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Investigation of Erodibility Indices of Soils in Ikwuano Local Government Area of Abia State in South-Eastern Nigeria

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A B S T R A C T

The devastation caused by soil erosion and degradation in many parts of Eastern Nigeria are alarming and pose a serious threat to life and economic activities of the region. An evaluation of the remote and immediate causes of this incidence is a huge challenge to the stakeholders, states and federal government. This study investigated the soil parameters such as soil permeability (k), soil texture, and soil classification index as bases for computing erosion factors in Ikwuano Local Government Area (LGA). Soil samples were randomly collected from ten locations in the four major communities of the LGA. The soil samples were analyzed to determine their erodibility indices using grain sieve analysis. The results of the grain sieve analysis showed that Umudike soils were predominantly sandy with the highest erodibility indices of 0.188 followed by Umuariga 0.134. Further analyses were carried out using hydrometer test to determine the clay and silt soils. The results obtained from the hydrometer analysis showed that Oloko and Ariam have the least erodibility indices of 0.0012 and 0.0021. Generally, Ikwuano soils were mainly consolidated sandy soils and possessing little binding materials to resist detachment and transportation by agents of erosion hence, adequate soil conservative measures are required to prevent severe erosions in these areas.

Introduction

Disasters can be natural or man-made. Soil erosion is a common disaster that can be caused by nature because of the soil properties and also by man as a result of improper environmental management (Ejaz, Akhtar, Hashmi & Naeem, 2010). Soil erosion can be described as the wearing away of the top soils by the natural physical forces of water and wind. Erosion is a serious threat to humans and infrastructures because of the devastation it can cause to homes, farmland, roads, water supply, communication, and migrations (Idah, Mustapha, Musa & Dike, 2008). Soil erodibility is a function of complex interactions of a substantial number of the soil physical properties. Generally, soils that are high in silt, low in organic matter are the most erodible (Bhattacharyya *et al*., 2015). A soil type becomes less erodible with decrease in silt fraction, regardless of the corresponding increase is in the sand fraction. A soil with a high erodibility index will suffer more erosion than a soil with low erodibility index if both are exposed to the same rainfall event (De Vente & Poesen, 2005).

Soil erodibility is a measure of soil susceptibility to detachment and transport by water, which is in turn determined by different soil properties as well as the rainfall characteristics. Aggregate stability, organic matter, clay mineralogy, and other chemical and physical soil properties are important factors, which affect soil erodibility as well as rainfall. Soil aggregate stability and erodibility indices are two main crucial factors, which contribute to soil erosion and runoff (Hammad, Børresen, & Haugen, 2006; Pimentel, 2000). Soil erosion occurs when soil particles are carried off by water or wind from a location and deposited in another location (Pimentel & Kounang, 1998; Toy, Foster & Renard, 2002). Erosion begins when rain or irrigation water detaches soil particles and moved across it to other place (Trout & Neibling, 1993).

Soils in Nigeria are predominantly alluvium deposits, coastal plain sands, sand stones, basement complex material and older granite, these soils exhibit variables resistances to erosion with the sandy soil being more vulnerable to erosion than clay (Onweremadu, 2007). Soil scientists have long realized that soils react at varying speed to raindrops attack and structural degradation. Some of the identified natural causes include tectonism and uplift, climatic factors, geotechnical properties of soil, among others. Anthropogenic causes include farming and uncontrolled grazing practices, deforestation, and mining activities (Abdulfatai, Okunlola, Akande, Momoh, & Ibrahim, 2014; Nuga, Eluwa, Akinbola, & Wokocha, 2006; Uwanuruochi & Nwachukwu, 2012).

Population growth, urbanization, industrialization, mining, agricultural practices and anthropogenic activities, have led to the increase of soil erosion and land degradation, particularly in the arid and semi-arid regions of the world (Hammad *et al*., 2006). Soil can be described as an essential input in agricultural production. Agricultural production is crucial to food availability, sustenance of livelihoods and national prosperity. Majority of the population depend on naturally abundant resources which agriculture provides. Agricultural land use in Nigeria often results in the degradation of natural soil fertility and reduces productivity. Soil degradation under farming often brings about soil erosion, sedimentation and leaching (Abdulfatai *et al*., 2014; Idah *et al*., 2008; Pimentel, 2000).

