



Effect of *Jatropha Curcas* Plant on Some Soil Quality in Part of the Semi-Arid Zone of Nigeria

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ABSTRACT

The global land productivity is continuously decline due to land degradation and subsequently reduce the soil quality. The research aimed at assessing the effects of *Jatropha Curcas* plant on some soil quality and evaluate the erodibility status of the area. The *Jatropha* plantation land was demarcated and adjacent to it cultivated land were used as sampling location. Ten soils samples were randomly collected in each of the sampling location using composite sampling techniques from 0 – 15 cm depth. The laboratory results were analysed using descriptive also student's t-test was used at 0.05 probability level. The results revealed that mean values of organic carbon (0.94%), organic matter (1.87%), Infiltration rate (12.56mm), %clay (8.8%), %silt (9.6%), soil carbon stock (2464.5ton) were all found higher at *Jatropha* site than control site. This implies that *Jatropha* have the capacity to enhance and retain some soil quality parameters. It was discovered that cultivated land is more susceptibility to erosion due to high erodibility status (24.54ton/ha) than the *Jatropha* site (23.29ton/ha). This signified that *Jatropha* plantation improve soil quality and reduce soil vulnerability to erosion. This is further, testified by t-test whereby significant difference in the mean values of organic matter, organic carbon, infiltration rate, soil carbon stock, soil erodibility was observed. It was concluded that *Jatropha curcas* have the ability improve soil quality parameter and therefore, reduce land degradation.

Keywords: *Jatropha*; Soil Quality; Erodibility; Erosion; Land Degradation

INTRODUCTION

Soil quality is an eminent characteristic of soil which enhance the productive capacity of the soil and when degraded will reduce its productive capacity, therefore there is need for urgent attention, globally. The severity level of land degradation increases in many parts of the world, with more than 20% of all cultivated areas, 30% of forests and 10% of grasslands undergoing degradation (Brabant, 2010). It is estimated that 2.6 billion people are affected by land degradation and desertification in more than a hundred countries, influencing over 33% of the earth's land surface. The declining in soil quality is more pronounced in the dry lands because of its peculiar nature of their climate and vegetation which subsequently influence soil quality (Brabant, 2010).

Land degradation results from both human activities and climatic variability resulted to deterioration of soil quality (UNFCCC, 2013). An estimated 65% of Africa's agricultural land is degraded due to erosion and/or chemical and physical damage. Thirty-one per cent of the continent's pasture lands and 19% of its forests and woodlands also are classified as degraded. Food and Agricultural Organization (FAO, 2010); International Food and Development (IFAD, 2010); United Nations Framework Convention on Climate Change (UNFCCC, 2013) reported that many areas in Africa were said to be losing over 50 tons of soil per hectare per year due to intense erosion of many forms, this led to the drastic reduction of some important soil nutrients. Consequently, this is roughly equivalent to a loss of about 20 billion tons of Nitrogen, 2 billion tons of Phosphorus and 41 billion tons of potassium per year.

Some plant were discovered to be used for soil conservation common among include *Jatropha curcas*, which is been used for a long period of time. The plants were currently used in almost all tropical and subtropical countries including Africa

and Asia (Openshaw, 2000). *Jatropha curcas* has a life span between 30-40 years (Austine and Echebiri, 2014), and even more than 50 years (Henning, 2008). *Jatropha curcas* is a tree that grows to a height of about 3-5 meters high (IFAD and FAO, 2010); 6m (Henning, 2008) and up to 8m (Mndeme, 2008) with numerous side branches arising from its main stem. The *Jatropha curcas* is among the prominence species because of its non-toxicity and some added features like excellent adaptability to various habitats and soil conservation (Henning, 2004; 2008).

The concept of soil quality has been one of the important methods of assessing soil (Wienhold *et al.*, 2004). This soil quality can be improved by planting trees, organic fertilizer application, water management and some climate smart agricultural practices such as zai pit, organic farming and agro forestry. The soil quality degradation in dry lands is one of the major environmental issues of the 21st century particularly due to its impact on world food security and environmental quality (Ravi *et al.*, 2010 Gregorich *et al.* (1994) in Shehu, (2013). Soil degradation form from various factors such as over cultivation, deforestation and overgrazing. These factors subsequently result in drastic reduction of soil quality.

