



# Nigerian Journal of Soil Science

Journal homepage: [www.soilsjournalnigeria.com](http://www.soilsjournalnigeria.com)



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

Alabi, K. O.

Department of Crop Production, Faculty of Agriculture, Kwara State University, P. M. B 1530, Malete, Ilorin, Kwara State, Nigeria.

### ARTICLE INFO

#### Article history:

Received June 26, 2021

Received in revised form July 20, 2021

Accepted August 27, 2021

Available online September 30, 2021

#### Keywords:

Slope positions

soil properties

Forest reserves

Landuse type

Soil suitability

### 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.

Corresponding Author's E-mail Address:

[alabioyebisi@gmail.com](mailto:alabioyebisi@gmail.com)

ISSN– Online 2736-1411

Print 2736-142X

© Publishing Realtime. All rights reserved.

### 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 sub-surface horizons due to plinthisation 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-

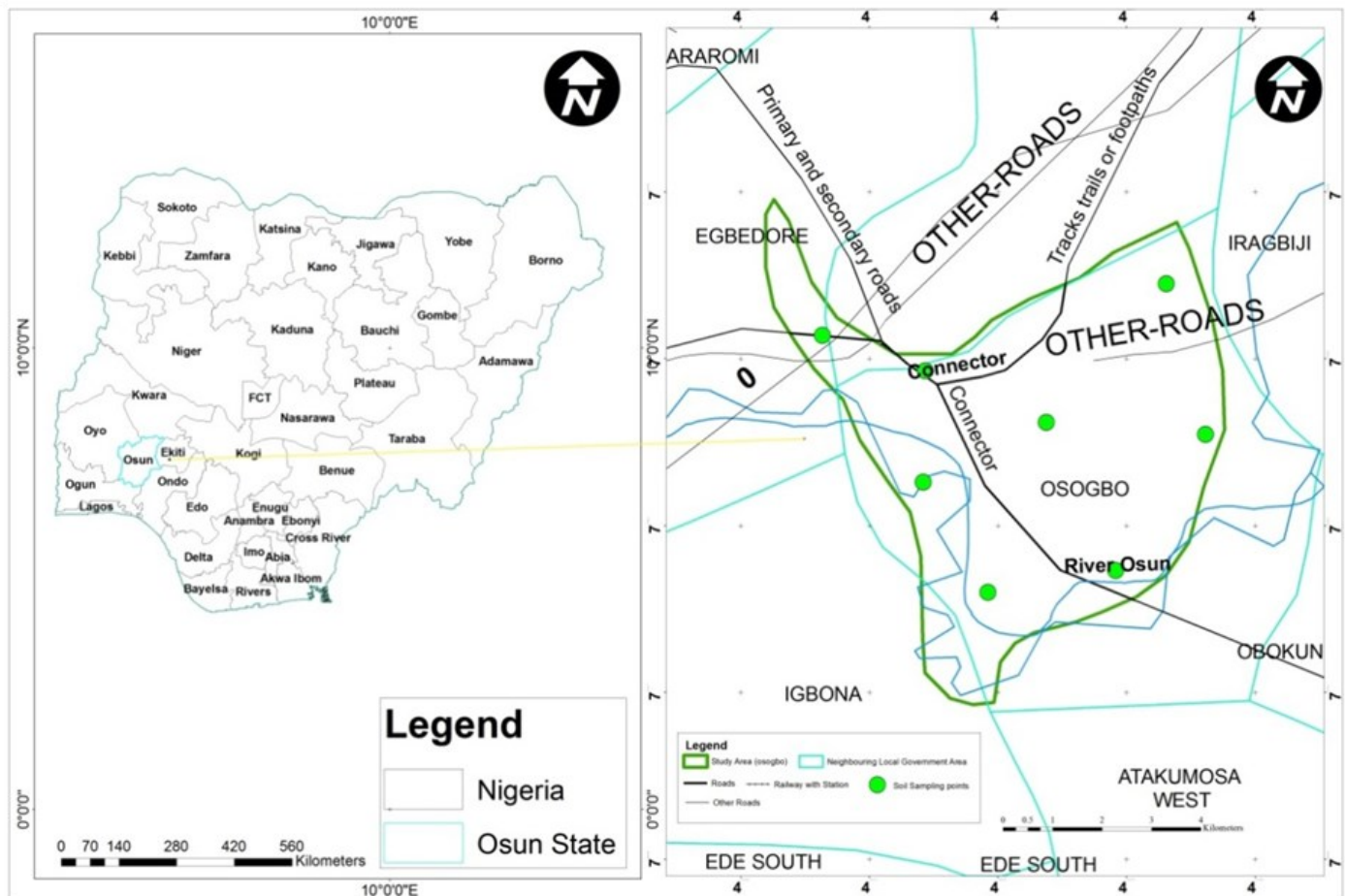


Figure 1: Location map of Osun Sacred Grove

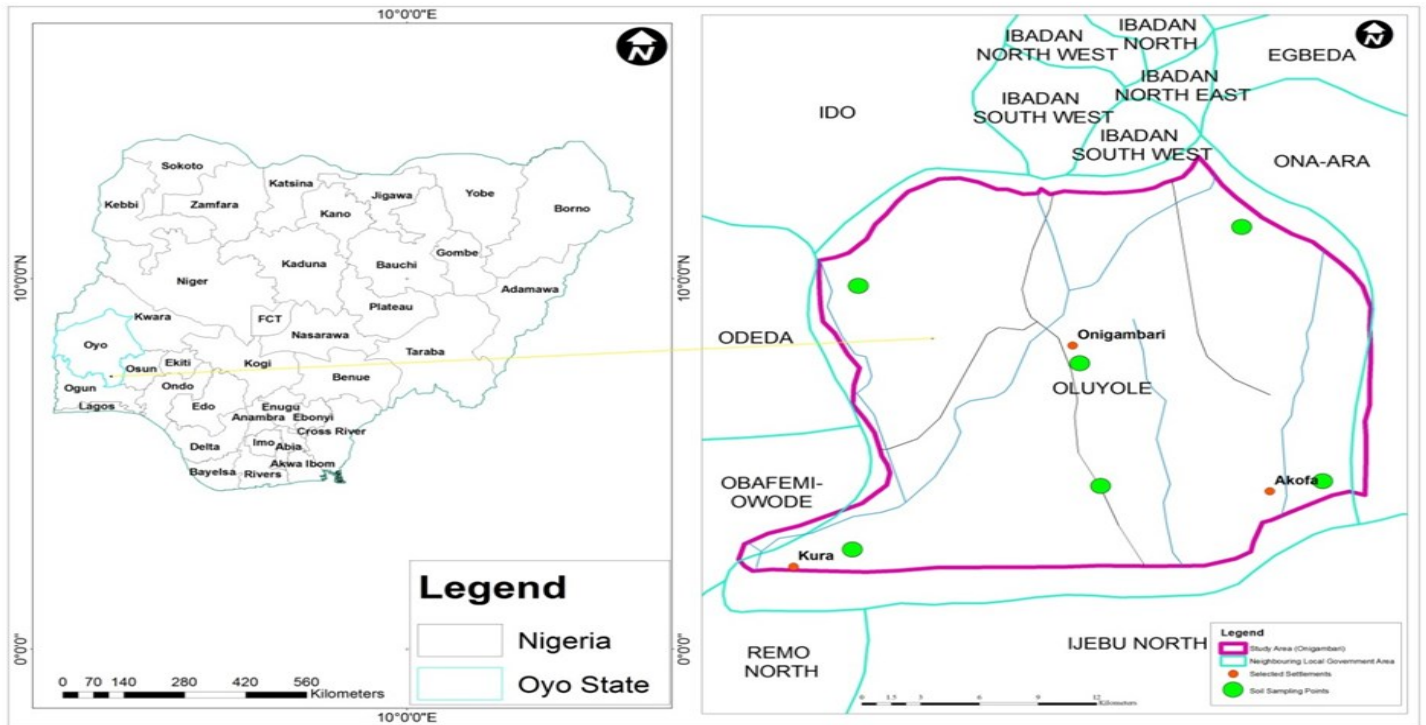


Figure 2: Location map of Onigambari Forest Reserve

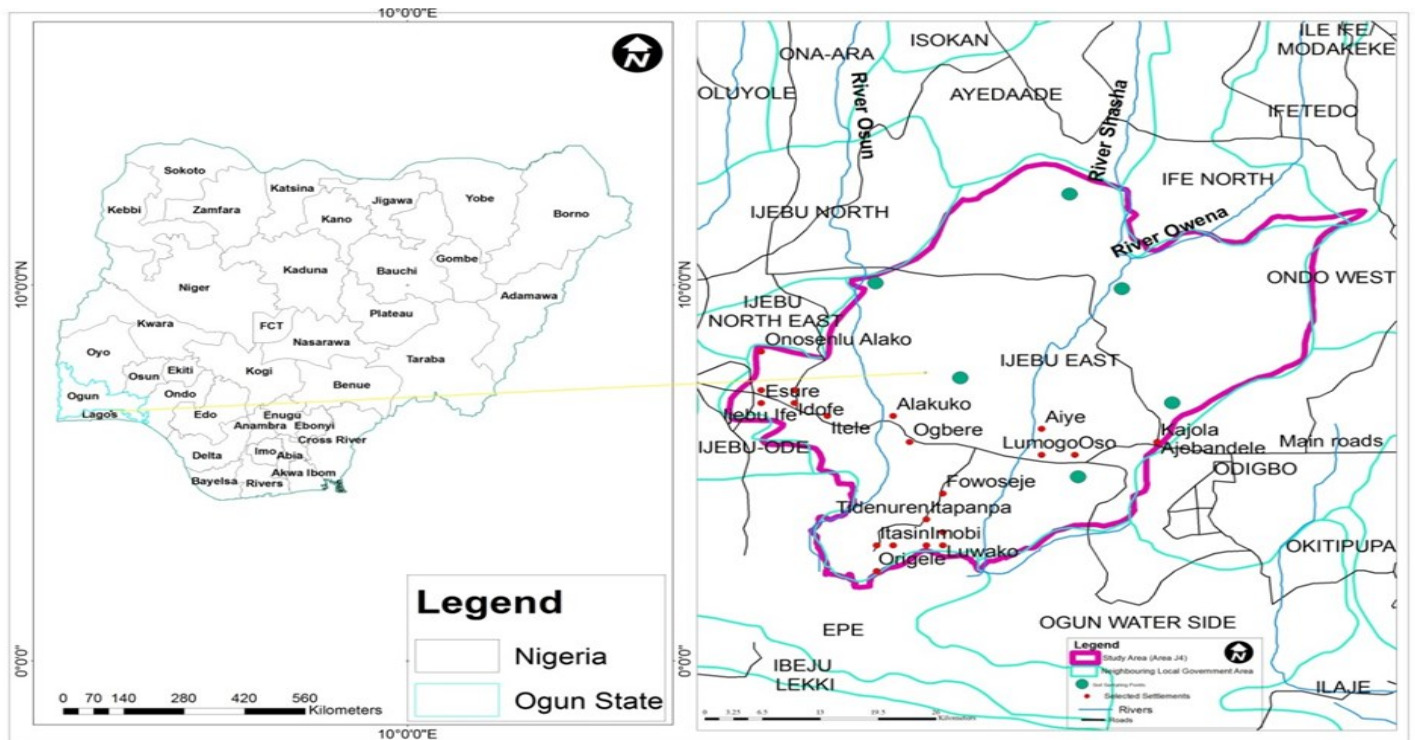


Figure 3: Location map of Omo Forest Reserve, Area J4

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°C. 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°C 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 Og-

