not dominant in the landscape.

The texture was sandy loam at the surfaces of EJ-1 and EJ-4 overlaying the subsurface sandy clay loam and sandy clay whereas, EJ-2 and EJ-3 had sandy clay loam surfaces underlain by sandy clay and clay. The trend of silt content in the surface horizon was EJ-1 < EJ-2 < EJ-3 <EJ-4. It was observed that EJ-4 had the highest amount of silt with average value of 137g kg^{-1} which may be linked to the colluvial material received from upper slopes (EJ-1, EJ-2 and EJ-3). Clay was higher in the subsurface than surface horizons. There was a progression in its distribution within the subsoil across the slope positions, characteristic of an argillic horizon, a marked eluviation-illuviation pedogenic process. The average silt/clay ratio was 0.40, 0.29, 0.25 and 0.80 respectively for EJ-1, EJ-2, EJ-3 and EJ-4. The silt/clay ratio is above 0.25, an indication that the soils are relatively young probably indicating that these soils still have weatherable minerals in them (Lawal *et al*., 2013).

Bulk density values ranged between 0.91 and 1.62 gcm^{-3}. These are within the acceptable values (1.0 - 1.6 mgm^{-3}) for agronomic activities in most mineral soils (Chude *et al.*, 2011; Chaudhari *et al*., 2013). The relatively higher bulk density observed under the upper slope position (EJ-2) compared to other slope positions (EJ-1, EJ-3 and EJ-4) may be attributed to the mechanical disruption of the pore arrangements by erosion (Olatunji, *et* al., 2007; Sakin *et al*., 2011). The lower bulk density generally recorded in the topsoil was as a result of the influence of organic matter on soil bulk density causing less soil compaction and its increase down the pedal depth could be attributed to a decrease in organic matter ((Oguike and Mbagwu, 2009). The total porosity ranged from 39.24 -65.66 mgm-3 and decreased with profile depth. Pravin, *et al* (2013) reported that over 50 % total porosity is ideal for soils; between 45 – 50 % satisfactory; 40 - 45 unsatisfactory; while 40 % and below are poor.

Table 2: Morphological and physical properties of the soils at different slope positions

Slope Position	Horizon	Depth (cm)	Colour (moist)	Structure	Consistence moist	wet	Sand	Silt $g\ kg^{-1}$	Clay	T/ Class	Silt/ clay	BD mgm^{-3}	TP (%)
Summit	Ap	0-18	5YR 3/2	1CCr	vfr	ns-np	761.00	111.00	128.00	SL	0.87	1.31	50.56
(EJ-1)	Bt1	20-48	5YR 5/4	2CCr	Fr	ss-np	643.00	105.00	252.00	SCL	0.42	1.46	44.90
	Bt2	48-76	2.5YR 4/6	2MSbk	Fm	ss-np	524.00	56.00	420.00	SC	0.13	1.59	40.00
	BC	76-162	5YR 4/4	2MSbk	Fm	ss-sp	416.00	80.00	504.00	C	0.16	1.61	39.86
Upper	Ap	0-7	5YR 6/3	3CCr	Fr	ss-np	672.00	101.00	227.00	SCL	0.44	1.46	44.90
(EJ-2)	Bt1	7-34	2.5YR 4/8	1MSbk	Fm	ss-np	582.00	100.00	318.00	SCL	0.31	1.42	46.41
	Bt2	34-66	2.5YR 4/6	2MSbk	Fm	ss-np	496.00	100.00	404.00	SC	0.25	1.44	45.66
	BC	66-158	5YR 5/6	3MSbk	Fm	s-sp	286.00	92.00	622.00	C	0.15	1.62	39.24
Middle	Ap	0–20	5YR 3/2	2CCr	Fr	ns-np	642.00	104.00	254.00	SCL	0.41	1.38	47.92
(EJ-3)	Bt1	20-68	5YR 4/4	2MSbk	Fm	ss-np	465.00	103.00	432.00	SC	0.24	1.42	46.41
	Bt2	68-77	5YR 6/6	3MSbk	Fm	ss-sp	396.00	100.00	504.00	C	0.20	1.44	45.66
	BC	77-140	5YR 7/8	3MSbk	Fm	ss-sp	246.00	92.00	662.00	C	0.14	1.59	40.00
Lower	Ap	0-25	10YR 4/2	1CCr	Fr	ns-np	704.00	164.00	132.00	SL	1.24	0.91	65.66
EJ-4)	Bg	25-49	10YR 5/2	2CCr	Fr	ss-np	716.00	112.00	172.00	SL	0.65	1.49	43.77
	Btg	49-68	10 YR 6/3	2MSbk	Fm	s-sp	601.00	135.00	264.00	SCL	0.51	1.24	53.20

Key: ***Texture*** **(T):** SL=sandy loam, SCL=sandy clay loam, SC=sandy clay, C=clay; ***Structure***: 1=Weak, 2=Moderate, 3=Strong. M=Medium, C=Coarse. Cr=Crumb, Sbk=Sub-angular blocky.***Consistence***: Fr = friable, Fm = firm, vfr = very friable, ns=non sticky, np=non plastic, ss=slightly sticky, s=sticky, sp=slightly plastic.

