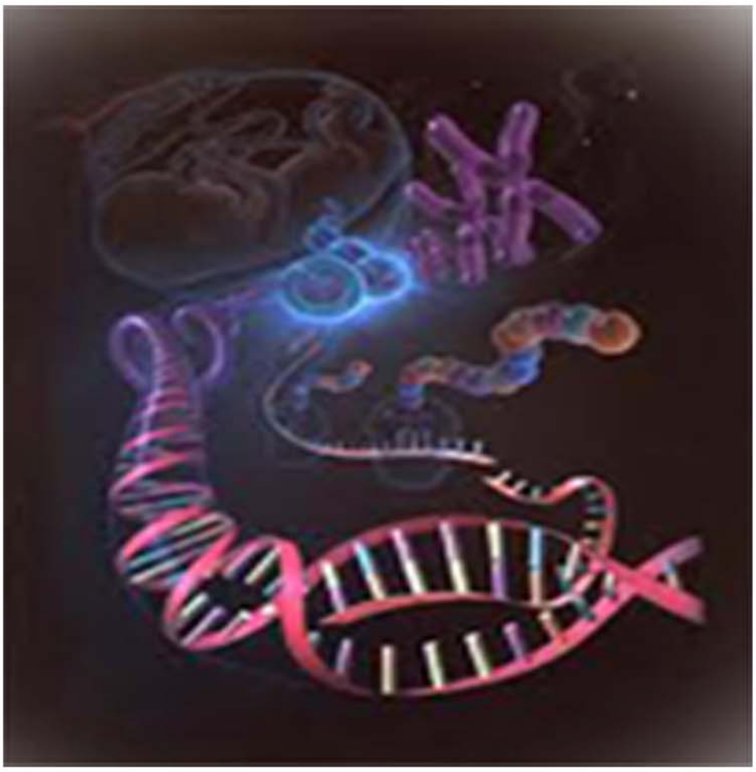
IJLBPR

ISSN 2250 - 3137
Vo1. I, No. 2, April 2012

International Journal of
Life Sciences Biotechnology and Pharma Research



www.ijlbpr.com

International Journal of Life Sciences Biotechnology and Pharma Research
Hyderabad, INDIA

Email : editorijlbpr@gmail.com or editor@ijlbpr.com

International Journal of Life Sciences Biotechnology and Pharma Research

ISSN 2250-3137 www.ijlbpr.com
Vol. 1, No. 2, April 2012

Research Paper

EFFECT OF SURFACE RUNOFF ON SEDIMENT YIELD OF SOME SOILS IN GIDAN KWANO AREA OF NIGER STATE NIGERIA

Musa J J[1*], Adewumi J K[2], Ohu J[3], and Bolaji G A[4]

Corresponding Author: **Musa J J, ✉ jogric2000@yahoo.com*

The process of surface runoff is made possible when the rainfall reaching the soil surface is more than the infiltration capacity, all the water is absorbed into the soil, and as the rain continues, plant surfaces become saturated, the interception-loss rate declines and infiltration capacity is reduced. Thus the detaching soil particles from its parent source which leads to the movement and transportation of soil particles from one point to another. An experimental runoff plot was established with a dimension of 3m by 6m of land was set up in areas where the various types of soil were being considered during the rainy season of the year 2010 with the slope of each of the plots determined. Disturbed sandy soil had the highest soil loss of 0.266kg/m2 while that of the undisturbed sandy soil is 0.192kg/m2 for the month of July. In the month of August, undisturbed sandy soils loss was calculated to be 0.183kg/m2 which shows a reduction in the total soil loss when compared with the month of July which could be due to the fact that most of the top loosed soils have been detached during the first sets of rainfall in the earlier months and also the August break experienced. Disturbed clay soil had the least quantity of soil loss of 0.128kg/m2 while that of the undisturbed clay soil was higher which may be due to the human and animal movement within the area before the plot was set up.

