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# Effect of Slope Gradient on Soil Physiochemical Fertility Indices across Two Distinct Depth Layers in Horticultural Farm at Ibeku Opi-Agu, Nsukka, Nigeria

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**ABSTRACT:** Topography is a critical determinant of the spatial distribution of soil properties, including nutrient retention and availability. The objective of the study was to assess the effect of slope gradient on soil physiochemical fertility indices across two distinct depth layers (0-20 cm and 20-40 cm) in a horticultural farm at Ibeku Opi-Agu in the Nsukka Local Government Area of Enugu State, Nigeria. The slope gradient at the crest, middle, and bottom was 8%, 5%, and 2%, respectively. The study employed appropriate standard procedures. The soil textures were loam, sandy loam and sandy clay loam across the slope gradients and soil depths. Slope gradients and soil depths and their interactions significantly ($p \leq 0.05$) affected the proportions of the > 2.00, 0.50-1.00, 0.25-0.50 and <0.25 mm water stable aggregates, percent aggregate stability and saturated hydraulic conductivity of the soils, while bulk density, total porosity and particle size distribution of the soils were not affected. Saturated hydraulic conductivity decreased with decreasing slope gradient (crest > middle > bottom). The concentrations of soil organic carbon, and exchangeable sodium and potassium cations were significantly higher at the crest compared to the middle and bottom slope gradients. The results for the other soil chemical properties were statistically similar across slope gradients, soil depths and their interactions. We conclude that the topographic influence of an 8% slope gradient on soil properties is dependent on slope position. However, changes in soil fertility with depth are limited to physical properties, and not chemical properties of the soils studied.

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The fertility of any soil reflects its potential to supply sufficient quantities of nutrients in the right proportions to sustain crop growth and nutrient recycling over time (Lal, 2015). According to the FAO (2006), the integration of soil quality indicators directly or indirectly influences nutrient dynamics and their availability. Despite the knowledge gained from the integration of soil biological and physiochemical indicators in relation to nutrient management, declining soil fertility remains a major constraint to food production in many parts of sub-Saharan Africa, including Nigeria (Negasa, 2020; Beyene *et al*., 2022; Okebalama *et al*., 2024). Studies have identified soil nutrient depletion as the major biophysical constraint to increasing *per* capita food production on most smallholder farms in Africa (Sanchez *et al*., 1997; Adesodun *et al*., 2007 and Powlson *et al*., 2011). Agricultural landscapes consisting of high and hilly slopes, medium slopes and foot slopes require different agricultural

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management practices and input levels due to topographic variability (Amede *et al*., 2020). Slope is the uneven, rising or falling of a land surface as opposed to an even, flat area (Strandgard *et al*., 2014). Different types of slope often reflect different levels of soil fertility (Nabiollahi *et al*., 2018; Eshetu and Wogi, 2024) and have different soil characteristics that affect crop health (Yasin and Yulnafatmawita, 2018). Topographic variables affect soil erosion (Hurni *et al*., 2015; Amede *et al*., 2020) and vegetation establishment and microclimate, which in turn affect soil quality due to soil nutrient depletion (Gou *et al*., 2015; Maren *et al*., 2015: Eshetu and Wogi, 2024). Zou *et al*. (2019) showed a significant effect of topography on soil properties, with lower slopes having higher soil organic matter, nutrient availability and cation exchange capacity than higher slopes.

