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Runoff, Soil Loss and Nutrient Losses from an Agricultural Field in Makurdi, Benue State, Nigeria

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Abstract:
A field experiment was conducted to assess runoff, soil loss and nutrient losses from an agricultural field during 2015 and 2016 cropping seasons in Makurdi area of Benue State, Nigeria using erosion plots under natural rainfall. Soil management practices namely, bare fallow (control), 4 and 8 t/ha mulched maize, maize + cowpea and unmulched maize were replicated three times. Runoff, soil loss and nutrient loss values indicated significant (p<0.05) differences among the treatments. Higher losses of runoff, soil, nutrients and lower infiltration rates were observed under the bare fallow plots followed by unmulched maize treated plots compared to the cover management treated plots. Lower values of losses and higher infiltration rates were noticed under 8 t/ha mulched maize management. The values of runoff varied from 1.4 to 127.02 mm and soil loss from 0 to 31.8 t/ha/yr during the two cropping seasons. The higher soil loss values of 31.8 t/ha/yr and 13.9 t/ha/yr in 2015 and 2016 respectively obtained under the bare fallow plots were beyond the tolerable limit. Correlation analysis between runoff and soil loss was significantly correlated (p<0.01), while runoff and nutrient losses were not significantly correlated. There was significant correlation (p<0.05) between soil loss and nutrients losses.

Keywords: *Runoff, soil loss, nutrient loss, erosion, infiltration rate*

1. Introduction

The Southern Guinea Savanna Agro ecological zone of Nigeria where Benue State is located is characterized by a diverse climatic, topographic and soil conditions. This region is one of the areas where various land degradation processes constitute key constraints to productivity. Accelerated erosion, drought and soil fertility decline are among the main causes of soil degradation (Idoga and Ejembi, 2003). Nigeria has a total surface area of 910,770km^2 (91.07 million hectares); of which 79.1% of the estimated area is agricultural land (World Bank, 2010). Benue State's surface area is 34.059km^2. Erosion poses the greatest threat to Nigerian soils, and affects over 80% of the land (World Bank, 2010).

The loss of fertile topsoil due to erosion on arable land is a growing concern in Benue State and has been identified as major cause of soil degradation. Removal of nutrients through runoff and sediments decline the fertility of soils in the region.

Despite a wide recognition of accelerated erosion as a serious global problem, assessing the dimensions like the magnitude, extent and the rate of soil erosion and its economic and environmental consequences precisely and reliably however, is still difficult (Lal, 1994). Besides, the readily available information in the literature is often based on reconnaissance surveys and extrapolations based on sketchy data.

Quantification of runoff and sediment loss from water erosion in areas of sloping topography continues to attract and sustain the attention of many researchers. In recent years, however, interest in soil erosion research has built up in the Southern part of Nigeria, some parts of which have degenerated into "disaster areas" following erosion. Works by Obi (1982), Mbah and Nneji (2011), and Uwah and Iwo (2011) are but a few of the attempts to evolve meaningful conservation practices in the Southern Nigeria.

Soil loss quantification appeared to have been simplified with the development of the Universal Soil Loss Equation of Wischmeier and Smith, (1978) and Soil Loss Estimation Model for Southern Africa (Elwell, 1978), and in particular with the development that enabled the prediction from some field observations and the results of some laboratory tests (Obi, 1982; Igwe *et al*., 1999).

The available literature shows that, runoff and soil loss quantification using field erosion plots have not been carried out in the Northern parts of Nigeria. There is certainly a great need for systematic field plot investigation in the Northern Nigeria and particularly Benue State where soil erosion by water has reached severe dimensions in recent years.

2. Materials and Methods

2.1. Experimental Site

The experimental plots were set up at the Teaching and Research Farm of the College of Agronomy, University of Agriculture, Makurdi, during the 2015 and 2016 cropping seasons. The experiment was conducted under four months' rainfall events from 7th July to 13th October, 2015 and 5th July to 14th October, 2016 during maize production.

The area is located at latitude 7°46' – 7°50'N and longitude 8°36' – 8°40'E (Fig. 1) and characterized by tropical climate with wet and dry seasons. The rainfall pattern is bimodal with annual rainfall varied between 900 and 1200mm. The wet season usually begins in April and ends in October/November. Temperature ranges between 21 – 35°C. Vegetation is guinea savannah type. The major crops cultivated in the area aremaize, cowpea, yam, cassava, rice, sorghum and millet.