Keywords: Rainfall, Sediment, Soil, Surface runoff, Vegetation

INTRODUCTION

Rainfall, if it is not intercepted by vegetation or artificial surfaces such as roofs or pavements falls directly on the earth and either evaporates, infiltrates, or lies in depression storage. When the losses arising in these ways are all provided for, there may remain a surplus that, obeying the gravitational laws, flows over or below the surface to the nearest stream channel or river and finally into the sea or ocean. Hence, the water travelling over the land from one point to another is referred to as the surface runoff (Wilson, 1984). This

[1] Department of Agricultural and Bioresources Engineering, Federal University of Technology, P M B 65, Minna, Nigeria.
[2] Department of Agricultural Engineering, University of Agriculture, P M B 2240, Abeokuta, Nigeria.
[3] Department of Agricultural Engineering, University of Maiduguri, Abeokuta, Nigeria.
[4] Department of Civil Engineering, University of Agriculture, P M B 2240, Abeokuta, Nigeria.

process is made possible when the rainfall reaching the soil surface is more than the infiltration capacity, all the water is absorbed into the soil, and as the rain continues, plant surfaces become saturated, the interception-loss rate declines and infiltration capacity is reduced.

When the rate of rainfall exceeds the rate of infiltration, shallow depression begins to fill with water. When these depressions are filled to overflow level, water begins to move by overland flow towards streams. The water required to fill depressions prior to the beginning of surface runoff is called initial detention or depression storage (Michael and Ojha, 2006). Runoff thus represents the output from a catchment area in a given unit of time. Based on time delay, surface runoff is divided into two categories which are the direct runoff and the base flow (Subramanya, 2006).The proportion of total rainfall that becomes runoff during a storm represents the runoff coefficient (Dooge, 1954). Though, several authors have proposed a dependence of runoff ratio on the percentage of impermeable catchments area (Schaake *et al*., 1967; Boughton, 1987; Hebson and Wood 1982), in their study assumed a constant runoff coefficient, interpreted as the percentage of contributing area of runoff generation.

The impact of rainfall on the soil causes the soil particles to disintegrate into smaller fragments or fine particles which are along surface runoff paths. The rainfall–runoff transformation is a non-linear process. The most important cause of non-linearity is represented by the effect of antecedent conditions; consequently the runoff coefficient depends on the initial conditions. It is well known that soil moisture is a major control on catchments response.

The necessity of estimating the hydrologic performance of a watershed and its effect on the soils of the environment has resulted in many proposed methods of analysis. Thus, the objective of this study is to determine the quantity of loss of some selected soils during the rainy season at the irrigation farm site of the Federal University of Technology, Gidan Kwano campus, Minna Nigeria.

METHODOLOGY

Study Area

The Federal University of Technology permanent site is known to have a total land mass of eighteen thousand nine hundred hectares (18,900 ha) which is located along kilometer 10 Minna – Bida Road, South-East of Minna under the Bosso Local Government Area of Niger State. It has a horse-shoe shaped stretch of land, lying approximately on longitude of 06^0 28’ E and latitude of 09^0 35’ N. The site is bounded at Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga. The entire site is drained by rivers Gwakodna, Weminate, Grambuku, Legbedna, Tofa and their tributaries. They are all seasonal rivers and the most prominent among them is the river Dagga. The most prominent of the features are river Dagga, Garatu Hill and Dan Zaria dam (Musa, 2003).

Runoff Plots and Site Set-up

A 3m by 6m of land was set up in areas where the various types’ soils were being considered during the rainy season of the year 2010. The slope of each of the plots was also determined. Care was taken to avoid sites with special problems such as rills, cracks or gullies crossing the plot. These would drastically affect the results which would not be representative for the whole area with similar soils. The gradient along the plot was regular and free of local depressions.

During construction of the plots, one out of the two plots were undisturbed and the other plot was thoroughly disturbed for each of the soil considered. A disturbed plot is one in which the structure of the soil has been changed sufficiently that test of structural properties of the soil will not be representative of in-situ conditions only properties of the grains (e.g., grain size distribution, atterberg limits, and possibly the water content) can be accurately determined. An undisturbed plot is one where the condition of the soil in the plot is close enough to the condition of the soil in-situ to allow tests of structural properties of the soil to be approximate to the properties of the soil in-situ. Care was taken not to disturb or change the natural conditions of the plots such as destroying the vegetation or compacting the soil for the undisturbed soils while for the disturbed soils, every form of shrubs present on the plots were removed and the plot completely cleared of grasses.

