*FUDMA Journal of Sciences (FJS)*
*ISSN online: 2616-1370*
*ISSN print: 2645 - 2944*
*Vol. 9 No. 12, December (Special Issue), 2025, pp 750 – 762*
*DOI: https://doi.org/10.33003/fjs-2025-0912-4394*

# SOIL ERODIBILITY INDICES ALONG RIVER BENUE BANKS AT MAKURDI, NIGERIA

**[*1]Malum Japhet Flayin, [2]Eze Ejike Colins, [2]Okafor Izuchukwu John**

[1]Department of Agricultural and Biosystems Engineering, Joseph Sarwuan Tarka University Makurdi, Benue State, Nigeria.
[2]Department of Agricultural and Environmental Engineering, University of Ibadan, Oyo State, Nigeria.

*Corresponding authors' email: jf.malum@uam.edu.ng Phone +2348027299176

**ABSTRACT**

Soil erosion along riverbanks is a major environmental challenge in Nigeria, particularly in Makurdi where the River Benue predisposes surrounding soils to degradation due to high rainfall, runoff, and fragile soil conditions. Understanding soil erodibility is crucial for predicting erosion rates and designing effective conservation measures. This study was conducted to determine the erodibility factor (K) of soils at different locations along the River Benue bank at Makurdi and to assess variations in soil erodibility within the study area. Six locations along the bank behind Benue state university were selected and named as location 1, 2, 3, 4, 5, and 6, respectively. Samples were collected at 30 and 60cm soil depth at each location to represent the crop root zone of the area. Particle size determination was carried out and hydrometer test to determine the various particle size distribution of soils in various location. The analysis of result showed that the erodibility factor (K) of soils varies with locations. The average k-values for the different locations were: 6.35 at 30cm;4.68 at 60cm soil depths for Location 1 respectively. At Location 2, at 30cm soil depth 7.6, at 60cm soil depth was 5.4, Location 3, at 30cm soil depth was 16.9; at 60cm soil depth 12.2, Location 4, 30cm soil depth was 9.42,at 60cm soil depth was 12.2, Location 5, at 30cm was 7.6, at 60cm soil depth was 6.35, Location 6 at 30cm soil depth was 9.42, at 60cm soil depth was 7.93 respectively. By implication, these results provides idea of selecting conservative measures appropriate for control of erosion at the Benue River Bank. The results further shows that the particle size analysis of soils in the study area are mainly silty sandy which makes them more susceptible to erosion.

**Keywords**: Soil, River Bank, Erodibility Factor, Erosion, Infiltration Rate

## INTRODUCTION

Agricultural land use in Nigeria often results in the degradation of natural soil fertility and reduced productivity. Soil degradation involves soil erosion, sedimentation and leaching, which impact negatively on soil productivity(Iorkpiligh, *et al.,* 2025). Soil erosion is the loosening, removal and transport of soil material from one place to another (detachment, transportation and deposition). The major predisposing factors are rainfall, runoff and fragile soil conditions. According to Relf (2001) flowing water at excessive speed damages the topsoil mostly on the riverbanks. Most areas on the bank of the river Benue in Makurdi are severely predisposed to erosion due to high rainfall and runoff in the wet seasons, coupled with the vulnerability of the soil to erosion.

Erodibility is specifically and solely a property of the soil, which can be quantitatively evaluated as the vulnerability and susceptibility of soil to erosion in each circumstance. It also refers to the ability of the soil to suffer erosion due to the forces causing detachment and transport of soil particles (Philippe and Benahmed, 2024). Erodibility can be measured or determined via a variety of methods. The purpose of such measurement is to compute the soil erodibility factor (K) (k-value), used to designate the rate of soil loss on annual basis. The k-values for the soils on the banks of the river Benue in Makurdi are not fully determine and this has posed a problem on developing effective erosion control measures for the area. Makurdi is the capital of Benue State in central Nigeria. Makurdi witnesses a rapid increase in socio–economic and physical development. Riverbank erosion in Makurdi is unpredictable because of the impacts of anthropogenic activities (Czatzkowska *et al.*,2022). The erosion involves the wearing away of the soil along the riverbed and banks. The amount of soil erosion loss depends on the strength of the rain and fragility of the soil (Mikolai,*et al*,2023; Xinyu *et al*, 2025).

Soils on the banks of the River Benue, particularly around Makurdi, are annually eroded due to the combined influence of rainfall, runoff, and the inherent vulnerability of the soil (Abah, 2012; Dominic and Benjamin, 2023). Unfortunately, there is insufficient knowledge regarding the erodibility values of these soils, which are essential for predicting erosion rates and guiding effective planning and conservation strategies. Therefore, the aim of this study was to determine the soil erodibility factors (K-values) of the Benue Riverbank soils at Makurdi, and to evaluate their spatial variation across different locations and depths to provide a scientific basis for appropriate erosion control measures.

### The Erodibility of Soils

Soil erosion is the process whereby particles of the soil is relocated, it involves the detachment and transportation of the soil particles from one location to another and the eventual deposition of such particles (Stresser and de Brum,2023).

Erodibility of soils is complex but based on the interaction of dynamic processes with climate and management systems, cation exchange capacity, and index of clay mineralogy, which is closely related to inter-particle forces, show erodibility to vary with soil structure (McKague and Eng,2024). Soil texture influences soil erosion because coarse particle required a higher fluid drag (wind or water than small particles (Wandra, 2021). In general, clay and size particles adhere to form large, heavy aggregates (Imeson, 2020).

The erodibility of soil is the vulnerability or susceptibility of soil to erosion. That is the reciprocal of its resistance to erosion (Kanwar *et al.,* 2025). A soil with a high erodibility will suffer more erosion than a soil with low erodibility if both are exposed to the same rainfall. Whereas erosivity which is specifically and solely by a property of rainfall, can be qualitatively evaluated as the potential capacity of rain to cause erosion in given circumstances.

The important soil physical properties that affect the resistance of soil erosion include texture, structure, water retention and transmission properties and unconfined compressive and shear strength(Parwada, *et al.,* 2020). Soil texture implies the usual appearance and feel of soil, particle size distribution refers to the diameter as determined by laboratory analysis. In relation to soil erosion, the particle size distribution should be characterized according to the system of the international society of soil science (Sowiński *et al.,* 2023).

**Soil Structure and Erodibility Hazards**

Soil structure as defined by the (USDA, 2022) is only qualitative description of soil peds and is not precise enough for predicting its behaviour as regards different management systems. Soil structure is defined as the arrangement of soil particles and of pore space between them.

Soil structure refers to the geochemical and geo-mechanical arrangement of soil particles. It is the arrangement of soil particle into easily recognizable geometric shape that influence the response behaviour of the soil to external constraints of raindrop impact or shearing forces of moving water or blowing wind (Juriga and Šimanský, 2018).

Soil structure is vital to the erodibility of soils, because it greatly ascertains or determines the infiltration rate of soils as well as resistance of soil particles detachment by rainfall impact and subsequent removal in the surface runoff.

**Soil Erodibility Factor (K)**

Soil erodibility is an integrated response of the soil inherent properties, properties of eroding fluids and their interaction with climate; there are no simple and measurable soil parameters that can represent the integrated response of this complex variable soil erodibility. The soil response to erosion depends on their mechanical make up and chemical composition because of the difference in their inherent properties soil exhibit different degree of erodibility to the forces generated by erosion agents (Shafii *et al.,* 2016; Radziuk and Marcin, 2021).

