Nigerian Journal of Soil Science 24 (2014) 174 – 182

Nigerian Journal of Soil Science

Journal homepage:www.soilsjournalnigeria.com

# EFFECT OF GULLY EROSION ON SOIL PROPERTIES IN SOME SOILS OF EDO STATE, NIGERIA

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## ABSTRACT

A study of gully erosion effects on soil properties in some soils of Edo State. Nigeria was investigated under natural conditions in five (5) gully sites from four Local Government Areas (Ekehuan Road in Oredo L.G.A. Ambrose Alli University, Ekpoma in Esan West L.G.A., University of Benin Campus in Ovia North East L.G.A., Agbo Motor Park Road and Temboga in Ikpoba Okha L.G.A.). Control and gully samples were collected at 0-30, 30-60, 60-90 and 90-120cm depths. Samples were analyzed for physico-chemical properties. The result showed that the soil texture varied from loamy-sand top to sandy clay loam sub soil in all the sites. The sand, silt and clay fractions varied from 57-83% for sand, silt from 1-4% and clay 14-41% in all samples. Soil bulk density varied from 1.48g/cm$^3$ in the surface to 1.71g/cm$^3$. Organic matter declined with depth in all sites varying from 26.50g/kg to 0.00 g/kg. Soils in eroded sites had lower values for cations and oxides such as K, Ca, Mg $Fe_2$ $O_3$, $Al_2O_3$ and pH than with soils of control sites. Generally, the eroded soils had lower clay and higher sand contents, higher bulk density and lower porosity. Gully erosion caused physical and chemical degradation of soils.

## INTRODUCTION

In many developing countries like Nigeria, management and control of erosion with minimal damage to the soil is desired. Social factors have greatly increased the accelerated rate of erosion. The planning and implementation of some development projects leave much to be desired. Those concerned with developmental construction have often neglected to provide appropriate runoff outlets on highways and civil structures.

In Nigeria, Gowon (1981) reported that 152,275,500 hectares centimeters of agricultural lands are washed away by rain alone. The heavy loses he attributed to careless use of land. Lal (1990), reported that Gully erosion is severe and even disastrous on soils developed in coastal sediments in Southeastern Nigeria. Lal attributed that social factors played havoc with the natural environment. Gully erosion is a major problem in some parts of Benin-City and Ekpoma areas of Edo State.

A gully is a land form created by running water eroding sharply into soil, typical on a hillside. Gullies resemble large ditches or small valleys, but are meters to tens of meters in depth and width. When the gully formation is in process, the water flow rate can be substantial, which causes the significant deep cutting action into the soil. Gullies are unstable, eroding channels formed at or close to valley heads, sides, or floors (Schumm *et al*., 1984).

Gulling or gully erosion is the process by which gullies are formed. Hillsides are more prone to gulling when they are cleared of vegetation, through deforestation, over-grazing or other means. The eroded soil is easily carried by the flowing water after being dislodged from the ground. Factors affecting accelerated erosion are included in the universal soil loss equation.

A = R x K x LS x C x P ... (equation 1)

Where: A= Predicate soil loss, R= Climatic factor, K= Soil Erodibility, L=Slope length, S=Slope gradient and steepness, C=Cover and management and P=erosion control practices (Brady and weil 1999).

Gullies reduce the productivity of farm land where they incise into land, and produce sediments that may clog downsteam water. The total loss from gully formation and subsequent downsteam river sedimentation can be sizable.

The aims of the study are to: (a). determine some of the soil physical and chemical properties of gully prone soils; and (b). propose soil management approach to improving the productivity and fertility of soils in gully prone sites.

**Materials and methods**

Field studies were conducted during the late rainy season in October 2008, Five (5) major gully sites and soils from adjacent sites in Edo state were used for study. Sampling locations were: Ekehuan Road; Agbor Motor Park Road; Temboga and University of Benin Campus and Ambrose Alli University Campus Ekpoma. Soil auger samples were collected from areas close to the gully sites and from fields with no trace of gully activities. Sampling depths were taken at 30cm intervals (0-30cm, 30-60cm, 60-90cm and 90-120cm). Five (5) core samples were taken in each of the locations and bulked together to obtain composite soil samples, the composite soil samples was air dried, sieve through a 2-mm sieve and passed in plastic containers before laboratory analysis.

