Assessment of Soil Infiltration Rate, Erodibility, Rainfall Intensity, Variability and their Influence on Soil Loss in Nuhu Bamalli Polytechnic, Zaria, Samaru-Kataf Campus

Aboshio Nehemiah[1*], Yahaya Alhasan[1], Bature James Boman[1] and Nale Biki Yusuf[2]
[1]Department of Agricultural and Bio Environmental Engineering, School of Agricultural Technology, Nuhu Bamalli Polytechnic Zaria, Kaduna State Nigeria
[2]Department of General Studies, School of Agricultural Technology, Nuhu Bamalli Polytechnic Zaria, Kaduna State Nigeria
*Corresponding Author:- Email: naboshio@yahoo.co.uk; Phone: +2348037313207

Abstract
The assessment of Soil infiltration rate, Soil erodibility, and Rainfall intensity was restricted to the experimental farm, Nuhu Bamalli Polytechnic Samaru-Kataf campus. Double ring infiltrometer was used to determine the soil infiltration rate. Likewise, Nomograph was used to determine the soil Erodibility. Similarly, a rain gauge was used to determine the rainfall intensities. Data were taken every week, depending on rainfall for seven months starting from April to October for three years (2018-2020). The results of the research show that the highest infiltration rate 131.8 mm/hr was recorded in April due to shrinkage cracks developed as the clay content of the soil dry. Moreover, it was as a result of high moisture storage capacity. The soil was highly susceptible to erosion.The changes in temperature, radiation, relative humidity, and wind velocity contribute immensely to the rise in rainfall intensity to 103.15 mm/hr in June. A substantial quantity of soil 20.100 Kg/m^2 was lost in June due to an increase in rainfall intensity, rainfall duration, runoff velocity, and decrease in infiltration rate. The result revealed a greater correlation between rainfall intensity and soil erosion. Likewise, infiltration rate contributes little to soil erosion in the study area.The soil erosion largely co-varied with rainfall intensity while infiltration rate exhibited very low covariance with soil erosion. It is highly recommended that agricultural practices such as contour ploughing, ploughing across the slope should be employed to minimize soil loss by reducing the runoff velocity.

***Keywords**: soil infiltration rate, soil erodibility, rainfall intensity, soil loss, experimental farm*

INTRODUCTION
The livelihoods of humankind are vastly influenced by soil erosion. The study conducted by Devatha *et al*., (2015) specifically identified some of the negative effects of soil erosion which include, but are not limited to pollution of nearby water bodies and wetland, a decline in cropland productivity, and disturbance of delicate aquatic ecosystems. In addition, most people in the world rely on soil resources as their main livelihood source (Benchettouh *et al*., 2017). Molla & Sisheber, (2017) reported that among the major causes of soil erosion is rainwater, which breaks up the soil, dislodges it from its surroundings, and washes it subsequently away as runoff. The prevalent of this environmental problem is also largely due to man-induced activities such as land management and agricultural practices which contribute to making the problem of soil erosion very difficult to deal with (Obeta & Adewumi, 2013). Soil erosion is a worldwide environmental problem that reduces the productivity of all-natural ecosystems and agriculture, which threatens the lives of most smallholder farmers (Flanagan *et al*., 2012). If left unchecked, as Avwunudiogba & Hudson, (2014) claims, this problem will lead to food insecurity, without healthy soils, farmers wouldn't be able to provide us with feed, fiber, and food.

The livelihoods of 75% of the poor of the world will continue relying on agriculture for the foreseeable future (Renard, Foster, Weesies, McCool, & Yoder, 1997). Agricultural activities are mostly rooted in saturated and unsaturated soils. These soils are fertile organic topsoils that have been used repeatedly over the years resulting in the deterioration in the qualities and properties of the soil against time. As a result, agricultural production may not be able to sustain population growth due to the inability to increase productivity(Critchley, Siegert, & Chapma, 1991).