Particle size distribution is important in sediment detachment and entrainment. Texture also determined the ease with which a soil can be dispersed. Soil containing low amount of clay are easily dispersed. The size of soil particles also determined the force required for detachment and entrainment, (Umi *et al.,* 2023). The larger the particle, the more the force needed for its transportation (lei *et al*, 2002; Xuchang,2023). Soil erodibility index is one of the factors of the Universal Soil Loss Equation (USLE), which according to Westheimer and Smith (1978; Rubianca *et al.,* 2018) is expressed in equation (1).

$$A = R \times K \times S \times C \times P \quad (1)$$

Where:

A = average annual soil losses (t. $ha^{-1}yr^{-1}$)

R = Rainfall Erosivity factor (MJ $mmha^{-1}\ h^{-1}\ yr^{-1}$)

K = Soil Erodibility factor (t. ha. $hha^{-1}\ MJ^{-1}\ mm^{-1}$)

S = Slope length and Steepness factor (dimensionless)

C = Cover Crop Management factor (dimensionless)

P = Conservative/Management practice factor (dimensionless)

The USLE is a conservation tool used to estimate erosion for disturbed land (Morgan,2011). It was done out of the necessity to understand the concept of soil loss due to environmental factors resulting in depreciation of soil quality leading to degradation. The USLE is an empirical model which has given rise to so many other models like LISEM (Limburg Soil Erosion Model), WEPP (Water Erosion Prediction Project), EUROSEM (European Soil Erosion Model), EGEM (Ephemeral Gully Erosion Model) and PESERA (Pan European Soil Erosion Risk Assessment). The USLE was developed on experimental plots and empirical erosion data collected from relatively small plots or sub-watershed on relatively uniform hill slopes resulted in limited estimates of existing situations so this necessitated the evolution of the RUSLE, (Revised Universal Soil Loss Equation) by Renard *et al,* (1997).The RUSLE still retains all the factors of the USLE, only with further modification in the concepts of obtaining the factors. Soil erodibility is designated by the letter K, (Radziuk andMarcin,2021). this factor is dependent on physical properties of the soil which could intrinsic or exogenic. K-Factor or value is expressed to represent organic matter content, ratios of sand, very fine sand, silt and clay contents, soil structure and permeability/hydraulic conductivity to determine the level of deformation a soil has undergone or is undergoing since the K-factor itself is dependent on the soil properties (SSSA, 2008).

**Determination of Soils Erodibility**

The soil erodibility factor *K* is a quantitative expression of the inherent susceptibility of a particular soil to erode at different rates when the other factors that affect erosion are standardized. Erodibility varies with soil textures, aggregates, stability, shear strength, soil structures, infiltration capacity, soil depth, buck density, soil organic matter and chemical constituents (Agassi and Bradford 1999; Yang *et al.,* 2017).

The depth of erosion is very often determined by the soil depth. Soils below the plough layers are often compact and less erodible. Rills will develop in areas where resistance bedrock is close to the surface if the parent material is unconsolidated such as sands and gravel *(*Morgan 2001;Yang *et al*., 2017*)*.

The organic and chemical constituents of the soil are important because of their influence on stability of aggregates. Soils with less than 2% organic matter can be considered erodible (Evans 1980). Most soils contain less than 15% organic content and many of the sands and sandy loams have less than 2%. Soil erodibility decreases linearly with increasing organic content over the range of 0 to 10%(Agbai *et al,* 2022; Debashis, 2023).

Based on the parameter required according to the soil erodibility indices, soil characteristics requirements for the evaluation of the various parameters found in the erodibility indices as shown in Table 1.

**Table 1: Measurement of Erodibility Indices**

| Erodibility Indices | Calculation |
|---|---|
| Dispersion Ratio (DR) | [(%Silt + %Clay) in undispersed soil]/[%Silt +%Clay) after dispersion of soil in water] |
| Clay Ratio (CR) | = (%Sand + %Silt)/%Clay |
| Modified Clay Ratio | (% Sand + % Silt)/ (% Clay + % Organic matter) |
| Erosion Ratio | DR/ (Colloidal Content/Moisture Equivalent Ratio) |

Source: (Okoro *et al.,* 2022; Akpa, *et al.,* 2025)

***River Bank Soils Erodibility***

Riverbank erosion is a geo-morphological process of alluvial floodplain rivers (Dey and Mandal, 2022). It is defined as the process of wearing of the banks of a stream river. It is because of bank adjustment, bank trampling, and changes in bed elevation and topography in reaction to modified flow conditions or bank resistance. Bank erosion is a natural process; without it rivers would not meander and change occurs (Konsoer *et al.*,2016).

Riverbanks are made up of cohesive soil and can be characterized by obvious vertical stratification structures of soil composition; these riverbanks are very erodible due to the lower clay-content and weak erosion-resistant strength in the bank soil.

Erodibility varies with soil textures, aggregates, stability, shear strength, soil structures, infiltration capacity, soil depth, bulk density, soil organic matter and chemical constituents (Agassi and Bradford 1999). This affect infiltration rate of soil, Infiltration rate depends upon permeability of soil, surface condition and presence of moisture in it.

Riverbank erosion is driven by two primary components, the characteristics of the riverbank and gravitational/hydraulic forces (Saadon *et al.*, 2016). Several commercial or human activities impact both components, which ultimately leads to accelerated erosion. Severe riverbank erosion causes heavy displacements along the bank line of the river sand impacts result in the socio-economic change.

## MATERIALS AND METHODS

### Study Area

Makurdi is the capital of Benue State located at the intersection of latitude $7^0$43” N and longitude $8^0$32” E, central Nigeria. It is a crossing point between the Northern and Eastern parts of Nigeria, an Inland water port town, a provincial headquarters and a State capital.

### Topography

Makurdi town is located in the plains of the River Benue in the Benue Trough. The relief is generally low-lying ranging from below 90 to 150 m on the average. There are interfluves in certain parts of the town where elevation is above the average. The River Benue is the main drainage channel traversing the town. It truncates the town into the North and South Banks. There are also several streams draining Makurdi town on both banks which are tributaries of the River Benue. Most of the streams are perennial and include Kbege, Adaka, Asase, Idye, Urudu and, Demekpe amongst other Areas. The land slope, length of slope and shape of slope are main factors which influences soil erosion. As slope of land increases from mild to steep, erosion increases (Nahib *et al.*, 2024).

### Site Selection and Sampling Points

This research work was carried out at the Benue Riverbank behind Benue State University in Makurdi metropolis, the capital of Benue State of Nigeria (Figure 1).

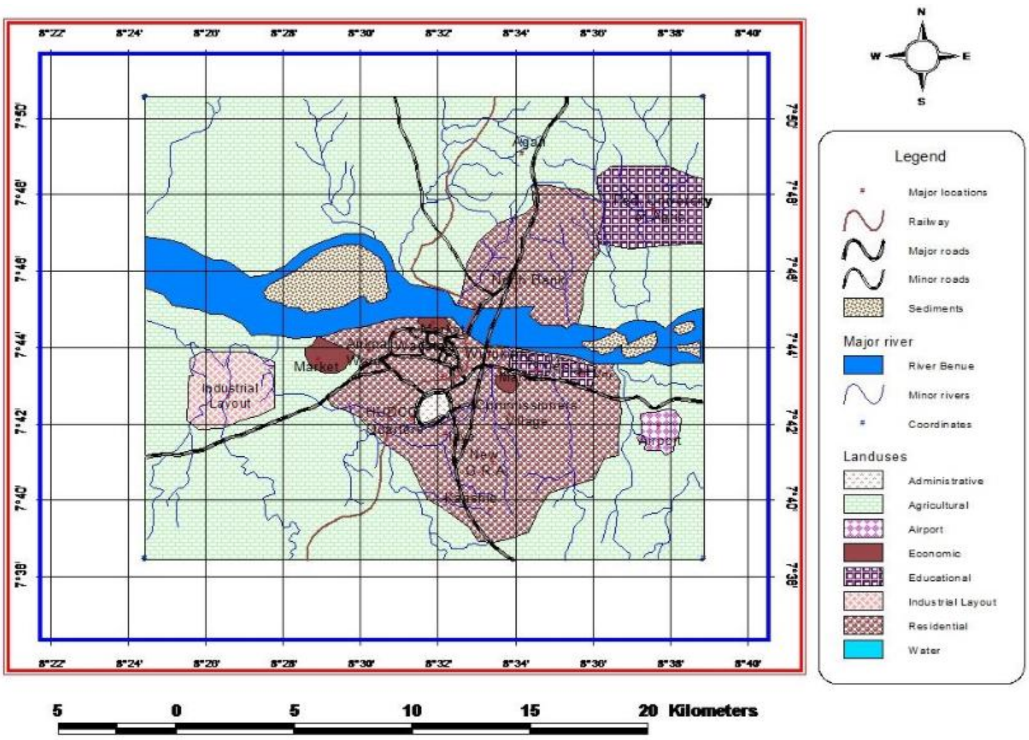


Figure 1: Map of Makurdi showing River Benue

The site selected for field experiment was the eroded and non-eroded zone along the bank of the river Benue found in Benue state of Nigeria. It is located at latitude and longitude of 7.8003° N, 6.7748° E. The site was contour-mapped to indicate the variability of slope as shown in Figure 2.