MATERIALS AND METHODS

Description of the Study Area

The study area is located between Latitude 9°45'N to 9°51'N and Longitude 12°37'E to 12°42'E and situated at the northern tip of Kaugama Local Government, Jigawa State. It shares a common border with Yobe State at the North, Birniwa Local Govt at the North Eastern part, Maigatari Local Government at the North Western Part. It covers an approximate land area of 400 hectares within the Yarda Babba Forest Reserve (Fig. 1). Temperature range is between 21°C in the coldest months of December /January to 36°C in the hottest months of April/May (Liman, Abdulkadir and Mohammed, 2014).

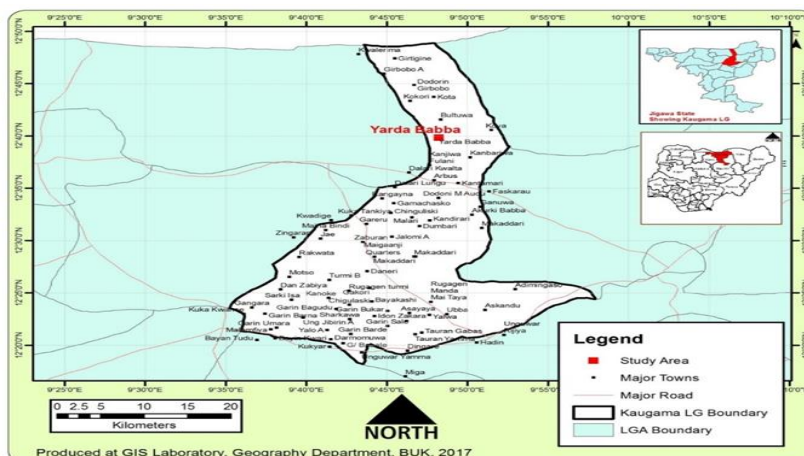


Figure 1: A map of Kaugama Local Government Area Showing the Study Area

The vegetation around the area include some scattered trees such as *Acacia albida*, *Piliostigma thonningii*, *Azadirata indica*, *Anogeissus leiocarpus* and *Tamarindus indica* also scrubs and shrubs were also found such as *Gueira senegalensis* (Badamasi, 2014). The soils of the area is dominated by ferruginous types which is resulting mostly from the Aeolian material (Usman, et al., 2014). They are poorly structured, excessively drained and low nutrient. The area consists mostly of unconsolidated sediments which are predominantly sandy (>70% sand) consequently, the soils are texturally sandy (Essiet, 2013). Hydromorphic soil are also found in some depression where some irrigation activities is taken place.

The materials used for data collection in this research include: Google Earth for downloading the satellite image of the area, ArcGIS 9.2 Software for geo-referencing of features, Global Positioning System (GPS) for taking coordinates of sampling points, polyethylene bags for storing soil sample, marker for leveling of soil sample and double ring infiltrometer for measuring infiltration rate, stop watch for recording time taken for infiltration.

Sampling Technique

The study location was demarcated in to two stratum: area where there is *Jatropha curcas* plant plantation land use and the adjacent cultivated land which served as control site. In each of the study location (*Jatropha curcas* site and its control) five small plots (Figure 2) were also demarcated for soil sampling. Five soil samples were collected in each study location making ten soil samples for the whole analysis. The samples were collected using composite soil samples methods from 0 – 15 cm depth.

The *Jatropha curcas* plantation was also divided into five (5) compartments based on the composition of the plant. whereby five (5) samples were collected using composite sampling technique based on the assumption that in each JC compartment exists uniformity in terms of some land properties (like soil type, vegetation species, and land use type) due to the homogenous nature of the area. This process was repeated in the control site.

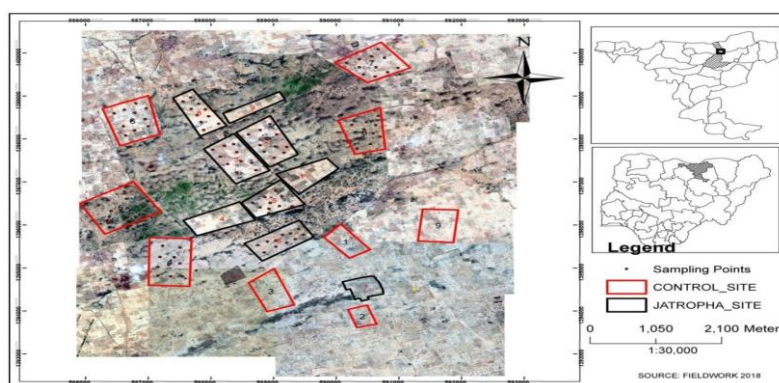


Figure 2: Sampling Locations for Jatropha and Control Sites

Laboratory Analysis

The soil samples collected were kept in polyethylene bags leveled appropriate and the utmost care was taken to avoid contamination the soil samples. The sample was taken to the laboratory for the analysis of some selected soil quality parameters using standard laboratory procedures.

