# ERODIBILITY OF SOIL IN ANGWAN RIMI, ZANGO KATAF LOCAL GOVERNMENT AREA, KADUNA STATE, NIGERIA

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**Abstract**

*The Soil is a vital component of the environment and serve as a medium for many biological and other non-biological activities on agricultural farms. The aim was to assess the erodibility indices of soils under different agricultural land. Four farmlands of Ginger, Beans, Maize and Fallow land were selected at a distance of 130km apart. The study plot size ranges between 1036m² to 8640m² and a total of 12 soil samples were collected at a depth of 0-10cm. Three (3) samples from each site were collected and analyzed for pH, electric conductivity, particle size distribution, organic carbon, exchangeable acidity and bases (exch. Na, Ca, and K) using standard laboratory procedures. Result showed that Clay Ratio (CR) did not significantly vary with the agricultural land uses, likewise mean value of clay ratio across the farmlands was found to be 9.92%. This result imply that there was loose soil structure and high susceptibility of the soils to erosion; the Maize farm had clay ratio of 68.07% and Ginger farm have 61.95% implying an unstable structure and erosion risk while the mean values of beans farm and fallow land implied lesser susceptibility to erosion with 59.18% and 59.95% respectively. Communal tree planting (re-vegetation), use of organic manure, farming across the slopes, crop rotation and grass fallowing are proffered solution.*

**Keywords: Erodibility, Farmland, Organic, Particles size, Soil**

## INTRODUCTION

Soil is a very important component of the environment and a primary medium for many biological and other non biological activities mainly agricultural, infrastructural construction and many more. Therefore it is very imperative to study and protect soil in relation to its diverse importance (Nam *et al*., 2003). Soil in different location of the world deserve considerable attention because soils are subject to natural and human induced erosion forces.

Very little amount of soil is loss when erosion occurs naturally without human influence with relatively little or no significant adverse impact whereas erosion become more apparent and severe with higher significant adverse impacts as a result of anthropogenic activities. Studies in Nigeria observed that as the population of the country increases rapidly, pressure is mounted on the country's soil to produce enough food to meet the requirement of the ever increasing population Yang *et. a.,l* 2007). There is also more pressure on soil for construction materials as demand for development and construction of houses, roads, bridges and other infrastructures increases. these increasing

demands for food and infrastructures made it necessary for the population to subject the soil into more agricultural practices (over cultivation) and over exploitation of the construction materials for development as such leads to degradation of soil structure, fertility and quality as well as increasing soil contamination and aggravating soil erosion (Deivid *et al.,* 2003).

Deivid et al (2003) noted that Soil erosion amounts to reduction of soil quality and fertility among other problems such as development of gullies and badlands, destruction of good roads and hindering transportation are linked to agents of denudation such as water, wind and less importantly ice. Water erosion is a more complicated process involving impacts from precipitation, detachment and subsequent transportation of the detached soil. Water erosion generally depend on erodibility of the soil surface, deposition and kinetic energy of water flow over land surface. This implies that soils prone to detachment and over land transportation can be eroded with ease.

Soil erodibility is an important index and a major factor in evaluating soil sensitivity to erosion. It is defined as the susceptibility of soils

to erosional processes (Igwe, 2003; Fu *et al*., 2014); Bagarello *et al.,* 2012 and Feraira *et al*, 2015). The term denotes the inherent susceptibility or vulnerability of soil to detachment, transportation and deposition by rain fall, run off, wind and ice. Soil erodibility is a complex concept that is influenced by many factors such as soil properties and human activities. Soil properties tend to determine the vulnerability of the soil aggregates and particles to detachment , disintegration, entrainment and their subsequent transportation ( Keli, *et al;* 2002 and Chem *et al.,* 2013), terrain (Wang *et al.,* 2012), climate( Hussein *et al.,* 2013; Sanchis *et al.,* 2015) vegetation ( Sepheveda Lozada *et al*., 2009), land use ( Cerda *et al.,* 1998; Tang et al., 2016), soil texture and aggregation, share strength, infiltration capacity, permeability, organic content, chemical content, soil profile, detaching and transportation force.