One of the most important topographic elements that affects drainage, runoff, and soil erosion as well as physiochemical properties is slope gradient (Farmanullah, 2013; Gao *et al*., 2020). Slope position can affect species composition, microclimate, soil qualities, or ecosystem processes and functions in various terrestrial environments. Undoubtedly, slope position is important for soil functions that affect water infiltration, soil formation, soil erosion, runoff and sedimentation processes. There is an increasing number of studies on the effects of slope position on the soil physical, chemical and morphological properties, indicating differences in clay, total nitrogen, soil organic carbon, potassium and phosphorus contents across slope gradients (Mulugeta *et al*., 2012; Yossif and Ebied, 2015; Mulugeta, 2015; Rezaei *et al*., 2015; Yimer, 2017; Mathewos, 2020; Okorie *et al*., 2022). Moreover, evaluating the physical and chemical properties of soils along the toposequence is essential for implementing site-specific management strategies (Yao *et al*., 2014; Isola *et al*., 2020). Ibeku Opi, located in Nsukka Local Government Area of Enugu State, Nigeria, is a rural town situated on upland - inland continuum and the major land use is arable farming. As documented in Okpara and Okebalama (2024), a horticultural farm has been operated as a semi-commercial farm for over a decade, growing a variety of vegetable crops (fluted pumpkin (*Telfairia occidentalis*), red pepper (*Capsicum annuum*), green pepper (*Capsicum annuum*) and tomato (*Solanum lycopersicum*) for both household and mainly commercial purposes. Despite the need to establish appropriate on-farm soil management practices for sustainable crop production, knowledge of the influence of slope gradient on soil quality is important in determining sustainable land-use and soil-management practices. It is imperative to understand the interplay between slope gradient and soil nutrient retention across soil layers, particularly in hilly regions susceptible to erosion due to high rainfall intensity. Although slope gradient is a key factor controlling soil erosion, Wang *et al*. (2023) found that slope gradient had less effect on N loss on sloping fields than rainfall intensity, mainly because rainfall intensity influences runoff depth. Eshetu and Wogi (2024) argued that understanding the effects of slope position on soil physiochemical properties is an important step in developing soil and water conservation, soil fertility and other agricultural management practices in hilly areas.

There is a complex mix of land use types and soil management practices across the topography of the farmland. Thus, the determination of soil fertility status across topo-positions and depths could provide essential information for planning appropriate environmental decisions, determining soil suitability for crop production and fertilizer recommendations, and also facilitating the design of effective soil and agricultural management strategies tailored to different slope gradients. This is important for maintaining soil health and improving effective techniques for future restoration programmes. The results of this study could provide some guidelines for future research. These guidelines would be instrumental in developing promising conservation technologies and implementation methodologies in horticulture. Horticultural crops are economically important and contribute significantly to global food security (Eigenbrod and Gruda, 2015). Therefore, the objective of this study was to assess the effect of slope gradient on soil physiochemical fertility indices across Two Distinct Depth Layers in a horticultural farm in Ibeku Opi-Agu in Nsukka Local Government Area of Enugu State, Nigeria.

## MATERIALS AND METHODS

*Description of study area*: This study was carried out in a horticultural farm that has been in operation for over a decade at Ibeku Opi-Agu in Nsukka Local Government Area of Enugu State. The study area is located between latitude $6^0$ 46' N and longitude $7^0$ 25' E with an altitude of between 534 and 538 m above sea level. The area is classified as a humid tropical environment with two distinct rainy and dry seasons (Asadu *et al*., 2022). The rainy season lasts from April to October, with maximum rainfall in June, July and again in September. There is a minor dry season in August, often referred to as the August break, and the main dry season runs from mid-November to March. The average annual rainfall is 1500 mm, with mean monthly rainfall ranging from

250 mm in April to 380 mm in October (Yakubu *et al*., 2022). The relative humidity of the area is 68.97 %. The mean annual temperature is uniformly high, rarely falling below 31.5$^o$C, and not exceeding 35$^o$C (Akamigbo and Asadu, 1983). The soils in the study area contain low activity clay and are coarse or moderately coarse in texture (Ezeaku and Iwuanyanwu, 2013; Okebalama *et al*., 2024). False-bedded sandstones are the geological materials that underlay the study area. The topography of the study area is hilly with a slope of 15 %.

The vegetation of the study area could be described as derived savanna, dominated by secondary forest, as most of the primary vegetation has been cleared for farming activities. A mixed cropping system that includes vegetables such as amaranthus (*Amaranthus spp*), pumpkin (*Cucurbita spp.*), tomato (*Solanum lycopersicum*), garden egg (*Solanum melongena*) and pepper (*Capsicum spp.*) are common. Tuber crops such as cassava (*Manihot esculenta)* and cocoyam (*Colocasia esculenta*) are also cultivated, while oil palm (*Elaeis guineensis*) and banana plantation (*Musa spp.*) are mostly found in small areas of the study location.