The soil in the South-Eastern Nigeria is poorly drained and is subjected to permanent or periodic flooding (Hulugalle, Lal, & Gichuru, 1990). The communities living in these areas encounter adverse effect of soil erosion and degradation especially the dreaded gully erosion (fig. 1). This problem is affecting the development of the area because infrastructures such as houses, roads and even life are lost yearly apart from constitutes an environmental menace (fig. 1) (Abdulfatai *et al*., 2014; Idah *et al*., 2008). To effectively tackle this problem, there is a need to identify those factors which contributes to soil erosion using scientific knowledge through laboratory investigations. Addressing the causes will ensure lasting solutions to the menace of erosion and degradation and prevent future damages to human and infrastructures of the region.

Soil is a basic necessity for agricultural production. Factors that affect the soil also affect agriculture and therefore a solution to such factors will increase food production. This research is targeted at solving a problem of erodibility in an agrarian region of Nigeria by studying those factors that contribute to the increased menace of erosion. This research will also serve as a baseline study for soil scientist and research institutions. Therefore the objective of this study was to determine the erodibility indices of soils at different sites in Ikwuano local government area of Abia state, to compare the erodibility indices of the various soils in Ikwuano in order to determine the areas that are more prone to erosion and to relate significant indices to land- use history.

Materials and Methods

The research was conducted in Ikwuano Local Government Area of Abia State in ten selected communities namely: Umuariga, Ndoro, Amaoba, Ariam, Amawom, Awomnebo, Ibere, Umudike, MOUAU and Oloko. Ikwuano LGA has a land mass of 600 square kilometers. Bende and Umuahia LGA in the south, Isiala Ngwa LGA in the West, Ikono, surround Ikwuano LGA and Oforo LGA's of Akwa Ibom state in the East. It is situated in latitude 5^{o} 28^{1} North at about 122 meters above sea level. More details can be found on the attached map fig. 3. The main occupation of the people in Ikwuano LGA is peasant farming. The soils are fertile and host the National Root Crop Research Institute and also Michael Okpara University of Agriculture Umudike. The mineral resources found in Ikwuano LGA are clay deposit and kaolin. The geology of Ikwuano represents a scenario of sparsely located slope and rich alluvial plains (Igboekwe, Okwueze, & Okereke, 2006; Nuga *et al*., 2006; Uloma, Samuel, & Kingsley, 2014).

Sampling and Analysis

The samples were collected randomly from the study sites using soil auger at varying depths of 0-60 cm to determine the soil erodibility according to method proposed by Wischmeier, Smith, and Uhland (1958). Briefly, the samples were air dried and then sieved through 2 mm sieves. Three major soil tests were carried out to determine the erodibility indices of the soil. Mechanical sieve analysis was used to determine the relative distribution of particles greater than 0.075mm, which corresponds to the opening size of a 2 mm sieve (coarse sand). This particle size is considered to be about the smallest individual particle that can be distinguished by the unaided human eye and represent the breakpoint between the macroscopic and microscopic region. A mechanical sieve shaker was also used in determining the particle size distribution. The grain size analysis test was used to determine the relative proportion of different grain sizes contained in the soil sample. Weighing balance was used for weighing the soil sample in each sieve. Electronic shaker was used for shaking the soils in the sieves.

The weight of the soil retained was obtained by subtracting the weight of sieve and soil from the weight of empty sieve.

$$\%\, soil\ retained = \frac{\text{weight of soil retained}}{200} x100 \quad \text{........1}$$

% cumulations of retained soil were calculated based on the % of soil retained

% finer = 100 - % cumulative retained. The value was computed and presented as grading curve in fig. 5.

Permeability analysis

Permeability test was determined by constant head for coarse soil by the method described by American Society for Testing and Materials (ASTM) D – 2434 standard test and computed using equ. 1 (Park & Egbert, 2005).

$k = \frac{QL}{Ath}$…………..2

Where:

k = coefficient of permeability (m/s)
L = length of specimen (m)
Q = volume of discharge in (m^3)
A = cross – sectional area of permeameter (1ml = $m^3 = \frac{\pi D2}{4}$)
D = inside diameter of the permeameter, h = hydraulic head difference across L

Determination of soil loss

Mean annual rainfall was obtained from the National Root Crop Research Institute Umudike and used to determine the rainfall factor (R) using the equ. 2 (Idah *et al*., 2008). R = 0.5H…………..3

Where H = mean annual rainfall. Revised universal soil loss equation (USLE) was used to predict the amount of soil loss in each of the studied communities (equ. 3)
A = 2.24RK ……………..4

Where A = soil loss (tons/ha/yr) x 2.24.
R = rainfall factor, K = erodibility factor (Hudson, 1993).