The particle size distribution was determined using hydrometer methods as described by Sarkar and Hardar (2005) whereby 50g of sieved soil was weighed into plastic bottle, 100 ml of sodium hexameta phosphate (Calgon) was

added into the bottle and the mixture placed on a mechanical shaker and agitated for 10 minutes. The particle sizes were calculated as using equation 1 – 5.

$$\% \text{ (clay + silt)} = \frac{\text{corrected 40 seconds hydrometer reading}}{\text{Weight of soil taken}} \times 100 \tag{1}$$

$$\% \text{ clay} = \frac{\text{corrected 2 hours hydrometer reading}}{\text{Weight of soil taken}} \times 100 \tag{2}$$

$$\% \text{ silt} = \% \text{ (clay + silt)} - \% \text{ clay} \tag{3}$$

$$\% \text{ sand} = 100 - \% \text{ (clay + silt)} \tag{4}$$

Infiltration rate was measure as described by (Brady and Weil, 2014; FAO, 2010) whereby the infiltrometer was inserted in to the soil and information was recorded and then evaluated using equation 5.

$$i = \frac{Q}{A \times T} \quad (5)$$

Where, I is the infiltration rate (LT-1), Q is the volume of water (L3) infiltrating, A is the area of the soil surface (L2) exposed to infiltration and T is the time (T).

Determination of Organic Carbon

Soil organic carbon was determined by wet oxidation method as described Walkley and Black (1986). One gram of 2 mm sieved soil sample was weighed into a 250 ml conical flask and 5 mls of 1N potassium dichromate ($K_2Cr_2O_7$) solution was added and gently swirled. 10 ml of concentrated Sulphuric acid (H_2SO_4) was added into the flask and allowed to stand for 30 minutes. Then 100 ml of distilled water was added and allowed to cool for 30 minutes. The organic carbon (OC) was determined by titrating this digest with 0.5N ferrous ammonium Sulphate [$(NH_4)_2SO_4 \cdot FeSO_4 \cdot 6H_2O$] to a red (maroon) end point. The organic carbon content and organic matter content were calculated using equation 6 and 7. However the calculated organic carbon was converted into organic matter carbon using equation 8.

$$OM(\%) = \frac{(\text{Blank titre} - \text{Actual titre}) \times 0.3 \times m \times f}{\text{Weight of air dried soil taken}} \quad (6)$$

$$m = \frac{\text{Concentration of } FeSO_4 = \text{Concentration of } K_2Cr_2O_7 \times \text{Volume of } K_2Cr_2O_7}{\text{Blank titer}} \quad (7)$$

$$OM (g/Kg) = OC (\%) \times 1.73 \quad (8)$$

Where: OM is organic matter, OC is the organic carbon, f is the correction factor which is 1.33

Determination of Aggregate Stability

Aggregate stability was determined by both wet and dry sieving as described by Kemper and Rosenau (1986). In the dry sieving method, a 200 g of air-dried soil was weighed and transferred into a nest of sieves consisting of diameters 2, 1, 0.25 0.052 and <0.052. The nest of sieves was placed on a mechanical shaker and shaken for 2 minutes, after which the weight of soil retained on each sieve was taken. Aggregate size distribution was calculated using equation 9.

$$\text{Aggregate size distribution} = \frac{\text{Weight of soil retained in a sieve}}{\text{Total weight of soil taken}} \quad (9)$$

Determination of Mean-Weight Diameter of Dry Aggregate

Mean-weight diameter of dry aggregates was measured by the method describe by the Kemper & Rosenau (1986). This method involved horizontal vibrating 200g of dry soil on a mechanical shaker for 10 minutes on top of a nest of sieves of diameters 2, 1, 0.5 and 0.25 mm. The mass of aggregates on each sieve that resisted break down were determined. The mean weight diameter of dry aggregate (MWDdry) was computed using equation 10.

$$MWD_{Dry} = \sum_{i=1}^n X_i W_i \quad (10)$$

Where: MWD_{Dry} is the Mean-Weight Diameter of Dry Aggregates (mm), X_i is the Mean Diameter of each size fraction (mm) and W_i is the proportion of total sample weight occurring in the corresponding size fraction. However, the Geometric mean diameter of the dry aggregates was calculated using the equation 11 as described by Nweke and Nnabude (2015).