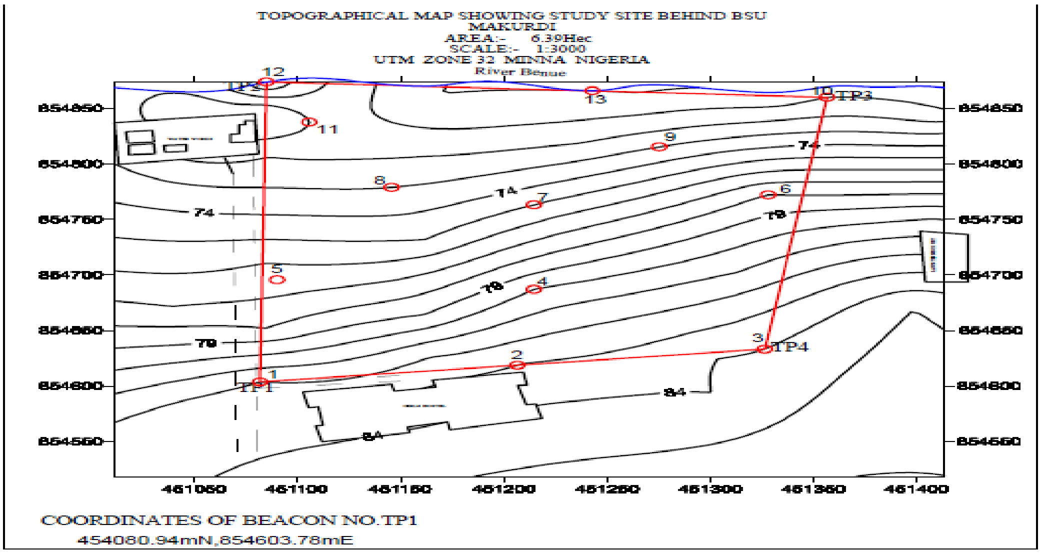


Figure 2: Variability of Slope of Study Site

**Collection of Samples and Analysis**

The soil samples were taken from five different points (Table 2), at 30cm and 60cm below soil surface at different location over the bank of the Benue River behind Benue State University, using soil auger, and turned into a polythene bag for preservation and transportation to the laboratory for analysis, under standard procedure. All the laboratory analyses were carried out in a Soil laboratory using the appropriate materials/ instruments according to standard methods. The hydrometer test result reading are shown in Table 15.

**Table 2: Coordinates of the Location of Samples**

| S/No. | Location | Latitude (n) | Longitude (e) | Elevation (m) |
|---|---|---|---|---|
| 1 | A | $07^0 43,892'$ | $008^0 33,436'$ | 88 |
| 2 | B | $07^0 43,917'$ | $008^0 33,430'$ | 73 |
| 3 | C | $07^0 43,944'$ | $008^0 33,419'$ | 76 |
| 4 | D | $07^0 43,937'$ | $008^0 33,481'$ | 76 |
| 5 | E | $07^0 43,910'$ | $008^0 33,400'$ | 75 |
| 6 | F | $07^0 43,912'$ | $008^0 33,411'$ | 75 |

## RESULTS AND DISCUSSION

### Results

The soil samples obtained from the study area (site A to F) were taken to the laboratory for analysis. Sieve analysis were done using the appropriate and standard methods for the determination. Studies carried out ranged from the erosion factors of the study area, grain sizes into gravels, sand finess. The results are as presented below:

Results of Sieve analysis from sites 1-6 where sample depths ranges from 30 to 60 cm below soil surface are tabulated in Tables 3 – 14. From the result of sieve analysis, the uniformity coefficient, $C_u$ and coefficient of gradation, $C_c$ were determined using the effective size of $D_{10}$, $D_{30}$, $D_{60}$, from the grain size distribution curve (Kalore and Sivakumar, 2023).

Where;

$$Cu = \frac{D60}{D10} \quad (2)$$

**Table 3: Results of Sieve Analysis at Location 1 at 30cm Below Soil Surface from the Bank of the Benue River**

| Sieve No. | Diameter (mm) | Mass Retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0 | 0 | 100 |
| 8 | 2.36 | 1.0 | 0.2 | 99.8 |
| 12 | 1.70 | 4.4 | 0.88 | 98.92 |
| 16 | 1.18 | 23.8 | 4.76 | 94.16 |
| 20 | 0.850 | 43.2 | 8.64 | 85.52 |
| 30 | 0.600 | 68.9 | 13.78 | 71.74 |
| 40 | 0.425 | 84.0 | 16.8 | 54.94 |
| 50 | 0.300 | 130.0 | 26 | 28.94 |
| 100 | 0.150 | 88.0 | 17.6 | 11.34 |
| 200 | 0.075 | 18.2 | 3.64 | 7.7 |
| Pan | | 39.3 | 7.86 | |

% passing = 100 – **Σ** % retained

**Table 4: Results of Sieve Analysis at Location 1 at 60cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass Retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0 | 0 | 100 |
| 8 | 2.36 | 0.2 | 0.04 | 99.96 |
| 12 | 1.70 | 1.5 | 0.3 | 99.66 |
| 16 | 1.18 | 6.3 | 1.26 | 98.4 |
| 20 | 0.850 | 56.4 | 11.28 | 87.12 |
| 30 | 0.600 | 86.4 | 17.28 | 69.84 |
| 40 | 0.425 | 106.2 | 21.24 | 48.6 |
| 50 | 0.300 | 101.2 | 20.24 | 28.36 |
| 100 | 0.150 | 73.6 | 14.72 | 13.64 |
| 200 | 0.075 | 26.9 | 5.38 | 8.26 |
| Pan | | 41.3 | 8.26 | |

% passing = 100 – **Σ** % retained

**Table 5: Results of Sieve Analysis at Location 2 at 30cm Below Soil Surface**

| Sieve No. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.3 | 0.06 | 99.94 |
| 8 | 2.36 | 0.7 | 0.14 | 99.8 |
| 12 | 1.70 | 1.6 | 0.32 | 99.48 |
| 16 | 1.18 | 5.4 | 1.08 | 98.4 |
| 20 | 0.850 | 14.1 | 2.82 | 95.58 |
| 30 | 0.600 | 49.8 | 9.96 | 85.62 |
| 40 | 0.425 | 86.6 | 17.3 | 68.32 |
| 50 | 0.300 | 121.2 | 24.2 | 44.12 |
| 100 | 0.150 | 151 | 30.2 | 13.92 |
| 200 | 0.075 | 26.2 | 5.24 | 8.68 |
| Pan | | 39.9 | 7.98 | |

% passing = 100 – **Σ** % retained

**Table 6: Results of Sieve Analysis at Location 2 at 60cm below Soil Surface**

| Sieve No. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0 | 0 | 100 |
| 8 | 2.36 | 0.6 | 0.12 | 99.88 |
| 12 | 1.70 | 1.2 | 0.24 | 99.64 |
| 16 | 1.18 | 4.8 | 0.96 | 98.68 |
| 20 | 0.850 | 22.8 | 4.56 | 94.12 |
| 30 | 0.600 | 59.7 | 11.94 | 82.18 |
| 40 | 0.425 | 80 | 16 | 66.18 |
| 50 | 0.300 | 105.2 | 21.04 | 45.14 |
| 100 | 0.150 | 142.1 | 28.42 | 16.72 |
| 200 | 0.075 | 37.9 | 7.58 | 9.14 |
| Pan | | 41.2 | 8.24 | |

% passing = 100 – **Σ** % retained

**Table 7: Results of Sieve Analysis at Location 3 at 30cm below Soil Surface**

| Sieve size | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.1 | 0.02 | 99.98 |
| 8 | 2.36 | 1.1 | 0.22 | 99.76 |
| 12 | 1.70 | 8.5 | 1.72 | 98.04 |
| 16 | 1.18 | 22.9 | 4.63 | 93.41 |
| 20 | 0.850 | 45.8 | 9.25 | 84.16 |
| 30 | 0.600 | 81.7 | 16.5 | 67.66 |
| 40 | 0.425 | 98.7 | 19.94 | 47.72 |
| 50 | 0.300 | 104.7 | 21.15 | 26.57 |
| 100 | 0.150 | 99 | 20 | 6.57 |
| 200 | 0.075 | 16.5 | 3.33 | 3.23 |
| Pan | | 16 | 3.23 | |