Basically, water erosion is controlled by four factors: climate, soil type, topography, and vegetation cover (Wolfgang & Desmond, 2002). The relationship between erosion, rainfall momentum and energy is determined by raindrop mass, size distribution, shape, velocity and direction (Flanagan *et al*., 2012). The most important climatic parameters controlling rainfall erosion are the intensity and duration of rainfall. Vilayvong, (2016)stated that, the measure of the power of a rainstorm is the product of rainfall energy, and the maximum 30-minute rainfall intensity. Raindrops impacting bare soil not only cause erosion, but also tend to compact the soil and decrease infiltration capacity. Critchley *et al*., (1991) reported that Raindrop impact on bare soil not only causes splash but also breaks down soil aggregates and causes deterioration of soil structure.

The research will provide soil conservationists, Engineers, farmers and other land users with the tools they need to examine the impact of various management strategies on soil loss and plan for the optimal use of the land.

Agriculture is one of the most important components of our society. Farmers and ranchers produce the food and fiber we use every day (Robichaud, 2015). Soil is a critical part of successful agriculture and is the original source of the nutrients that we use to grow crops (Sindelar, 2015). The nutrients move from the soil into the plants that we eat. In the end, we benefit from healthy soil. The healthiest soils produce the healthiest and most abundant food supplies. (Sindelar, 2015).

The displacement of the upper layer of the soil by natural processes caused by the dynamic activity of erosive agents continues to increase day in day out. The soil degradation evident in Samaru includes loss of soil cohesion, soil fertility, gradual reduction in land used for cultivation. Carter, (1993) reported that significant erosion can reduce crop productivity in fields and degrades the water quality of receiving water bodies.

AIM AND OBJECTIVES

The aim of this research work is to evaluate the effect of the variability of Soil infiltration rate, Soil erodibility, and Rainfall intensity on soil loss at the experimental farm, School of Agriculture Technology, Nuhu Bamalli Polytechnic Samara Kataf campus.

The objectives of this research include:

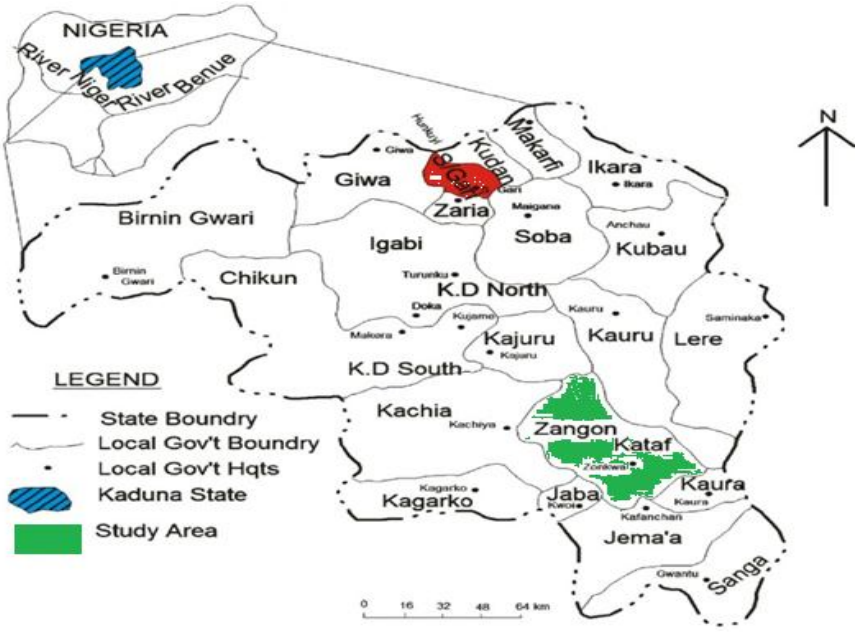
1. To compute the soil erodibility of the study area
2. To measure rainfall intensity of the study area
3. To determine the vegetation density of the study area
4. Evaluate the effect of change of soil erodibility, rainfall intensity and vegetation density on the soil.