*Field work and soil sampling*: A visual field survey of the area was carried out by means of a reconnaissance visit in order to get a general view of the study area. A Global Positioning System was used to determine the geographical location and coordinate system, while clinometers were used to determine the slope of the sampling sites. After identifying a representative site with a gentle slope gradient (a topographic range not exceeding 15 %), the topo-positions were identified and classified as crest (8 %), middle (5 %) and bottom (2 %) slopes. To assess the influence of slope position on soil properties, the three slope positions were considered irrespective of the land use types. From each of the slope positions, three replicate soil samples of approximately 1 kg were collected using an auger sampler in a random sampling pattern at depths of 0-20 cm (representing the topsoil layer) and 20-40 cm (subsoil layer). The experimental design and plot layout were established using a transect line (Anderson and Ingram, 1993). A total of 18 soil samples [3 slope positions, 2 soil depths (0-20 cm and 20-40 cm) and 3 replicates] were collected, and properly packed in labelled nylon bags. In addition, an equal number of undisturbed soil samples were collected from each soil depth using a 5 cm diameter x 5 cm high (98.2 $cm^3$) core sampler for determination of bulk density, total porosity and saturated hydraulic conductivity.

*Laboratory analysis*: Soil samples collected from the different slope gradients of the horticultural farm were air-dried at room temperature, homogenized and sieved through a 2 mm mesh in preparation for laboratory analysis of soil pH, organic carbon, total nitrogen, available P, exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$, $Na^+$) and exchangeable acidity ($Al^{3+}$ and $H^+$). The physical and chemical properties of the collected soil samples were determined using the standard laboratory procedures at the Department of Soil Science Laboratory, University of Nigeria, Nsukka.

Soil particle size distribution (clay, silt and sand) was determined using the hydrometer method after soil dispersion with a sodium hexametaphosphate solution (Hillel, 2004). Soil textural class was determined using the USDA soil textural triangle classification system (Creek, 2010). Bulk density and total porosity were measured using the core method (Black *et al*., 1965). Saturated hydraulic conductivity (Ksat) was determined using the constant head permeameter method (Klute and Dirksen 1986). Darcy's equation for the analysis of the constant head method, as described by Young *et al*., (2001) was used for the calculation of Ksat.

Aggregate stability was estimated using the wet sieving method of aggregate size separation (Kemper and Rosenan, 1986), followed by the calculation of the mean weight diameter (MWD) of each aggregate fraction (Hillel, 2004). In this method, fifty grams (50 g) of the air-dried soil sample retained on a 4.75 mm sieve was weighed and placed on the top of the nest of 2.00, 1.00, 0.50 and 0.25 mm sieves. The contents were first soaked for 5 minutes to prevent slaking, and then oscillated vertically in water for 5 minutes at a rate of 30 oscillations per minute and amplitude of 4 cm. The soil aggregates remaining on each sieve were then oven-dried at 105˚C for 24 h and weighed. The percentage of each water-stable aggregate (WSA) fraction was determined according to equation 1. The percent aggregate stability and the MWD of the soils were calculated according to equations 2 and 3.

$$\%\ \text{WSA} = \frac{mass\ of\ WSA}{mass\ of\ sample} * 100 \quad (1)$$

$$\%\ \text{AS} = \frac{\text{mass of WSA } (\geq 0.50) - \text{mass of sand}}{\text{mass of sample} - \text{mass of sand}} * 100 \quad (2)$$

Where % AS = percentage aggregate stability, WSA (≥ 0.50) = water-stable aggregate ≥ 0.50 mm.

$$\text{MWD} = \sum_{i=1}^{n} X\text{i}\ \text{W}_\text{i} \quad (3)$$

Where MWD = mean weight diameter of aggregates (mm), $X_i$ = mean diameter of each size fraction (mm), $W_i$ = proportion of the total sample weight occurring in the corresponding size fraction.

Soil pH was measured in a 1:2.5 suspension of soil in distilled water using a pH meter. Soil organic carbon (SOC) was determined by the Walkley-Black wet oxidation method (Nelson and Sommers, 1982), while total nitrogen was determined by the Kjeldahl digestion, distillation, and titration method (Bremner, 1996). Available phosphorus was determined by the Bray II bicarbonate extraction method (Olsen and Sommers, 1982). Exchangeable bases ($Ca^{2+}$, $Mg^{2+}$, $Na^{+}$ and $K^{+}$) were extracted in ammonium acetate pH 7 (Thomas, 1982) and measured by the flame photometer (for $Na^{+}$ and $K^{+}$), and the complexometric EDTA titration (for $Ca^{2+}$ and $Mg^{2+}$). Exchangeable acidity ($Al^{3+}$ and $H^{+}$) was determined using extracts of 1 N KCl (McLean, 1982). The effective cation exchange capacity (ECEC) was determined by the summation of the exchangeable bases and exchangeable acidity.