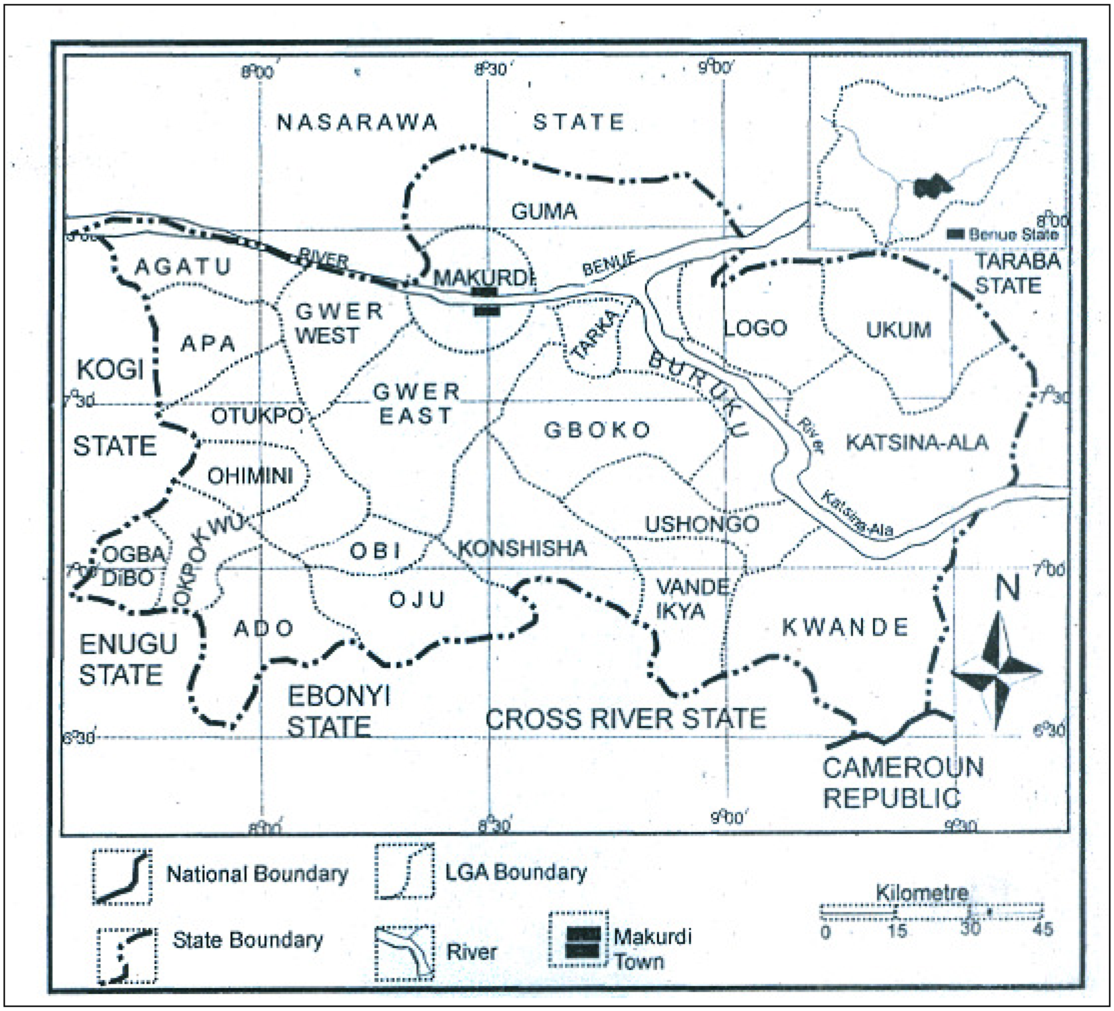

Figure 1: Map of Benue State showing Makurd
Source: Ministry of Land and Survey, Makurdi

2.2. Experimental Plots

The experimental plots were laid out on cultivated lands under a slope gradient of about 2.5% before the onset of the rainfall season. Fifteen (15) runoff plots measuring 20m x 3m (plus 1.5m^2 triangular down slope end) (i.e.61.5m^2) each were bordered by corrugated iron sheets which were inserted into the soil to a depth of 20cm leaving 25cm above the soil surface to prevent lateral flows from the plots to the adjacent area.