MATERIAL AND METHOD

Study Area

The research was conducted at the experimental farm, School of Agriculture Technology, Nuhu Bamalli Polytechnic Zaria, Samara-Kataf Campus along Kachia-Kafanchan Road *N90°46`35" E008 22`46"*. Samaru- Kataf is located in the Southern part of Kaduna State, Zangon Kataf Local Government Area,

approximately 200km from the state capital as shown in the map presented in Figure1. It has two predominant seasons, dry and wet. The wet season starts early April and extends to October during which many agricultural activities are carried out while the dry season commences late October and persists until late March. Predominantly grow crops like Yam, Beans, Maize, Guinea-Corn, Ginger, Sweet Potatoes, Vegetables, Tomatoes, Onions, and Pepper.



Source: Obeta & Adewumi, 2013
Figure1: Map of Kaduna State showing Zangon Kataf L.G.A

Materials

The following materials were used to assess the parameters in the field: British standard test sieves, Weight balance, thermostatic control drying oven, 12 metal trays, Mechanically sieve agitator, Soil hydrometer, Thermometer, High-speed stirrer, Stop-watch readable to 1s, Steel rule, Evaporating dish, Constant temperature bath, Muffle furnace, Porcelain dish, Spatula, Tape rule, Ranging pole, Theodolite.

Determination of Variables

Soil Infiltration Rate

A double-ring infiltrometer was used to determine the soil infiltration rate.

Method:

1. The ring was placed with the cutting edge facing down on the ground as shown in plate 1.
2. The driving plate was set on top of the ring (ring fits over, between or within the pins on the bottom of the driving plate)
3. An Impact-absorbing hammer was used to insert the infiltration ring about 5cm vertically into the soil.
4. The driving plate was removed from the inserted infiltration ring.
5. The depth of placement was limited as possible so as not to disturb the top layer.
6. The ground was pushed back to the ring.
7. The measuring bridge was placed with a measuring rod and floated on the inner ring.

8. Vegetation that may hamper the free movement of the float or affect the measuring was removed, without disturbing the soil structure.
9. To protect the ground surface when pouring the water, plastic foil was used to pour the water on the ground.
10. The outer ring was filled with water, then the inner ring, to approximately 5 to 10 cm.
11. The measurement was started immediately to determine the infiltration curve.
12. The water level within the infiltration rings was kept as low as possible to ensure vertical infiltration.
13. Water was added to the ring steadily.
14. The new level in column B of the list was recorded. The water in the inner and outer rings was kept at a similar level to prevent incorrect measurements.
15. Measurement was stopped when the infiltration rate has reached a constant value.
16. The ring was removed using the pull-out hooks.
17. The ring was rinsed to make sure no earth sticks and set to the ring.



Plate1: Measurement of infiltration rate using double-ring infiltrometer

Soil Erodibility K

Nomograph was used to determine the soil Erodibility;

Procedure:

1. Soil sample was taken from each experimental plot (A, B, C, D, E, F)
2. Particle Size Analysis by Simple Dry Sieving BS 1377:Part2:1990
3. Determination of Clay and Silt Particle Sizes Using Hydrometer Analysis
4. Determination of Soil-Structure Code
5. Determination of Permeability Class of Each Soil Sample
6. Determination of Organic Matter Content of the Soil Sample (Walkey- Black Method)
7. Nomograph was used to determine the soil erodibility as described by Wischmeier & Smith, (1978)