*Statistical analysis*: The soil analysis data obtained were subjected to a two-way analysis of variance (ANOVA) for a completely randomized design (CRD) using GenStat Discovery Edition. In the case of significant treatment effects, mean separation was performed using the Fisher's least significant difference (F-LSD) procedure at the 5 % probability level ($P \leq 0.05$).

## RESULTS AND DISCUSSION

*Effects of slope position and soil depth on selected soil physical properties:* The results in Table 1 show the particle size distribution, textural classification, bulk density, total porosity and saturated hydraulic conductivity (Ksat) of the soils at the different slope positions, soil depths, and their interactions. The soil particle sizes distribution was not affected by slope position, soil depth, or their interactions. The soil at the crest had 53.90 % sand, 26.90 % silt, and 19.10 % clay, resulting in a textural class of sandy loam (SL). The middle and bottom slopes had 45.60 % and 46.90 % sand, 27.90 % and 29.80 % silt, and 26.50 % and 22.50 % clay, respectively, and are classified as loam (L). Overall, the sand, silt and clay had coefficients of variation (CV) of 16, 25 and 24 %, respectively. In general, the soils had more sand fraction compared to silt and clay, which is consistent with the report of Okpara and Okebalama (2024).

With the exception of Ksat, no significant differences were observed in bulk density and total porosity of the soils, which ranged from 1.48 to 1.53 g $cm^{-3}$ and from 41.70 to 44.20 cm $hr^{-1}$, respectively, across slope positions and soil depths. These bulk density values (> 1.60 g $cm^{-3}$) are within the ideal values for adequate plant root growth (NRCS, 2001). The moderately high total porosity values are also typical of their respective soil textures. However, the Ksat of the soils ranged from 0.30 to 10.67 cm $hr^{-1}$, with a CV of 80 %. These Ksat values are low, consistent with the findings of Okpara and Okebalama (2024) who worked on the same study site being investigated. The soil Ksat showed a decreasing trend from the crest (8.18 cm $hr^{-1}$) to the middle (3.22 cm $hr^{-1}$) to the bottom (1.62 cm $hr^{-1}$) slope positions. The observed variations in Ksat across these slope positions could be related to the variations in their organic C content, which contributed to enhanced macroaggregate formation and hence, macroporosity, attributable to the higher proportion of the > 2.00 mm water-stable aggregates at the crest, as shown in Table 2. This suggests enhanced water movement and water infiltration, which affects root development, nutrient uptake, and crop growth at the crest position. A higher Ksat value was recorded at the 0-20 cm (5.66 cm $hr^{-1}$) than at the 20-40 cm soil depth. Also, the soils at the crest position had the highest Ksat value (10.67 cm $hr^{-1}$) at the 0-20 cm soil depth, while the soil at the bottom position had the lowest (0.30 cm $hr^{-1}$) at the 20-40 cm soil depth. Despite the differences in Ksat between the soil depths, the Ksat values are in the low range. Consequently, the soils would exhibit analogous slow water infiltration, permeability and aeration status (Celik *et al*., 2010).

*Effects of slope position and soil depth on aggregate stability of the soils:* Table 2 shows the aggregate size distribution, aggregate stability and mean weight diameter of aggregates at different slope gradients and soil depths. With the exception of the 1.00-2.00 mm water-stable aggregate fraction, the other aggregate size fractions (> 2.00, 0.50-1.00, 0.50-0.25, and < 0.25 mm) with higher CV (between 60 and 88 %) were significantly influenced by slope position, soil depth and their interactions. The crest slope had the highest proportion of > 2mm (20.89 %) macroaggregates compared to the middle (12.96 %) and bottom (3.96 %) slopes. On the other hand, the bottom slope had a higher proportion of < 0.25 mm microaggregates, suggesting that soils at the crest with larger macroaggregates have a better soil structure. This explains the significantly higher percent aggregate stability observed at the crest and middle compared to the bottom. According to USDA NRCS (2008), improved soil erosion resistance, water retention, and plant root growth may result