The soil samples were analyzed for its physical and chemical properties. Particle size was determined by the hydrometer method (Okalebo et al., 1982). Bulk density "pb" was determined by Core method (Black, 1965):

$$Pb = \frac{Mass\ of\ dry\ soil}{Total\ Volume} = \frac{Ms}{Vt} = \frac{Ms}{Vs + +Va + Vw}\ g.cm^{-3}$$

Where Ms = Mass of dry Soil, Vt = Total Volume of Soil, Vs = Volume of Solid particles, Va = Volume of Air and Vw = Volume of Water.

Porosity "f" was calculated from the value obtained for bulk density. (Black, 1965):

$f = 1 - \frac{Pb}{Ps}$ Where Pb = Bulk density, Ps = Particle density 2.65g/cm$^3$.

Vbid ratio "e" was calculated from values obtained from porosity. (Black, 1965):

$$e = \frac{Va + Vw}{Vs} = \frac{Vf}{(Vt - Vf)} = \frac{f}{1 - f}$$

Where Vs = Volume of Solid particles, Va = Volume of Air and Vw = Volume of Water; Vf = Void volume, Vt = Total Volume and F = Porosity.

Water holding capacity was estimated as the difference between the water content at field capacity and the water content at permanent wilting point (Black, 1965). Soil pH was measured in 1:1 soil-water suspension using glass electrode pH meter (Maclean, 1982). Organic matter was determined by wet dichromate acid oxidation method (Nelson and Sommers 1982). Aluminum oxide ($Al_2O_3$) and iron oxide ($Fe_2O_3$) were determined as described by McKeague and Day (1966). Exchangeable bases (Ca, Mg, K and N) were extracted with 1 N $NH_4$ OAc buffered at pH 7.0 (Thomas 1982). Exchangeable K and N contents of the extracts were read on EEL flame photometer, while exchangeable Ca and Mg were determined with atomic absorption spectrophotometer.

It was a complete randomized design experiment consisting of five locations and replicated two times. The levels were the location which were: Ekehuan Road; Agbor Motor Park Road; Temboga and University of Benin Campus and Ambrose Alli University Campus Ekpoma. Replicate were the mean values of the prone and control sites.

## RESULTS AND DISCUSSION

Physico-Chemical properties of Ekehuan gully prone and control sites is shown in Table 1. The prone soils had sand, silt and clay content varying from 75 to 83% for sand, 3 to 4% for Silt while Clay had 14 to 21%. Water holding capacity varied from 7 to 23%; porosity (f) 38 to 41%, bulk density 1.56 to 1.66 g.cm$^{-3}$ and void ratio varied from 0.62 to 0.70. Organic matter had values of 4.55g/kg – 5.77g/kg. While Ca, Mg, K and Na had mean value of 7.33 and 1.98% respectively. The control samples had mean values of sand silt and clay being 74.25, 3.25 and 22.50% respectively. The sand contents were lower in the control samples, while mean values of silt were not different. Clay content was slightly higher in control soils than the prone sites. Soils textures for both sites varied from sandy loam, sandy-clay loam and loamy sand respectively.