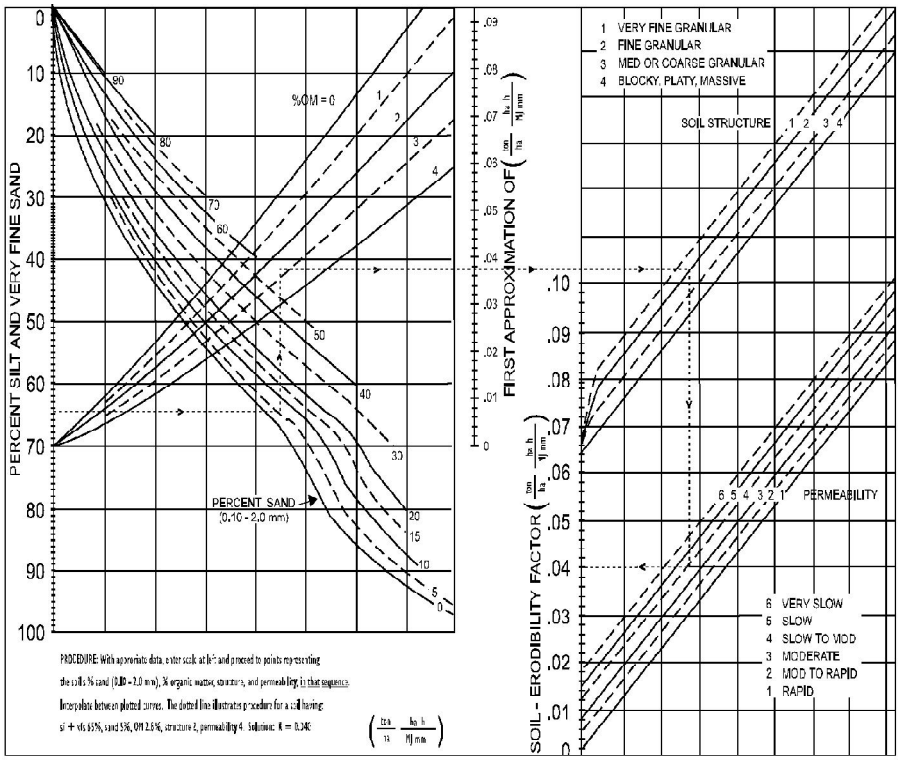


Figure 2 : The Soil Erodibility Nomograph (Nearing *et al*., 1989)

Rainfall Intensity R_i

The rain gauge was used to determine the rainfall intensities:

Method

1. The rain gauge was placed on the land in the field two minutes after the start of the rain.
2. The duration of rain was time and recorded.
3. The rise in levels of water in the gauge was recorded.
4. Rainfall intensity was calculated as

$$= \frac{\text{rise in levels of water in the gauge}}{\text{duration of rainfall}}$$

RESULTS

The data obtained in the study area is presented in Table1. It's obtained from the field for the month of April to October covering field data of Infiltration rate, Soil Erodibility, Rainfall intensity, and Soil erosion. The statistical analysis of the data obtained in the field is presented in Table 2. through Table 6.

Table 1. Average weekly field data

Month	Week	Infiltration (mm/hr)	Soil erodibility factor K (Kg.hr/Nm2)	Rainfall intensity (mm/hr	Soil erosion Kg/m^2
April	1	128.51	0.62		
	2	125.40	0.61	60.03	0.45
	3	130.10	0.62	92.95	0.62
	4	131.80	0.61		
May	1	124.33	0.62	78.22	3.76
	2	126.16	0.62		
	3	124.78	0.62	85.52	6.20
	4	129.54	0.62	96.11	12.70
June	1	120.55	0.62	103.15	20.10
	2	118.93	0.62	88.52	6.80
	3	120.10	0.62	78.94	16.92
	4	101.79	0.61	69.50	14.50
July	1	112.70	0.62	82.33	16.81
	2	92.11	0.62	76.41	12.10
	3	94.58	0.61	90.37	4.20
	4	79.45	0.62	51.60	8.50
August	1	73.50	0.58	34.31	8.20
	2	55.89	0.61	53.84	4.40
	3	52.98	0.62	44.81	12.60
	4	76.65	0.62	69.52	6.30
September	1	82.70	0.61	77.48	6.50
	2	101.20	0.61	52.92	18.80
	3	105.80	0.61	40.20	10.20
	4	111.50	0.62	43.58	7.20
October	1	108.33	0.60	68.55	8.80
	2	115.35	0.58	59.40	15.21
	3	124.84	0.58	32.22	5.66
	4	118.26	0.58	28.75	4.60

Statistical Analysis

The statistical analyses of the data obtained in the field are presented in Table2. through Table 5. The analysis of variance is presented in Table 2. also, the descriptive statistics in Table 3.3. Similarly, the correlation between variables in Table 3.4, and likewise, covariance in Table 5.