**Table 1:** Particle size distribution, textural classification and some physical properties of the soils at different slope positions and soil depths

| Slope position | Soil depth cm | Sand % | Silt % | Clay % | Textural class | BD g cm$^{-3}$ | Total porosity % | $K_{sat}$ cm hr$^{-1}$ |
|---|---|---|---|---|---|---|---|---|
| **Main effect of slope position** | | | | | | | | |
| Crest | | 53.90 | 26.90 | 19.10 | SL | 1.53 | 41.70 | 8.18 |
| Middle | | 45.60 | 27.90 | 26.50 | L | 1.48 | 44.20 | 3.22 |
| Bottom | | 46.90 | 29.80 | 22.50 | L | 1.50 | 43.40 | 1.62 |
| **$LSD_{(0.05)}$** | | **NS** | **NS** | **NS** | | **NS** | **NS** | **1.50** |
| **Main effect of soil depth** | | | | | | | | |
| 0-20 | | 51.40 | 26.20 | 21.40 | SCL | 1.49 | 43.60 | 5.66 |
| 20-40 | | 46.20 | 30.30 | 24.00 | SCL | 1.51 | 42.60 | 3.02 |
| **$LSD_{(0.05)}$** | | **NS** | **NS** | **NS** | | **NS** | **NS** | **1.22** |
| **Interaction effect of slope position and soil depth** | | | | | | | | |
| Crest | 0-20 | 56.9 | 26.6 | 16.5 | CL | 1.59 | 40.0 | 10.67 |
| | 0-40 | 50.9 | 27.3 | 21.8 | SCL | 1.48 | 43.5 | 5.70 |
| Middle | 0-20 | 47.6 | 28.6 | 23.8 | SCL | 1.41 | 46.9 | 3.37 |
| | 0-40 | 43.6 | 27.3 | 29.1 | SCL | 1.55 | 41.4 | 3.08 |
| Bottom | 0-20 | 49.6 | 23.3 | 23.8 | SCL | 1.49 | 43.9 | 2.93 |
| | 0-40 | 44.2 | 36.3 | 21.1 | SCL | 1.51 | 42.9 | 0.30 |
| **CV %** | | **16.26** | **25.21** | **24.53** | | **9.44** | **12.53** | **79.46** |
| **$LSD_{(0.05)}$** | | **NS** | **NS** | **NS** | | **NS** | **NS** | **2.12** |

*BD = bulk density, Ksat = saturated hydraulic conductivity, $LSD_{(0.05)}$ = least significant difference at 5 % probability level, NS = not significant, CV = coefficient of variation.*

**Table 2:** Aggregate size distribution and mean weight diameter of the soil at different slope positions and soil depths

| Slope position | Soil depth cm | Water-stable aggregates (mm) | | | | | AS % | MWD |
|---|---|---|---|---|---|---|---|---|
| | | >2.00 % | 2.00 - 1.00 % | 1.00-0.50 % | 0.50 - 0.25 % | < 0.25 % | | |
| **Main effect of slope position** | | | | | | | | |
| Crest | | 20.89 | 1.68 | 0.57 | 0.38 | 1.53 | 73.10 | 3.06 |
| Middle | | 12.96 | 2.49 | 2.84 | 2.67 | 4.05 | 68.00 | 2.04 |
| Bottom | | 3.96 | 2.04 | 1.80 | 3.63 | 13.57 | 28.2 | 2.00 |
| **$LSD_{(0.05)}$** | | **1.33** | **NS** | **0.68** | **1.06** | **2.13** | **10.17** | **NS** |
| **Main effect of soil depth** | | | | | | | | |
| 0-20 | | 14.64 | 1.99 | 1.10 | 1.95 | 5.37 | 60.70 | 2.24 |
| 20-40 | | 10.57 | 2.15 | 2.37 | 2.51 | 7.40 | 52.10 | 2.49 |
| **$LSD_{(0.05)}$** | | **1.09** | **NS** | **0.56** | **NS** | **1.74** | **8.31** | **NS** |
| **Interaction effect of slope position and soil depth** | | | | | | | | |
| Crest | 0-20 | 22.17 | 1.26 | 0.28 | 0.23 | 1.17 | 74.10 | 3.27 |
| | 0-40 | 19.62 | 2.11 | 0.58 | 0.52 | 1.90 | 72.10 | 2.84 |
| Middle | 0-20 | 16.43 | 2.48 | 1.67 | 2.17 | 2.33 | 74.40 | 2.44 |
| | 0-40 | 9.49 | 2.49 | 4.06 | 3.17 | 5.78 | 61.60 | 1.63 |
| Bottom | 0-20 | 5.33 | 2.23 | 1.39 | 3.43 | 12.62 | 33.70 | 1.01 |
| | 0-40 | 2.58 | 1.86 | 2.21 | 3.83 | 14.52 | 22.70 | 2.99 |
| **CV %** | | **59.86** | **35.96** | **75.41** | **70.84** | **87.89** | **67.57** | **39.18** |
| **$LSD_{(0.05)}$** | | **1.89** | **NS** | **0.97** | **NS** | **NS** | **NS** | **NS** |