Soil management practices were as follows:(T1) bare fallow; (T2) 4 t ha^{-1} surface mulch + maize; (T3) 8 t ha^{-1} surface mulch + maize; (T4) maize + cowpea; (T5) maize. The experiment was laid out in randomized complete block design (RCBD) of five (5) treatments and replicated three (3) times.

2.3. Natural Rainfall, Runoff and Sediment Collection, Nutrient Losses Determination

The rainfall data of the study site was collected in 2015 and 2016 at University of Agriculture, Makurdi; College of Agronomy Meteorological Station located 41 meters away from the site.

Runoff and sediments were collected in barrels at the lower outlet of the plots and measured after each rainfall event. The sediment yield (amount of soil washed by runoff water from the plots) was determined after oven-drying an aliquot sample of the runoff and weighing the sediments.

The physical and chemical properties of the runoff and soil loss from each plot were analyzed individually at each runoff event to determine the nutrient dynamics. A portion of runoff and soil loss samples were collected in containers for analyzing nutrient losses. The total nutrients losses were calculated by summing the nutrient losses through runoff and through soil loss in 2015 and 2016 cropping seasons. Runoff and soil loss were analyzed as follows, mechanical analysis of the soil loss was determined by the Bouyoucous (1951) hydrometer method (Udo *et al*., 2009), Organic matter was determined by the Walkley and Black (1934) method as modified by Allison (1965). Total nitrogen was determined by micro-kjeldahl distillation method (Udo *et al*., 2009).Available phosphorus was determined by the method of Bray and Kurtz (1945) (Udo*et al*., 2009). The complexiometric titration method, described by Chapman (1965) was used for the determination of calcium and magnesium. Sodium and potassium were extracted using 1Nammonium acetate (NH_4 OAC) solution and determined by Flame Photometry. Exchangeable acidity was extracted using the titrimetric method of Mclean, (1982).The cation exchange capacity of the soil was obtained by summation of the exchangeable bases and exchangeable acidity (Udo*et al*., 2009).

2.4. Statistical Analysis

The data collected on runoff, soil loss and nutrient losses were analyzed using analysis of variance test based on randomized complete block design (RCBD) using GenStat Release 10.3DE (Rothamsted Experimental Station, 2011). The means of the various erosion parameters (runoff, sediment yield and nutrient loss) were compared among the different treatments. Correlation analysis using the IBM SPSS version 20 was performed to test the relationships among the various erosion parameters (rainfall, runoff, sediment yield and nutrient loss) as influenced by soil management practices.

3. Results and Discussion

3.1. Runoff

Runoff occurs when rainfall intensity exceeds infiltration capacity of the soil (Morgan, 1995). Surface runoff under the various soil management practices are given in Table 1. Table 2 shows the runoff as percentage of rainfall. The results indicated that the mean runoff collected at the bare fallow was significantly higher than those from cover management practices (p>0.01). This implies that cover management practices reduced runoff significantly as compared to the bare fallow plots.

The total monthly rainfall recorded at the study site during the time of the experiment in 2015 was 1991.4, 145.4, 92.8 and 15.6mm during July, August, September and October respectively. In 2016, the total monthly rainfall recorded was 58, 75.7, 155.8 and 59.2mm during July, August, September and October respectively. Of these quantities a total of 88.79, 18.30, 15.26, 26.40 and 37.48mm appeared as surface runoff in 2015 under the bare fallow (control), 4t/ha mulched maize, 8t/ha mulched maize, maize + cowpea and unmulched maize treated plots respectively. In 2016, quantities that appeared as runoff were 127.02, 6.54, 1.40, 14.00 and 48.43mm under the bare fallow, 4t/ha mulched maize, 8t/ha mulched maize, maize + cowpea and unmulched maize treated plots respectively. The highest monthly values were recorded in August and September in 2015 and 2016, the months of peak rainfall in Benue State.

