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Effect of Slope Positions on Properties of Soils of some Forest reserves in South-West Nigeria

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ABSTRACT

Topography has an influence on soil erosion and consequently on the properties of soils. The effect of slope position on soil properties is of great importance in soil suitability assessment. This study assessed the effect of topographic position on the characteristics of soil of basement complex rocks derived soils under Teak (*Tectona grandis*) and Gmelina (*Gmelina arborea*) plantations in Osun sacred grove, Onigambari and Omo forest reserves situated within South-West Nigeria. Three soil profiles were dug in each landuse type, sited at the upper, middle and lower slope positions along a toposequence. Soil samples were collected according to their pedogenetic horizons and were analyzed using standard methods. Results showed variations in colour, depth of soil profile, soil structure, texture, drainage and soil consistence. The high sand content dominated the particle size fraction in all the soils formed from the three locations, and base saturation was rated very high with values >90% irrespective of the toposequence or slope position. The result of correlation analysis between slope position and content of N, P, K and CEC showed a significant relationship irrespective of locations with N($r = 0.019<0.05$), P ($r = 0.041<0.05$), K($r = 0.033<0.05$) and CEC($r =0.025< 0.05$) respectively. Despite variation in soil properties as influenced by topography, the studied soils can sustain the current land use type. It was concluded that soils on different topographic positions should be managed differently.

1.0. Introduction

The relative impact of factors of soil formation on the characterization of soil varied from one location to another. Thus, in an undulating area, the impact of topography on soil formation is expected to be more than in an area with flat or gentle slope land (Aruleba, 2011).

The properties of soils are a result of the interaction among the soil-forming factors and processes, hence, making soil to be heterogeneous. As a factor of soil formation, topography, for instance, may hasten or delay the work of climatic factors. It influences soil morphological, chemical and physical properties and affects the pattern of soil distribution over landscape even when the soils are derived from the same parent material (Ogunkunle, 1993). Studies have shown that the extent of variability in soil properties may be significant even for a simple change in topography. Consequently, soils on hill slopes exhibit a remarkable difference in properties from those on the summits because of percolating water which tends to move laterally across a profile instead of vertically. According to Reynolds, 1993, water velocity on a slope affect the deposition of materials in suspension. Sand drops out of suspension first, while clay size particles can be carried further away from the base of the slope before they are deposited. This kind of geological sorting brings about variation in the soil in relation to landscape (Lawal *et al*., 2014). They affirmed that topography had an effect on the soil colour and particle size distribution of the soils, especially on the surface horizon.

Soil profile variation, therefore, occurs due to land form processes of transformation and deposition. These have resulted from non-uniformity and discontinuity in parent materials; such additions (deposition) include volcanic ash, loess or variations in the sedimentation conditions of alluvial materials and colluviums (Ahn, 1970).

Smyth and Montgomery (1962) reported that on a landscape shoulder, the soil properties reflect a combination of characteristics inherited during the erosional evolution of the landscape. This is as a result of pedologic processes acting on the present surface. The relative importance of these processes was considered to vary within the same landscape segments because different soil types have been noticed to be associated with different parts of the landscape. Ojo-Atere *et al*. (1988) reported that in upper slope soils, the surface horizons may be developed from transported materials while the subsurface horizons may be derived from underlying rock.

Pedogenic processes operate simultaneously at varying rates. All pedogenic processes appear to operate to some degree in all soils. However, they operate at different rates at different times, and the dominant processes in any one soil body cause it to develop distinctive properties (Ojo Atere *et al*., 2012).

The studied areas were developed from basement complex rocks of South-West, Nigeria. Some have impervious subsurface horizons due to plinthization processes been observed, and the plinthite do limit vertical water flow and encourage the horizontal flow of water in soils which may affect the distribution of soil properties in a predominantly rolling landscape of these studied sites. Therefore, this study was undertaken to assess the effect of slope position on morphological, physical and chemical properties of soils of a toposequence under a teak (*Tectona grandis*) and Gmelina (*Gmelina arborea*) plantation in Osun sacred grove, Onigambari and Omo forest reserves.

2.0. Materials and methods

2.1. Study area

The research was carried out at the forest Reserves in Ogun, Osun and Oyo States. The forest reserves include: Omo Forest Reserve (Area J4), Osun sacred grove and Onigambari Forest Reserves, all in South-West Nigeria, as shown in Figures 1, 2, and 3.