*AS = percentage aggregate stability, MWD = mean weight diameter, $LSD_{(0.05)}$ = least significant difference at 5 % probability level, NS = not significant, CV = coefficient of variation.*

from the enhanced structural stability at the crest and mid-slope. The 0-20 cm soil depth had a higher proportion of the > 2.00 mm and a lower proportion of < 0.25 mm water-stable aggregates, while the reverse was true for the 20-40 cm soil depth. This accounts for the higher aggregate stability in the 0-20 cm soil depth than in the 20-40 cm depth, attributable to the contribution of higher SOC, $Na^+$ and $K^+$ contents (Table 2) to aggregate formation and stability in the soils. There was no effect of slope gradient and soil depth on the MWD of aggregates.

*Effects of slope positions and soil depth on selected soil chemical properties:* Among the soil chemical properties investigated (Table 4), SOC, $K^+$ and $Na^+$ were significantly affected by slope position, but not by soil depth and their interaction (Table 3). The other chemical properties were not significantly affected by slope position and soil depth. The pH in $H_2O$ indicates a slightly acidic soil condition, which may favourably impact nutrient availability to plants (Oshunsanya, 2019). Soil organic carbon content (2.25 %) was higher at the crest compared to the middle and bottom slope positions (0.98 and 0.70 %, respectively), due to the addition of organic agricultural inputs and organic matter (leaves and branches) from the surrounding trees at the crest. Gao *et al*. (2020) reported that vegetation cover plays a crucial role in reducing soil erosion and nutrient loss. In contrast, Zou *et al*. (2019) showed a significant influence of topography on soil properties, with higher soil organic matter, nutrient availability, and cation exchange capacity on lower slopes than on higher slopes. Eshetu and Wogi (2024) found that the lower slope had relatively better soil nutrients than the upper and middle slopes. The similar low total N content (0.08-0.11 %) across slope positions may be due to leaching and runoff losses, given the topography of the farmland and the high rainfall in the study area. The available P content of the soil was high, and similar to that reported by Okpara and Okebalama (2024). As with the SOC content, exchangeable Na and K contents were significantly higher at the crest position in comparison to the middle and bottom of the slope. This could be due to variations in organic matter and nutrient cycling within the soils (Nelson and Sommers, 1982). Our results contradict those of Li *et al*. (2021), who conducted a field experiment on four slope gradients (5°, 10°, 15°, and 20°) and found that nutrient loss increased significantly with increasing slope gradient. The ECEC of the soil, a measure of soil's ability to retain and exchange cations (Hendershot *et al*., 2008), is low.