% passing = 100 – **Σ** % retained

**Table 8: Results of Sieve Analysis at Location 3 at 60cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.6 | 0.12 | 99.76 |
| 8 | 2.36 | 3.4 | 0.68 | 98.78 |
| 12 | 1.70 | 5.3 | 1.07 | 97.72 |
| 16 | 1.18 | 11.4 | 2.30 | 95.44 |
| 20 | 0.850 | 23.4 | 4.72 | 90.76 |
| 30 | 0.600 | 48.7 | 9.82 | 81.02 |
| 40 | 0.425 | 181.0 | 36.49 | 44.82 |
| 50 | 0.300 | 117.9 | 23.77 | 21.24 |
| 100 | 0.150 | 57.4 | 11.57 | 9.76 |
| 200 | 0.075 | 29.2 | 5.89 | 3.92 |
| Pan | | 19.6 | 3.95 | |

% passing = 100 – **Σ** % retained

**Table 9: Results of Sieve Analysis at Location 4 at 30cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.5 | 0.1 | 99.9 |
| 8 | 2.36 | 0.7 | 0.14 | 99.76 |
| 12 | 1.70 | 17.3 | 3.50 | 96.26 |
| 16 | 1.18 | 35.3 | 7.16 | 89.1 |
| 20 | 0.850 | 52.2 | 10.52 | 78.58 |
| 30 | 0.600 | 79.6 | 16.05 | 62.53 |
| 40 | 0.425 | 86.5 | 17.44 | 45.09 |
| 50 | 0.300 | 77 | 15.52 | 29.57 |
| 100 | 0.150 | 86.9 | 17.52 | 12.05 |
| 200 | 0.075 | 18.1 | 3.67 | 8.38 |
| Pan | | 39.3 | 7.97 | |

% passing = 100 – **Σ** % retained

**Table 10: Results of Sieve Analysis at Location 4 at 60cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 1.0 | 0.2 | 99.8 |
| 8 | 2.36 | 3.9 | 0.8 | 99.0 |
| 12 | 1.70 | 5.0 | 1.0 | 98 |
| 16 | 1.18 | 13.8 | 2.8 | 95.2 |
| 20 | 0.850 | 21.4 | 4.3 | 90.9 |
| 30 | 0.600 | 45.9 | 9.2 | 81.7 |
| 40 | 0.425 | 193.5 | 38.7 | 43.0 |
| 50 | 0.300 | 110.0 | 22 | 21.0 |
| 100 | 0.150 | 56.3 | 11.3 | 9.7 |
| 200 | 0.075 | 15.4 | 3.08 | 6.62 |
| Pan | | 33.4 | 6.68 | |

% passing = 100 – **Σ** % retained

**Table 11: Results of Sieve Analysis at Location 5 at 30cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.5 | 0.1 | 99.9 |
| 8 | 2.36 | 0.6 | 0.12 | 99.78 |
| 12 | 1.70 | 2.8 | 0.56 | 99.22 |
| 16 | 1.18 | 31 | 6.24 | 92.98 |
| 20 | 0.850 | 44.3 | 8.91 | 84.07 |
| 30 | 0.600 | 57.8 | 11.63 | 72.44 |
| 40 | 0.425 | 72.8 | 14.65 | 57.79 |
| 50 | 0.300 | 97.1 | 19.54 | 38.25 |
| 100 | 0.150 | 125.8 | 25.31 | 12.94 |
| 200 | 0.075 | 36.7 | 7.38 | 5.56 |
| Pan | | 28.3 | 5.69 | |

% passing = 100 – **Σ** % retained

**Table 12: Results of Sieve Analysis at Location 5 at 60cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.4 | 0.08 | 99.92 |
| 8 | 2.36 | 1.1 | 0.22 | 99.7 |
| 12 | 1.70 | 4.0 | 0.80 | 98.9 |
| 16 | 1.18 | 33.6 | 6.75 | 92.15 |
| 20 | 0.850 | 52.2 | 10.48 | 81.67 |
| 30 | 0.600 | 71.1 | 14.28 | 67.39 |
| 40 | 0.425 | 78.6 | 15.78 | 51.61 |
| 50 | 0.300 | 94.1 | 18.9 | 32.71 |
| 100 | 0.150 | 111.8 | 22.45 | 10.26 |
| 200 | 0.075 | 21.4 | 4.38 | 6.12 |
| Pan | | 29.9 | 6.12 | |

% passing = 100 – **Σ** % retained

**Table 13: Results of Sieve Analysis at Location 6 at 30cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0 | 0 | 100 |
| 8 | 2.36 | 1.2 | 0.2 | 99.5 |
| 12 | 1.70 | 10.5 | 2.1 | 97.8 |
| 16 | 1.18 | 21.2 | 4.2 | 93.4 |
| 20 | 0.850 | 33.5 | 6.7 | 86.7 |
| 30 | 0.600 | 41.0 | 8.2 | 78.5 |
| 40 | 0.425 | 111.7 | 22.3 | 56.2 |
| 50 | 0.300 | 141.3 | 28.1 | 28.1 |
| 100 | 0.150 | 70.2 | 14.0 | 14.1 |
| 200 | 0.075 | 38.4 | 7.7 | 6.4 |
| Pan | | 29 | 6.4 | |

% passing = 100 – **Σ** % retained

**Table 14: Results of Sieve Analysis at Location 6 at 60cm below Soil Surface**

| Sieve no. | Diameter (mm) | Mass retained | % Retained | % Passing |
|---|---|---|---|---|
| 4 | 3.35 | 0.3 | 0.06 | 99.94 |
| 8 | 2.36 | 1.4 | 0.28 | 99.66 |
| 12 | 1.70 | 5.2 | 1.04 | 98.62 |
| 16 | 1.18 | 11.2 | 2.25 | 96.37 |
| 20 | 0.850 | 20 | 4.02 | 92.35 |
| 30 | 0.600 | 56.2 | 11.29 | 81.06 |
| 40 | 0.425 | 88.3 | 17.7 | 63.36 |
| 50 | 0.300 | 116.8 | 23.45 | 39.91 |
| 100 | 0.150 | 133.3 | 26.77 | 13.14 |
| 200 | 0.075 | 31 | 6.22 | 6.92 |
| Pan | | 34.1 | 8.57 | |

% passing = 100 – **Σ** % retained

$$Cc = \frac{D30^2}{D10xD60} \quad (3)$$

The result of grain size analysis by mechanical method are shown in Table15. Graphs of particle sizes and percentage retain and passing of the soil distribution are shown in Figures 5-10. The hydrometer test data and computation of the percentage Sand, Clay and Silt was done using the formula by Bouyoucos, (1935) for the Erodibility index (K):

$$Sand = 100 – (H_1 + 0.2\ (T_1 – 68) – 2.0)2\% \quad (4)$$

**Table 15: Mechanical Grain Size Analysis**

| Location | Depth of Sample(cm) | Mass of dry sample + dish(g) | Description of soil |
|---|---|---|---|
| 1 | Sample A at 30 | 549.2 | Light clay silty-sandy soil |
| | B at 60 | 549.2 | |
| 2 | Sample A at 30 | 545.2 | Light clay silty-sandy soil |
| | B at 60 | 544.2 | |
| 3 | Sample A at 30 | 544.2 | Dark brown sandy soil |
| | B at 60 | 544.2 | |
| 4 | Sample A at 30 | 542.0 | Dark brown sandy soil |
| | B at 60 | 542.0 | |
| 5 | Sample A at 30 | 547.4 | Light brown sandy soil |

| Location | Depth of Sample(cm) | Mass of dry sample + dish(g) | Description of soil |
|---|---|---|---|
| | B at 60 | 546.4 | |
| 6 | Sample A at 30 | 547.0 | Light brown sandy soil |
| | B at 60 | 547.0 | |

Clay = ($H_2$ + 0.2 (T – 68) – 2.0)2% (5)

Silt = 100 – (%sand + %clay) (6)

Where;

$H_1$ = Initial Hydrometer Reading in g/litre

$T_1$ = Initial Temperature in F

$H_2$ = Final Hydrometer Reading in g/litre

$T_2$ = Final Temperature in F.