Osun Sacred Grove is located along the banks of Osun River in Osogbo Local Government Area of Osun State, South West Nigeria. Osun Sacred Grove is located approximately between latitudes 7˚44'50.0" - 7˚46'00.0" N and longitudes 4˚32'40"- 4˚33'40" E. The micro climate within the grove is less humid than it is in a greater part of South-

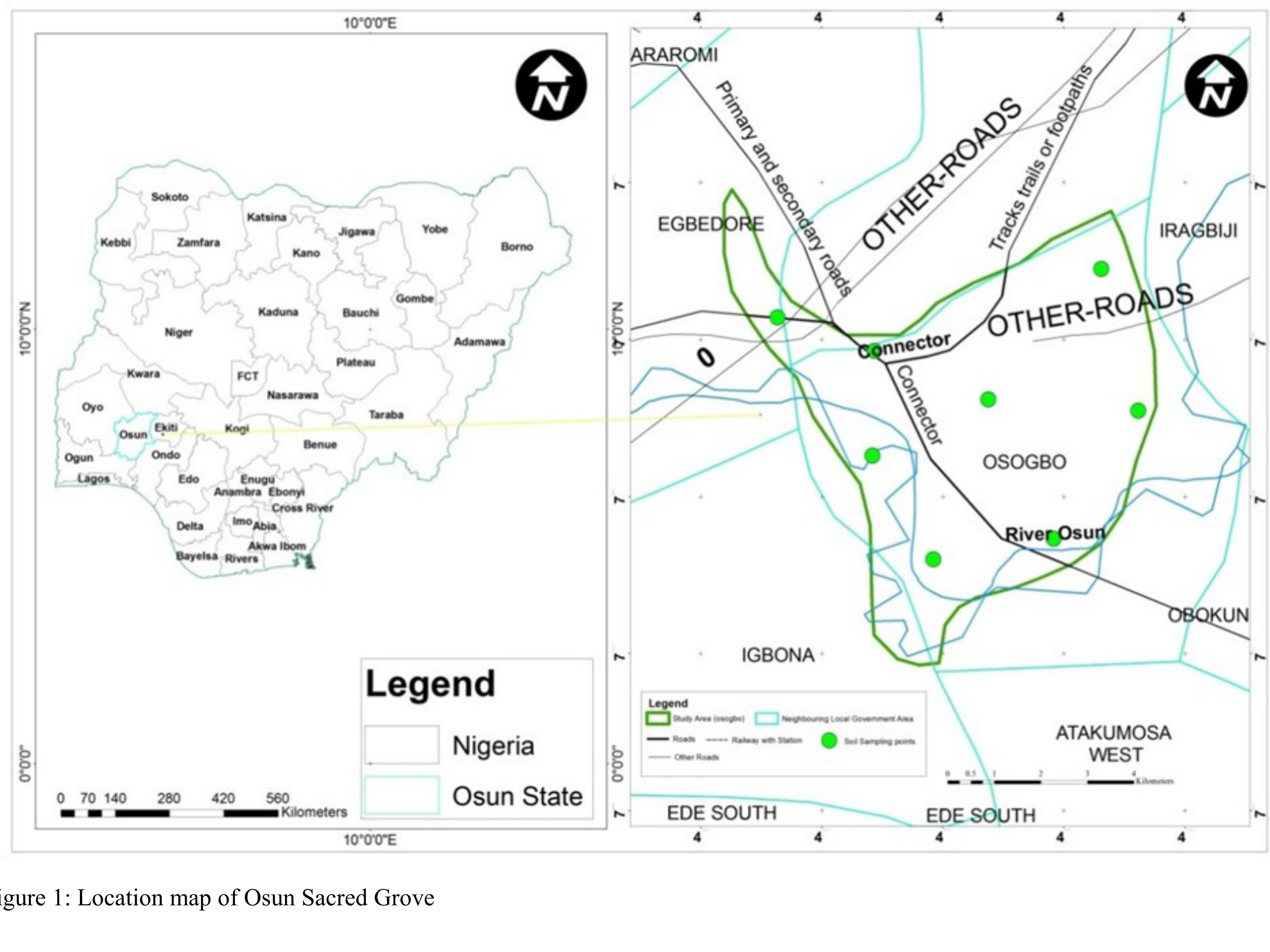

Figure 1: Location map of Osun Sacred Grove

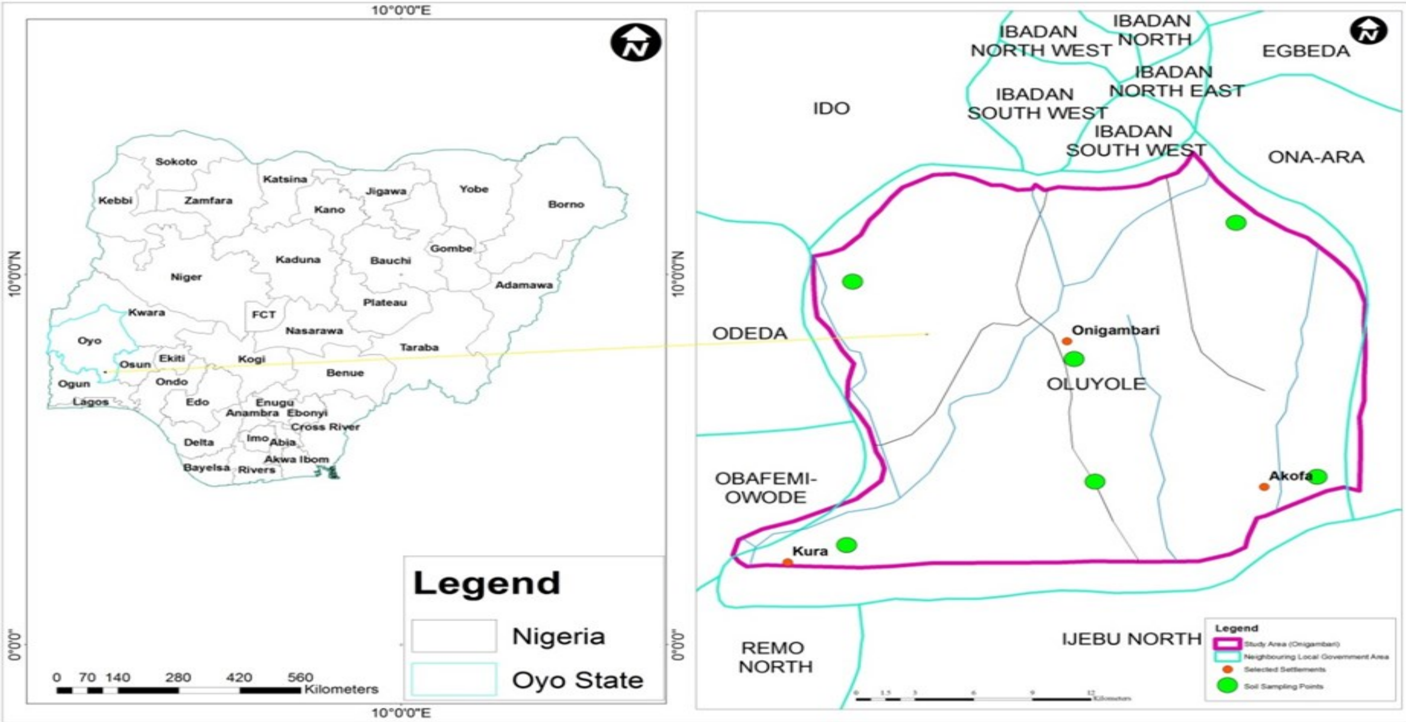

Figure 2: Location map of Onigambari Forest Reserve

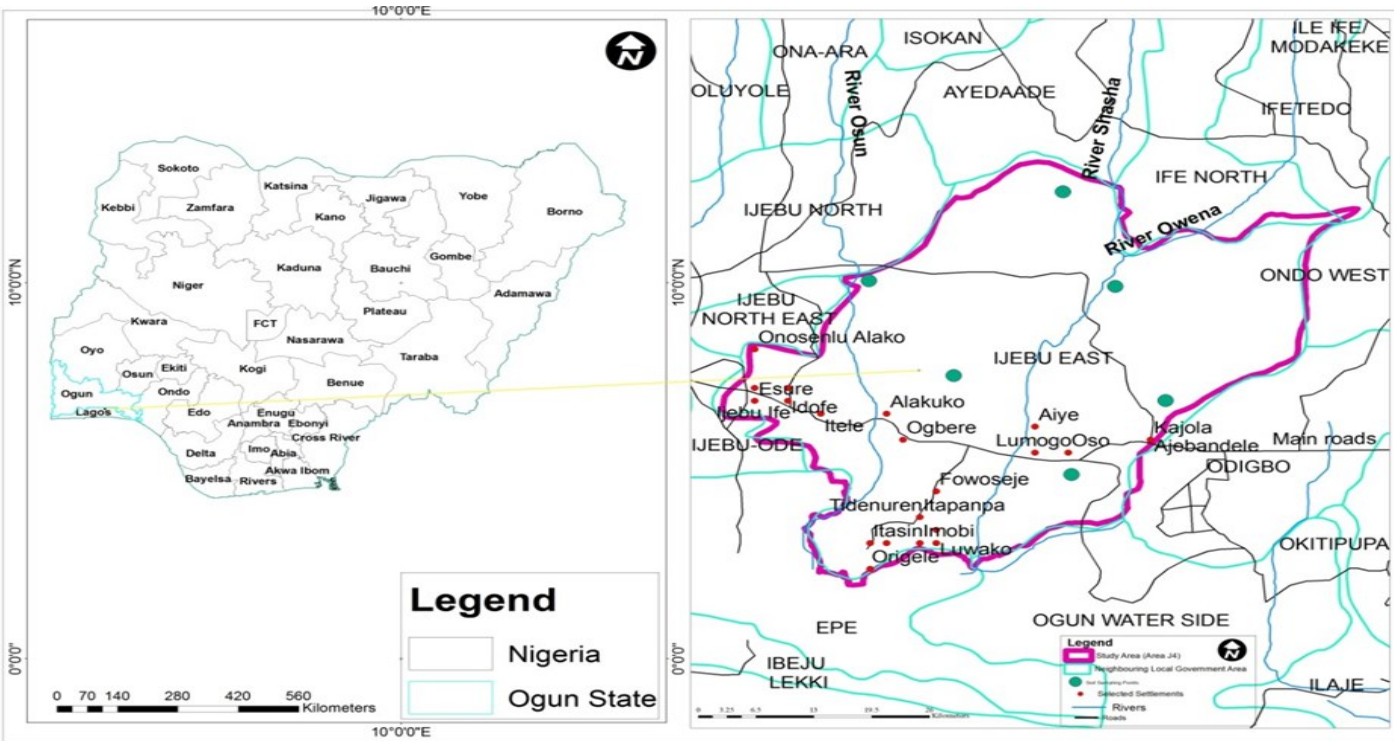

Figure 3: Location map of Omo Forest Reserve, Area J4

ern Nigeria. The average rainfall is between 1250 mm and 1450 mm per annum. The temperature in this area is almost