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ASSESSMENT OF SOME SOIL ERODIBILITY INDICES ON AGRICULTURAL LAND USES IN FADAN KAGOMA AREA OF JEMA'A LOCAL GOVERNMENT AREA, KADUNA STATE, NORTHERN NIGERIA.

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ABSTRACT: *A field study was carried out in Fadan Kagoma, Kaduna State to assess some erodibility indices on different agricultural land uses. Five plots made up of Yam, Beans, Groundnut, Ginger and Fallow were selected. 80 soil samples were collected in all at a depth of 0-22.5cm. 16 samples from each site, out of which 4 composite samples were generated and analyzed for pH, electric conductivity, particle size distribution, organic carbon, exchangeable acidity and bases (exch. Na, Ca, and K) using standard laboratory procedures. While the soil erodibility indices were derived from the results of data from laboratory. Analysis of Variance compared erodibility indices amongst and between agricultural land use types was carried out at α = 0.05 significance level. Result showed, Clay Ratio (CR), Modified Clay Ratio (MCR) and Critical Level of Soil Organic Matter concentration (S_t) did not significantly vary with the agricultural land uses. Results also showed mean values of 4.96% and 4.01% for critical level of soil organic matter content in Yam and Beans plots respectively, these results imply that there was loose soil structure and high susceptibility of the soils to erosion; the Fallow plot had an S_t value of 7.05% implying an unstable structure and erosion risk while the mean values of G/nut and Ginger implied stable structure and lesser susceptibility to erosion with 11.36% and 10.52% respectively. Soil erodibility indices further showed mean values of 7.58% for critical level of soil organic matter content, 11.48 for clay ratio and 9.41 for modified clay ratio. Communal tree planting, farming across the slopes, crop rotation and grass fallowing were among the recommendations proffered.*

KEYWORDS: Soil Erodibility, Agricultural Landuse, Soil Erodibility Indices

INTRODUCTION

Agricultural soils are inherently low in nutrients and, have poor structure that cannot withstand the high-erosive power of rain and wind thereby constituting some of most marginally fragile soils (Ayuba and Dami, 2011); this is true of the Northern region of the country. Soil erosion remains the world's biggest environmental problem threatening plants and animals sustainability. Foth (1978) further observed that splashing and scattering of the smaller soil particles by raindrops' impact has received little attention until recent years. Essentially in assessing soil erosion in fields and farmlands, the soil's potentials for erosion and soil properties that can be managed to minimize erosion need by assessed. For the past few decades, pressure on/and misuse of agricultural lands have exerted problems in the study area towards sustainable agricultural productivity; these practices have not only accelerated the soil erosion but also have resulted in soils of low fertility. Threat to soil is threat to life (Okin, 2002); hence, the assessment of soil erosion on agricultural lands has great significance not only to soil productivity but also to agricultural sustainability through improved or stabilized soil conservation.

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Research has shown that about 72% of the major part of cultivable land in sub-Saharan Africa suffers from low fertility, loss of soil nutrients, poor soil drainage, and steep slopes, and is unlikely to support the populations (FAO, 2010).

Therefore, the more one learns about good farmland and the part it plays in the welfare of people, the more respect one has for the soil (Foth, 1978). Land use refers to the various ways land is utilized, depending on its physical location and economic attributes (Harvey, 1996), of which agriculture is the most dominant from earliest times.

Very little scientific information is available on the extent to which agricultural soils are degrading as a result of cultivation practices, yet there is need for information on present and possible future erosion rates to furnish a basis for reducing adverse effects of accelerated soil erosion (Mgbanyi and Alhassan, 2011).

Several authors have opined that the establishment of cultivation practices leads to accelerated decline in soil fertility and eventually soil degradation mostly erosion (Nye and Greenland, 1960; Russell, 1961; Sanchez, 1976; Juo and Lal, 1977; Adepetu et al., 1979; and Mgbanyi and Alhassan, 2011); food crops are the worst hit due to their shallow rooting systems. Because of the decline in agricultural production there has been food shortages, rising food prices, and famine, adversely effects nutrition and health of the people and decline in labour productivity.