**Table 3:** Chemical properties of the soil at different slope positions and soil depths

| Slope position | Soil depth cm | pH $H_2O$ | Organic carbon % | Total N % | Avail. P mg kg$^{-1}$ | $Ca^{2+}$ cmol kg$^{-1}$ | $Mg^{2+}$ cmol kg$^{-1}$ | $Na^{+}$ cmol kg$^{-1}$ | $K^{+}$ cmol kg$^{-1}$ | $Al^{3+}$ cmol kg$^{-1}$ | $H^{+}$ cmol kg$^{-1}$ | ECEC cmol kg$^{-1}$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Main effect of slope position** | | | | | | | | | | | | |
| Crest | | 6.25 | 2.25 | 0.11 | 5.90 | 1.57 | 0.76 | 0.08 | 0.14 | 0.50 | 2.10 | 4.94 |
| Middle | | 6.52 | 0.98 | 0.08 | 4.97 | 1.43 | 0.90 | 0.04 | 0.06 | 0.40 | 1.83 | 4.49 |
| Bottom | | 6.55 | 0.70 | 0.10 | 4.20 | 1.43 | 0.80 | 0.03 | 0.07 | 0.40 | 1.67 | 4.20 |
| **$LSD_{(0.05)}$** | | **NS** | **1.08** | **NS** | **NS** | **NS** | **NS** | **0.004** | **0.05** | **NS** | **NS** | **NS** |
| **Main effect of soil depth** | | | | | | | | | | | | |
| 0-20 | | 6.38 | 1.40 | 0.11 | 4.77 | 1.38 | 0.80 | 0.05 | 0.10 | 0.49 | 1.62 | 4.32 |
| 20-40 | | 6.50 | 1.22 | 0.09 | 5.28 | 1.58 | 0.84 | 0.04 | 0.10 | 0.40 | 2.11 | 4.77 |
| **$LSD_{(0.05)}$** | | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |
| **Interaction effect of slope position and soil depth** | | | | | | | | | | | | |
| Crest | 0-20 | 6.27 | 2.72 | 0.16 | 5.91 | 1.93 | 0.73 | 0.10 | 0.16 | 0.67 | 1.67 | 4.97 |
| | 0-40 | 6.23 | 1.78 | 0.07 | 5.90 | 1.20 | 0.80 | 0.06 | 0.12 | 0.40 | 2.53 | 4.92 |
| Middle | 0-20 | 6.30 | 1.12 | 0.08 | 5.29 | 1.20 | 1.07 | 0.04 | 0.09 | 0.40 | 1.93 | 4.53 |
| | 0-40 | 6.73 | 0.84 | 0.09 | 4.66 | 1.67 | 0.73 | 0.04 | 0.08 | 0.40 | 1.73 | 4.45 |
| Bottom | 0-20 | 6.57 | 0.36 | 0.09 | 3.11 | 1.00 | 0.60 | 0.02 | 0.05 | 0.40 | 1.27 | 3.46 |
| | 0-40 | 6.53 | 1.05 | 0.11 | 5.29 | 1.87 | 1.00 | 0.04 | 0.10 | 0.40 | 2.07 | 4.94 |
| **$LSD_{(0.05)}$** | | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

*Total N = total nitrogen, Avail. P = available phosphorus, $Ca^{2+}$, $Mg^{2+}$, $Na^{+}$, $K^{+}$, $Al^{3+}$, $H^{+}$ = exchangeable calcium, magnesium, sodium, potassium, aluminium and hydrogen, respectively, ECEC = effective cation exchange capacity, $LSD_{(0.05)}$ = least significant difference at 5 % probability level, NS = not significant.*

There was no significant difference in the soil chemical properties between the 0-20 cm and 20-40 cm soil depths. This could be due to the observed similarities in soil bulk density and total porosity at both soil depths, which consequently influence nutrient retention and losses.

The interaction effect of slope position and soil depth showed no variation in any of the soil chemical properties. The results of the study thus show that the variation in soil fertility between the topsoil and subsoil layers is limited to the physical and not the chemical characteristics of the soils studied. The previously discussed differences in Ksat, water stable aggregates and aggregate stability between the soil depths illustrate the varying influence of topo-position on some physical properties of soils.

*Conclusions:* The study of a horticultural farmland at Ibeku Opi, Nsukka revealed various loamy soil textures, characterized by an acid pH and high soil organic carbon (SOC) concentration, but low cation exchange capacity. The slope gradient had no significant effect on the majority of the soil physiochemical properties; however, it influenced the SOC, and exchangeable Na and K concentrations. The upper slope position supported higher concentrations and retention of SOC, exchangeable Na and K, and also improved the soil saturated hydraulic conductivity.

The crest and middle slope positions exhibited superior aggregate stability compared to the bottom slope, and also demonstrated enhanced aggregate stability and saturated hydraulic conductivity at 0-20 cm than at 20-40 cm soil depth, indicating better soil structure. Therefore, a gentle slope of 8% gradient influences soil physiochemical properties based on topo-position; and the soil properties varies physically but not chemically between the top- and sub-layers of loamy textured soils.

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*Data Availability:* Data are available upon request from the corresponding author.

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