**Table 1: Physico-Chemical Properties of Ekehuan Gully Prone and Control sites.**

| | **Control Depth (cm)** | | | | | **Prone Depth (cm)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** |
| Sand ↑ | 79 | 75 | 73 | 70 | 74.25a | 82 | 80 | 75 | 83 | 80.00b |
| Silt | 3 | 4 | 3 | 3 | 3.25a | 3 | 3 | 4 | 3 | 3.25a |
| Clay % | 18 | 21 | 24 | 27 | 22.50a | 15 | 17 | 21 | 14 | 16.75b |
| WHC | 24 | 4 | 17 | 20 | 16.25a | 23 | 12 | 13 | 7 | 13.75a |
| f ↓ | 39 | 43 | 41 | 40 | 40.75a | 39 | 40 | 41 | 38 | 39.50a |
| $P_b$gcm$^{-3}$ | 1.61 | 1.50 | 1.54 | 1.58 | 1.56a | 1.60 | 1.58 | 1.56 | 1.66 | 1.60a |
| e | 0.64 | 0.75 | 0.70 | 0.67 | 0.69a | 0.64 | 0.67 | 0.70 | 0.62 | 0.66a |
| **Texture** | **Sandy Loam** | **Sandy Clay Loam** | **Sandy Clay Loam** | **Sandy Clay Loam** | | **Loamy Sand** | **Sandy Loam** | **Sandy Clay Loam** | **Loamy Sand** | |
| pH | 5.06 | 4.96 | 4.36 | 4.33 | 4.68a | 5.77 | 5.00 | 4.72 | 4.55 | 5.01a |
| Org.C | 8.90 | 5.00 | 3.90 | 2.50 | 5.07a | 7.7 | 5.8 | 3.3 | 2.1 | 4.72a |
| g/kg | 1.00 | 0.52 | 0.72 | 0.56 | 0.70a | 1.16 | 1.00 | 0.36 | 0.72 | 0.81a |
| Ca ↑ | 0.48 | 0.10 | 0.09 | 0.08 | 0.19a | 0.24 | 0.20 | 0.08 | 0.08 | 0.15a |
| Mg | 0.13 | 0.08 | 0.06 | 0.03 | 0.08a | 0.06 | 0.04 | 0.03 | 0.01 | 0.03a |
| K | 0.07 | 0.06 | 0.07 | 0.08 | 0.07a | 0.10 | 0.11 | 0.11 | 0.10 | 0.10a |
| (cmol.kg$^{-1}$) | 8.89 | 10.2 | 10.72 | 11.73 | 10.38a | 6.98 | 7.51 | 7.44 | 7.41 | 7.33a |
| | 2.04 | 2.91 | 3.69 | 3.22 | 2.97a | 1.53 | 1.86 | 1.86 | 2.66 | 1.98a |
| Na ↓ | | | | | | | | | | |
| $Fe_2O_3$% | | | | | | | | | | |
| $Al_2O_3$% | | | | | | | | | | |

Key: $P_b$ = Bulk Density, f = Porosity, WHC = Water Holding Capacity, e = Void ratio and DMRT = Duncan Multiple Range Test.

Mean values for sand, silt and clay in Table 2 were 63.50, 2.25 and 34.25% in the prone samples, while those of the control were 77.75, 1.75 and 20.50% respectively. Duncan multiple range tests for mean values for sand, Clay, Water Holding Capacity (WHC) and Organic matter were low in both the prone and control samples. Soil Texture varied from Sandy-Clay-Loam to Sandy-Clay in the prone site while the control site varied from Sandy-Loam to Sandy-Clay. The prone site had bulk density varying from 1.48 to 1.55g.cm$^{-3}$, while water holding capacity varied from 16 to 25%, while those of the control sites had bulk density values varying from 1.5 to 1.70g.cm$^{-3}$. Water holding capacity values ranged 9 to 16%.

The soils at the prone site in Table 3 varied from 71 to 81% for sand, 1 to 3% silt and 16 to 27% clay; while water holding capacity varied from 12% to 17%. Sand, clay and water holding capacity of the prone soils were significantly different from that of the control. Organic carbon content, pH, exchangeable cations and Fe and Al oxides were low in both sites.

Table 4 shows the results of the soil physic-chemical properties for Queen Ede gully prone and control soil samples. Results show no significant difference between the prone and control sites. The Prone soils had sand, silts, and clay content varying 68 to 79% for sand, 1 to 4% for Silt, while Clay had 19 to 31% respectively. Water holding capacity varied from 9 to 17%, porosity (f) 39 to 42%, bulk density 1.51 to 1.61 g.cm$^{-3}$ and void ratio varied from 0.64 to 0.72. The chemical properties varied with organic matter having values of 4.21 g/kg – 4.68g/kg, while ca, Mg, k and Na had mean values of o.46cmol.kg$^{-1}$, 0.05cmol kg$^{-1}$ and 0.06cmol.kg$^{-1}$.