Agricultural lands have different levels of soil erosion based on the type of crop, nature of cultivation method and intensity of cultivation. But, it is through the recognition of the above named factors and the rate of erosion, and individual and collective actions that soil erosion problems can be addressed effectively because people, particularly farmers, will only act when they perceive that a problem really exists and the threat it poses to their existence. This study therefore, will be to assess soil erodibility as it is affected by agricultural land uses in the study area.

This study assesses soil erodibility on agricultural land uses in Fadan Kagoma of Jema'a Local Government Area, Kaduna State, Nigeria. This aim was achieved through objectives which includes, assessing some soil erodibility indices on the various agricultural land uses, examination of the impacts of agricultural land uses on soil erosion and the evaluation of the effects of agricultural land uses on soil productivity.

The study area

The area of coverage or location of the study area is Fadan Kagoma, which is located at the southeastern part of the Jema'a Local Government of Kaduna State.

Jema'a Local Government Area is located between Latitude 9^0 11' – 9^0 30' North of the Equator and Longitude 8^0 00' – 8^0 30' East of the Greenwich Meridian (Figure 1).

The bedrock geology of Jema'a 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.

The study area just as all the areas in the middle belt of Nigeria, has the Aw type of climate as classified by Köppen, a typical Tropical Continental climate with distinct seasonal regimes,

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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 25^0C, while the relative humility is about 62%. Generally, the soils are typical red brown to red yellow tropical ferruginous soils. The soils in the upland areas are rich in red clay and sand but poor in organic matter

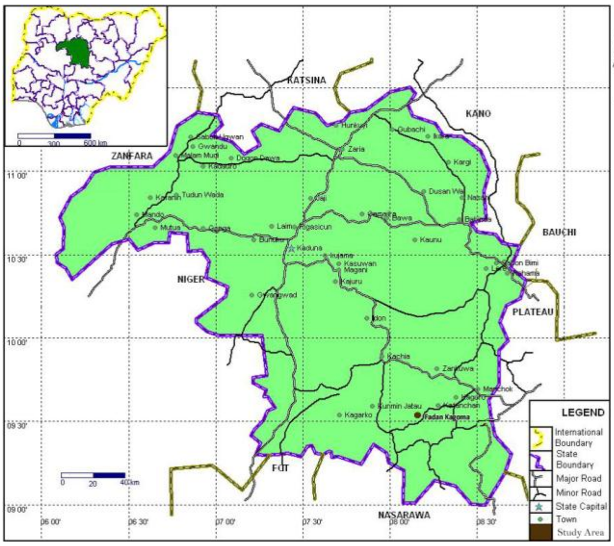

Figure 1: Map of Kaduna State showing the Study Area

MATERIALS AND METHODS

The data required for this study was gathered from two main sources: primary and secondary sources.

Primary sources: The data in this category were from the use of reconnaissance survey, field observations and investigation, interviews and the photographs of the plots under study.

Secondary sources: The library and internet were used in the collection of secondary data for this study. A wide variety of textbooks, journals, magazines, newspapers, and seminar papers, unpublished articles and dissertations relevant to this study were used also.

The reconnaissance survey provided insight on the number of personal or field assistants that was needed during actual field investigation/survey; also to identify field/sampling plots.

Field Investigation/Survey: For the purpose of this study, soil samples were collected from five (5) plots, four were different agricultural land uses and a fallow plot as control. The agricultural land uses were selected based on dominant crops cultivated with use or agronomic classification.

Materials Used: Materials used for the survey include: soil auger, soil core samplers, iron pegs, wooden buffer, measuring tape (50m), masking tape (for tagging soil samples), leather bags (for collecting soil samples), iron mallet (for driving core sampler into the soil), permanent marker pen (for marking soil samples for recognition), line/rope (for dissecting the plot into quadrants), and paper and pen (for note taking of field details).