The erodibility factor (K) was converted using the formula (Wawer *et al.* 2005; Emeka-chris,2014):

$$K = \frac{\%sand + \%silt}{\%clay} \quad (7)$$

Thus, results of the soil texture parameters, K-values and K-index for the various locations are shown in Table 16.

## Discussions

Soil erodibility is the relative ease with which a soil can be eroded, the extent at which the soil can be detached or transported, soil with high proportion of silt and very fine sand are more easily eroded than other soils, organic matter, larger structural aggregates and rapid soil permeability all less on the k-factor.

The particle size analysis by hydrometer method also shows that, various sample point has tendency of being closely eroded with respect to the proportion of sand, clay and silt that are presented along and across the Bank of the Benue River. Grain size analysis determined by the grade curve shows relative proportion of different soil grain sizes contents from various locations were predominantly sandy soils with percentage (%) range from 88.2 -99.4(Figure 5-10), while Fine soils range from 0.6 – 11.8%. Due to the porous nature of sandy soil, and tendency to allow easy passages of water and air, high permeability rates are encouraged, and water flows rates are flows through the soil at ease, which induces landslide and erosion (Idah *et al*., 2008).

It is a known fact that the higher the percentage of fine grains, the lower the permeability value since the fine fraction fills the pore space between the particles.

Percent finer was obtained from the result of sieve analysis, while the uniformity coefficient, $C_u$ and coefficient of gradation, $C_c$ was determined using the effective size of $D_{10}$, $D_{30}$, $D_{60}$, from the

**Table 16: Soil Texture Parametres, K-Values and K-index of the Study Site**

| Location | Sample | Temp ($^0$C$_1$) | Temp ($^0$F$_1$) | $H_1$ | $H_2$ | Temp($^0$C$_2$) | Temp ($^0$F$_2$) | % Sand | % Clay | % Silt | K-Value | K Average | K-index = Average/ 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A | 25 | 77 | 22 | 7 | 25 | 77 | 56.4 | 13.6 | 30.0 | 6.35 | | |
| | B | 25 | 77 | 26 | 9 | 25 | 77 | 48.4 | 17.6 | 34.0 | 4.68 | 5.52 | 0.0552 |
| 2 | A | 25 | 77 | 24 | 6 | 25 | 77 | 52.4 | 11.6 | 36.0 | 7.6 | | |
| | B | 25 | 77 | 25 | 8 | 25 | 77 | 50.4 | 15.6 | 34.0 | 5.4 | 6.5 | 0.065 |
| 3 | A | 25 | 77 | 06 | 03 | 25 | 77 | 88.4 | 5.6 | 6.0 | 16.9 | | |
| | B | 25 | 77 | 08 | 04 | 25 | 77 | 84.4 | 7.6 | 8.0 | 12.2 | 14.6 | 0.1455 |
| 4 | A | 25 | 77 | 10 | 05 | 25 | 77 | 80.4 | 9.6 | 10.0 | 9.42 | | |
| | B | 25 | 77 | 07 | 04 | 25 | 77 | 86.4 | 7.6 | 6.0 | 12.2 | 10.8 | 0.108 |
| 5 | A | 25 | 77 | 18 | 06 | 25 | 77 | 64.4 | 11.6 | 24.0 | 7.6 | | |
| | B | 25 | 77 | 20 | 07 | 25 | 77 | 60.4 | 13.6 | 26.0 | 6.35 | 6.98 | 0.0698 |
| 6 | A | 25 | 77 | 14 | 05 | 25 | 77 | 72.4 | 9.6 | 18.0 | 9.42 | | |
| | B | 25 | 77 | 15 | 04 | 25 | 77 | 70.4 | 7.6 | 21.28 | 7.93 | 7.26 | 0.0726 |

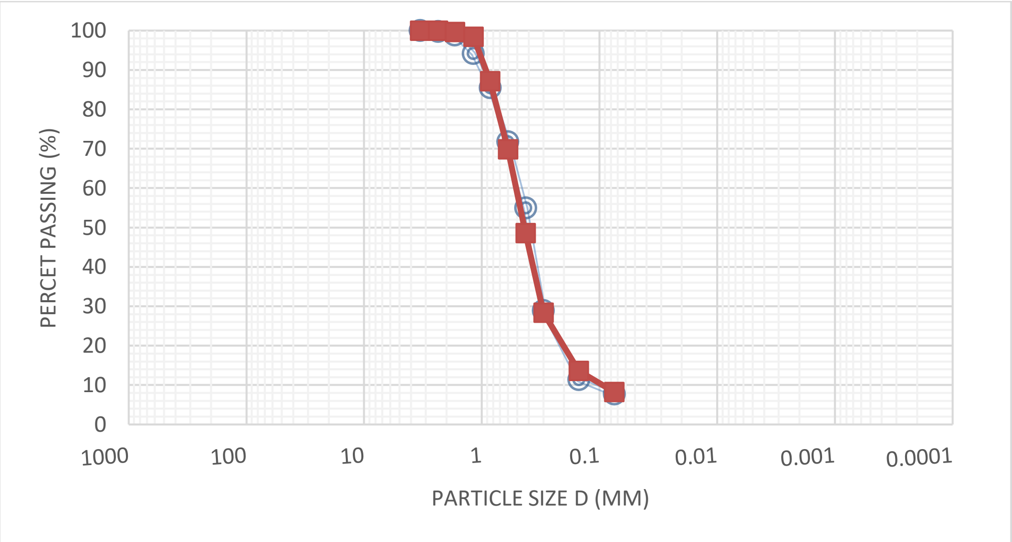


Figure 3: Graph Obtained from Location 1 at 30cm and 60cm below Soil Surface

**Table 17: Curve from Sample Point 1 at 30cm below Soil Surface**

| | | | | | |
|---|---|---|---|---|---|
| **Grain Size Distribution Curve from Sample Point 1 at 30cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.2mm | $C_c$ | 1.0 |
| % Sand | 98.4 | $D_{30}$: | 0.3mm | $C_u$: | 3 |
| % Fines | 1.3 | $D_{60}$: | 0.6mm | | |
| **Grain Size Distribution Curve Sample Point 1 at 60cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.1mm | $C_c$ | 0.9 |
| % Sand | 98.9 | $D_{30}$: | 0.5mm | $C_u$: | 9 |
| % Fines | 1.1 | $D_{60}$: | 0.9mm | | |

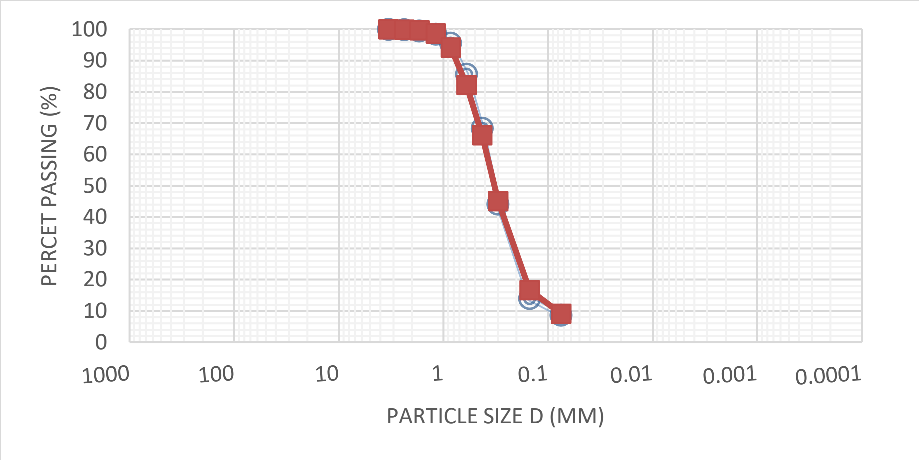


Figure 4: Graph Obtained from Location 2 at 30cm and 60cm Below Soil Surface

**Table 18: Curve from Sample Point 2 at 30cm below Soil Surface**

| | | | | | |
|---|---|---|---|---|---|
| **Grain Size Distribution Curve from Sample Point 2 at 30cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.1mm | $C_c$ | 0.9 |
| % Sand | 88.2 | $D_{30}$: | 0.2mm | $C_u$: | 4 |
| % Fines | 11.8 | $D_{60}$: | 0.4mm | | |
| **Grain Size Distribution Curve Sample Point 2 at 60cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.1mm | $C_c$ | 1.0 |
| % Sand | 98.8 | $D_{30}$: | 0.2mm | $C_u$: | 4 |
| % Fines | 1.2 | $D_{60}$: | 0.4mm | | |