Around the edge of each plot, long plywood which does not leak was placed, following the direction of the slope in a rectangular pattern to permit only runoff delivery and sediment within the experimental plot. The plywood extends 20cm above the ground surface and 10cm below the ground surface. A broad collector 1.2m long and 30cm wide was placed at the base of each of the plots to collect all the runoff and sediment produced during the rain event. On the collector are spouts (15 cm in diameter) through which runoff delivery empties into a collecting tank (250 lts) installed in pits just below ground level. Placed over the spout is a mesh to collect the sediment. It is important to note that only short duration rainfall was considered such that the collecting water tank of 250 liter capacity was not over filled.

The plots were categorized into the disturbed and undisturbed soils for the various types of soils considered within the Federal University of Technology, Minna Niger State. Records of rainfall depth for each storm were taken using a locally constructed rain-gauge.

Runoff Delivery and Sediment Load

During each rainfall event, runoff and sediment load produced are channeled through the collector placed at the lower end of the plot into the receiving container which is placed inside a hole dogged at the end of the plot and the container placed inside it. The sediment loads trapped on the collector by the mesh placed over it were scooped off into a soil bag. Sediments channeled into the tank were allowed to settle after which the runoff volume was determined. The clear water was collected with a bucket and measured with a graduated container. The sediment collected at the bottom of the tank plus the sediment collected on the collector were taken for oven drying to a constant weight. The sediment weights were determined after oven drying using a weigh balance. The sample weight divided by the area of the experimental plot gives the total soil loss from the plot.

RESULTS AND DISCUSSION

Runoff and Sediment Yield Result

The result of the runoff yield and sediment yield for undisturbed and disturbed soils for the three months during the rainy season of the year 2010 are shown in Tables 1, 2, and 3.

Table 1: Erosion Parameters for the Month of July During the Rainy Season of the Year 2010

Month/ Year	Type of Soil	Condition of Soil	Type of vegetation on the plot	Average Runoff (l)	Average Sediment Yield (kg)	Soil Loss (kg/m²)
July	Sandy	Undisturbed	Grassed	76.78	3.46	0.192
		Disturbed	Bare soil	81.37	4.79	0.266
	Clay	Undisturbed	Grassed	73.26	2.98	0.166
		Disturbed	Bare soil	79.49	2.31	0.128
	Silt	Undisturbed	Grassed	77.22	3.65	0.203
		Disturbed	Bare soil	81.76	2.67	0.148
	Sandy Loam	Undisturbed	Grassed	79.57	3.45	0.192
		Disturbed	Bare soil	83.65	4.98	0.277
	Loam	Undisturbed	Grassed	79.72	3.69	0.205
		Disturbed	Bare soil	86.87	4.37	0.243

Table 2: Erosion Parameters for the Month of August During the Rainy Season of the Year 2010

Month/ Year	Type of Soil	Condition of Soil	Type of vegetation on the plot	Average Runoff (l)	Average Sediment Yield (kg)	Soil Loss (kg/m²)
August	Sandy	Undisturbed	Grassed	121.56	3.30	0.183
		Disturbed	Bare soil	128.14	4.24	0.235
	Clay	Undisturbed	Grassed	118.36	1.77	0.098
		Disturbed	Bare soil	123.64	2.25	0.125
	Silt	Undisturbed	Grassed	124.75	2.92	0.162
		Disturbed	Bare soil	132.46	3.66	0.203
	Sandy Loam	Undisturbed	Grassed	124.58	2.78	0.154
		Disturbed	Bare soil	128.56	3.12	0.173
	Loam	Undisturbed	Grassed	119.23	1.98	0.110
		Disturbed	Bare soil	125.17	2.42	0.134

The variation in short duration rainfall depth over the study period is observed in the amount of run-off and sediment yield produced within each of the plots. The month of July recorded the second highest period of rainfall while September had the least recorded depth of rainfall among the three months considered; this is presented in Figure 1 below. Though, there were reasonably high rainfall in the months of May and October but they were not considered because of its duration and frequency. It was observed that runoff yield was higher for the month of August than the other months (July and September), July having the lowest yield for the five types of soil considered under different conditions.

Tables 1, 2 and 3 shows the sediment yield produced from each plots for the various type of soils considered under different soil conditions.