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Systematic sampling technique was used to select soil samples from each plot; surface (0-22.5cm depth) to determine soil properties using standard laboratory methods. The properties determined were particle size distribution of soil, soil pH, electric conductivity, organic carbon content, and exchangeable bases of soils. 16 Soil samples were collected each from 5 plots, using quadrant soil sampling method; a total of 80 soil samples were collected from the field and taken to the laboratory; 20 soil sample composites were generated and used for the laboratory analysis.

The collected bulk soil samples were air-dry in the laboratory for several days. Part of the samples were gently crushed with porcelain pestle and mortar and passed through a 2mm sieve to remove coarse fragments. The less than 2 mm portion were stored in polythene bags for laboratory analysis. While the other uncrushed part were passed through 5mm sieve and used for aggregate size analysis.

Laboratory Procedures

The soil physical and chemical properties were determined in the Laboratory. They include particles size distribution, organic carbon, soil pH, electrical conductivity, total nitrogen, exchangeable acidity, and exchangeable bases.

Particle size distribution/textural class: 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 were shaken on a reciprocating shaker after which particle size distribution were 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.

$$C = R - R_L + (0.36T) \quad [3.1]$$

where: C = corrected hydrometer reading (g/l)

R = hydrometer reading (g/l)

R_L = Blank reading (g/l)

T = temperature of the suspension (^{0}C)

$$\%Clay = \frac{}{} \times \frac{}{} \quad [3.2]$$

$$\%Silt = \frac{}{} - \%Clay \quad [3.3]$$

$$\%Sand = 100 - (\%Clay + \%Silt) \quad [3.4]$$

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 ($K_2Cr_2O_7$) solution were pipette into the flask and swirled gently for soil dispersion. Then 20ml concentrated H_2SO_4 were rapidly added, the flask were gently swirled immediately until soil and reagent mixed. After swirling the flask it were allowed to stand on a sheet of asbestos for about 30 minutes. One hundred mills of distilled water were

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added and allowed to cool before adding 3 drops of indicators. A blank were run without soil to standardize the dichromate. Both were titrated against Ferrous Sulphate ($FeSO_4$).

$$\%OC = \frac{(blank - titre) \times 0.3 \times m \times f}{weight\ of\ soil} \quad [3.5]$$

where: f = corrected factor (1.33).

m = concentration of $FeSO_4$.

Soil pH

Soil pH was determine in water and in 0.01M CaCl at 1:2.5 soil/solution ratio, 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 were determined using a direct EC meter at room temperature. Results were expressed in micromhos cm-1 and thereafter converted to decisiemens per meter (dsm-1) were 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 (NH_4) and determination of the NH_4 in the digest by titration. One gram of soil were weighed into a digestion tube, followed by 5 g of Kjeldahl catalyst mixture then by 10mls of concentrated sulphuric acid (H_2SO_4). The solutions were heated on a digestion block at 300˚C (maximum) until digestion is completed. After cooling, the contents were washed into a 100 ml volumetric flask and make up 100mls with distill water.

Ten mls of the aliquot were transferred into a distillation flask using a pipette. Ten mls of 10N NaOH solution were added and then attached to a distillation apparatus immediately where NH_4-N was trapped into 10 mls of 2% boric acid (H_3BO_3). These distillates were titrated with 0.025M H_2SO_4 to a pink or purple end point. Blank titration will also be determined without soil sample. Percentage Nitrogen content in the soil was calculated thus;

$$\%N = \frac{gms\ nitrogen}{gms\ sample} \times 100 \quad [3.6]$$

Cation exchange capacity (CEC)

Cation exchange capacity is usually expressed in centimole per kilogram of soil (cmol/kg Soil) and is a measure of the quantity of readily exchangeable cations neutralizing negative (-ve) charges in the soil. The CEC values were measured using ammonium acetate (1N NH_4OAC) at pH 7 as described by Rhoades and Thomas (1982).