**Table 2: Physico-Chemical Properties of Ekpoma Gully Prone and Control sites**

| | **Control Depth (cm)** | | | | | **Prone Depth (cm)** | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** |
| Sand ↑ | 81 | 78 | 79 | 73 | 77.75a | 63 | 57 | 58 | 58 | 63.50b |
| Silt | 2 | 3 | 1 | 1 | 1.75a | 2 | 3 | 1 | 1 | 2.25a |
| Clay % | 17 | 19 | 20 | 26 | 20.50a | 35 | 40 | 41 | 41 | 34.25b |
| WHC | 9 | 13 | 14 | 16 | 13.75a | 16 | 25 | 23 | 23 | 22.00b |
| f ↓ | 39 | 38 | 36 | 42 | 38.75a | 41 | 41 | 43 | 43 | 41.50a |
| $P_b gcm^{-3}$ | 1.61 | 1.65 | 1.70 | 1.51 | 1.62a | 1.55 | 1.55 | 1.48 | 1.48 | 1.53a |
| e | 0.64 | 0.62 | 0.57 | 0.72 | 0.64a | 0.70 | 0.70 | 0.75 | 0.75 | 0.71a |
| **Texture** | **Sandy Loam** | **Sandy Loam** | **Sandy Loam** | **Sandy Clay Loam** | | **Sandy Clay Loam** | **Sandy Clay** | **Sandy Clay** | **Sandy Clay** | |
| pH | 7.30 | 7.22 | 7.17 | 6.97 | 7.17a | 6.63 | 6.02 | 5.41 | 5.41 | 5.79a |
| Org.C | 3.70 | 6.00 | 3.30 | 0.20 | 3.30a | 26.5 | 8.1 | 5.1 | 5.1 | 10.70b |
| g/kg | 3.48 | 2.00 | 2.04 | 1.92 | 2.61a | 2.32 | 2.32 | 2.20 | 2.20 | 2.17a |
| Ca ↑ | 1.36 | 1.24 | 0.53 | 0.41 | 0.88a | 0.84 | 0.16 | 0.20 | 0.20 | 0.34a |
| Mg | 0.19 | 0.15 | 0.17 | 0.04 | 0.14a | 0.05 | 0.02 | 0.02 | 0.02 | 0.02a |
| K | 0.09 | 0.12 | 0.12 | 0.13 | 0.11a | 0.16 | 0.17 | 0.21 | 0.21 | 0.17a |
| (cmol.kg$^{-1}$) | 8.45 | 8.38 | 8.41 | 7.38 | 8.16a | 9.37 | 9.28 | 8.92 | 8.92 | 9.11a |
| | 3.82 | 3.95 | 4.28 | 4.33 | 4.10a | 2.66 | 2.78 | 2.13 | 2.13 | 2.46a |
| Na ↓ | | | | | | | | | | |
| $Fe_2O_3$% | | | | | | | | | | |
| $Al_2O_3$% | | | | | | | | | | |

Key: $P_b$ = Bulk Density, f = Porosity, WHC = Water Holding Capacity, e = Void ratio and DMRT = Duncan Multiple Range Test.

**Table 3: Physico-Chemical Properties of Temboga Gully Prone and Control sites.**

| | Control Depth (cm) | | | | | Prone Depth (cm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** |
| Sand ↑ | 76 | 69 | 67 | 65 | 69.25a | 61 | 75 | 74 | 71 | 75.25b |
| Silt | 3 | 2 | 2 | 3 | 2.50a | 3 | 3 | 1 | 2 | 2.25a |
| Clay % | 21 | 30 | 31 | 32 | 28.50a | 16 | 22 | 25 | 27 | 22.50b |
| WHC | 17 | 11 | 25 | 21 | 18.50a | 14 | 17 | 16 | 12 | 14.75b |
| f ↓ | 41 | 40 | 40 | 42 | 40.75a | 39 | 41 | 38 | 41 | 39.75a |
| $P_b gcm^{-3}$ | 1.55 | 1.59 | 1.59 | 1.53 | 1.56a | 1.63 | 1.54 | 1.65 | 1.56 | 1.59a |
| e | 0.70 | 0.67 | 0.67 | 0.72 | 0.69a | 0.64 | 0.70 | 0.62 | 0.70 | 0.66a |
| **Texture** | **Sandy Clay Loam** | **Sandy Clay Loam** | **Sandy Loam** | **Sandy Clay Loam** | | **Sandy Clay Loam** | **Sandy Clay** | **Sandy Clay** | **Sandy Clay Loam** | |
| pH | 4.68 | 4.75 | 4.69 | 4.71 | 4.71a | 4.89 | 4.34 | 2.25 | 4.44 | 4.48a |
| Org.C g/kg | 8.80 | 8.00 | 5.90 | 1.30 | 6.00a | 9.7 | 6.8 | 5.0 | 1.6 | 5.78a |
| Ca ↑ | 0.68 | 0.52 | 0.32 | 0.24 | 0.44a | 0.80 | 0.40 | 0.44 | 0.44 | 0.52a |
| Mg | 0.18 | 0.12 | 0.10 | 0.07 | 0.12a | 0.14 | 0.06 | 0.08 | 0.09 | 0.09a |
| K (cmol.kg$^{-1}$) | 0.12 | 0.10 | 0.04 | 0.03 | 0.07a | 0.05 | 0.03 | 0.01 | 0.00 | 0.02a |
| Na ↓ | 0.08 | 0.08 | 0.07 | 0.07 | 0.08a | 0.10 | 0.11 | 0.11 | 0.09 | 0.10a |
| $Fe_2O_3$% | 5.92 | 6.13 | 6.18 | 5.86 | 6.02a | 4.69 | 5.88 | 5.11 | 5.03 | 5.18a |
| $Al_2O_3$% | 1.40 | 1.33 | 1.20 | 1.15 | 1.27a | 0.91 | 0.80 | 0.71 | 0.72 | 0.79a |