here 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°C could be recorded. The temperature is lower during the rainy season and ranges between 21°C and 28°C.

## 2.2 Laboratory analysis of soil samples

Collected soil samples were air-dried under room temperature (25 -28°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 pro-

cedure 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 NH<sub>4</sub>OAc) solution buffered at pH 7.0, as Anderson and Ingram (1998) described. The exchangeable sodium (Na<sup>+</sup>) and potassium (K<sup>+</sup>) content of the filtrates were determined by Flame photometer, while the exchangeable calcium (Ca<sup>2+</sup>) magnesium (Mg<sup>2+</sup>) 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 NH<sub>4</sub>OAc (1M ammonium acetate), buffered 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 g cm<sup>-3</sup>. Aggregate size distribution and stability were determined using the wet-sieving method

Table 1: Effect of Topographic positions on Soil Characteristics

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

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

TABLE 2A. Slope against Nitrogen

| Correlations |                     |       |       |
|--------------|---------------------|-------|-------|
| slope        | Pearson Correlation | slope | N     |
|              | Sig. (2-tailed)     | 1     | .754* |
|              | N                   | 9     | .019  |
| 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        | Pearson Correlation | slope | P     |
|              | Sig. (2-tailed)     | 1     | .686* |
|              | N                   | 9     | .041  |
| 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.

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 2c; slope against potassium

| Correlations |                     |       |       |
|--------------|---------------------|-------|-------|
| slope        | Pearson Correlation | Slope | K     |
|              | Sig. (2-tailed)     | 1     | .708* |
|              | N                   | 9     | .033  |
| 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        | Pearson Correlation | slope | CEC   |
|              | Sig. (2-tailed)     | 1     | .732* |
|              | N                   | 9     | .025  |
| 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 ( $1.3 - 1.7 \text{ g/cm}^3$ ) 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.

## References

- Ahn, P.M. 1970. West African soils. Oxford University Press, London. 332pp.
- Ande, O.T. and Senjobi.B.A. 2010. Lithologic discontinuity and Pedogenetic characterization on an aberrant toposequence associated with a rock hill in South-Western Nigeria. *International Journal of the Physical Sciences* 5(5): 596-604.