Exchangeable Bases (EB)

Soils were analyzed for Ca, Mg, K and Na, following the extraction with 1N ammonium acetate (1N NH_4OAC) at pH 7, using 1:10 soil/solution ratio. Na^+ and K^+ in filtered extracts were

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determined with a Gallen Kamp Flame Analyzer while Ca^{2+} and Mg^{2+} were determined by a Palkin-Elmer Model 290B atomic absorption spectrophotometer (Chapman, 1965).

RESULTS AND DISCUSSIONS

Particle Size Distribution (PSD): The Table 1 below shows the distribution of particle sizes on the various plots. According to the values, the soils are typically sandy in texture.

Table 1: Particle Size Distribution of Agricultural Land uses

S/N	Agricultural Land Use Type	%SAND	%CLAY	%SILT	TEXTURAL CLASS
1	Yam	79.62	8.00	12.38	LFS
2	Beans	68.21	20.00	12.79	SCL
3	G/nut	83.80	6.00	10.20	LFS
4	Ginger	86.30	5.50	8.20	LFS
5	Fallow	78.30	11.50	10.20	SL

Source: Field work, 2014

The USDA Soil Texture Calculator classified the Yam, Ginger and Groundnut plots under the Loamy Fine Sand (LFS) textural class with Beans and Fallow plots under Sandy Clay Loam (SCL) and Sandy Loam (SL) textural classes respectively. While the textural soil of Fadan Kagoma was generally classified as Sandy Loam (SL) with percentage mean of sand, clay and silt to be 79.25%, 10.20% and 10.75% respectively.

Exchangeable Acidity (EA), Bases and Cation Exchange Capacity (CEC): According to Table 2 below, Cation Exchange Capacity of each plot is given. The distribution of the CEC value shows that all the plots have low exchange capacities despite the low values of exchangeable acidity, with the Yam plot having the lowest value of all (6.46 meq/100 g). The highest value of CEC occurs in the Fallow plot.

Table 2: Exchangeable Acidity, Bases and Cation Exchange Capacity

S/N	Agricultural Land Use Type	EA	Na	K	Ca	Mg	CEC
1	Yam	0.50	1.56	0.06	1.78	2.56	6.46
2	Beans	0.88	1.40	0.23	2.50	2.80	7.81
3	G/nut	0.57	1.39	0.03	2.98	2.78	7.74
4	Ginger	0.48	1.57	0.03	2.45	2.93	7.46
5	Fallow	0.67	1.46	0.03	3.19	4.06	9.40

Source: Field work, 2014

Organic Carbon (OC), Organic Matter (OM) and Total Nitrogen (TN): Values of Organic carbon on the various plots have very minimal variation as they are generally low and range from an average of 0.58% to 1.04% of the soils sampled. The Table 3 results show the organic matter content to be low with the Groundnut plot having the highest value of 1.79% and the Yam plot having the lowest value of 1.00%.

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Table 3: Organic Carbon, Organic Matter and Total Nitrogen

S/N	Agricultural Land Use Type	%OC	%OM	%TN
1	Yam	0.58	1.00	0.05
2	Beans	0.76	1.31	0.07
3	G/nut	1.04	1.79	0.12
4	Ginger	0.83	1.43	0.04
5	Fallow	0.88	1.52	0.02

Source: Field work, 2014

Total Nitrogen values were also low ranging from 0.02% to 0.12%; the Groundnut plot has the highest (0.12%) while the Fallow plot has the lowest (0.02%).

Soil pH and Electrical Conductivity (EC): Soil pH and Electric Conductivity assessment results are given in Table 4. The soils in all the plots have acidic reaction being below neutral pH value of 7, Average pH values were generally low in the Groundnut plot with 5.46 and lowest in the Beans plot with 4.49. Electric conductivity ranged, averagely from 13.57 to 22.35, with highest in the Ginger plot with a value of 28.65 and lowest in the Fallow plot with 13.57.