Key: $P_b$ = Bulk Density, f = Porosity, WHC = Water Holding Capacity, e = Void ratio and DMRT = Duncan Multiple Range Test.

**Table 4: Physico-Chemical Properties of Queen-Ede Gully Prone and Control sites.**

| | Control Depth (cm) | | | | | Prone Depth (cm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** |
| Sand ↑ | 80 | 71 | 69 | 62 | 70.50a | 79 | 73 | 69 | 68 | 72.25a |
| Silt | 1 | 1 | 1 | 3 | 1.50a | 2 | 4 | 2 | 1 | 2.25a |
| Clay % | 19 | 28 | 30 | 35 | 28.00a | 19 | 23 | 29 | 31 | 25.80a |
| WHC | 15 | 14 | 17 | 27 | 18.25a | 9 | 16 | 16 | 17 | 15.00a |
| f ↓ | 37 | 41 | 41 | 41 | 40.00a | 41 | 39 | 40 | 42 | 40.50a |
| $P_b gcm^{-3}$ | 1.69 | 1.54 | 1.54 | 1.59 | 1.58a | 1.56 | 1.61 | 1.58 | 1.51 | 1.56a |
| e | 0.59 | 0.70 | 0.70 | 0.70 | 0.67a | 0.70 | 0.64 | 0.67 | 0.72 | 0.68a |
| **Texture** | **Sandy Loam** | **Sandy Loam** | **Sandy Loam** | **Sandy Clay Loam** | | **Sandy Clay Loam** | **Sandy Clay** | **Sandy Clay** | **Sandy Clay** | |
| pH | 7.08 | 6.44 | 5.85 | 5.50 | 6.22a | 4.68 | 4.32 | 4.21 | 4.44 | 4.41a |
| Org.C g/kg | 7.20 | 3.50 | 3.90 | 2.50 | 4.27a | 7.0 | 5.4 | 4.0 | 3.6 | 5.00a |
| Ca ↑ | 4.12 | 1.52 | 1.32 | 1.08 | 2.01a | 0.56 | 0.40 | 0.40 | 0.48 | 0.46a |
| Mg | 1.73 | 0.09 | 0.07 | 0.66 | 0.64a | 0.06 | 0.04 | 0.05 | 0.06 | 0.05a |
| K (cmol.kg$^{-1}$) | 0.09 | 0.11 | 0.04 | 0.005 | 0.06a | 0.03 | 0.02 | 0.01 | 0.00 | 0.01a |
| Na ↓ | 0.14 | 0.10 | 0.08 | 0.08 | 0.10a | 0.07 | 0.07 | 0.05 | 0.06 | 0.06a |
| $Fe_2O_3$% | 5.49 | 5.61 | 4.68 | 4.83 | 5.15a | 6.09 | 6.18 | 5.35 | 5.36 | 5.75a |
| $Al_2O_3$% | 1.53 | 1.62 | 1.64 | 1.82 | 1.65a | 2.42 | 2.53 | 2.66 | 3.00 | 2.65a |

Key: $P_b$ = Bulk Density, f = Porosity, WHC = Water Holding Capacity, e = Void ratio and DMRT = Duncan Multiple Range Test.

respectively $Fe_2O_3$ and $Al_2O_3$ had mean values of 5.57% and 2.65% respectively. Values from the two sites were not significantly different.

The control samples had mean values for sand silt and clay varying from 70.50%, 1.50% and 28.00% respectively. There was little variation in the values of sand for the control and prone samples. Soil texture ranged from sandy-loamy to sandy – clay loam is the prone site and sandy-loamy, sandy-clay-loam and sandy-clay in the control site. Results from University of Benin gully site are shown in table 5. Mean values for sand, silt and clay showed a higher sand content with no significant difference. Mean values for sand, silt and clay were 78.50, 2.50 and 19.00% respectively in the prone samples, while those of the control were 77.25, 2.25 and 20.50%. Soil texture varied from sandy-loamy to sandy-clay in the prone site while the control site was sandy-loamy.