Similarly, important soil characteristics, properties and their corresponding qualities with respect to erodibility have been outlined by Edward (1961) as follows; texture, permeability,

nature of clay, infiltration, water holding capacity, soil structure, detachability , organic matter content, ease with which particles moves, thickness of significant layers degree of consolidation or cementation of soil particles impacts on erodibility status of soils. Loose particles aggregates will be prone to detachment and transportation by agent of denudation and ease with which excess water can leave the soil. These factors influence soil susceptibility to erosion. However, Salako (2003) in his work observed the research conducted in Nigeria by Aina, 1980; Obi and Salako, 1989 agree that rainfall erosivity in the tropics can be linked to intensity, amount and sizes of rain drops.

## MATERIALS AND METHODS
### Study Area.
Zangon Kataf Local Government Area (LGA) of Kaduna State, Nigeria lies between latitudes 9º 25´N and 10º 20´N and longitude 7º 45´E and 8º 40´E, with a total land area of about 5,625km2 and density of 167.0/km$^2$ (Abaje *et al.,* 2009) (Fig 1). The area of study is Angwan Rimi area.
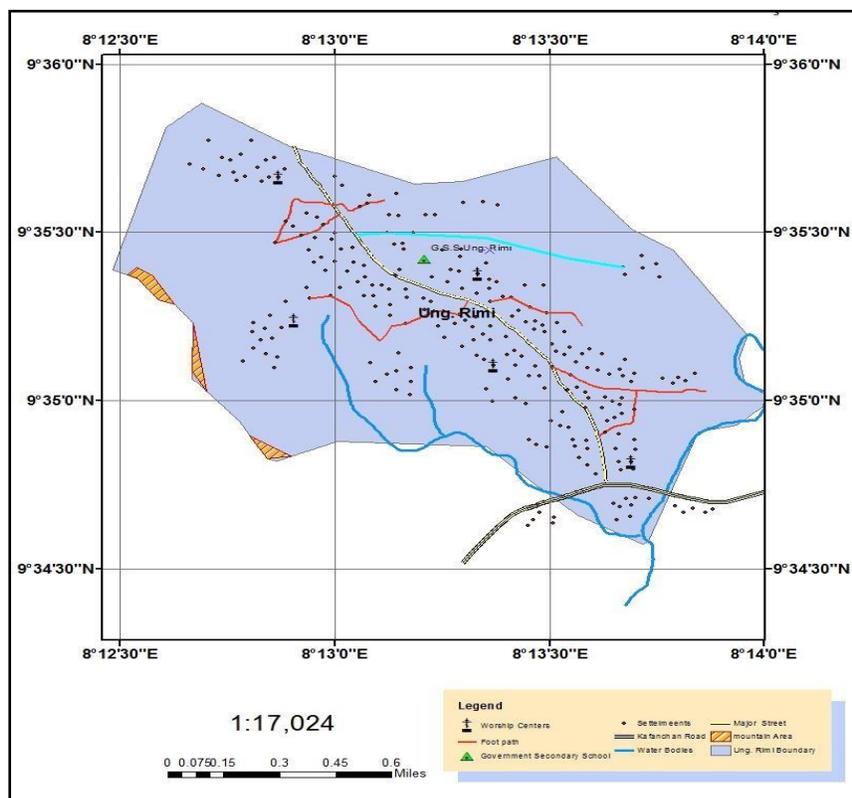


**Figure 1** Angwan Rimi, Zangon Kataf, Kaduna State (Study area).

*Geology*

The bedrock geology of Zangon Kataf Local Government, Kaduna State is predominantly metamorphic rocks of the Nigerian Basement Complex consisting of biotic gneisses and older granites; young granites and batholiths are evident. Deep chemical weathering and fluvial erosion, influenced by the bio-climatic nature of the environment, have developed characteristic high undulating plains with subdivided interfluves (Oluyori *et al.,* 2016).