Hydrometer Analysis

Hydrometer analysis is performed if the grain sizes are too small for sieve analysis. The base for this test is Stokes law for falling spheres in viscous fluid in which the terminal velocity of fall depends on the grain diameter and the densities of the grain in suspension and of the fluid. The grain diameter thus can be calculated from knowledge of the distance and time of fall (Morgan, 2009). The sample was added into glass cylinder 500 ml of water and treated with a dispersing agent (calgon) to help to break bind clay and silt particles into aggregates. The density of the soil suspended was determined with a hydrometer. The values obtained were computed and presented in Table 1

Results and Discussion

The permeability values for samples were 0.134, 0.188, 0.124, 0.134, 0.112, 0.118, 0.0012, 0.0021, 0.018, and 0.042 respectively. The laboratory investigation results of the study show clearly that some parts of the study areas are prone to erosion with a higher indication of factors of erodibility indices. It can be clearly seen from fig. 3 that Umudike has the highest permeability (k value) of 0.188. High permeability could be attributed to the presence of sandy soils in Umudike. The ease of water to flow in sandy soils makes it prone to detachment and transportation by water and wind erosion and increase in the erodibility factors (Toy *et al*., 2002).

It is also noted from fig. 4 that Umudike has the highest soil loss with the predicted soil loss as 301.73 tons/ha/yr. This may not be a surprise indication because major factors of the soil loss in fig. 3 clearly show the possibilities of high soil loss in the location. From the historical record, erosions and flooding cases are regular in Umudike than other locations. This may be attributed to the population increase and human activities because of the two institutions in the area.

Grain size analysis determined by the grade curve fig. 5 shows relative proportion of different grain size contain in soil sample from the various locations. The results of the grain size analysis show that the various soils at the locations were predominantly sandy soils. Due to the porous nature of the sandy soil, and tendency to allow easy passages of water and air, high permeability rates are encouraged and water 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 coarser particles. For example, percentage of fine sand is significant for the grains retained on sieve #40 (medium sand size). In addition, the influence of each fine fraction is greater than the fraction that is just coarser than the fine fraction. That is, the effect of silt and clay is greater than the effect of fine sand (Blott & Pye, 2001; Onur, 2014; Sezer, Göktepe, & Altun, 2009).

From the grade curve of the sieve analysis fig. 5, all the locations tend to appear unilaterally aligned together because of the resemblance and uniformity of the grain size distribution since the study areas are mainly sandy loam soils. Serious concerns about erosion and degradation should be raised to create awareness in order to forestall incessant occurrence.

Table.1 Results of hydrometer analysis of samples

Location	% sand	% silt	% clay	Textural class
Oloko	44.2	22.6	33.2	**Clay loam**
Ariam	42.8	23.6	33.6	**Clay loam**
Ibere	52.7	29.1	18.2	**Sandy loam**
Ndoro	50	20	30	**Sandy clay loam**

Table.2 Standard erodibility indices corresponding to the studied locations

Group	K – Value	Nature of soil	Location
i	0.0 – 0.1	Permeable gracia outwash well drain soils having stony substrata	Oloko,Ariam, ibere, Ndoro.
ii	0.11 – 0.17	Well drained soils in sandy grade free material.	Amawom, Awomnebo, umuariga, MOUAU, Amaoba
iii	0.29 -0.48	Graded loams and silt, loam	Umudike
iv	0.29 -0.48	Poorly graded moderately fine and textured soil	
v	0.49 – 0.64	Poorly graded silt or very fine sandy soil, well and moderately drain soils.	

Fig.1 Devastating impacts of gully erosion in the Eastern Nigeria (Abdulfatai *et al*., 2014)

Fig.2 Map of Ikwuano LGA of Abia state

Fig.3 Permeability Analysis (k). Results are presented in mean ± standard deviation (SD), n=3. Means that do not share the same letters are significantly different at p<0.05.

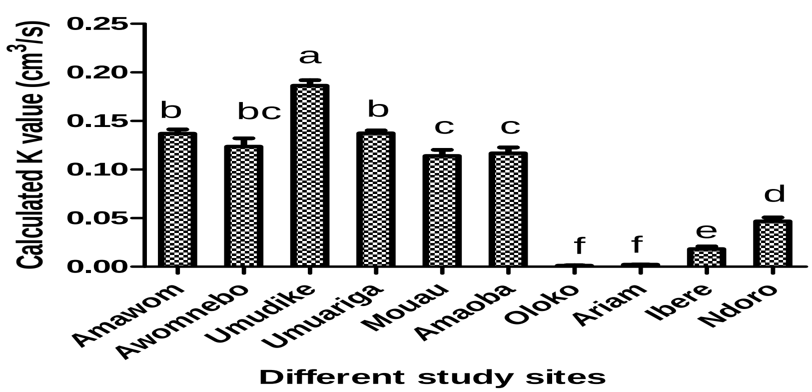


Fig.4 Soil loss analysis. Results are presented in mean ± standard deviation (SD), n=3. Means that do not share the same letters are significantly different at $p<0.05$.