In contrast to high runoff in the bare fallow, runoff was significantly reduced on cover management treated plots. moderate runoff was observed under unmulched maize followed by maize + cowpea, 4t/ha mulched maize and fall drastically under 8t/ha mulched maize with lowest total runoff in 2015 and 2016 cropping season as shown in Table 1. The effectiveness of the mulching in reducing runoff was also reduced with increasing rainfall with time. Visual observation of the experimental plots during the study period revealed that gradual redistribution of the mulch within the plots and its loss with time made the soil surface more exposed to the impacts of rainfall energy. The other reason could be due to the high frequency rainfall that usually falls on already saturated surfaces that results in early initiation and more volume of runoff (i.e. under 4t/ha mulched maize), which may even carry the mulch materials thereby reducing the effective surface cover. Generally, these management practices apparently provided sufficient canopy vegetation to dissipate the energy of the rainstorms. Cruse *et al*. (2001) reported a similar reduction in the rate of overland flow with increasing mulch cover. Works reported by Obi, (1982) indicated that cover management practice drastically reduced runoff compared to bare fallow (Control plots) from an oxisol in southeastern Nigeria under various management practices. Adekalu et al. (2007) investigated the mulching effect of elephant grass on surface runoff from three agricultural soils, runoff decreased with the amount of mulch used. Smerts *et al*. (2008) observed that erosion rates, as indicated by the amount of sediments in the runoff water were decreased greatly by all cover treatments.

In July 2015 and 2016, sporadic high intensity rainfall was recorded with minimal and no runoff respectively, these could easily be absorbed by freshly tilled soil which increased the infiltration capacity of the soil. Later with successive rainstorms, there is appreciable soil water recharge. Compaction and crusting eventually developed with consequent runoff. Detailed examination of daily records showed that rainfall of up to 736.6mm in 2015 and 14.4mm in 2016 failed to produce runoff in the freshly tilled bare soil in July. Furthermore, following a cessation of rain for any 24 hour period during the rainy required initiating runoff in the bare soil was about 2mm. Higher runoff at the later stages of the rainfall season was associated with reduction in the matric potential of the soil due to the saturation of pore spaces with water and surface sealing during the first rainfall events.

Treatment	2015					2016				
	July	Aug.	Sept.	Oct.	Total	July	Aug.	Sept.	Oct.	Total
(T1) Bare fallow	11.50	40.72	33.87	2.70	88.79	0.00	43.53	58.61	24.88	127.02
(T2) 4t/ha Mulch + Maize	2.12	15.84	0.34	0.00	18.30	0.00	0.78	3.83	1.93	6.54
(T3) 8t/ha Mulch + Maize	1.99	13.05	0.22	0.00	15.26	0.00	0.28	0.97	0.15	1.40
(T4) Maize + cowpea	1.94	22.78	1.68	0.00	26.40	0.00	4.99	7.26	1.75	14.00
(T5) Maize	2.36	28.03	6.26	0.79	37.48	0.00	12.21	28.48	7.75	48.43
LSD (P<0.05)	0.112	1.023	1.217	0.072	1.461	0.000	1.323	2.681	0.967	2.864
CV (%)	1.5	2.3	7.6	5.4	2.1	0.0	5.7	7.2	7.0	3.9

Table 1: Runoff (mm) under Different Management Practices

Treatment	**2015**				**2016**				
	July	**Aug.**	**Sept.**	**Oct.**	**July**	**Aug.**	**Sept.**	**Oct.**	
(T1) Bare fallow	1.35	52.28	42.51	50.0	0.0	59.87	48.84	28.77	
(T2) 4t/ha Mulch + Maize	0.74	13.84	0.62	0.0	0.0	1.47	3.28	5.73	
(T3) 8t/ha Mulch + Maize	0.70	10.30	0.45	0.0	0.0	1.11	1.08	0.41	
(T4) Maize +	0.74	26.52	2.31	0.0	0.0	7.67	5.53	5.27	
(T5) Maize	0.77	33.47	8.38	14.63	0.0	17.04	21.57	22.03	

Table 2: Percentage Runoff Coefficient (%) under Different Management Practices

3.2. Soil Loss

Soil loss under the various management practices are given in Table 3. The result indicated that all plots treated with cover management practices reduced soil loss significantly ($p<0.01$) compared to the bare fallow plots. The result shows that the higher soil loss was obtained in the bare fallow.