*Climate and Vegetation.*

The study area is located in the middle belt of Nigeria, Zango – Kataf LGA is located within the tropical continental climate (Koppen"s AW) with two distinct seasons –wet and dry. A typical Tropical Continental climate with distinct seasonal regimes oscillating between cool to hot dry and humid to wet Rainfall occurs between the months of April to October with a peak in August. The mean annual rainfall is about 1800mm, the mean monthly temperature at $25^0$c, while the relative humility is about 62%, (Hussein *et al.,* 2013). Generally, the soils are typical red brown to red yellow tropical ferruginous soils which is related to the climate, vegetation and topography of the study area, likewise The soils in the upland areas are rich in red clay and sand but poor in organic matter. Clay and sandy soils are also found at the banks of the rivers. The relief of the area is relatively flat and undulating (Abaji, Ati and Ishaya 2009).

The vegetation type found in the study area is Southern Guinea Savanna type characterized by thick woodlands, tall grasses and herbs with riparian forest along streams and river banks (Igwe, 2003 and Udo, 1981).

*Population and Economic Activities.*

According to National Population Census (2006) the Local Government had a population size of 318,991. However, the National Bureau of Statistics (2012) estimated the projected population size of 370,615 by the year 2011. Average population density of the Local Government is about 76 persons per squares kilometer. The sex ratio of this population (NPC, 2006) stood at: 162,047 males to 156,944 females (approximately 50.8: 49.2). The structure of the

population indicates that a higher proportion are children and youths who constitute about 65% of the entire population, a relative low middle and old age group. About 70% of the total population are farmers, engaged in at least one form of subsistence farming, cultivation of cash crops especially ginger and rearing of animals. The most cultivated crops are mostly yam, maize, ginger, beans and cocoyam (Abaji, Ati and Ishaya 2009).

**Methods of Data Collection and Analysis.**

Five various methods were applied in the experiment on soil erodibility. Measurement of soil physiochemical properties (water and wind erosion research), measurement by scouring experiment, simulated rainfall experiment, plot experiment (water erosion research), wind tunnel experiment (wind erosion research). Likewise soil erosion models and nomogram were also used to calculate soil erodibility, adopting Song Yang *et al.,* (2007) method.

*Data Requirement*

Primary data required on soil physiochemical properties that are known to have influence on soil erodibility in the study area are:

1. Physical properties of the soil under study; physical soil properties such as; Bulk density, porosity, soil moisture content, soil aggregate stability and particle size distribution.
2. The chemical properties of the soil under study; soil ph, soil organic carbon, soil organic matter, exchangeable acidity, exchangeable bases and effective cat ion exchange capacity.

**Experimental Design**

*Site Selection and Sample Collection.*

The farmlands under study were selected using purposive and sample random sampling technique for sample collection and laboratory analysis. Four farm lands under different cropping systems showing moderate to catastrophic erosion problem were selected. The agricultural land uses were selected based on dominant crops cultivated and three soil samples were taken from each of the four farmlands (beans, maize, ginger and fallow land) at different points (10m distance between each point) and at a depth of 0cm to 15cm. The distance between

the selected farmlands are not equally distributed, however, the distance between beans and maize farm is 130km and between ginger farm and fallow land is 150km. Similarly, the total area for the different farm lands under study are not equal, the largest is the maize farm which have $8640m^2$, beans farm have total area of $2400m^2$, fallow land have $1800m^2$ and ginger farm have $1036m^2$ respectively.

**Laboratory Analysis of Soil Samples**
Laboratory analysis of soil samples were conducted in soil Laboratory. Standard laboratory procedures were followed throughout the analysis to determine the following soil physiochemical characteristics that affects soil erodibility

*Particle size distribution*
Particle size distribution was determined by hydrometer method as described by Gee and Bauder (1986). Clay, silt and sand were determined by dispersing the soil sample in calgon (hexametaphosphate) solution. The dispersed sample is to be shaken on a reciprocating shaker after which particle size distribution is determined with aid of Boyoucous hydrometer at 40 seconds (clay + silt) and 2 hours (clay only) interval. The textural classes were determined with the aid of USDA textural triangle.