uniform throughout the year, with minimal deviations from the mean annual temperature of 27^0C. The relative humidity of the area is between 92- 99%.

Gambari Forest in Oluyole Local Government area of Oyo State is situated between the River Ona on the West and the primary motor road from Ibadan to Ijebu-Ode on the east. Onigambari Forest Reserve is located between latitude 7° 26'N and longitude 3°54'E. The climate had a long wet season lasting from March to October alternating with a short dry season. The rainfall regime is a double – peak, and the mean annual rainfall is about 1300 mm. The mean annual temperature is about 27^oC with no marked seasonal or monthly departure from the annual average.

Omo Forest Reserve is situated between latitudes 6' 35' to 7' 05' N and longitude 4' 19' to 4' 40' E in the Ijebu area of Ogun State in South-West Nigeria. The reserve is bounded by Ogbere town in West and Oluwa Forest reserve and Oluwa River in the East, the Oni River flowing in the North--South direction and the Benin–Lagos express road in the South. The reserve lies within the Equatorial belt and has a mean annual rainfall range of 1200 to 1600 mm per year. Sometimes, double maximal rainfall is experienced when a dry period exists between July and August, commonly referred to as August break. Temperatures are high in the dry season when up to 33^0C could be recorded. The temperature is lower during the rainy season and ranges between 21^0C and 28^0C.