$$GMD_{Dry} = \exp \left[\frac{\sum_{i=1}^n W_i \log x_i}{\sum_{i=1}^n W_i} \right] \quad (11)$$

Where: GMD is the Geometric Mean Diameter, W_i is the weight of aggregate of each size class (g) and $\log x_i$ is the logarithm of the mean diameter of the size classes. Mean-

weight diameter of wet aggregates was determined based on Kemper and Rosenau (1986) methods whereby 40 g of soil was pre-soaked for 5 minutes on the top most sieves of diameters 2, 1, 0.5 and 0.25 mm, then vertically oscillated for 20 times at the rate of 1 oscillation per second. The resistant aggregates were oven-dried and their masses were recorded and the mean weight diameter of wet aggregates (MWDwet) was calculated from equation 12.

$$MWD_{Wet} = \sum_{i=1}^n X_i W_i \quad (12)$$

Where, MWD_{wet} is the Mean-Weight Diameter of Wet Aggregates (mm), X_i is the Mean Diameter of each size fraction (mm) and W_i is the Proportion of total samples weight occurring in the corresponding size fraction. Therefore the Geometric mean diameter of the wet aggregates was calculated using equation 13.

$$GMD_{Wet} = \exp \left[\frac{\sum_{i=1}^n W_i \log x_i}{\sum_{i=1}^n W_i} \right] \quad (13)$$

Where: GMD is the Geometric Mean Diameter, w_i is the weight of aggregate of each size class (g) and $\log x_i$ is the logarithm of the mean diameter of the size classes (Nweke and Nnabude, 2015).

Determination of Bulk Density

Bulk density, Bulk density was calculated using equation 14.

$$Db. = Ms / Vt \quad (14)$$

Where: Ms is the Mass of oven-dried soil (g) and Vt is the Volume of soil, equivalent to volume of core ring, (cm^3).

Determination of Total Porosity

Total porosity was evaluated by core method. A saturated undisturbed soil core was weighed, volume of core determined and thereafter oven dried at $105^{\circ}C$ for 24 hours. The total pore space is the volume of the water at soil saturation obtained from its mass using equations 15.

$$\text{Total Porosity (f)} = \frac{\text{total pore volume}}{\text{Bulk soil volume}} \times 100 \quad (15)$$

Where: Pore volume is the mass of water in gram over densit in gram per centimeter cube.

Evaluation of Soil Erodibility

Soil erodibility was determined using the soil erodibility factor (The K-Factor). The K factor is a measure of the susceptibility of soil particles to detachment and transport by rainfall and runoff. The k- factor was evaluated using equation 16.

$$K = 2.8 M^{1.14} \times 10^{-7} \times (12 - \% OM) + 4.3 \times 10^{-3} (S-2) + 3.3 \times 10^{-3} (P-3) \quad (16)$$

Where: K is the Soil Erodibility (mg/h), M is (100 - % clay) \times (0.005-0.1mm) + % silt

OM is the Organic Matter, P is the Infiltrations rate and S is the Shape and size of the soil aggregate.

RESULTS AND DISCUSSION

The laboratory results of some soil quality parameters were evaluated and presented in table 1. The soil of the area have high percentage of sand, this influence the leaching of soil nutrients down to lower horizon and consequently leaving the upper portion with high sand contents. This is supported by Brady and Weill (2014) who explained that soil with high leaving may lead to the migration of some dissolved nutrient and consequently leaving the top horizon with high accumulation of sand. The mean values of organic carbon in the area is 0.94 and 0.34 % for *Jatropha* and control site respectively. Consequently, the values of organic carbon is considered low based on the ranking of London (1991). The values of organic carbon is lower than the mean values reported by Mohammed and Yusif (2020). This implies that there is spatial variability of organic carbon around the area.

Table 1: Soil Quality Parameters in the Study Sites

Study Locations	Statistics	Sand (%)	Silt (%)	Clay (%)	Db (gm ³)	Inf (mm/hr)	OC(%)	OM (%)
Jatropha Site	Mean	80.4	9.6	8.8	1.32	470.77	0.94	1.84
	±SD	3.29	3.85	1.1	0.06	382.72	0.42	0.54
	CV	4.1	40.1	12.4	4	81.3	65	29.4
Control Site	Mean	88.8	4.4	6.8	1.57	398.93	0.34	0.7
	±SD	1.79	0.89	1.1	0.01	487.53	0.09	0.92
	CV	2	20.3	16.1	10.5	122.2	26.2	31.1