In 2015, the total soil loss obtained was in the decreasing order of 31.8, 9.19, 4.6, 4.25 and 2.62 t/ha for bare fallow, unmulched maize, maize + cowpea, 4t/ha mulched maize and 8t/ha mulched maize respectively. The least soil loss was observed under 8 t/ha mulched maize management. In 2016, soil loss followed a similar trend to that of 2015 under all treatment. Soil loss obtained were 13.9, 1.83, 0.49, and 0.12 t/ha under bare fallow, maize, maize + cowpea and 4t/ha mulched maize treated plots respectively. In contrast, no soil loss was observed under 8t/ha mulched maize management. Similar result was observed by Erenstein (2002) as soil erosion tends to decline asymptotically to zero as cover increases. Runoff often follows tortuous paths on the mulched plots, thus decreasing the average flow velocity. Sediments are also obstructed and filtered by the mulch reducing the overall sediment discharge. Higher soil loss where observed in 2015 compared to 2016 cropping season, this could be a result of higher rainfall intensities in 2015 more than that of 2016. In the bare fallow plots appreciable soil losses of 31.8 and 13.9 t/ha occurred in the first and second years respectively. Corresponding losses from the unmulched maize plots were 9.19 and 1.83 t/ha, respectively, followed by maize + cowpea plots with 4.6 and 0.49 t/ha in 2015 and 2016 respectively and 4 t/ha mulched maize had 4.25 and 0.12 t/ha losses in 2015 and 2016 respectively. Much smaller losses of 2.62 and 0 t/ha occurred under the 8t/ha mulched maize plots in 2015 and 2016 respectively. Obi, (1982) reported a similar reduction under various management practices in southeastern Nigeria. Adekalu *et al*. (2007) investigated the mulching effect of mulch on soil loss from three agricultural soils, soil loss decreased with the amount of mulch used. Sediment loss also decreased in mulch treated plots as similarly reported by Smerts *et al*. (2008).

This study indicated that surface application of a given rate of mulch is more effective in reducing runoff and soil loss as compared to legume cover management (i.e. maize + cowpea treatment). This is because of the exposure of soil during the early stage of crops growth where there was no or sparse vegetation cover to dissipate the energy of the rainfall compared to mulched plots where maximum surface cover was provided. Surface application of 8 t/ha mulch effectively protected runoff and soil loss during the entire cropping season. The fact that appreciable runoff and soil loss occurred on the mulched maize treated plots during the rainfall season could be attributed to the gradual reduction in the mulch cover due to removal by overland flow and its disintegration through time.

Clearly, values in Tables 1 and 2 is that higher runoff did not necessarily mean higher soil loss. The complex interaction of the soil loss surface condition, antecedent moisture and the rainfall pattern cannot, therefore, be overemphasized. The soil under investigation has porous topsoil. According to Obi (1982), maize production records suggest that a loss of up to 10 t/ha of this soil can be tolerated without much appreciable loss in production capacity. The major management problem from the erosion view point appears to be that of attempting to offset rainfall impact by ensuring adequate vegetative cover. This is particularly critical at the early stages of growth of a crop like maize when canopy cover is usually very sparse. Increasing the plant density would, no doubt, increase rainfall interception but beyond an optimum density, the benefit may be offset by decreased yield. Planting across the contour will reduce particles transportation and, therefore, soil loss to a considerable extent. However, the most obvious management practices are mulching and timely introduction of crops that provide adequate vegetative cover.

The dominant proportion of the soil loss was sand (73%) followed by clay (17%) and silt (10%). Sand dominated soil were found to be more susceptible to particle detachment as soil loss under the different soil management practices (treatments) compared to silt and clay. This could be due to the relative transportability of coarse and none aggregated sand particles (Morgan, 1995) as compared to the fine silt and clay particles. This high erodibility of the sand-dominated soil is in line with Morgan, (1995). According to Morgan, (1995), the medium and coarse soil particles are the most easily detached from the soil mass and that high clay particles resist detachment. This may be because the rain drop energy has to overcome the adhesive or chemical bonding force by which the minerals comprising clay particles are linked (Morgan, 1995). Soils with a restricted clay fraction, between 9 and 30% are most susceptible to erosion (Morgan, 1995). Ben-Hur *et al*. (1985) also indicated the medium textured soils (loamy sand and silt) are often the most susceptible to crusting and erosion. If has also been stressed however, that interaction between texture and other parameters like clay mineralogy and organic matter content could modify this relationship.