2.2 Laboratory analysis of soil samples

Collected soil samples were air-dried under room temperature (25 -28^o C). After air drying, some physical properties were carried out and subsequently sieved using a 2 mm sieve and 0.5 mm sieve (for organic carbon and Nitrogen determination). The sieved soil samples were used for the laboratory determination of the soil properties.

Particle size analysis was determined using the hydrometer method (Bouyoucos, 1962, modified by Gee and Or 2002)

Soil pH was determined electrometrically in 1:1 soil water suspension (IITA, 1982). Total soil organic carbon was determined using the acid dichromate wet-oxidation procedure of the Walkley and Black method (1934). The total nitrogen content of the soil was determined using the micro-Kjeldahl technique as described by Bremner (1982). Exchangeable Ca, Mg, Na and K were extracted with 1M ammonium acetate (1M NH4OAc) solution buffered at pH 7.0, as Anderson and Ingram (1998) described. The exchangeable sodium (Na^+) and potassium (K^+) content of the filtrates were determined by Flame photometer, while the exchangeable calcium (Ca^+) magnesium (Mg^+) were determined by EDTA titration method and were read with Atomic Absorption Spectrophotometer (AAS). The cation exchange capacity of the soil was determined with 1M NH4OAc (1M ammonium acetate), buttered at pH 7.0 (Rhoades, 1982). The Effective Cation Exchange Capacity (ECEC) was obtained by the summation of exchangeable bases and exchange acidity. Available phosphorus was extracted using the Bray No.1 method (Bray and Kurtz, 1945). The Bulk density was determined using the core method (Anderson and Ingram, 1993). Saturated hydraulic conductivity (Ks) was estimated by the constant head soil core method as described by Reynolds (1993). The total porosity of the soils was estimated from the bulk density (BD) of the soil by assuming that the particle density (PD) of the soil was 2.65 $gcm^{-3.}$ Aggregate size distribution and stability were determined using the wet-sieving method

Table 1: Effect of Topographic positions on Soil Characteristics

		Location			
Soil parameter	Topography	OFR	OGB	OGR	SED
Depth of true soil	LOWER	145ns	130ab	181.5ab	
	MIDDLE	145ns	70c	145.5ab	
	UPPER	142.5ns	135a	210a	
BD g/cm^3	LOWER	1.356 a	1.338b	1.48ns	
	MIDDLE	1.294ab	1.361ab	1.528ns	0.0748
	UPPER	1.261b	1.496a	1.461ns	
TP %	LOWER	83.7c	39.3ns	39.7bc	
	MIDDLE	133a	35.1ns	26c	10.33
	UPPER	109.5b	38.5ns	50.1a	
GW	LOWER	4461ns	3994ab	2466ns	
	MIDDLE	5380ns	4970a	3831ns	778.5
	UPPER	5237ns	2718b	3359ns	
ECEC	LOWER	4.61ns	9.97a	4.11ns	
	MIDDLE	4.12ns	7.26b	3.81ns	1.14
	UPPER	4.66ns	5.99b	4.71ns	
CEC/Clay	LOWER	3.91ns	4.8a	3.85ns	
	MIDDLE	3.02ns	3.7b	3.48ns	0.618
	UPPER	3.97ns	3.98b	4.25ns	
B.sat.	LOWER	95.95a	98.33ns	96.58b	
	MIDDLE	95.23b	97.9ns	96.6b	0.519
	UPPER	94.92b	97.69ns	97.74a	
OC	LOWER	0.892ns	1.084ns	0.864ns	
	MIDDLE	0.711ns	0.872ns	0.781ns	0.1347
	UPPER	0.855ns	0.891ns	0.945ns	
TN	LOWER	0.0943ns	0.1159ns	0.0926ns	
	MIDDLE	0.0763ns	0.0943ns	0.0838ns	0.01499
	UPPER	0.0918ns	0.0954ns	0.1034ns	
Fe	LOWER	27.36ns	27.31ns	26.74ns	
	MIDDLE	22.71ns	29.87ns	27.21ns	2.53
	UPPER	23.6ns	25.4ns	26.32ns	
Mn	LOWER	55.9ab	65.2a	44.9ns	
	MIDDLE	39.1b	51b	45.9ns	7.05
	UPPER	56.6a	53.9ab	57.3ns	
Silica %	LOWER	55.49ns	55.97ns	57.09ns	
	MIDDLE	53.69ns	58.25ns	59.29ns	1.865
	UPPER	53y.61ns	57.63ns	57.16ns	