Table 2. Analysis of Variables

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Rows	10003.33	27	370.4935	1.082639	0.379989	1.623786
Columns	205033.4	3	68344.47	199.713	2.55E-37	2.717343

Error	27719.29	81	342.2135

The Analysis of variance for variables indicates that the variation is more within the variables and less variation was observed between the variables.

Table 3. Descriptive Statistics

	Infiltration (mm/hr)	Soil erodibility factor K (Kg.hr/Nm2)	Rainfall intensity (mm/hr	Soil erosion Kg/m^2
Mean	106.7082	0.610714	59.25821	8.290357
Standard Error	4.282886	0.002619	5.50384	1.123508
Median	114.025	0.62	64.29	7
Standard Deviation	22.6629	0.013859	29.12358	5.945045
Sample Variance	513.6071	0.000192	848.1831	35.34356
Kurtosis	0.121177	1.256683	-0.22603	-0.77861
Skewness	-1.02083	-1.57525	-0.67122	0.362403
Range	78.82	0.04	103.15	20.1
Minimum	52.98	0.58	0	0
Maximum	131.8	0.62	103.15	20.1
Sum	2987.83	17.1	1659.23	232.13
Count	28	28	28	28
Largest(1)	131.8	0.62	103.15	20.1
Smallest(1)	52.98	0.58	0	0
Confidence Level(95.0%)	8.787756	0.005374	11.29295	2.305248

Table 4. Correlation between Variables

	Infiltration	Soil erodibility factor K	Rainfall intensity	Soil erosion
Infiltration	1			
Soil erodibility factor K	0.036313	1		
Rainfall intensity	-0.01663	0.312503	1	
Soil erosion	-0.17756	0.018967	0.445749	1

The result revealed a greater correlation between rainfall intensity and soil erosion. This implies that rainfall intensity contributes more to soil erosion than the remaining variables. Likewise, infiltration rate contributes little to soil erosion in the study area.

Table 5. Covariance between Variables

	Infiltration	Soil erodibility factor K	Rainfall intensity	Soil erosion
Infiltration	495.264			
Soil erodibility factor K	0.010998	0.000185		
Rainfall intensity	-10.5819	0.121626	817.8908	
Soil erosion	-23.0682	0.001507	74.4211	34.08129

The soil erosion largely co-varied with rainfall intensity while infiltration rate exhibited very low covariance with soil erosion.

DISCUSSION

Infiltration Rate

The statistical analysis of the monthly and annual rainfall intensity of Samaru Kataf is presented in figure 3. and Table 2. through Table 5. The small margin of error Z_t (8.24) observed for infiltration rate indicates that the results of the experiment are reliable, true and reflect the result of the entered population with high confidence. Also, the standard deviation δ 22.254 reveals that the data point tends to be close to the mean.