Table 3: Erosion Parameters for the Month of September During the Rainy Season of the year 2010

Month/ Year	Type of Soil	Condition of Soil	Type of vegetation on the plot	Average Runoff (l)	Average Sediment Yield (kg)	Soil Loss (kg/m²)
September	Sandy	Undisturbed	Grassed	92.48	2.35	0.131
		Disturbed	Bare soil	98.58	2.95	0.164
	Clay	Undisturbed	Grassed	86.70	1.65	0.098
		Disturbed	Bare soil	81.20	1.25	0.069
	Silt	Undisturbed	Grassed	91.37	2.24	0.124
		Disturbed	Bare soil	85.69	2.66	0.148
	Sandy Loam	Undisturbed	Grassed	93.30	2.11	0.117
		Disturbed	Bare soil	99.12	2.12	0.118
	Loam	Undisturbed	Grassed	88.16	2.26	0.126
		Disturbed	Bare soil	94.65	2.49	0.138

The yield was observed to increase with increase in rainfall intensity and run-off depth depending also on the type and condition of soil. However, the quantity produced varied for each plots depending on the type of vegetation that is present on the plot for the undisturbed soils. For the vegetated surface, sediment yield was not excessively high compared with the disturbed soil which may be because the soils have been set loose from each other. The reduced rate of soil loss observed for the undisturbed should be as a result of the soil structure and good stability of the soil with the protective action of the vegetation. In sediment yield, the disturbed sandy soil had the highest soil loss of 0.266kg/m^2 while that of the undisturbed sandy soil is 0.192kg/m2 for the month of July. In the month of August it was observed that undisturbed sandy soil loss was calculated to be 0.183kg/m^2 which shows a reduction in the total soil loss when compared with the month of July which could be due to the fact that most of the top loosed soils have been detached during the first sets of rainfall in the earlier months; the same was also observed for that of disturbed soil. Disturbed clay soil had the least quantity of soil loss of 0.128kg/m^2 while that of the undisturbed clay soil was higher which may be due to the human and animal movement within the area before the plot was set up.

Table 4 below shows the analysis of variance for the average runoff for the three months while the Table 5 shows the F test for the months of July and August.

Table 4: Analysis of Variance for the Average Runoff for the Three Months in the Year 2010

Source of Variation	SS	df	MS	F	*p*-Value	F crit
Rows	357.958	9	39.77311	3.049069	0.021091	2.456281
Columns	10813.31	2	5406.653	414.4825	8.84E-16	3.554557
Error	234.7982	18	13.04435			
Total	**11406.06**	**29**				

Table 5: F-Test for the Months of July and August

Source of Variance	Observations	Mean	Variance	df	F	Fcritical
July	10	79.969	14.39	9	0.7698	0.315
August	10	124.645	18.695	9		
Total	20	204.614	33.085	18	0.7698	0.315

It was observed that the F or F calculated value was higher that the F critical or tabulated which means that when comparing the values obtained within the rows they were highly insignificant.

When the results of surface runoff for the month of July and August were statistically compared with each other, it was observed that July had a mean value of 79.969 with a variance of 14.39. On comparing the values of F or F calculated with that of the F critical or tabulated, it was observed that the value of F was higher than that of F critical which means that the surface runoff for the months of July and August were highly insignificant. When the results of surface runoff for the month of July and September where compared with each other, it was observed that mean value for the months of July and September were 79.969 and 91.125; there variance values were 14.392 and 32.774 while when the values for F calculated or F (0.439) was compared with the F critical or F tabulated (0.315), it was discovered that the F value was slightly higher than the F critical or F tabulated which means that it is not significant. For that of the months of August and September, it was observed that the mean values for the months of August and September were 124.645 and 91.125; the value for variance of 18.695 and 32.774 respectively. It was discovered that the value of F critical or F tabulated of 0.315 was lower when compared to the F or F calculated value of 0.570 which means that it is not significant. Figure 1 to 3 shows graphically the average runoff, the average sediment yield (kg) and the average soil loss (kg/m^2) for the three months of rainy season in the year 2010 respectively.