BD=Bulk density, TP=Total porosity, GW=Gravel weight, ECEC=effective cation exchange capacity, OC=Organic carbon, TN=Total Nitrogen, Fe= Iron, Mn=Manganese, B.sat=Base saturation SED=standard error difference of means, OFR=Omo forest reserve, OGB=Onigambari forest reserve, OGR= Osun grove

(Kemper and Rosenau, 1986). The electrical conductivity of the soil was taken using a standard electrical conductivity meter.

Analysis of Variance was carried out to compare the soil characteristics of the three locations, and the means were separated using Standard error difference of means (SED). Correlation analysis was also done to study the relationship between slope positions and some soil properties of the three locations.

3.0. Results and Discusion

The effects of Topographic positions on soil characteristics are shown in Table 1. For the depth of true soil, there were no significant differences between the slope segments at Area J4, but significant differences existed at Onigambari forest reserve and Osun sacred grove with the middle slope significantly lower than the other two slope segments, particularly at Onigambari forest reserve. At Osun grove, although the highest depth of the true soil (210 cm) was obtained at the upper slope, this was similar to the other two slope segments.

The bulk density at area J4, the upper slope was significantly lower compared to lower slope while at Onigambari forest reserve the reverse was the case as the upper was superior to lower slope. There was no significant difference existed. However, at Osun sacred grove in comparing the slope positions with respect to total porosity, the middle slope was superior to upper and lower slopes at Area J4, while the upper slope was superior to the lower and middle slope at Osun sacred grove. No significant difference existed at Onigambari.

There were no significant differences at area J4 and Osun sacred grove slope segments with respect to the gravel weight. But middle slope at Onigambari was significantly different. The effective cation exchange capacity (ECEC) followed a similar trend with gravel weight except that the lower slope was significantly higher from the upper and middle slope at Onigambari forest reserve. The same trend was also observed with the CEC of the clay fraction.

In terms of base saturation, the lower slope was superior compared to the other slope positions at area J4, while the upper slope was superior to other slope segments at Osun sacred grove. There was no significant difference observed at the Onigambari forest reserve. The organic carbon of the three locations does not show any significant difference across the slope segments.

The total nitrogen, iron and silica content of the soils followed the same trend with organic carbon. However, the upper slope was superior to the middle and lower slopes in comparing the Manganese content of the soil at area J4. The middle slope was significantly lower compared to the upper slopes at Onigambari while no significant difference was observed at Osun sacred grove.

4.0. Discussion

Topographic position or slope accounted for most of the variations observed in this study. The differences occurred in the depth of soil profile with respect to the soil structure, texture, colour, drainage and soil consistence. It was observed that all profile pits at Osun sacred grove were well deep except the middle slope pit under teak plantation where parent material was encountered at a depth of about 85 cm. Also, at Onigambari forest reserve, the middle slope pit under the teak plantation and the upper slope pit under the Gmelina plantation were shallow due to the observance of hard pans. The deep soils encountered in most of the profile pits within the toposequence are reflections of well-developed soils, as confirmed by Jim (2003) and Salako *et al.* (2006). The variation difference in soil colour as was mainly due to varying quantities of organic matter content as well as the presence of iron (Fe) content. The sand, silt and clay contents of the soils across the three locations indicated that soil texture is sandy loam to sandy clay loam. The high sand content dominated the particle size fraction in all the soils formed from the three locations irrespective of the toposequence. This is in harmony with the previous studies in soils formed on basement complex rocks in different re-

TABLE 2A. Slope against Nitrogen

Correlations			
		slope	N
slope	Pearson Correlation	1	.754*
	Sig. (2-tailed)		.019
	N	9	9
N	Pearson Correlation	.754*	1
	Sig. (2-tailed)	.019	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

The result of the Pearson product-moment correlation (PPMC) shows that there is a significant relationship between the slope of the soil and the nitrogen content ($r=0.019<0.05$). This positive sign also shows a direct relationship between the two variables, which indicates that the higher the slope, the higher the Nitrogen contents.