$$C = R - RL + (0.36T) \qquad (1)$$

where: C = corrected hydrometer reading (g/l)
R = hydrometer reading (g/l)
RL = Blank reading (g/l)
T = temperature of the suspension ($^0$C)

$$\%Clay = \ldots\ldots.. \; x \; \ldots\ldots\ldots \qquad (2)$$
$$\%Silt = \ldots\ldots.. - \%Clay \qquad (3)$$
$$\%Sand = 100 - (\%Clay + \%Silt) \qquad (4)$$

*Organic Carbon*
Soil organic carbon was analyzed by wet oxidation method of Walkey- Black (Nelson and Sommer, 1986). One gram of air dried, less than 2 mm soil were placed in 250 ml flask. 10 ml of 1N Potassium dichromate (K2Cr2O7) solution

will pipette into the flask and swirled gently for soil dispersion.

*Soil pH*
Soil pH will be determine electrometrically using a pH meter with a glass electrode, after equilibrating for 30 minutes (Jurinak, 1978).

*Electrical conductivity (EC)*
The EC (1:2.5) soil/ water ratio extract will be determined using a direct EC meter at room temperature. Results will be expressed in micromhos cm-1 and thereafter converted to decisiemens per meter (dsm-1) will be adjusted to that of 25˚C, using the appropriate factors (US Salinity Lab. Staff, 1954).

*Soil Nitrogen (TN)*
Total Nitrogen (N) was determined by Kjeldahl method (Bremner, 1982), a wet oxidation method which involves digestion of the soil sample to convert N to ammonium (NH4) and determination of the NH4 in the digest by titration.

*Cation exchange capacity (CEC)*
The CEC values was measured using ammonium acetate (1N NH4OAC) at pH 7 as described by Rhoades and Thomas (1982).

*Exchangeable Bases (EB)*
Soils was analyzed for Ca, Mg, K and Na, following the extraction with 1N ammonium acetate (1N NH4OAC) at pH 7, using 1:10 soil/solution ratio. Na+ and K+ in filtered extracts will be determined with a Gallen Kamp Flame Analyzer while Ca2+ and Mg2+ are determined by a Palkin-Elmer Model 290B atomic absorption spectrophotometer (Chapman, 1965).

*Determination of erodibility index.*
The erodibility indices and values of the study soils was determined by the use of the formulation suggested by Boyoucous (1935). The clay ratio proposed by Bouyoucos (1935) is a measure of the amount binding due to clay. When clay ratio decreases with increase in depth. This may be interpreted to mean that the binding influence of clay and hence the resistance of the soils to erosion increased with increase in depth. Higher clay ratio here indicates lower binding

influence due to clay and therefore greater susceptibility to erosion. The formula is given as:

$$Clay\ ratio = \frac{(\%Silt + \%\ Sand)}{\%Clay} \qquad (5)$$

## RESULTS AND DISCUSSION
### Soil Physiochemical Parameters
*Soil organic matter and porosity*
The soil of the study area have a considerable amount of organic matter whose mean values ranges from 3.35 for fallow land as the highest and 1.53 as the lowest in beans farm, ginger farm have 2.25 and maize farm have 2.19 respectively. The mean result shows that mean percentage of Soil Organic Matter is 1.42%, this mean result is considered to be slightly moderate as similar result of 1.41% obtained by Oluyori (2016) work on assessment of some soil erodibility indices on agricultural land uses in Fdan kagoma area of Jema'a local government area, Kaduna state, northern nigeria and 1.01% obtained by Mgbanyi's (2011) work on rates of soil wash on miniature badlands and bare surface in the FCT with the obtained soil texture of Sandy Loam (S.L) on this study, low organic matter does not encourage soil aggregation and thus poor soil structure making it prone to particle detachment and entrainment. This is as a result of influence

of exposure to physical stresses as observed by Bryan (2000). These stresses are linked to human activities which involve vegetation change, alteration of organic inputs, and physical disruption of the soil, which transforms soil climate and organic decomposition rates. These were noticed in the study area, and the results further show other effects such as influence of bush burning (Giovannini et al., 1958; Fernandez et al., 1997) and animal trampling (Steffens et al., 2008) which significantly change aggregation characteristics by reducing organic material or precipitating hydrophobic substances which temporarily "water-proof" aggregates.