Figure 1: Map of the Permanent Site Farm of the Federal University of Technology, Minna

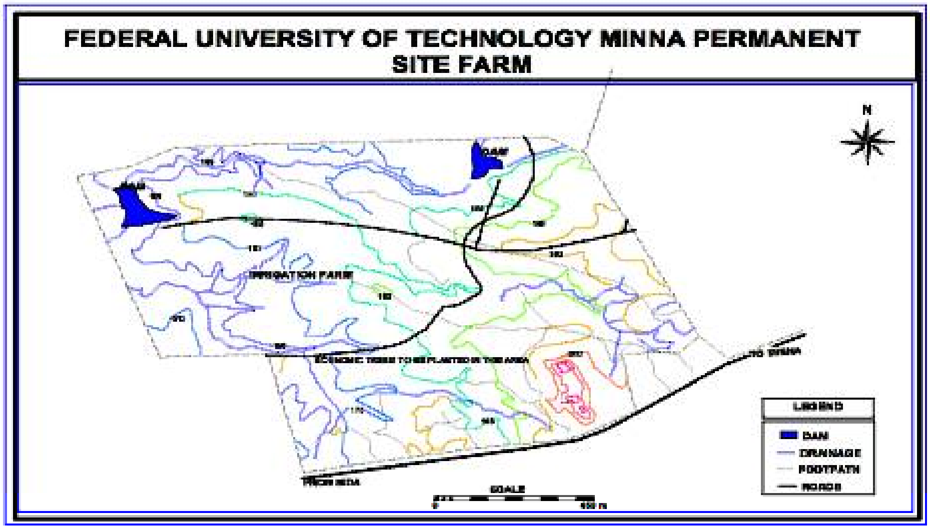


Figure 2: Rainfall Intensity for the Year 2010

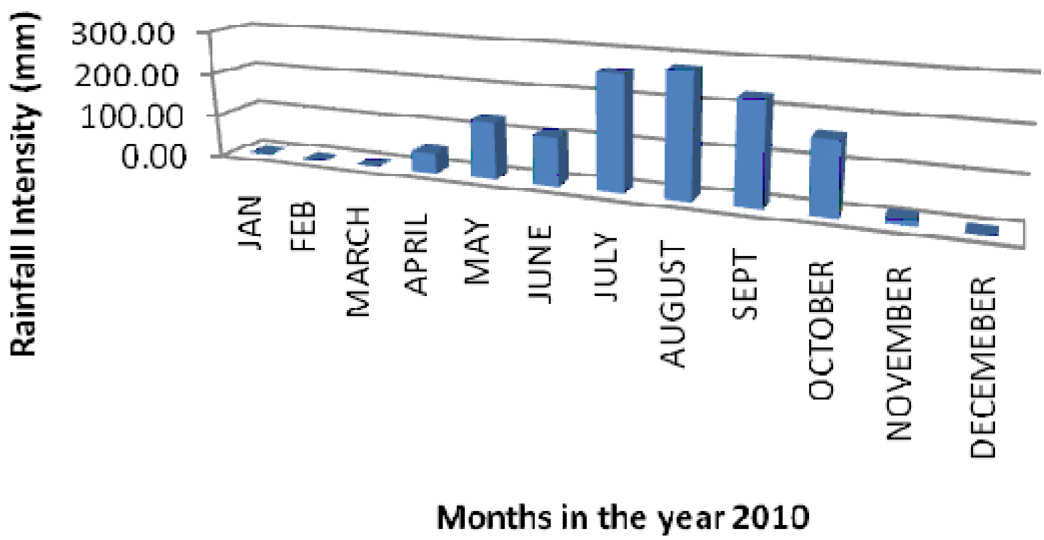


Figure 3: Graphical Representation of Average Runoff per Plot

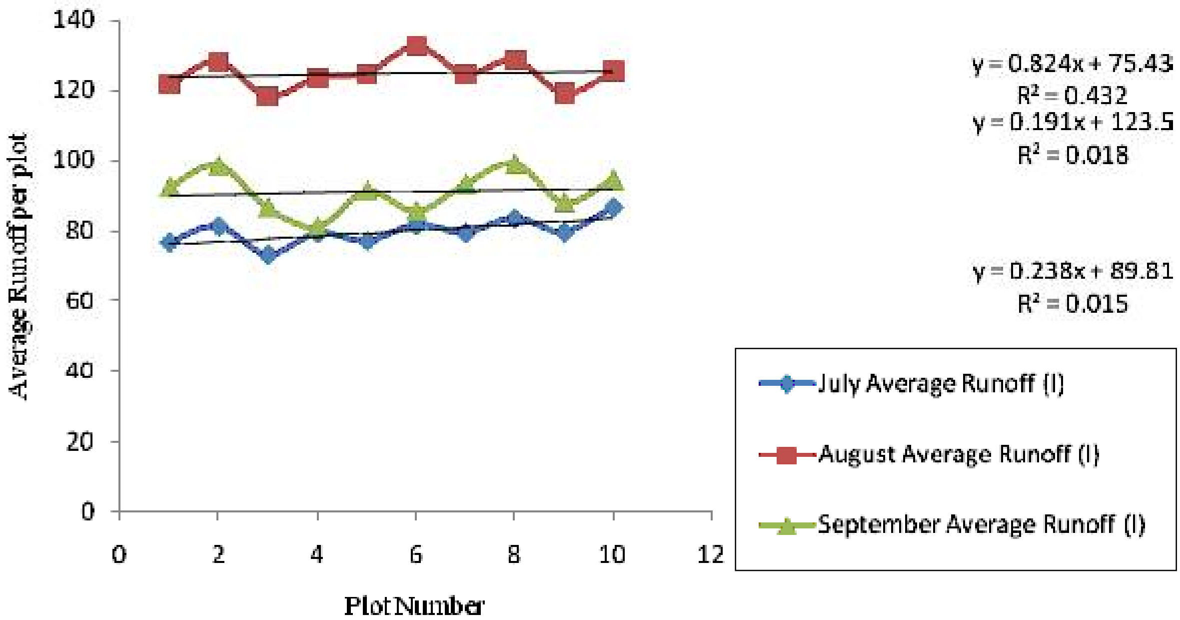


Figure 3 shows the graphical representation of the average runoff per plot during the rainy season and the average R-square value for each of the month. It was observed that the month of July had the highest value of 0.432 while the month of August had the lowest value 0.015. Figure 4 shows the graphical representation of the average sediment yield within the three months of rainfall under consideration and it was observed that the month of August had the least R-square value of 0.004 while the month of September had the highest value of 0.12. The