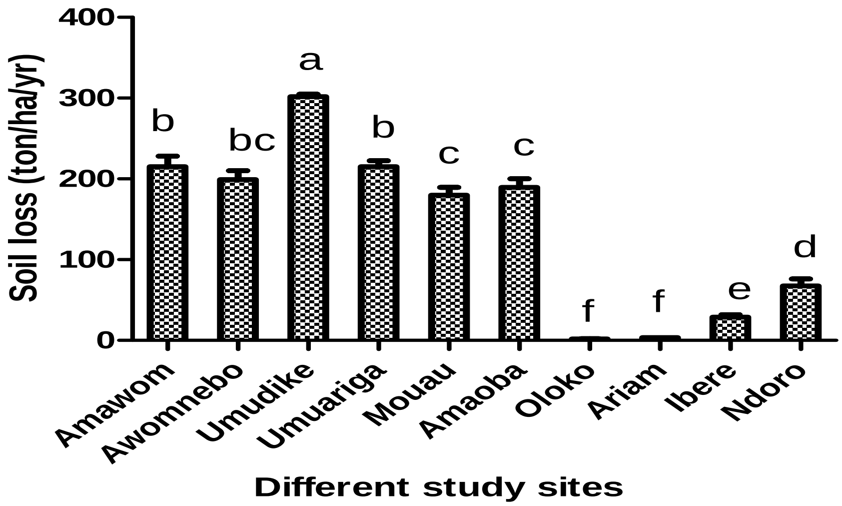
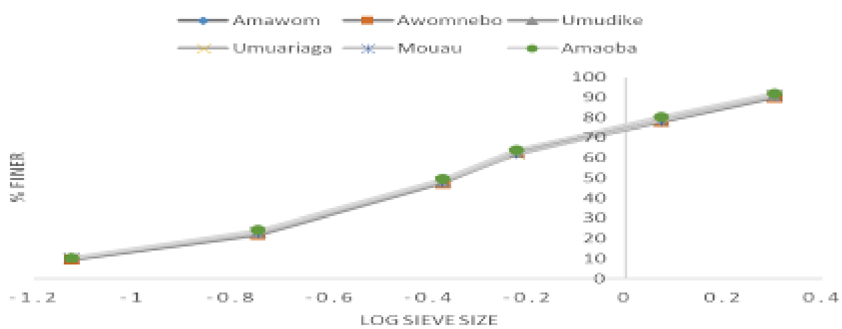


Fig.5 Grading curve for sieve analysis



Hydrometer analysis was carried out to determine the percentage of sand, silt and clay in the samples of soils taken from Oloko, Ariam, Ibere and Ndoro due to the texture of the soils in those locations. High clay content indicates low erosion potentials and low soil loss because of higher binding and inter-binding forces that help in resisting detachability of soil by water.

The results of hydrometer analysis are presented in table 1 and clearly indicate that Oloko, Ariam and Ndoro have clay particles while Ibere has only sandy loam particles based on (Lado, Ben-Hur, & Shainberg, 2004; Xinbao, Higgitt, & Walling, 1990). Soil classification is very crucial in determining the grain size of the soil, which is important in predicting soil erodibility and other factors that influence soil erosion. Grain size distribution and density are known to influence the permeability of sandy soils. Permeability is a function of the sizes and shapes of interconnections between adjacent pores that, in turn, are subjective by the entire grain size distribution (Onur, 2014; Sezer *et al*., 2009).

Standard erodibility indices presented in the table 2 were used to compare the erodibility indices for the ten communities studied. The comparison shows that Ikwuano local government soils fall into group I, II, and III (Table 2).

Conclusion

The erodibility indices of soils in Ikwuano LGA were investigated in both field and laboratory experiments. Soil samples were randomly collected from ten locations in the four major communities of Ikwuano Local Government Area of Abia State. The soil samples were analyzed to determine the erosion factors by subjecting them to three analyses (hydraulic permeability, grain size analysis, and hydrometer analysis). The results of the analysis show that Umudike community soils were predominantly sandy with the erodibility indices of 0.188, followed by Umuariga with 0.134. Further analysis was carried out using hydrometer test was used to determine the texture of Oloko and Ariam with the least erodibility indices of 0.0012 and 0.0021 which was shown to be clay and silt.. Generally, Ikwuano soils were mainly sandy soils with weak binding materials are easily leached by erosion therefore, there is the need for adequate soil conservative measures to prevent severe erosions in these areas.

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