Table 2b: slope against phosphorus

Correlations			
		slope	P
slope	Pearson Correlation	1	.686*
	Sig. (2-tailed)		.041
	N	9	9
P	Pearson Correlation	.686*	1
	Sig. (2-tailed)	.041	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

The result of the Pearson product-moment correlation (PPMC) shows that there is a significant relationship between the slope of the soil and the phosphorus content ($r=0.041<0.05$). This positive sign also shows a direct relationship between the two variables, which indicates that the higher the slope, the higher the Phosphorus contents.

Table 2c; slope against potassium

Correlations			
		Slope	K
slope	Pearson Correlation	1	.708*
	Sig. (2-tailed)		.033
	N	9	9
K	Pearson Correlation	.708*	1
	Sig. (2-tailed)	.033	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

The result of the Pearson product-moment correlation (PPMC) shows that there is a significant relationship between the slope of the soil and the potassium content (r=0.033<0.05). This positive sign also shows a direct relationship between the two variables, which indicates that the higher the slope, the higher the potassium contents.

Table 2d: slope against CEC

Correlations			
		slope	CEC
slope	Pearson Correlation	1	.732*
	Sig. (2-tailed)		.025
	N	9	9
CEC	Pearson Correlation	.732*	1
	Sig. (2-tailed)	.025	
	N	9	9

*. Correlation is significant at the 0.05 level (2-tailed).

The result of the Pearson product-moment correlation (PPMC) shows that there is a significant relationship between the slope of the soil and the CEC (r=0.025<0.05). This positive sign also shows a direct relationship between the two variables, which indicates that the higher the slope, the higher the CEC.

gions of Nigeria as documented by Malgwi *et al*. 2000; Odunze 2006; Fasina *et al*. 2007; Ande 2010. Soil bulk density was also found to differ from one location to another across the toposequence. Basement complex rocks are principally composed of Igneous and metamorphic rocks. The findings of this study revealed that soils developed on three basement complexes; Osun sacred grove formed from coarse- grained Granites, Onigambari from Quartzites and Area J4 from mica schists. The increase in bulk density at a subsurface of some profile pits could be caused by translocation of clay from eluvial horizons, with simultaneous loss of structure and closer packing of sand grains in the eluvial horizon as reported by Mbagwu *et al*. (1984), while the higher bulk densities observed in these profiles may be due to higher sand content in all the profiles since sandy soils usually have higher bulk densities (1.3 – 1.7 g/cm^3) than fine silts and clay because they have larger, but fewer pore spaces. This is in conformity with the works of NLWRA (2001); Creswell and Hamilton (2002). And the critical value can cause hindrance to root penetration, as observed by Lawal *et al*. (2014). The higher total porosity observed in some soils was due to higher clayey content present, especially soils of area J4 and in some that showed the evidence of argilluviation at Osun grove and Onigambari, while the lower total porosity observed in some other parts was due to coarse texture soil materials such as high gravel weight and sand content present in them.

5.0 Conclusion and recommendation

The result affirmed that slope position accounted for variations in soil properties, especially morphological ones, like colour variations, texture, structures, bulk density and drainage characteristics of soils in all locations studied. Upper slopes were well-drained, while lower slopes were poorly drained, especially at Osun sacred grove and Onigambari forest reserve.

The implication of variation in soil properties is that plantations of the same age occurring on different topographic positions would have to be managed differently.

The physical status of soils was poor in terms of fluctuation in Bulk density, high total porosity and high gravel weight, both capable of causing hindrance to root penetration. The soil physical status of soils under exotic plantation of teak and Gmelina was also found to be poor by Aweto, 1990. This was presumably because teak and Gmelina are deciduous, with maximum leaf fall occurring during the dry season when the plantations are particularly vulnerable to fires, especially teak plantation, which exposes the soil to the weather hazard. Soil exposure after burning usually results in worse physical conditions (Aweto, 1990). the Exchangeable bases (Ca, Mg, K and Na) in all the studied sites were presently adequate to sustain the current land use, but Organic Carbon, total nitrogen and organic matter contents of the soils are generally low and therefore require a build-up of these nutrients in the soils. Measures to improve their replenishment may include preventing of burning of litters and encouraging practices of incorporating organic residues, as also suggested by Lawal *et al*., 2014. The study also recommended that plantations varying slope segments be managed differently to cater for topographic variation.

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