Table 4: Soil pH and Electrical Conductivity

S/N	Agricultural Land Use Type	pH (H_20)	EC
1	Yam	4.94	14.86
2	Beans	4.49	22.35
3	G/nut	5.46	16.97
4	Ginger	5.20	28.65
5	Fallow	4.99	13.57

Source: Field work, 2014

Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP)

Results of analysis from soil sample show that SAR and ESP are 1.07 and 24.40 in the Yam plot, in the Beans plot 0.86 and 18.03 respectively, 0.82 and 17.97 in G/nut plot respectively. In the Ginger plot SAR and ESP are 0.98 and 21.59 respectively, and on the Fallow plot are 0.77 and 15.60 respectively (Table 5).

Table 5: Sodium Adsorption Ratio (SAR) and Exchangeable Sodium Percentage (ESP)

S/N	Land Use	SAR	ESP
1	Yam	1.07	24.40
2	Beans	0.86	18.03
3	G/nut	0.82	17.97
4	Ginger	0.98	21.59
5	Fallow	0.77	15.60

Source: Field work, 2014

Based on the classification of soils as Saline, Saline-Alkali, Nonsaline, or Normal, on basis of the relative numerical values of ESP and EC of the saturation extract of soils, a soil is Saline if ESP < 15% and EC > 4, Saline-Alkali if ESP > 15% and EC > 4, Nonsaline-alkali if ESP > 15% and EC < 4, and Normal if ESP < 15% and EC < 4. The result therefore shows that the

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soil is Saline-Alkali because ESP > 15% and EC > 4. The Yam, Beans, G/nut and Ginger plots showed more Saline-Alkalinity than the Fallow plot ESP values, the Yam plot however showed more Saline-Alkalinity (ESP = 24.40).

Analysis of Soil Erodibility Indices

Clay Ratio: Results in Table 6 show that clay ratio value for Ginger, G/nut, Yam, Fallow and Beans in the order of increase of resistance to erosion is 17.57, 16.14, 11.70, 7.90 and 4.11 respectively.

Table 6: Soil Erodibility Indices under Different Agricultural Land uses

S/N	Land Use	CR	MCR	CLSOM
1	Yam	11.70	10.36	4.96
2	Beans	4.11	3.85	4.01
3	G/nut	16.14	12.09	11.36
4	Ginger	17.57	13.80	10.52
5	Fallow	7.90	6.93	7.05

Source: Field work, 2014

The above result implies that the Beans and Fallow plot are more resistant to soil erosion than the Yam, Beans and Ginger plots; however, the Ginger plot was more susceptible to erosion (17.57) while the Beans plot was the least susceptible (4.11).

Modified Clay Ratio

The modified clay ratio (MCR) in soil represents the modification of clay ratio by incorporating the effect of organic matter in estimating soil susceptibility to erosion and resembles the results observed in clay ratios. MCR in soils under Ginger, G/nut, Yam, Fallow and Beans were 13.80, 12.09, 10.36, 6.93 and 3.85 respectively.

Critical Level of Soil Organic Matter Concentration (S_t)

Soil organic matter concentration plays a major role in forming and stabilizing aggregates (Zhang and Wenying, 2002). Results in Table 6 show that critical level of S_t in the Yam, Beans, G/nut, Ginger, and Fallow was 4.96, 4.01, 11.36, 10.52 and 7.05 respectively.