The prone site had bulk density which ranged from 1.54 to 1.70g.cm$^{-3}$, while water holding capacity varied from 5 to 7%. The control site had bulk density values varying from 1.56 to 1.71g.cm$^{-3}$, water holding capacity 9 to 22%. $Fe_2O_3$ and $Al_2O_3$ varied from 5.85 to 6.78 to 9.31% and 3.51 to 3.89%.

## CONCLUSION

The study of soil physical and chemical properties at five gully erosion sites and nearby uneroded (control) sites were carried out in order to promote management practices for the eroded sites. The soils at the gully sites had lower values for cations and oxides such as K, Ca, Mg, $Fe_2O_3$ and $Al_2O_3$ and lower pH compared with control sites but was not significantly different. The soils at both gully and control sites were physically degraded as indicated by the lower clay and higher sand contents, higher bulk density and lower void ratio. This goes further to show the loss of soil fertility at the sites.

The management implications of the observation above conclude the following:

(i) the need to restore the osils near eroded sites by establishing erosion control measures that will stabilize the soil, reduce or control runoff and loss of clay particles and organic matter which are responsible for moisture and nutrient retention. Control measures could include afforestation, mulching, conservative tillage, reduced tillage and permanent cropping.

(ii) soil productivity and fertility should be improved through application of organic manures, locally sourced lime materials for raising soil pH.

(iii) to avoid creation of gullies, adequate care is needed in planning and implementation of some development projects. The histories of the initiation of these gullies in the study sites were due to bad land use and poor control of food water. Adequate provision should be included in future development plans towards a safe delivery of peat floods.

**Table 5: Physico-Chemical Properties of University of Benin Gully Prone and Control sites**

| | Control Depth (cm) | | | | | Prone Depth (cm) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** | **0-30** | **30-60** | **60-90** | **90-120** | **Mean (DMRT)** |
| Sand ↑ | 82 | 80 | 78 | 69 | 77.25a | 80 | 79 | 80 | 75 | 78.50a |
| Silt | 2 | 1 | 3 | 3 | 2.25a | 1 | 2 | 4 | 3 | 2.50a |
| Clay % | 16 | 19 | 19 | 28 | 20.50a | 19 | 19 | 16 | 22 | 19.00a |
| WHC | 15 | 22 | 9 | 17 | 15.75a | 7 | 5 | 8 | 7 | 6.75a |
| f ↓ | 41 | 36 | 36 | 37 | 37.50a | 36 | 36 | 39 | 41 | 38.00a |
| $P_b$gcm$^{-3}$ | 1.56 | 1.70 | 1.71 | 1.68 | 1.66a | 1.70 | 1.70 | 1.63 | 1.54 | 1.64a |
| e | 0.70 | 0.57 | 0.57 | 0.59 | 0.61a | 0.57 | 0.57 | 0.64 | 0.70 | 0.62a |
| **Texture** | **Sandy Loam** | **Sandy Loam** | **Sandy Loam** | **Sandy Clay** | | **Sandy Loam** | **Sandy Loam** | **Sandy Loam** | **Sandy Clay Loam** | |
| pH | 5.59 | 5.97 | 5.92 | 4.94 | 5.60a | 4.76 | 5.22 | 5.18 | 4.96 | 5.03a |
| Org.C | 13.70 | 8.50 | 3.90 | 3.70 | 7.45a | 1.7 | 0.3 | 0.0 | 0.2 | 0.55a |
| g/kg | 2.28 | 1.64 | 1.24 | 1.00 | 1.54a | 0.64 | 0.96 | 0.88 | 1.00 | 0.87a |
| Ca ↑ | 0.87 | 0.59 | 0.47 | 0.33 | 0.56a | 0.24 | 0.32 | 0.19 | 0.28 | 0.26a |
| Mg | 0.06 | 0.05 | 0.05 | 0.05 | 0.05a | 0.04 | 0.02 | 0.01 | 0.00 | 0.02a |
| K | 0.08 | 0.08 | 0.05 | 0.04 | 0.06a | 0.09 | 0.10 | 0.08 | 0.07 | 0.08a |
| (cmol.kg$^{-1}$) | 8.78 | 9.12 | 9.31 | 9.27 | 9.12a | 5.85 | 5.98 | 6.58 | 6.75 | 6.29a |
| | 3.51 | 3.62 | 3.75 | 3.89 | 3.69a | 1.55 | 1.60 | 1.51 | 1.98 | 1.66a |
| Na ↓ | | | | | | | | | | |
| $Fe_2O_3$% | | | | | | | | | | |
| $Al_2O_3$% | | | | | | | | | | |