Figure 4: Graphical Representation of Average Sediment Yield per Plot

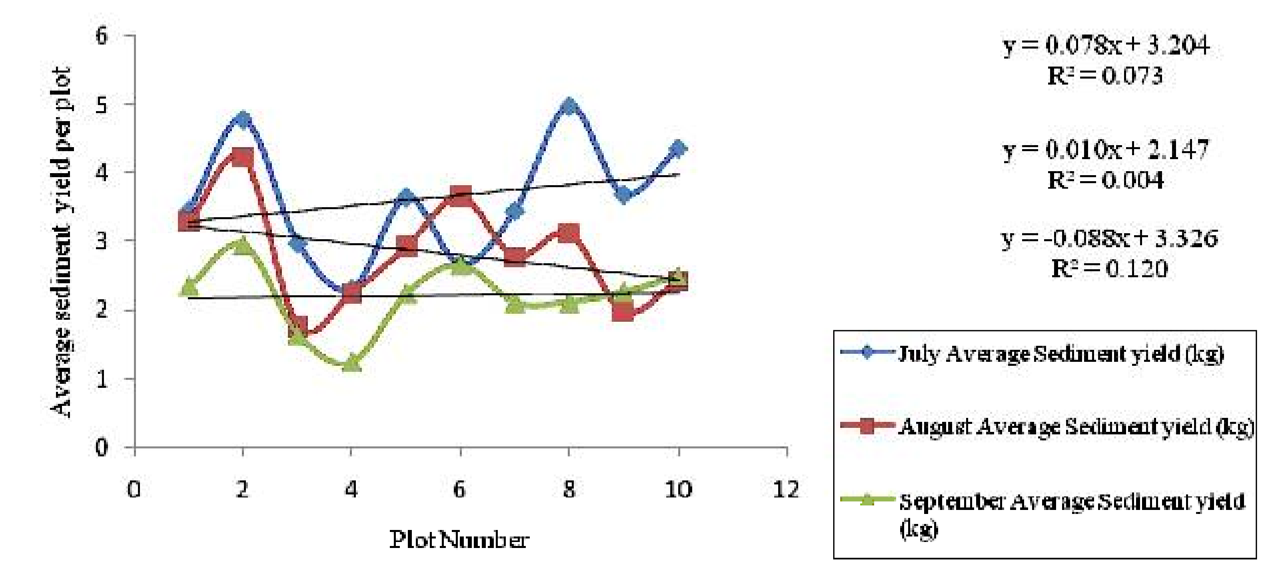
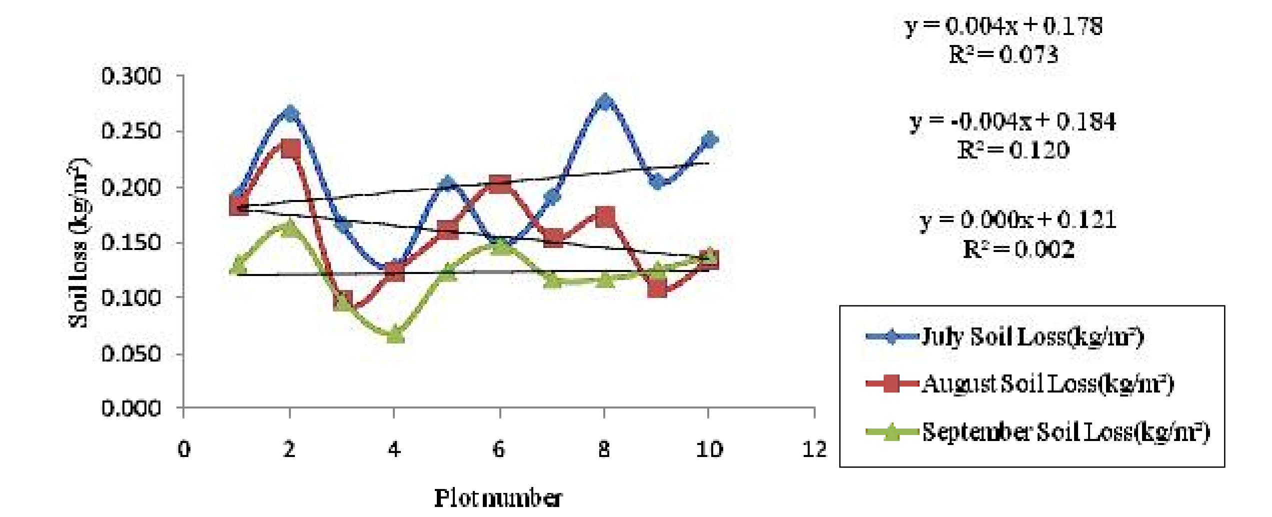


Figure 5: Graphically Representation of Soil Loss



highest quantity of soil loss was observed during the month of August since that was when rainfall was highest during the year 2010 which also implies that that is when the highest quantity of runoff was observed. The month of August had the lowest R-square value of 0.120 while the month of September had the lowest value of 0.002.

CONCLUSION

The study revealed that with different surface condition, sediment yield and runoff yield varied and also the variations in rainfall characteristics over the study period resulted in different erosion parameter between each plots. The month of August recorded a higher amount of rainfall, producing higher run-off volume and sediment load from the experimental plots than the month of July and September, producing lower erosion rates. The difference is between plots with vegetative cover and the bare soil. The plot with

Bermuda grass had higher runoff volume and sediment yield than that from the Broadleaf carpet grass plot. Soil losses and runoff production was on the average 0.40 and 0.64 times greater in the bare plot compared to the Bermuda grass, while 0.37 and 0.62 times greater compared to the Broadleaf carpet grass. Both grass gives good soil protection. This is reflected by their values of sediment and runoff yield when compared to the bare surface condition. However, the Broadleaf carpet grass had more pronounced effect on soil loss giving better soil protection.

This study finding also revealed that the major factor influencing sediment load is rainfall intensity and runoff depth. The sediment load is observed to increase with increased rainfall intensity and runoff depth. Thus, the greater rainfall intensity, greater the runoff volume resulting in increase the sediment yield. This finding is consistent with research expectation.

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ISSN 2250-3137