- Anderson, J; Ingram J (1998) Tropical Soil Biology and Fertility, A Handbook of Methods. Second Edition, Centre for Biosciences and Agriculture International (CABI), Wallington, 221.
- Aruleba, J.O. 2011. Elements of Soil Science Gospel press and Publishing Company. Nigeria. 157pp.
- Aweto, A.O. 1990. Plantation forestry and forest conservation in Nigeria. *Environmentalist* 10:127–134. Available from: <http://link.springer.com/article/10.1007/BF02244389>
- Bouyoucos, G.J., 1962. Hydrometer method improved for making particle size analyses of soils. *Agronomy Journal* 54(5): 464-465.
- Bray, R.H and Kurtz, L.T. (1945): Determination of total organic and available forms of phosphorus in soils. *Soil Science*. 59:39-45.
- Fasina, A.S., Omolayo, O.S., Faladun, A.A. and Ajayi, O.S. 2007. Granitic derived soils in humid forest of southwestern Nigeria. Genesis, classification and sustainable management. *American-Eurasian Journal of Agriculture and Environmental Science* 2(2): 189-195.
- Gee, G.W. and Or, D. (2002). Particle size analysis, In: J.H, Dane and G.C. Topp (eds). *Methods of Soil Analysis. Part 4. Physical methods. Soil Science Society of America*. Book Series No 5. American Society Agronomy and Soil Science Society of America, Madison, WI, PP 255-293.
- Jim, C. 2003. Quantitative assessment of the treescape and cityscape of Nanjing, China. *Landscape Ecology* 18, 395–412. <https://doi.org/10.1023/A:1026146123459>
- Kemper, W. and Rosenau, R. 1986. Aggregate Stability and Size Distribution. In: Klute, A., Edition *Methods of Soil Analysis, Part 1. Physical and Mineralogical Methods*, Agronomy Monograph, *American Society of Agronomy and Soil Science Society of America*, Madison, 425-442.
- Lawal, B.A., Tsado, P.A., Eze, P.C., Idefoh, K.K., Zaki, A.A. and Kolawole, S. 2014. Effect of Slope Positions on some Properties of Soils under a *Tectona grandis* Plantation in Minna, Southern Guinea Savanna of Nigeria. *International Journal of Research in Agriculture and Forestry* 1(2): 37-43.
- Malgwi, A.G, Ojanuga, W.B. Chude T. Kparmwang and Raji, B.A. (2000). Morphological and Physical Properties of some soil at Samaru, Zaria, Nigeria. *Nigeria Journal of Soil Research*, Vol. 1, pp. 58-64.
- Mbagwu, J. S. C.; Lal, R. ; Scott , T. W. 1984. Effects of Artificial Desurfacing on Alfisols and Ultisols in Southern Nigeria: II. Changes in Soil Physical Properties. *Soil Science Society of America Journal*, 48 (4): 834-838 <https://doi.org/10.2136/sssaj1984.03615995004800040027x>
- Odunze, A. C. (2006) Soil properties and management strategies for some sub-humid savanna zone Alfisols in Kaduna State, Nigeria. *Samaru Journal of Agricultural Research* 22: 3-14.
- Ogunkunle, A.O. 1993. Variation of some soil properties along two toposequences on quartzite schist and banded gneiss in southwestern Nigeria. *GeoJournal* 30(4): 397-402.
- Ojo-Atere, J.O., Ogunwale, J.A. and Oluwatosin, G.A. 2012. *Fundamentals of Tropical Soil Science*. Evans Brothers Limited, Ibadan.
- Ojo-Atere, J.O; Oladimeji, M.O. 1988. Characteristics and Classification of Some Slope Soils in Savanna Ecosystem of South Western Nigeria. *Ife Journal of Agriculture, Ile-Ife*, 5(1-2): 22-442
- Reynolds, W.D. 1993. Saturated hydraulic conductivity: laboratory measurement. In: MR Carter (edition), *Soil Sampling and Methods of Analysis*. Lewis Publishers, Boca Raton, FL. pp 589–598.
- Rhoades, J.D., 1982. Cation Exchange Capacity. In: A.L. Page (Ed.) *Methods of Soil Analysis, Part 2 Chemical and Microbiological Properties*, 2<sup>nd</sup> Edition. *Agronomy* 9: 149 – 157.
- Salako F.K, Tian G., Kirchhof G., Akinbola G.E. (2006). Soil particles in agricultural landscapes of a derived savanna in southwestern Nigeria and implications for selected soil properties. *Geoderma*, 137, 90-99.
- Smyth, A.J. and Montgomery, R.F. 1962. Soils and Land Use in Central Western Nigeria. *Soils and Land Use in Central Western Nigeria*. Government Printer, Ibadan.
- Walkley, A. and Black, I. A. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science*. 37: 29-38.