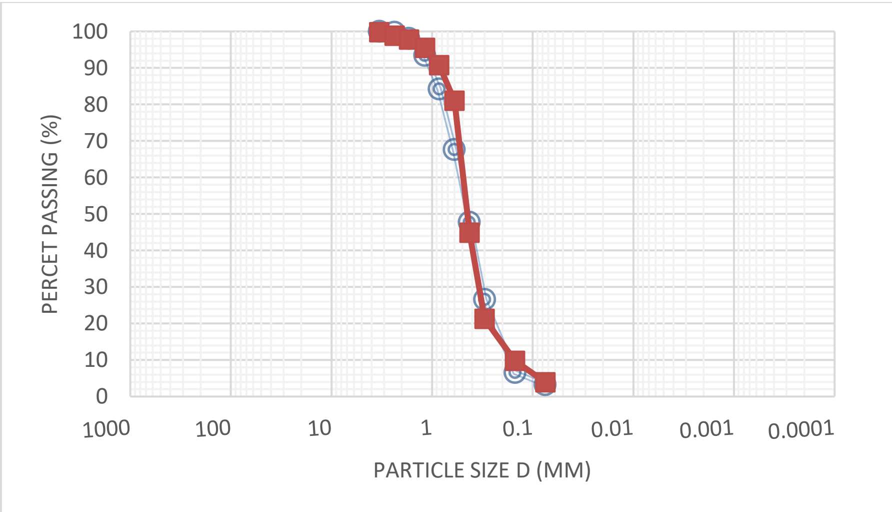


Figure 5: Graph Obtained from Location 3 at 30cm and 60cm Below Soil Surface

**Table 19: Curve from Sample Point 3 at 30cm below Soil Surface**

| | | | | | |
|---|---|---|---|---|---|
| **Grain Size Distribution Curve from Sample Point 3 at 30cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.1mm | $C_c$ | 1.0 |
| % Sand | 95.3 | $D_{30}$: | 0.3mm | $C_u$: | 2.6 |
| % Fines | 4.7 | $D_{60}$: | 0.5mm | | |

| Grain Size Distribution Curve Sample Point 3 at 60cm below Soil Surface | | | | | |
|---|---|---|---|---|---|
| % Gravel | 0 | $D_{10}$: | 0.1mm | $C_c$ | 1.0 |
| % Sand | 95.3 | $D_{30}$: | 0.3mm | $C_u$: | 2..0 |
| % Fines | 3.9 | $D_{60}$: | 0.5mm | | |

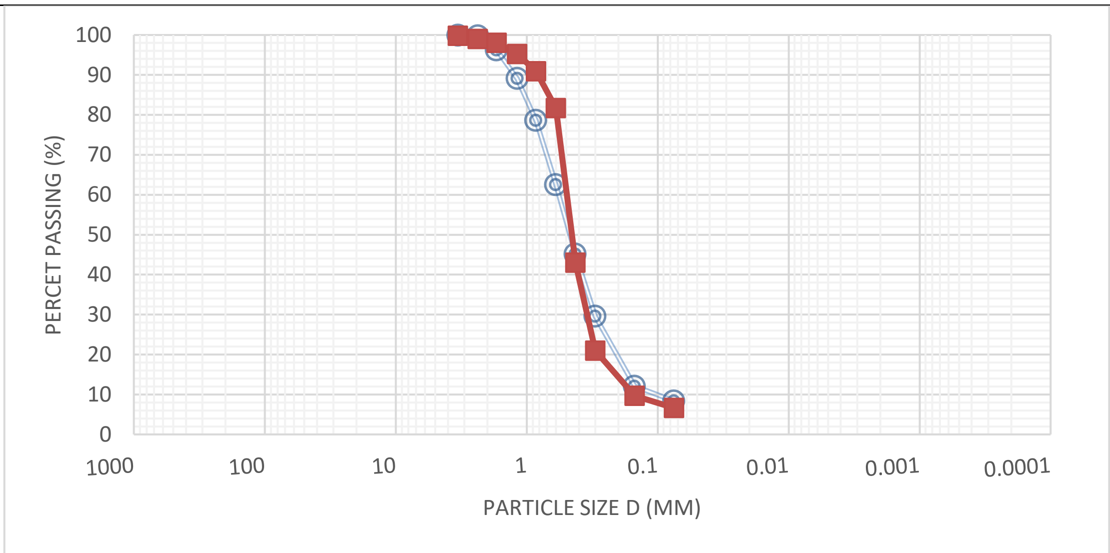


Figure 6: Graph Obtained from Location 4 at 30cm and 60cm Below Soil Surface

**Table 20: Curve from Sample Point 4 at 30cm below Soil Surface**

| Grain Size Distribution Curve from Sample Point 4 at 30cm below Soil Surface | | | | | |
|---|---|---|---|---|---|
| % Gravel | 0 | $D_{10}$: | 0.2mm | $C_c$ | 1.6 |
| % Sand | 97.3 | $D_{30}$: | 0.3mm | $C_u$: | 3.5 |
| % Fines | 4.4 | $D_{60}$: | 0.7mm | | |
| **Grain Size Distribution Curve Sample Point 4 at 60cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.2mm | $C_c$ | 1.6 |
| % Sand | 96.3 | $D_{30}$: | 0.4mm | $C_u$: | 3 |
| % Fines | 3.6 | $D_{60}$: | 0.6mm | | |

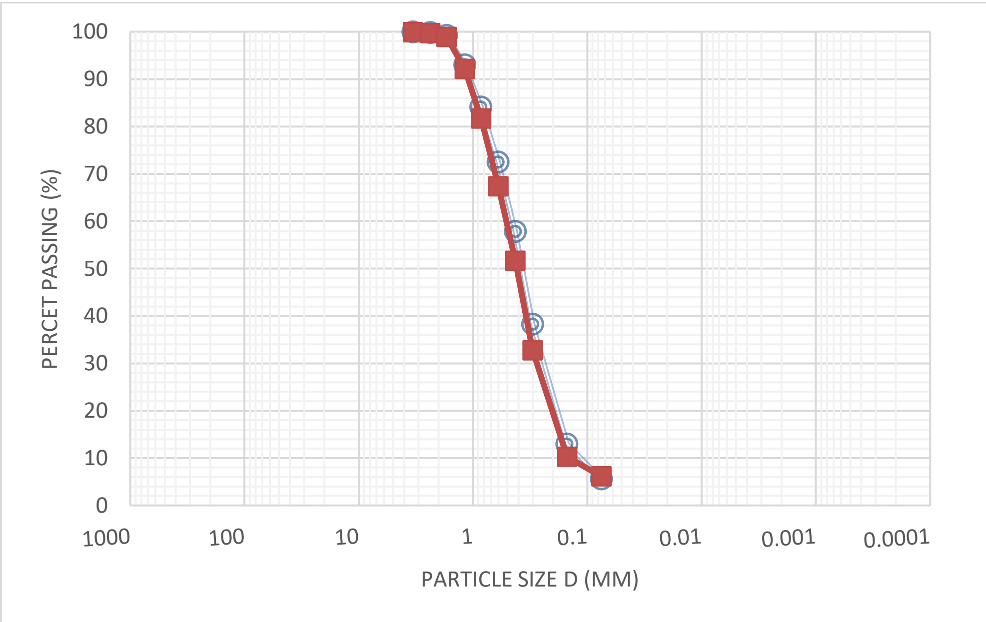


Figure 7: Graph Obtained from Location 5 at 30cm and 60cm Below Soil Surface

**Table 21: Curve from Sample Point 5 at 30cm below Soil Surface**

| Grain Size Distribution Curve from Sample Point 5 at 30cm below Soil Surface | | | | | |
|---|---|---|---|---|---|
| % Gravel | 0 | $D_{10}$: | 0.2mm | $C_c$ | 1.6 |
| % Sand | 97.1 | $D_{30}$: | 0.4mm | $C_u$: | 3 |
| % Fines | 2.9 | $D_{60}$: | 0.6mm | | |

| Grain Size Distribution Curve from Sample Point 5 at 60cm below Soil Surface | | | | | |
|---|---|---|---|---|---|
| % Gravel | 0 | $D_{10}$: | 0.2mm | $C_c$ | 1.1 |
| % Sand | 99.2 | $D_{30}$: | 0.4mm | $C_u$: | 3 |
| % Fines | 0.8 | $D_{60}$: | 0.6mm | | |