3.3 Chemical properties of the soils across the slope positions

Soil pH (H_2O) surface horizons across the slope positions ranged between strongly (5.1) to slightly (6.3) acid while the sub-surface horizons varied from very strongly (4.7) to strongly (5.4) soil acid reaction. The acidic nature of the sub-surface soils of the site may be attributed to the nature of the parent material (Nnaji, *et al*., 2002). Lower pH value was recorded on sloping soil unit (i.e., EJ-2) as compared to gentle slopes (i.e., EJ-1, EJ-3 and EJ-4), which could be attributed to the relatively high erosion of exchangeable bases from steep slopes. Soil pH values increased down the slope indicating that the prevalence of acidity at the upper slopes is attributable to strong chemical weathering and washing away of plants nutrients as reported by Babalola, *et al*. (2007). This was corroborated by Onweremadu (2007) that increased pH at foot slopes accounts for high total nitrogen, cation exchange capacity and organic matter. This means soils at foot slopes have high capacity for supporting crop growth compared to other slope positions. The exchange complex of the soils was dominated by Ca followed by Mg, K and Na (Table 3). The decreasing trend of the status of organic carbon, total nitrogen as well as available phosphorus in the soil units with depth may be consequent upon root activities which concentrated in the surface soils. The organic carbon content varied across the different slope positions. The values were low (1.02 %) in EJ-2 and high (> 2.0) in the other soil units. The low organic carbon of EJ-2 is attributed to its steep nature thus; this makes the soil unit vulnerable to water erosion. Similarly, Dinku, *et al*. (2014) reported that an organic carbon content of less than 1.16 % for tropical soils is an indication of soil degradation involving a highly raised risk of soil erosion.

Table 3: Chemical properties of the soils at different slope positions

Slope Position	Horizon	Depth	pH		OC	TN	Av.P	Exchangeable bases				EA	CEC	BS (%)
								Ca^{2+}	Mg^{2+}	K^{+}	Na^{+} (cmolgkg^{-1})			
Position		(cm)	(H_2O)	(KCl)	%	%	(mgkg^{-1})	(cmolgkg^{-1})						
Summit (EJ-1)	Ap	0-18	5.60	4.80	2.03	0.21	22.40	8.80	4.80	0.39	0.33	1.22	15.55	92.15
	Bt1	20-48	5.40	4.50	0.98	0.15	17.00	5.00	2.80	0.21	0.19	1.36	9.55	85.75
	Bt2	48-76	5.00	4.10	0.57	0.06	15.40	5.20	2.00	0.21	0.16	1.48	9.10	83.73
	BC	76-162	5.20	4.10	0.49	0.05	14.20	4.20	1.20	0.17	0.16	1.60	7.34	78.20
Upper (EJ-2)	Ap	0-7	5.10	4.30	1.02	0.13	20.20	7.40	5.60	0.31	0.29	1.28	10.88	87.36
	Bt1	7-34	4.90	3.90	0.69	0.11	19.30	5.60	3.20	0.31	0.29	1.42	10.82	86.87
	Bt2	34-66	4.60	3.60	0.58	0.07	12.40	4.10	1.60	0.20	0.18	1.68	7.76	78.35
	BC	66-158	4.70	3.70	0.54	0.04	13.70	4.40	1.60	0.18	0.16	1.68	8.02	79.05
Middle (EJ-3)	Ap	0-20	5.80	4.60	2.15	0.18	27.40	8.80	4.80	0.48	0.41	0.72	15.21	95.26
	Bt1	20-68	5.40	4.10	1.06	0.12	19.54	5.20	2.00	0.21	0.16	1.48	9.10	83.73
	Bt2	68-77	5.00	4.10	0.91	0.06	19.32	5.00	2.80	0.21	0.19	1.36	9.55	85.75
	BC	77-140	4.70	3.70	0.64	0.06	17.77	4.20	1.20	0.17	0.16	1.60	7.34	78.20
Lower EJ-4)	Ap	0-25	6.30	5.00	3.44	0.48	34.80	12.80	7.10	0.59	0.47	0.88	21.84	95.97
	Bg1	25-49	5.40	4.60	2.56	0.28	23.50	8.80	4.80	0.48	0.41	0.72	15.21	95.26
	Bg2	49-68	5.10	4.00	1.86	0.17	20.10	6.80	3.40	0.41	0.37	1.24	12.22	89.85

Key: OC=Organic carbon; TN=Total nitrogen; Av. P=Available phosphorus; CEC=cation exchange capacity; BS=base saturation

4.0 Conclusion

The study assessed the **r**elationship between landscape positions and selected soil properties in Isiama, Umuahia Area of Abia State, Nigeria for sustainable crop production. Topography has been found as the major landscape feature controlling the development and characteristics of soils in the area. The soil units, located on topographic gradient of the summit, upper, middle and foot slope classes, showed variability in some of soil quality indicators such as organic carbon, total nitrogen, pH and exchangeable bases. The aforementioned values of soil quality indicators increased with this order: EJ-4 > EJ-3 >EJ-1 >EJ-2. Topography has also influenced site characteristics. The colour the upland soils were dark reddish brown and bright compared to the foot slope soils which were dark reddish gray and dull. Soil drainage condition deteriorated from the summit to the foot slope positions.

The variability of soil properties across the different slope positions on the landscape would require different management practices such as liming, organic manuring, cover cropping, terracing and adequate drainage to ensure sustainable crop production and environmental protection in the area

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