Table 1 shows that the mean values of silt, clay, Db, infiltration and organic carbon were found to be higher in jatropha site. The high values of these soil quality parameters is attributed to the accumulation of the fallen leaves of the *Jatropha* plant which decomposes to enhance the soil quality and therefore, revealed that *Jatropha* have positive effect on the enhancing some soil quality. It was observed the bulk density around the *Jatropha* site (1.32gm⁻³) is lower than the control site. This signifies that *jatropha* site is not compacted compared to control site. This is due to the animal trampling around the control site. Low bulk density led to the high values of infiltration because the soil have low compaction with high porosity. The results obtained is in line with the findings of Shehu *et al.*, (2013) who reported that *Jatropha* plant significantly enhance soil quality.

Moreover, the distribution in mean values of Mean Weight Diameter of aggregates (MWD) in both dry and wet shows that the values were highest in *Jatropha* than its control site. This implies that different soil management attributed to the variation of the Mean Weight Diameter of aggregates due to the over cultivation, tillage and animal trampling which consequently influence the organic matter depletion due to inadequate ground vegetation cover in the in the control site. However, the statistical variation (Table 2) shows that there is significant variation in the mean values of OC, OM, infiltration, porosity, Clay and particle size distribution between *Jatropha* and control site at alpha values of 0.05, while no significant variation observed in Db, MWD, and GMD among the study locations. This revealed that *Jatropha* have significant influence on some soil quality parameters.

Table 2: Statistical Variability of Some Soil Quality Parameter among the Area

Parameters	Std. err	t-stat	df.	p-value	t-crit	Sig.	effect r
OC	0.190263	3.153533	8	0.006763	1.859548	Yes	0.744438
OM	0.246171	4.630933	8	0.00843	1.859548	Yes	0.853412
Inf	244.4096	5.131386	8	0.000447	1.859548	Yes	0.875771
Db	0.025717	0.139986	8	0.446066	1.859548	No	0.049432
Porosity	0.010931	1.921196	8	0.045474	1.859548	Yes	0.561883
MWD dry	103.6776	16.51152	8	9.130608	1.859548	No	0.985643
MWD wet	0.014832	53.26179	8	8.56E612	1.859548	No	0.998593
GMD dry	0.012166	6.575959	8	8.680005	1.859548	No	0.91863
GMD wet	0.019799	17.17259	8	6.722208	1.859548	No	0.986706
SCS	430.7954	3.947644	6	0.003779	1.943148	Yes	0.849714
% Clay	0.692822	2.886751	8	0.01015	1.859548	Yes	0.714286
% Silt	1.766352	2.943922	8	0.009299	1.859548	Yes	0.721171
% Sand	1.673322	5.019960	8	0.000513	1.859548	Yes	0.871227

The Geometric Mean Diameter of the dry aggregates (GMD dry) distribution has shown that *Jatropha* site has a low mean value of 0.348mm as compared to that of the control site, 0.428mm (Figure 3 and Figure 3). Whereas the distribution in

the wet aggregates, *Jatropha* site has high mean value of 0.556mm while the control site has a low mean value of 0.216mm.

Table 3: Mean Wet Diameter in the Area

Locations	Statistics	MWDdry	GMDdry	MWDwet	GMDdry	K-Values
Jatrpah site	Mean	1	0.56	0.35	0.22	23.29
	±SD	0.05	0.07	0.069	0.035	0.1
	CV	4.7	12.8	24.7	13.99	0.4
Control Site	Mean	0.93	0.43	0.21	0.28	24.54
	±SD	0.05	0.07	0.042	0.023	0.08
	CV	5.1	16.6	28.51	15.9	0.2

High values of mean weight and geometric diameter is due to nature of the soil and high organic matter content which facilitates the improvement in the textural class of the soil from sandy to loamy sand. This agrees with what was reported by Food and Agricultural Organisation and International Fund

for Agricultural Development (FAO & IFAD, 2010) who explained that *Jatropha curcas* plant improves soil water infiltration rate. This coincided with the high values of infiltration in an area that recorded high values of organic matter and infiltration rate.