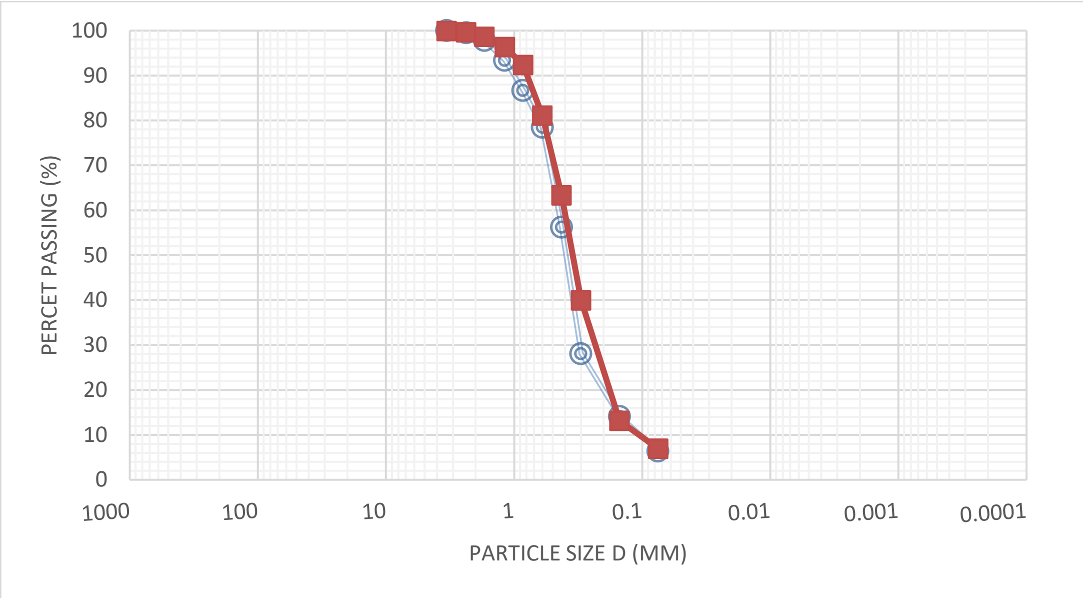


Figure 8: Graph Obtained from Location 6 at 30cm and 60cm Below Soil Surface

**Table 22: Curve from Sample Point 6 at 30cm below Soil Surface**

| Grain Size Distribution Curve from Sample Point 6 at 30cm below Soil Surface | | | | | |
|---|---|---|---|---|---|
| % Gravel | 0 | $D_{10}$: | 0.15mm | $C_c$ | 1.0 |
| % Sand | 93.6 | $D_{30}$: | 0.3mm | $C_u$: | 2.7 |
| % Fines | 6.4 | $D_{60}$: | 0.4mm | | |
| **Grain Size Distribution Curve from Sample Point 6 at 60cm below Soil Surface** | | | | | |
| % Gravel | 0 | $D_{10}$: | 0.15mm | $C_c$ | 1.1 |
| % Sand | 99.4 | $D_{30}$: | 0.3mm | $C_u$: | 2.7 |
| % Fines | 0.6 | $D_{60}$: | 0.4mm | | |

grain size distribution curve. From the values obtained the uniformity coefficient ($C_u$) and the coefficient of gradation ($C_c$) were calculated.
The uniformity coefficient ($C_u$) is the parameter which indicates the range of distribution of grain sizes in a given soil sample. For well-graded soil $C_u$ is large, usually greater than 6 for sandy soils. Poorly graded soils have $C_u$ that is nearly equal to 1, which means that the soil particles are approximately equal in size (Kalore and Sivakumar, 2023). For this study, Cu was found to range from 2-9(Figures 3-8), a confirmation that the soils of the study site is dominated by sandy soils.
The coefficient of gradation ($C_c$) is a parameter that is also referred to as coefficient of curvature (Davarpanah *et al.*, 2025). For soil to be well-graded, $C_c$ is usually between 1 and 3 as indicated by all the sampled locations(1-6), the Cc ranges from 0.9 – 1.6(Figures 3-8).
The K- values results shown in Table 16, varied with different locations. Erodibility factor (K) in locations 3 and 4 had high K-index average value of (0.1455 and 0.108), but slightly varied in locations 1, 2, 5and 6 with low K- index average value of (0.0552, 0.065,0.0698 and 0.0726). Thus, from the graphs of Figures 1, 2, 5 and 6, the grain size distribution curve showed uniform variability, while location 3 and 4 show difference in variability at 30cm and 60cm below soil surface. The implication of the high k-value indicates that soil in location 3 and 4 are more erodible compare to location 1,2, 5 and 6 of same Benue River bank area. This could be attributed to the high presence of sandy soils in location 3. The ease of water to flow in sandy soils makes it prone to detachment and transportation by water and wind erosion thereby increasing the erodibility factors (NRCCA, 2019).

## CONCLUSION

The erodibility factor of soil at the Bank of Benue River were investigated for six different Location at 30cm and 60cm below soil surface, to give the average crop root zone. Erosion factors were determined; most of the soil were predominantly sandy and silty making the soil to be classified as sandy silty soil. The soil physical properties had significant effect on the erodibility parameters of the soil that most of the soils were largely silty sandy soil in nature which makes them more susceptible to erosion. Generally, the banks of the River Benue are predominantly sandy soils with weak binding materials, hence are easily eroded. There is the need for adequate soil conservation measures to prevent severe erosion in these areas. Control measures should be adopted to avoid more soil loss and further development of gullies. Drainage structure such as gutter and culverts should be constructed to control and guide channel runoff water, to avoid detachment and transportation of soil particles by the runoff water.

Adequate vegetative cover should be planted along the embankment to resist erosion.

**REFERENCES**


Agassi, M and Bradford, J.M. (1999).Methodologies for Interill.*Soil Erosion Studies. Soil and Tillage Research. (49)4: 277 - 87*.

Agbai,W.P.,Efenudu,U.I.,Kosuowei,M.T.and Ehigiator, E.F.(2021).Determination of Soil Erodibility Status under Different Land-Use Types Using Some Erodibility Indices: A Case of Yenagoa and Southern Ijaw Local Government Area of Bayelsa State. EJES& M 15(2): 201 – 214. doi: https://ejesm.org/ doi/ v15i 2.6

Bouyoucos, G.J. (1935). The Clay ratio as a Criterion of Susceptibility of Soils to Erosion. JASA. 27(9*): 738 – 741*

Combeau, A. and Monnier, G. (1961). A Method of Study for Structural Stability Application to Tropical Soils, *African Soils. 1: 33 – 51.*

Czatzkowska,M.,Wolak,I.,Harnisz,M.,andKorzeniewska,E.( 2022).Impactofanthropogenic activi- ties on the dissemination of ARGs in the environment—A review. *IJERPH19*(19), 12853. https://doi.org/10.3 390/ijerph1919 12853

Davarpanah,S.M.,Narimani,S.,Sharghi,M.,andVásárhelyi,B.( 2025).Introducing coefficients of curvature (Cc) and uniformity (Cu) based on RQD for rock mass characterization.*Rock Mechani- cs Letters*, *2*(1), Article 10. https://doi.org/10.70425/rml.202501.10

Debashis, S.(2023).Eroded Soil. *https://www.researchgate.net/publ/374229013/Eroded/Soil* *DOI:* https://doi.org/10.13140/RG.2.2.25451.52002

Dey,S.,and Mandal,S.(2022).*Riverbank erosion hazards and channel morphodynamics:A perspe- pective of fluvial geomorphology* (1st ed.). Routledge India. https://doi.org/ 10.4324/978 10032 76685

Dominic, I.W. Benjamin, Y.(2023). Flood and Food Security in the Benue Valley Stylized Facts. *AJSMS, Vol. 4, No. 2, 2023, pages 318-337* https://doi.org/ 10.53982/ajsms. 2023.0402. 09-j

Emeka-chris,C.C. (2014). Determination of Erodibility Index (K) Of Soil in Michael Okpara University of Agriculture, Umudike.