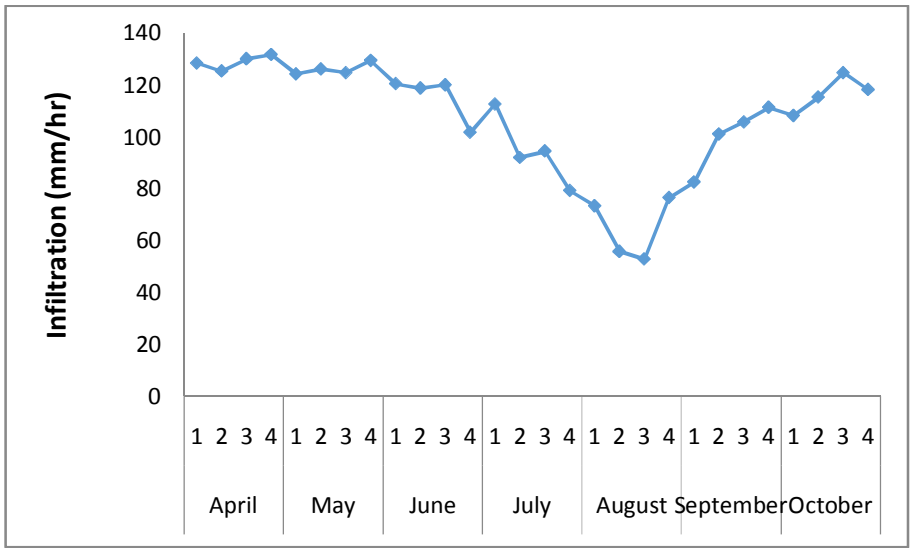


Figure 3. Graph of soil infiltration rate

The highest infiltration rate 131.8 mm/hr was recorded in the fourth week of April due to shrinkage cracks developed as the clay content of the soil dry. The cracks were direct conduits for water entering the soil. Moreover, it was as a result of high moisture storage capacity i.e., low moisture content of the soil. Certainly, an increase in soil infiltration rate with a decrease in runoff velocity leads to lesser damage to the soil.

The low soil infiltration rate of 52.98 mm/hr was recorded in the third week of August as the soil moisture storage capacity was exhausted. Low soil

infiltration rate with low rainfall intensity has little or less effect on runoff and soil loss, while a low infiltration rate with high rainfall intensity has a damaging effect on the soil.

This is in line with the findings of Arab *et al*., (2016)that study the performance evaluation of selected infiltration equations for irrigated (F*adama*) soils in Southern Kaduna Plain, Nigeria.

Soil Erodibility

The analysis of the monthly and annual Soil erodibility K of Samaru Kataf presented in figure 4. and Table 2., shows little variation in Soil erodibility K, from April to October. The small margin of error Z_t (0.005) indicates that the outcomes of the experiment are reliable, true and reflect the result of the entered population with high confidence. The standard deviation δ of 0.0136 shows that the data point tends to be close to the mean.

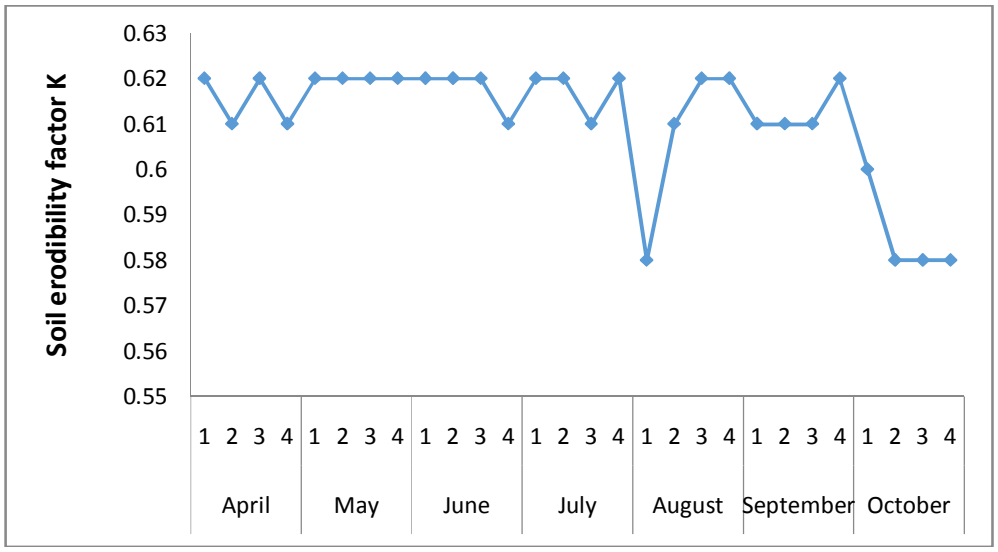


Figure 4. Graph of soil erodibility factor K

The little variation observes in the data was due to the uniform soil structure, organic matter content and permeability recorded during the period from April to October.