Porosity across the land uses is highest with 33.09 in ginger farm and beans farm record the lowest value with 9.00, fallow land has porosity mean of 14.92 and maize farm has 19.75 respectively (Table 1).

*Soil bulk density and particle density.*
The soils in all the farm lands generally have low mean values of Bulk Density and Perticle size (Table 1). The farm land with highest value for B.D is maize farm with 1.44; fallow land is 1.40; beans farm have 1.36; and the lowest is ginger farm with 1.31. While P.D on the other hand is highest in beans farm with mean value of 1.50, maize farm have 1.44, ginger farm have 1.33 and fallow land is the lowest with 1.30.

**Table 1** Soil physiochemical properties under different agricultural land uses

| PARAMETERS | Fallow land | Giger Farm | Maize Farm | Beans Farm |
|---|---|---|---|---|
| Organic Carbon | 2.19 | 1.3 | 1.21 | 0.92 |
| Nitrogen | 0.19 | 0.18 | 0.19 | 0.12 |
| Potassium | 0.8 | 0.18 | 0.31 | 0.23 |
| Sodium | 0.68 | 0.29 | 0.35 | 0.27 |
| Magnesium | 2.16 | 1.32 | 1.2 | 0.94 |
| Bulk Density | 1.4 | 1.31 | 1.44 | 1.36 |
| Particle Size Density | 1.3 | 1.33 | 1.44 | 1.5 |
| Soil PH | 6.44 | 6.38 | 6.46 | 5.98 |
| Organic Matter | 3.35 | 2.25 | 2.19 | 1.53 |
| Phosphorus | 8.22 | 32.3 | 41.2 | 25.43 |
| Calcium | 8 | 5.06 | 6.3 | 3.51 |
| Cation Ex. Capacity | 11 | 7.41 | 8.86 | 5.32 |
| Porosity | 14.92 | 33.09 | 19.75 | 9 |

*Particle size distribution (sand %, clay % and silt)*

The textural soil of all the agricultural uses are generally classified as Sandy Loam (S.L) Percentage mean of sand, clay and silt was found to be 58.00%, 15.00% and 27.00% for fallow land respectively. The mean of sand, clay and silt to be 59.00%, 13.00% and 28.00% for ginger farm, mean of sand, clay and silt to be 57.33%, 16.66% and 26.66% for beans farm and mean of sand,

clay and silt to be 66.00%, 10.66% and 22.66% for maize farm respectively. The result implies that clay is highest in beans farm and lowest in maize farm. the farmlands under examination generally have low silt content. silt is highest in fallow land and lowest in ginger farm whereas Maize farm have the highest mean value of sand, in contrast beans farm have the lowest sand value across the farmlands examined (Fig 2).
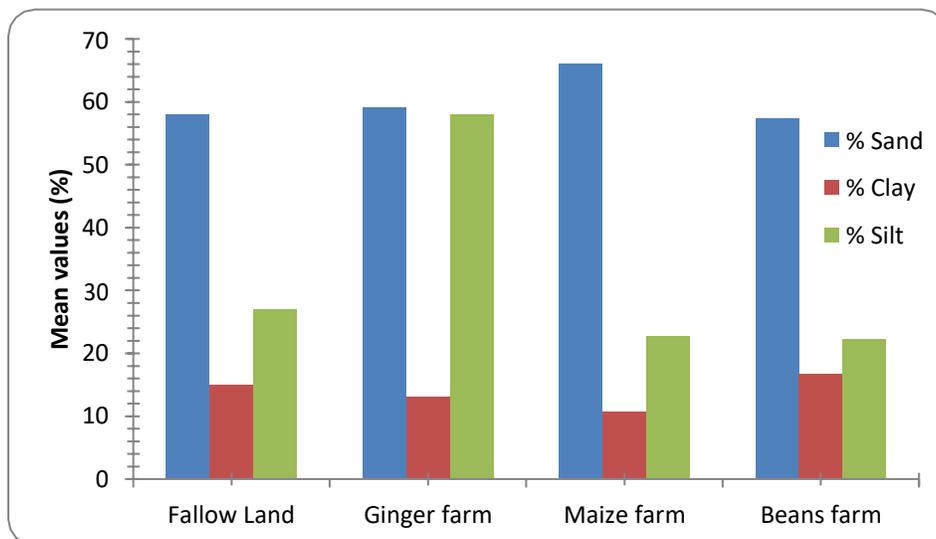