Key: $P_b$ = Bulk Density, f = Porosity, WHC = Water Holding Capacity, e = Void ratio and DMRT = Duncan Multiple Range Test.

**Table 6: Complete Randomized Design showing the Effect of Location and Depth**

| | Control | | | | | | Prone | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Ekehuan** | **Ekpoma** | **Temboga** | **Queen Ede** | **Uniben** | **Mean (DMRT)** | **Ekehuan** | **Ekpoma** | **Temboga** | **Queen Ede** | **Uniben** | **Mean (DMRT)** |
| Sand ↑ | 74.25 | 77.75 | 69.25 | 70.50 | 77.25 | 73.80a | 80.00 | 63.50 | 75.25 | 72.25 | 78.50 | 73.90a |
| Silt | 3.25 | 1.75 | 2.50 | 1.50 | 2.25 | 2.25a | 3.25 | 2.25 | 2.25 | 2.25 | 2.50 | 2.50a |
| Clay % | 22.50 | 20.50 | 28.50 | 28.00 | 20.50 | 24.00a | 16.75 | 34.25 | 22.50 | 25.50 | 19.00 | 23.60a |
| WHC | 16.25 | 13.75 | 18.50 | 18.25 | 15.75 | 16.50a | 13.75 | 22.00 | 14.75 | 15.00 | 6.75 | 14.45a |
| f ↓ | 40.75 | 38.75 | 40.75 | 40.00 | 37.50 | 39.55a | 39.50 | 41.50 | 39.75 | 40.50 | 38.00 | 39.85a |
| $P_b gcm^{-3}$ | 1.56 | 1.62 | 1.56 | 1.58 | 1.66 | 1.60a | 1.60 | 1.53 | 1.59 | 1.56 | 1.64 | 1.58a |
| e | 0.69 | 0.64 | 0.69 | 0.67 | 0.61 | 0.66a | 0.66 | 0.71 | 0.66 | 0.68 | 0.62 | 0.67a |
| | 4.68 | 7.17 | 4.71 | 6.22 | 5.60 | 5.68a | 5.01 | 5.79 | 4.48 | 4.41 | 5.03 | 4.94a |
| **pH** | | | | | | | | | | | | |
| Org.C g/kg | 5.07 | 3.30 | 6.00 | 4.27 | 7.45 | 5.22a | 4.72 | 10.70 | 5.78 | 5.00 | 0.56 | 5.35a |
| Ca ↑ | 0.70 | 2.61 | 0.44 | 2.01 | 1.54 | 1.46a | 0.81 | 2.17 | 0.52 | 0.46 | 0.87 | 0.97a |
| Mg | 0.19 | 0.88 | 0.12 | 0.64 | 0.56 | 0.48a | 0.15 | 0.34 | 0.09 | 0.05 | 0.26 | 0.18a |
| K ($cmol.kg^{-1}$) | 0.08 | 0.14 | 0.07 | 0.06 | 0.05 | 0.08a | 0.03 | 0.02 | 0.02 | 0.01 | 0.02 | 0.02a |
| Na ↓ | 0.07 | 0.11 | 0.08 | 0.10 | 0.06 | 0.08a | 0.10 | 0.17 | 0.10 | 0.06 | 0.08 | 0.10a |
| $Fe_2O_3$% | 10.38 | 8.16 | 6.02 | 5.15 | 9.12 | 7.77a | 7.33 | 9.11 | 5.18 | 5.75 | 6.29 | 6.73a |
| $Al_2O_3$% | 2.97 | 4.10 | 1.27 | 1.65 | 3.69 | 2.74a | 1.98 | 2.46 | 0.79 | 2.65 | 1.66 | 1.91a |

Key: $P_b$ = Bulk Density, f = Porosity, WHC = Water Holding Capacity, e = Void ratio and DMRT = Duncan Multiple Range Test.
Test and Uniben = University of Benin.

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