Treatment	**2015**					**2016**				
	July	**Aug.**	**Sept.**	**Oct.**	**Total**	**July**	**Aug.**	**Sept.**	**Oct.**	**Total**
(T1) Bare Fallow	6.98	20.33	2.79	1.69	31.80	0.00	4.41	6.58	2.91	13.90
(T2) 4t/ha Mulch + Maize	2.96	1.32	0.00	0.00	4.25	0.00	0.12	0.00	0.00	0.12
(T3) 8t/ha Mulch + Maize	1.72	0.89	0.00	0.00	2.62	0.00	0.00	0.00	0.00	0.00
(T4) Maize + Cowpea	2.98	1.63	0.00	0.00	4.60	0.00	0.49	0.00	0.00	0.49
(T5) Maize	4.08	4.81	0.307	0.00	9.19	0.00	1.13	0.70	0.00	1.83
LSD (P<0.05)	0.898	2.893	0.415	0.451	3.870	0.000	1.464	1.382	0.436	2.913

Table 3: Soil Loss under different Management Practices

3.3. Nutrient Losses by Runoff and Soil Loss

The total values of nutrients concentration in the runoff and soil loss are given in Tables 4, 5, 6 and 7 during the two cropping seasons. The combined total nutrients concentration in runoff and soil loss is given in Tables 8 and 9 for 2015 and 2016 respectively. Higher nutrients concentration were obtained under the bare fallow plots followed by unmulched maize, maize + cowpea, 4t/ha mulched maize and the lower nutrients were obtained under 8 t/ha mulched maize. The results showed that the nutrient concentration in runoff and soil loss were significant (p<0.01) among the treatments. Generally, higher concentrations of nutrients in runoff and soil loss were observed in the bare fallow plots compared to other treatments. More concentration of nutrients was obtained in soil loss compared to runoff as also reported by Mandal *et al*. (2012).

Nutrients concentrations in runoff and soil loss were more during the initial stage of crop growth. The first two months period after planting is called the 'critical period' in terms of soil erosion (Mandal *et al*., 2012). In this study, the 'critical period' was considered in July and August. During this periods there were high runoff and sediment concentration compared to other periods. During the later part of the growing season, runoff and sediment concentrations remained relatively constant with low or no values. In October 2015, nutrients concentration in runoff were not observed under 4t/ha mulched maize (T2), 8 t/ha mulched maize (T3) and maize + cowpea plots (T4) due to lack of runoff as a result of low rainfall. While in September and October of the both seasons, nutrients concentrations in soil loss were not observed under cover treatments. This is because there was no soil loss as a result of lack of runoff due to low rainfall.

In contrast, no runoff and soil loss were observed under all the treatments in July, 2016.Early in the cropping season (July) sporadic high intensity rainfall could easily be absorbed by freshly tilled soil, as a result there was no data taken for nutrients concentration in runoff and soil.

The concentration of P, Mg and Ca were high in runoff and sediment among all the nutrients analyzed and P had higher concentration. The higher P was also reported by Mandal *et al*. (2012), and Lal and Mishra, (2015).

Nutrients in the runoff and soil loss came fundamentally from the applied fertilizers (i.e. NPK), chemical weathering, biological processes and rainfall, although the contribution at the last was minimal. The dominance of phosphorus (P) in the treated (cover management and unmulched maize) plots suggested that, the dissolved P in runoff and soil loss came mainly from NPK fertilizers applied and native phosphorus in soil. Appreciable amount of N and K determined in runoff and sediment suggest they origin would be from the NPK fertilizer applied. The high nutrients concentration from the bare fallow plots came mainly from inorganic soil minerals and the nutrient's origin would have a relationship with native minerals in the soil and the amount of runoff and soil loss collected at each rainfall events.

In the present study, the nutrient loss through runoff and soil loss was not very high at each rainfall event; nevertheless, this meager escape of nutrients from agricultural lands was a matter of serious concern from the environmental safety as well as nutrient management points of view in rainfed agriculture. Farmers in Benue State where the research was carried out do not use adequate and balanced amount of fertilizer nutrients. This is because of failure of the State Government to supply fertilizer to farmers on time and poor economical conditions of farmers. In many cases they hardly apply any fertilizer or organic matter for their crops. Any amount of removal of nutrients through runoff and sediments is a great loss to the fertility of the land as well as productivity of the crop.