**Figure 2** Particle Size Distribution across the Farmlands Under Study

*Soil pH and exchangeable acidity*

The soils in all the plots of agricultural land uses under study have acidic reaction below neutral pH value of 7, mean Average pH values were generally low in the beans farm with 5.98 while the highest mean value is in the maize farm with 6.46. Exchangeable acidity on the other hand have the same value of 0.40 across the different agricultural uses under study.

*Effective cation exchange capacity and phosphorus*

General mean values in the distribution shows that there is low exchange capacities across the farmlands under study. The highest value (11.00) is obtained in fallow land, maize farm have 8.86 while ginger farm contain 7.41 and the lowest is the beans farm with 5.32. Available phosphorus which is vey essential for improving plant

resistance to disease is found in an appreciable amount, table four shows the result of available phosphorus obtained in the samples collected. Mean values of phosphorus in fallow land, ginger, maize and beans farms are 8.22 MgKg$^{-1}$, 32.20 MgKg$^{-1}$, 41.26 MgKg$^{-1}$ and 25.43 MgKg$^{-1}$ respectively. Highest value is found in maize farm while the lowest value is found in beans farm.

*Total nitrogen and magnesium*

Results of analysis from soil sample show that Nitrogen content is more in fallow land (0.29), maize farm is 0.19, Ginger farm 0.18 and the least is in beans farm 0.12. Similarly, magnesium is more in fallow land (2.16), maize farm is 1.70, Ginger farm IS 1.32 and beans farm is the least with 0.94 (Figure 3).
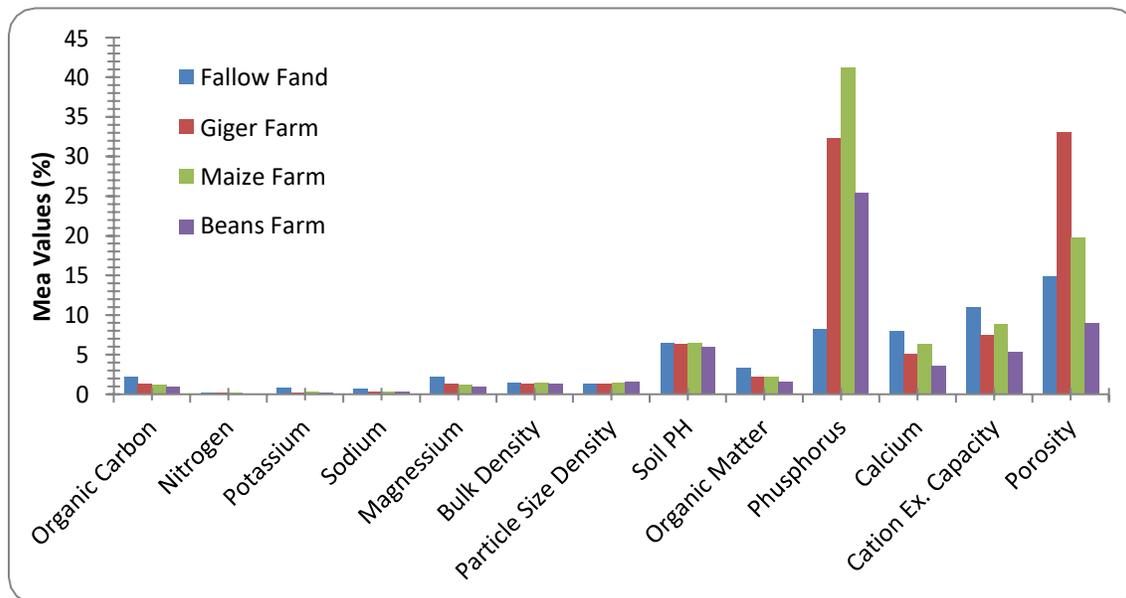
**Figure 3** Soil Physiochemical Properties Under Different Agricultural Land Uses