Evans, R.(1980): Mechanics of water erosion and their spatial and temporal controls. An empirical viewpoint. In: M. J. Kirkby and R.P.C. Morgan (eds.) Soil ErosionChichester, Wiley: 109-28.
*Soil Resources Reports 84, FAO, Rome.*

Imeson,A.(2020).Geomorphological processes,soil structure,and ecology.In Soil Erosion and Conservation:EcologicalandHydrologicalConsequences(pp.71–88).Routledge.*https://doi. .org/10. 4324/9780429274923-5.*

Iorkpiligh, I. T., Maakura, K. K., Aondoakaa, D. A., Agbo, C., & Igbum, G. O. (2025). Assessment of The Physicochemical Parameters and Heavy Metals Concentrations of Soils around Hostels in Benue State University, Makurdi, Nigeria. *Fudma Journal of Sciences*, *9*(12), 132137.https:// doi.org/ 10.33003/fjs-2025-0912-3987

Juriga,M.,and Šimanský,V.(2018).Effect of biochar on soil structure – review.Acta Fytotechnica Zootechnica,21(1), 11–19. https://doi.org/10.15414/AFZ.2018.21.01.11-19

Kalore,S.A.,and Sivakumar,B.G.L.(2023).Significance of Cu and Cc inEvaluatingInternal stabili- ty with application to design of subbase gradation in pavements.*TransportationGeotechni cs, 40*,Article 100972.https://doi.org/10.1016/j.trgeo.2023 .100972

Kanwar, H.,Ghanshyam, and Roy,T.(2025).Recent advances in assessment of soil erodibility: A comprehensive review.IJSC,52(3), 176. https://doi.org/10.59797/ijsc.v52.i3.176

Konsoer,K.M.,Rhoads,B.L.,Langendoen, E.J.,Best, J.L.,Ursic,M.E.,Abad,J.D.,and Garcia,M.H. (2016).Spatial variability in bank resistance to erosion on a large meandering, mixed bedrock-alluvial river.*Geomorphology*,*252*,80-97. https://doi.org/10.1016/j.geomorph. 2015.08.002

Lei,T.W. Zhang, Q.W.Zhao,J., Xia,W.S. Pan,Y.H.(2002).Soil Detachment Rates for Sediment Loaded Flow in Rills. ASAE 45(6). DOI: 10.13031/2013.11440

McKague,K. and Eng,P.(2024). Soil Erosion -Causes and Effects. https://www.ontario.ca/files/2024-05/omafra-soil-erosion-24-019-en-28-05-2024-v1

Mikolai,M.,Aleksandra, C.,and Marcinak,M.(2023).Impact of rainfall intensity on soil erosion based on experimental research.Landform Analysis 42: 25-36. DOI: 10.12657/landfana-042-002.

Morgan, R.P.C. (2001). A simple approach to soil loss prediction: a revised Morgan-Morgan-Finney model. Catena 44(4): 305-22.

Nahib,I.,Wahyudin,Y.,Amhar, F.,Ambarwulan,W.,Nugroho,N.P.,Pranoto,B.,Cahyana,D.,Ramad hani,F.,Suwedi,N.,Darmawan,M.,Turmudi,T.,Suryanta,J.,an dKarolinoerita,V.(2024).Anal lysis of factors influencing spatial distribution of soil erosion under diverse subwater shed based on geospatial perspective:Acase study at CitarumWatershed,WestJava,Indonesia. *Scientifica*,Article 7251691.https://doi.org/10.1155/2024/ 7251691

NRCCA (Northeast Region Certified Crop Adviser),(2019). Soil and Water Management – Study Guide. Soil and Water Management. https://www.Certifiedcropadviser. org/files/certified cropadviser/ northeast-region-performance-objectives.

Okoro A.C.,Orakwe L.C.,Nwachukwu C.P.,Ugwu, E.I.,Nzekwe. C.A.,Nwanna E.C and Nzekwe M.I(2022).Erodibility index of soils along Ezeagu-Umulokpa road, Enugu State.JEAS, Vol. (1).

Parwada, C.Tol, J. and Mandumbu,R.(2020).Characterisation of soil physical properties and resistance to erosion in different areas of soil associations.

https://www.semanticscholar.org/paper//a68a9ff0ba0c6a1dfcacd6eadf68135d7a5a6532

Philippe,P.,and Benahmed,N.(2024).Quantifying soil surface erosion.*Comptes RendusPhysique* Advance online publication.https://doi.org/10.5802/crphys.225

Relf, D.(2001).Reducing Erosion and Runoff. *Virginia Co-operative Extension, PublicationNo.426–722, Virginia Polytechnic Institute and State University, Blackburg, VA USA.*

Renard, K.G.,Foster, G.R.,Weesies,G. A.,McCool, D.K.,and Yoder,D.C., (1997), Predicting Soil Erosion by water: A guide to Conservation Planning with the Revised Universal Soil loss equation (RUSL E). USDA, Agriculture Handbook No.703, Washington DC.

Rubianca,B.,Bethanna,J.,Maxwell D.,and Norton,K.(2018).A review of the (Revised) Universal Soil Loss Equation (R/USLE): with a view to increasing its global applicability and improving soil loss estimates.

Saadon, A.,Ariffin, J.,Abdullah, J.,and Daud,N.M.(2016).Dimensional analysis relationships of streambank erosion rates. *JTSE),78*(5-5),79–85.https://doi.org/10.11113/jt.v78.8580

Shafii,I.,Briaud,J.,Chen,H.,and Shidlovskaya,A.(2016).Relationship between soil erodibility and engineering properties. In Proceedings of the 8th International Conference on Scour and Erosion (pp.1055–1060).CRCPress. https://doi.org/10.1201/9781315375045-134

Sowiński,P.,Smólczyński,S.,Orzechowski,M.,Kalisz,B.,andBieniek,A.(2023).Effect of soil agric- ultural use on particle-size distribution in young glacial landscape slopes.*Agriculture,13(* 3),584. https://doi.org/10.3390/agriculture13030584

SSSA(Soil Science Society of America) (2008). Defining Soil Quality for a Sustainable Environment. Soil Science Society of America. Special Publication 35. SSSA-ASA,Madison, Wisconsin. USA.

Stresser,C.,and de Brum,P.,L.(2023).Soil erodibility rates through a hydraulic flume erosometer: Test assembly and results in sandy and clayey soils.*OJCE,13*(1),155–170.https://doi.org /10.4236 /ojce.2023.131011

Umi,M.A.,Sholihah,N.P.,andFathi,A.R.(2023).Soil Erodibility:Influencing Factors and Its Relation to Soil Fertility in Nawungan, Selopamioro, Bantul Regency.

USDA(2022).Soil Quality Indicators: Soil Structure Macropores. https://www.nrcs.usda.gov/sites/default/files/2022-10/Soil Structure and Macropores.

Wandra, A.(2021).Soil Erosion - Causes, Effects, and Prevention .IJAEB, Vol. 06, No. 06. https://doi.org/10.35410/ IJAEB.2021.5696

Wawer, R. Nowocień, E. Podolski,B.(2005).Real and Calculated K-USLE Erodibility Factor for Selected Polish Soils. *PJES Vol. 14, No 5 (2005), 655-658.*

Wischmeier,W.H.,and Smith,D.D(1978).Predicting rainfall erosion losses.Agriculture Handbook No. 537, (537), 285–291. http://doi.org/10.1029/TR039i002p00285

Xinyu, Z., Shouhong, Z., Fan, Z., Jingyi, S., and Jingqiu, C. (2025). Rainfall amount shapes the soil erosion and vegetation protection effectiveness in soil conservation. Journal of Hydrology, Vol. 633.Part A. https://doi.org/10.1016/j.jhydrol.2025.134219

Xunchang,J.Z.(2023).Roles of raindrop impact in detachment and transport processes of interrill soil erosion.*ISWCR,Vol.(11), PP591-601.* https://doi.org/10.1016/j.iswcr.2022.11.001

Yang,X.,Gray,J.,Chapman,C.,Zhu,Q.,Tulau,M.,and McInnes-Clarke,S.(2017).Digital mapping of soil erodibility for water erosion in New South Wales,Australia.*SoilResearch,56(2)158 –170.* https://doi.org/10.1071/SR17058