Treatment	**N**	**P**	**K**	**Na**	**Mg**	**Ca**	**EA**	
	(%)	**(mg/kg)**	←			**(Cmol/kg)**	→	
(T1) Bare fallow	6.21	39.31	3.42	3.56	41.10	42.00	13.81	
(T2) 4t/ha Mulch + Maize	4.39	25.28	2.75	2.59	16.80	18.63	8.35	
(T3) 8t/ha Mulch + Maize	2.11	10.02	1.42	1.27	9.13	10.27	5.35	
(T4) Maize +	5.27	32.46	3.21	2.95	29.20	30.97	11.43	
(T5) Maize	6.33	45.76	4.39	4.18	36.40	40.10	14.77	
LSD (P<0.05)	0.668	6.665	0.454	0.327	1.980	1.284	0.431	

Table 4: Total Nutrient Loss by Runoff in 2015

Treatment	OM	N	P	K	Na	Mg	Ca	EA	CEC
	(%)	(%)	(mg/kg)	←			(Cmol/kg)		→
(T1) Bare fallow	22.35	4.78	53.99	3.51	3.51	37.27	39.70	15.31	98.68
(T2) 4 t/ha Mulch+ Maize	8.55	1.95	12.70	1.79	1.64	12.60	13.57	7.54	37.15
(T3) 8 t/ha Mulch+ Maize	5.84	0.97	5.73	1.38	1.34	7.30	8.13	4.92	23.08
(T4) Maize +	13.30	4.02	37.00	2.39	2.09	21.97	23.40	8.31	58.17
(T5) Maize	18.14	4.50	42.93	3.09	2.69	28.23	28.43	10.57	75.72
LSD (P<0.05)	2.937	0.175	3.481	0.189	0.140	1.899	3.257	1.117	3.455

Table 5: Total Nutrient Loss by Soil Lossin 2015

Treatment	N	P	K	Na	Mg	Ca	EA	
	(%)	(mg/kg)	←			(Cmol/kg)	→	
(T1) Bare fallow	8.46	43.35	5.27	4.28	44.65	46.03	18.90	
(T2) 4 t/ha Mulch + Maize	3.55	20.23	2.46	2.25	20.30	21.07	10.91	
(T3) 8 t/ha Mulch + Maize	1.55	8.65	2.16	1.64	10.00	12.11	5.59	
(T4) Maize +	6.27	28.75	3.26	3.34	29.70	32.13	14.43	
(T5) Maize	7.38	40.06	4.12	3.59	38.64	42.69	15.26	
LSD (P<0.05)	0.859	1.962	0.222	0.294	4.04	5.526	0.825	

Table 6: Total Nutrient Loss by Runoff in 2016

Treatment	OM	N	P	K	Na	Mg	Ca	EA	CEC
	(%)	(%)	(mg/g)	←		(Cmol/kg)			→
(T1) Bare fallow	22.08	5.85	48.76	21.4	4.24	47.03	51.47	36.55	126.77
(T2) 4 t/ha Mulch + Maize	3.087	0.69	6.28	0.5	0.57	5.60	6.00	2.08	14.76
(T3) 8 t/ha Mulch + Maize	0.00	0.0	0.00	0.0	0.00	0.00	0.00	0.00	0.00
(T4) Maize + Cowpea	6.13	1.53	12.40	1.1	1.25	12.00	12.93	4.11	31.41
(T5) Maize	14.76	2.99	26.90	2.3	2.47	25.33	25.20	8.59	65.92
LSD (P<0.05)	0.660	0.172	0.747	16.76	0.546	1.214	2.575	1.95	2.572

Table 7: Total Nutrient Loss by Soil Lossin 2016

Treatment	N (%)	P (mg/kg)	K	Na	Mg	Ca	EA
			←		(Cmol/kg)		→
(T1) Bare fallow	10.99	93.3	6.93	7.07	78.37	81.70	29.12
(T2) 4t/ha Mulch + Maize	6.34	38.0	4.55	4.23	29.40	32.20	15.89
(T3) 8t/ha Mulch + Maize	3.08	15.8	2.80	2.61	16.43	18.40	10.28
(T4) Maize + Cowpea	9.29	69.5	5.60	5.05	51.17	54.37	19.74
(T5) Maize	10.83	88.6	7.48	6.88	64.63	68.53	25.35
LSD (P<0.05)	0.726	8.59	0.384	0.234	3.305	3.667	1.290