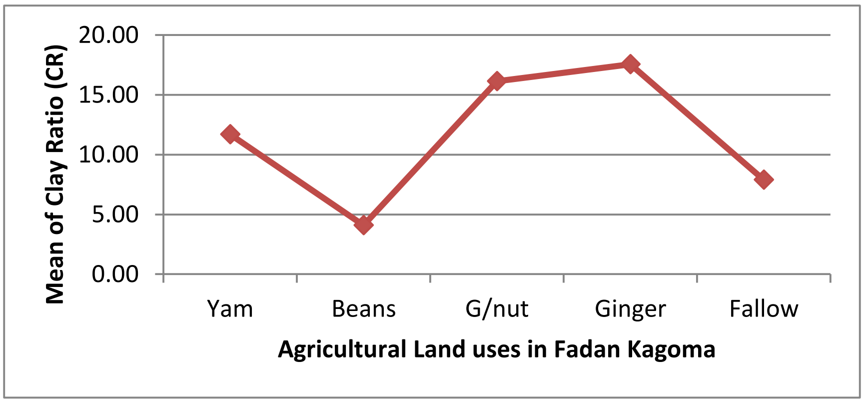

Figure 2: Means plot for Clay Ratio

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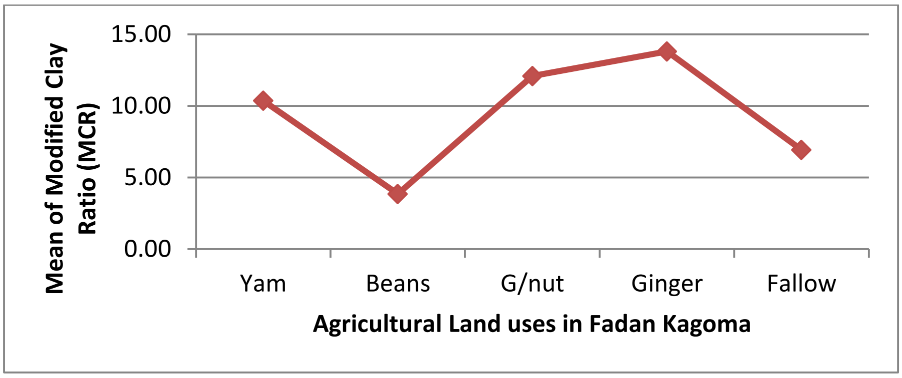

Figure 3: Means plot for Modified Clay Ratio

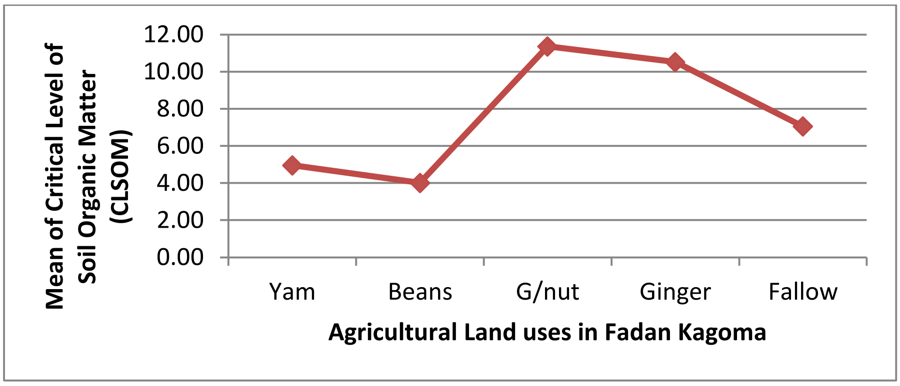

Figure 4: Means plot for Critical Level of Soil Organic Matter

DISCUSSION OF FINDINGS

Sodium Adsorption Ratio and Exchangeable Sodium Percentage

The soil samples show that in the Yam plot SAR is 1.07 and ESP is 24.40. In the Beans plot the SAR is 0.86 and ESP is 18.03, in the G/nut and Ginger plots the SAR is 0.82 and 0.98 while the ESP is 17.97 and 21.59 respectively. In the Fallow plot SAR is 0.77 and ESP is 15.60. The result therefore shows that the soil is Saline-Alkali in all plots because ESP > 15% and EC > 4 based on the classification of Saline and Alkaline soils by Stromberg (Page 27). The soil in the Yam plot is more Saline-Alkaline (ESP = 24.40), followed by Ginger (ESP = 21.59) and then Beans, G/nut and Fallow (18.03, 17.97 and 15.60 respectively).