Based on the results recorded for the 'k' factor the soil is said to be highly susceptible to erosion. This is in line with the findings of Aminu, (2014) that assess soil degradation in Zaria area, Kaduna State, Nigeria. Likewise, the result is in agreement with the findings of Oluyori & Lazarus, (2016) that assess some soil erodibility indices on agricultural land uses in Fadan Kagoma area of Jema'a local government area, Kaduna state, Northern Nigeria.

Rainfall Intensity

The statistical analysis of the monthly and annual rainfall intensity of Samaru Kataf is presented in Figure 5. and Table 2. through Table 5. The small margin of error (Z_t) of 8.26 shows that the results of the experiment are reliable, true and reflect the result of the entered population with high confidence. The standard deviation δ of 21.07 shows that the data point tends to be close to the mean.

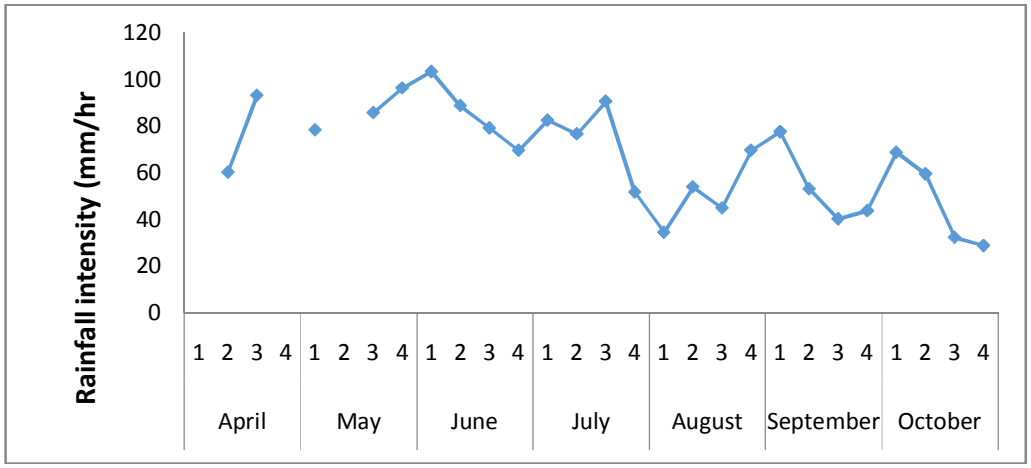


Figure 5: Graph of rainfall intensity

The high rainfall intensity of 103.15 mm/hr recorded in the first week of June was due to the climate changes because the parcels of air were warm and cool slower than the atmosphere (instability). The changes in temperature, radiation, relative humidity, and wind velocity contribute immensely to the rise in rainfall intensity. High-intensity rainfall with a long duration has a damaging effect on soil. A greater quantity of soil was lost in this period.

The low rainfall intensity of 28.75 mm/hr was recorded in the fourth week of October because the uplifted parcels of air are stable i.e. cooling faster than the atmosphere. It has little effect on soil therefore less soil was eroded. This is in line with the findings of Abaje *et al*., (2018)that study the Spatio□Temporal analysis of rainfall distribution in Kaduna State, using monthly and annual rainfall data for Kafanchan, Kaduna, and Zaria for the period 1961-2016.

The result is also in agreement with Abaje & Oladipo, (2019) that studies the Recent Changes in the Temperature and Rainfall Conditions in Kaduna State, Nigeria**.**

Soil Erosion

The general analyses of the monthly and annual Soil erosion of Samaru Kataf are presented in figure 6. and Table 2. through Table 5. The small margin of error (Z_t) 2.13 implied that the results of the experiment are reliable, true and reflect the result of the entered population with high confidence. The standard deviation (δ) 5.429 shows that the data point tends to be close to the mean.