*Sodium and calcium*

Results indicated that the mean values of calcium is higher than values of sodium obtained across the farmlands under study. However, sodium and calcium were found more in fallow land and maize farm. Fallow land has 8.00 calcium and 0.69 sodium, maize 'farm has 6.30 calcium and 0.35 sodium, Ginger farm has 5.06 calcium and 0.29 sodium and finally the least is beans farm which contains 3.51 calcium and 0.27 sodium.

*Potassium*

Potassium content was found generally to be low across the farmland under study. The highest value is obtained in fallow land (0.80) while the lowest is obtained in ginger farm (0.18). Maize farm have 0.31 and beans farm have 0.23

respectively. Maize farm contain more of phosphorus among all the physiochemical soil properties under study

**Clay Ratio Index (Erodibility Value)**

Finding revealed that the fallow land and beans farm are more resistant to soil erosion than the maize and Ginger farm land. The decrease in Clay Ratio in soils reflects the increase of resistance to erosion. Higher clay ratio here indicates lower binding influence due to clay and therefore greater susceptibility to erosion. However, the maize farm is most susceptible to erosion with clay ratio of (68.07) while the Beans and fallow land are the least susceptible to erosion with clay ratio of 59.95 and 59.18 respectively (Figure 4).
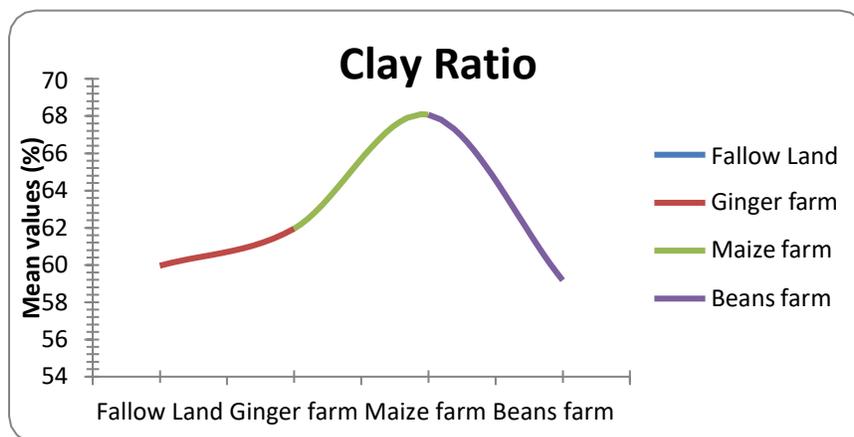
**Figure 4** Mean Plot for Clay Ratio

The result shows an existing relationship between clay ratio and soil erodibility index. Soil with larger clay ratio are more vulnerable to water erosion due to lack of stability of the soil particle. Soil texture with large particles are resistant to transport because of the greater force required to entrain them and fine particles are resistant to detachment because of their cohesiveness (Figure 5). The least resistant particles are silts and fine sands. Thus, soils with silt content above 40 percent are highly erodible. While the textural soil of Angwan Rimi is generally classified as Sandy Loam (SL).