Table 8: Combined Total Nutrient Loss by Soil Loss + Runoffin 2015

Treatment	N (%)	P (mg/kg)	K	Na	Mg	Ca	EA
			←		(Cmol/kg)		→
(T1) Bare fallow	14.31	92.11	26.6	8.53	91.68	97.77	55.45
(T2) 4 t/ha Mulch + Maize	4.25	26.51	3.0	2.82	25.90	27.07	12.99
(T3) 8 t/ha Mulch + Maize	1.55	8.65	2.2	1.64	10.33	12.11	5.59
(T4) Maize + Cowpea	7.80	41.15	4.4	3.96	41.70	45.07	18.53
(T5) Maize	10.38	66.96	65	6.07	64.18	67.89	23.85
LSD (P<0.05)	0.941	2.231	16.62	0.923	3.744	4.9	1.788

Table 9: Combined Total Nutrient Loss by Soil Loss + Runoffin 2016

3.4. Relationships among the Erosion Parameters

3.4.1. Rainfall and Runoff

There was no correlation between rainfall and runoff in the study area due to soil conditions. Detailed daily records showed that heavy rainstorm produced little or no runoff under all the treated plots in the freshly tilled bare soils in July of both years. In contrast, small amount of rainfall could be erosive and produced high runoff in the bare soil and unmulched maize plots later with successive rainstorms.

3.4.2. Runoff and Soil Loss

The relationship between runoff and soil loss showed high significant ($p<0.01$) correlation. The relationship showed that the more runoff was produced, the greater the sediment yields. This is similar to that reported by Morgan, (2001), Erenstein, (2002) and Mandal *et al*. (2012). Mulch could decrease the runoff amount and sediment yield in a short time. This shows that reducing the sediment yield had a direct relationship with decreasing the runoff amount. The mulch also could protect the soil surface against raindrops (Obi, 1982; Morgan, 2001; Mandal *et al*., 2012), thus decreasing the sediment yield by reducing splash erosion.

3.4.3. Nutrient Loss and Runoff, and Soil Loss Relationships

The relationship between nutrient losses and runoff showed that EA and K concentration in runoff water were significantly correlated ($p<0.05$), while N, P, Na Mg and Ca concentration in runoff were not significantly correlated in the two cropping seasons. This means, increased in runoff produced low or insignificant nutrient losses, except EA and K which had high concentration in runoff.

The relationship between nutrient losses and soil loss showed that O.M, P, K, Mg, Ca and CEC concentration in soil loss were not significant, while Na and EA were significantly correlated ($p<0.05$) in 2015. The result of 2016 showed that O.M was not significant but N, P, Na, Mg, Ca and CEC were significantly correlated ($p<0.05$), while K and EA were highly significantly correlated ($p<0.05$) with soil loss. This means that nutrients losses increased with increase in soil loss.

The nutrients losses were high in the soil loss as compared to the dissolved losses (i.e. runoff). Nutrients concentration in soil loss and runoff was found to be more during the initial stage of crop growth. The initial stage of crop growth cycle considered as the critical period in terms of soil erosion (Mandal *et al*., 2012; Lal and Mishra, 2015). In the present study, crops were planted during the first week of July (5th July, 2015 and 7th July, 2016). Therefore, the critical period for current study was considered in July and August, during which high amount of runoff, sediment concentrations and nutrients loss were observed as compared to other periods. All the values of nutrients in Tables 43 – 46 were plotted against the corresponding total runoff and soil loss values for each cropping season. These relationships revealed that a poor correlation existed between nutrients and runoff in 2015 and 2016. Correlation between nutrients and soil loss was generally poor in 2015 and good correlation existed in 2016.

4. Conclusion

The present study quantified the variation in runoff, soil loss and nutrient loss from an agricultural field under natural rainfall conditions for two cropping seasons. The findings of the study will aid in estimation of runoff, soil and nutrient conservation potential for sustainable land management systems. The nutrient losses were dependent on total soil loss and runoff. Soil and nutrient losses from agricultural land may have in-situ environmental impacts due to decline in soil productivity, reduction in soil depth, soil crusting and sealing. Extreme events or erosive events are important for runoff and soil losses even if they occur rarely.

Soil losses under the bare fallow plots throughout the two seasons were of the magnitude of 31.8 t/ha/yr and 13.9 t/ha/yr in 2015 and 2016 respectively, while that of unmulched maize plots were of magnitude of 9.19 t/ha/yr and 1.83 t/ha/yr in 2015 and 2016 respectively. These losses may greatly contribute to soil degradation

From the study, 8 t/ha mulch is recommended for sustainable soil management practices in Makurdi area of Benue State.

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