In respect to research question two, the above results on Exchangeable Sodium Percentage (ESP) show that Yam and Ginger had the most impact on soil erosion followed by Beans and G/nut, while Fallow had the least impact on soil erosion and impoverishment.

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Soil Organic Matter (SOM)

The mean result shows that mean percentage Soil Organic Matter is 1.41%. The mean result is considered to be slightly moderate. This result is similar to that obtained (1.01%) by Mgbanyi's (2011) work on rates of soil wash on miniature badlands and bare surface in the FCT.

In respect to research question two, this kind of texture (SL) with 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 by 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.

The most common and important effect is the exposure by tillage of organic material formerly protected in almost anaerobic conditions in micro-aggregates to active decomposition; human activity and particularly intensive agriculture almost inevitable result in long-term reduction of soil organic matter, and particularly the persistent binding agents (Bryan, 2000).

Soil Erosion Indices

Soil erosion indices calculated for the different plots are Critical Level of Soil Organic Matter index (S_t), Clay Ratio (CR) and Modified Clay Ratio (MCR).

Critical Level of Soil Organic Matter index (S_t): According to Pieri (1991), Critical Level of Soil Organic Matter index (S_t) <5% show loss of soil structure and high susceptibility to erosion; S_t = 5% to 7% show unstable structure and risk of soil degradation and S_t = >9% show stable structure. The results for this index on all plots show unstable structure and risk of soil degradation. Based on the result, the Yam and Beans plots are more erodible followed by the Fallow plot and then G/nut and Ginger plots. CLSOM (S_t) is calculated to 7.58% in Fadan Kagoma; since it is within 5% to 7%, it shows unstable structure and susceptibility to erosion (Pieri, 1991).

It varies to result obtained by Mgbanyi (2011) of 2.48% in miniature badlands of the FCT. This variation exists as the present study area is more vegetated and plant roots help in aggregating and binding soil separates together.

Clay Ratio (CR): Decrease in Clay Ratio in soils reflects the increase of resistance to erosion (Singh and Khera, 2008). The mean result show that Fadan Kagoma has a mean clay ratio index of 11.48 . 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; as the present study area had equal clay to silt ratio (10.20%:10.75%) compared to the FCT badlands that had higher clay to silt ratio (30.62%:10.68%).

Modified Clay Ratio (MCR): In Fadan Kagoma, the modified clay ratio (MCR) index has a mean of 9.41. The mean result is higher than mean value of 2.23 obtained by Mgbanyi (2011).

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Analysis of Variance (ANOVA)

Though according to mean plots in Figures 2 to 4, there was variation in the levels of soil erodibility indices (S_t, CR and MCR), there was no significant variation of each of S_t, CR and MCR among the agricultural land uses at the 0.05 level of significance level.

IMPLICATION TO RESEACH AND PRACTICE

Based on the findings of erodibility indices, it is apparent that the agricultural land uses under consideration are deteriorating. This implies that erosion processes are been enhanced and may continue except they are checked. The soils of this environment can be consequently be rated as very low in essential nutrients and organic matter which cannot support increased agricultural productivity that is expected to feed the seemly rising population.

CONCLUSION

In conclusion, the study showed that the soils of Fadan Kagoma are relatively poor and are highly susceptible to erosion. The Groundnut and Ginger plots had the least susceptibility of soils to erosion and could be the best agricultural land uses for the purpose of soil conservation and management in the study area.

FUTURE RESEARCH

For the purpose of remediation and rehabilitation of soils, organic matter should be resurrected in the study area by revegetating the affected areas and by encouraging the use of organic manure. This will gradually supply organic matter content needed to bind soil aggregates, as these parameters influence plant growth indirectly through their effects on primary soil physical properties including soil water, soil air (oxygen), soil temperature and soil mechanical impedance (Sharma and Verma, 2006). Secondly, there is a need to carry further research on other agricultural crops to identify the most suitable crops that could thrive within such ecological environment and could also to check the erosion menace.

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