**Figure 5** Erodibility Indices under Different Farmland Uses

The result obtained from this study showed that mean value of clay ratio of the farmlands under study is 9.92 which is lower than 11.8 that was obtained by Oluyori et al (2016) that assessed some soil erodibility indices on agricultural land uses in Fadan Kagoma area of Jema'a Local Government. This is higher than mean value of 7.87 obtained by Oluyori and Mgbanyi's (2014) work on soil aggregate stability and erodibility in different gully sites in parts of Kaduna and more higher than the mean value of 2.31 obtained by Mgbanyi (2011) in the FCT badlands; However, in contrast to this findings, textural structure of the soil under study varies with the findings of Oluyori and Mgbanyi (2014) who worked on soil aggregates stability and erodibility in different gully sites in parts of Kaduna State especially parts of Zaria with the aim to provide

'quantitative information on the variation of some soil properties and their interaction with eroding agents and how this affects soil erosion on the sites, they found that Soil particle size distribution in all the gully sites show soil textural classes of silt loam, sandy loam, sandy loam and sandy clay loam at Guga, Saye, Kubanni and Yashi gully sites respectively and the results show there is a significant variation of clay, silt, sand, clay ratio and aggregate stability with gully sites at 0.05 levels of significance.

Pearson's correlation matrices that describe the interrelationships and similarities between the physiochemical soil properties of the agricultural land uses under study (fallow land, maize farm, ginger farm and beans farm). There is a strong positive correlation between the physiochemical properties of the farm lands under study where the values imply that soil physiochemical properties are highly correlated at 95% probability level and with N-1 degree of freedom. however, soil physiochemical properties of fallow land and beans farm show the least similarities with value of (0.57) and the similarities between soil physiochemical properties of beans farm and maize farm is near perfect with is the highest (0.98).

Similarly, the result of correlation analysis of variables of soil particle size distribution (clay, sand and silt) and clay ration (erodibiliy) indices shows a positive strong relationship between percent of sand and clay ratio (0.99), where as percent of clay showed high negative correlation with clay ratio (- 0.94) and the correlation between percent of silt and clay ratio was highly negatively low. Correlation between percent of sand to percent of clay is highly negatively poor (-0.90) and between sand and silt is low (-0.22).

According to the results obtained, there is no significant difference (variation) in the levels of soil erodibility indices (Clay Ratio), percent of sand, percent of silt, and soil organic matter among the agricultural land uses at 0.05 level of significance level. However, other soil physiochemical properties such as potassium, magnesium, nitrogen, sodium, organic matter, calcium, phosphorus, clay, effective cation exchange capacity, porosity, bulk density and particle size density all showed that there is significant difference among the agricultural land uses at 0.5 level of significance. This result is similar to the work of Oluyori et al (2016) that assessed some soil erodibility indices of agricultural land uses in Fadan Kagoma they found that erodibility indices (clay ratio) amongst and between agricultural land use types did not significantly vary with the agricultural land uses. In contrast to the result obtained in this study, similar attempts were made to compare the erodibility of different land uses and gully sites. Oluyori, Nenadi R. and Lazarus, James (2016) assessed soil aggregate stability and erodibility in different gully sites in parts of Zaria, Kaduna State, Nigeria. Their results showed that there is a significant variation of clay, silt, sand, clay ratio and aggregate stability with gully sites at 0.05 levels of significance. Ezeabasili et al (2014) also assessed Relative erodibilities of some soils from Anambra basin where Some properties of soils relevant to their erodibilities was studied in twelve locations where severe gully erosion were observed, result of clay ratio obtained were generally low ranging from 0.21 to 24.64% implying high resistance to erosion.

**CONCLUSION**

The results obtained from this study showed that the soils of Angwan Rimi are generally highly susceptible and vulnerable to erosion compared to global results. Among other factors, this may for a larger extent come as a result of human activities that are responsible for destroying vegetation cover and continuously degrading the physiochemical properties of soil that affects soil structure, share strength and aggregates stability. The most vulnerable is the soil under maize cultivation and the least vulnerable is the soil under beans cultivation.

Result from correlation analysis implies that there is a highly positive relationship between the soil physiochemical properties across the farmlands under study. The highest similarity was obtained between the properties of maize farm and beans farm. However, there exist a negative similarity between soil particle size distribution of the soil under study. Generally, there is a positive relationship between percent of sand and clay ratio, a negative one between clay and clay ratio and a negative low relationship between silt and clay ratio. It is therefore concluded that the relationships observed among

the soil characteristics and soil erodibility could not have occurred by chance, thus erodibility is significantly influenced by soil characteristics.

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