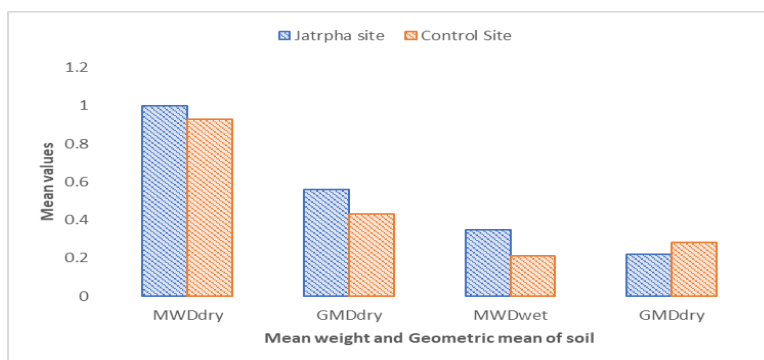


Figure 3: Mean Weight Diameter and Geometric of the Area

Generally, there is an increase of 3.85% in the MWD dry aggregates in the *Jatropha* site over the control site. Though insignificant difference, but the value show that the dry aggregates in the control site are more vulnerable to wind erosion than those in the *Jatropha* site. This may be due to the mulch provided by the fallen leaves of the *Jatropha* plant which reduces the effects of water and wind erosion. This agrees with what was discovered by Henning, (2004) who reported that *Jatropha Curcas* is used in Soil erosion control and sand dunes stabilization.

Soil Erodibility

The level of the soil lost at each study locations (*Jatropha* and control site) shows that *Jatropha* site recorded low mean values of erodibility (23.29 ton/ha), while control level recorded high mean values (24.54 ton/ha) of the amount of soil lost in the area. This implies that *Jatropha curcas* site have low susceptibility to erosion than its control site. This is

due to low aggregate stability of the soil which makes the soil to be less resistance to water and wind erosion as well as minimal trampling of animal in *Jatropha curcas* site than the control which is considered as grazing land. Thus, considered that *Jatropha curcas* plant reduce the hydrolic impact on soil surface and also improved some soil quality which further reduces the rate of erosion in the area. This is an evidence that *Jatropha curcas* site have less infiltration rate which is inversely proportional to compaction and consequently, have low rate of erosion. This is adduced by Songu et al. (2021) who explained that soil erodibility influence hydrogeologic activities which determine the amount of sediment generated in the area. However, there is spatial variability (Figure 4) of the erodibility status in the study locations which revealed that even with the *Jatropha curcas* location there is variability of the amount of soil lost. This is due to the variability of some soil quality parameter within the study locations.

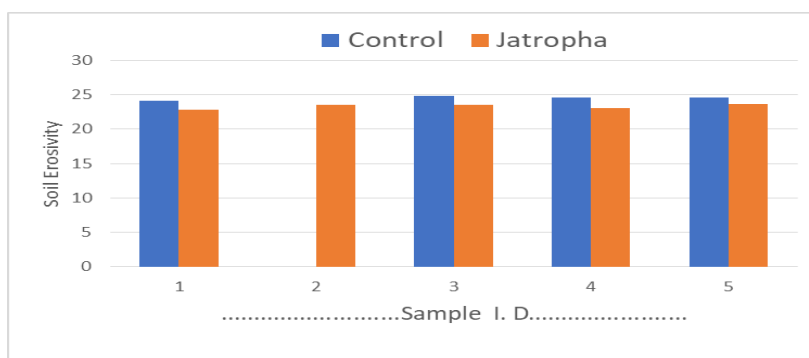


Figure 4: Variability of Erodibility among the Study Locations

However, statistical variability (Table 4) was also observed between *Jatropha* and its control location which shows that

Jatropha plantation have significant effect on the soil quality such as hydrolic activities

Table 4: Statistical Variability of Erodibility among the Study Location

	p-Value	t-Crit	Lower	Upper	Significant Status
One Tail	1.71053E-07	2.353363			yes
Two Tail	3.42106E-07	3.182446	22.99739	23.79761	yes

Table 4 revealed that there is significant variation on mean values of soil erodibility between *jatropha* and its control site. This implies that *jatropha* site have some inherent capacity that make it less vulnerability to erosion and therefore considered *jatropha* plantation as mean of remediating and mitigating the eroded land. Conclusively, the area is classified as an area which high vulnerability to soil loss based on the revised universal soil loss equation erodibility classification which rate erodibility values of 22.4 to 33.6ton/ha as high susceptible to erosion.

CONCLUSION

The decomposition of leave letter from the *Jatropha curcas* plant, interception of rain drop from the leave and root biding to the soil particles enhanced soil quality parameters influenced hydrologic characteristic of the soil and considered to reclaim and mitigate the loss of soil in the area. It was recommended that *Jatropha curcas* seedling should be available and accessible to farmers to be used in their farm in order to enhance the soil quality of the area.

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