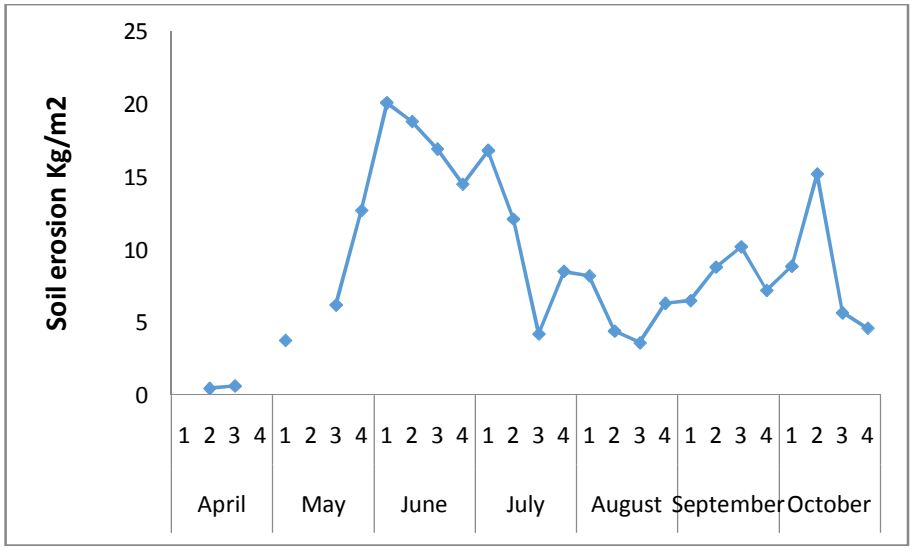


Figure 6. Graph of soil erosion

The highest soil loss 20.100 Kg/m^{2}was recorded in the first week of June due to an increase in rainfall intensity, rainfall duration, runoff velocity, and decrease in infiltration rate.

The result is in agreement with the findings of Oluyori & Lazarus, (2016) that assess some soil erodibility indices on agricultural land uses in Fadan Kagoma area of Jema'a local government area, Kaduna state, Northern Nigeria.

CONCLUSION

The assessment of Soil infiltration rate, Soil erodibility, and Rainfall intensity was restricted to the experimental farm, School of Agriculture Technology, Nuhu Bamalli Polytechnic Samaru- Kataf. Field data and soil samples were taken to a laboratory for analysis.

The statistical analysis of the monthly, annual soil infiltration rate, rainfall intensity and Soil erodibility K of Samaru-Kataf show a small margin of error Z_t observed which indicates that the results of the experiment are reliable, true and reflect the result of the entered population with high confidence. It also shows that more rainfall infiltrates the soil in the fourth week of April due to shrinkage cracks developed as the clay content of the soil is dry. The cracks were direct conduits for water entering the soil. Moreover, it was as a result of high moisture storage capacity i.e., low moisture content of the soil. In addition, less rainfall infiltrates the soil in the third week of August as the soil moisture storage capacity was exhausted. Low soil infiltration rate with low rainfall intensity has little or less effect on runoff and soil loss, while a low infiltration rate with high rainfall intensity has a damaging effect on the soil.

Also, little variation in Soil erodibility K, from April to October was observed. The little variation observes in the data was due to the uniform soil structure, organic matter content and permeability recorded during the period.Based on the results recorded for the 'k' factor the soil is said to be highly susceptible to erosion.

The high rainfall intensity of 103.15 mm/hr recorded in the first week of June was due to the climate changes, because the parcels of air were warm and cool

slower than the atmosphere (instability). The changes in temperature, radiation, relative humidity, and wind velocity contribute immensely to the rise in rainfall intensity. High intensity rainfall with long duration has a damaging effect on soil. A greater quantity of soil was lost in this period.

The low rainfall intensity of 28.75 mm/hr was recorded in the fourth week of October because the uplifted parcels of air are stable i.e. cooling faster than the atmosphere. It has little effect on soil therefore less soil was eroded.

The highest soil loss 20.100 $Kg/m^2$was recorded in the first week of June due to an increase in rainfall intensity, rainfall duration, runoff velocity, and decrease in infiltration rate.

RECOMMENDATIONS

It is highly recommended that agricultural practices such as contour ploughing, ploughing across the slope should be employed to minimize soil loss by reducing the run-off velocity.

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