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Determination of Nutrients Loss from an Agricultural Field in Makurdi, Benue State, Nigeria

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ABSTRACT
A review on nutrients loss from a field experiment conducted at the Teaching and Research Farm of the College of Agronomy, University of Agriculture, Makurdi (Latitude 7°46' – 7°50'N and Longitude 8°36' – 8°40'E) during the 2015 and 2016 cropping seasons. Soil erosion plots (runoff plots) were set up under a slope gradient of 2.5 % to assess nutrient losses through runoff and soil loss under rainfed conditions. Soil management practices namely, bare fallow (control), 4 and 8 t/ha mulched maize, maize + cowpea and unmulched maize were replicated three times. Runoff and soil loss were collected and analyzed for nutrients dynamics under various management practices using analysis of variance test based on randomized complete block design (RCBD). Higher losses of nutrients were observed under the bare fallow plots followed by unmulched maize treated plots compared to the cover management treated plots. Lower values of losses were noticed under 8 t/ha mulched maize management. Analysis of variance test shows significant differences ($p<0.05$) among the treatments.
Keywords: Runoff, soil loss, nutrient loss, erosion plots, cover management.

INTRODUCTION

The Southern Guinea Savanna Agroecological 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 (Ajon *et al*., 2017). 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 and over 142,200ha of the land is cultivated (Ayuba *et al*., 2007; Ajon *et al*., 2014). 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 (Ajon *et al*., 2017).

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 (Ajon *et al*., 2017). 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), Uwah and Iwo (2011), Ajon *et al*. (2017) are but a few of the attempts to evolve meaningful conservation practices in Nigeria.

The available literature shows that, nutrients loss quantification using field erosion plots have not been carried out in the Northern parts of Nigeria (Ajon *et al*., 2017). 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.

MATERIALS AND METHODS

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^{o}46' – 7^{o}50'N and longitude 8^{o}36' – 8^{o}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^{o}C. Vegetation is guinea savannah type. The major crops cultivated in the area are maize, cowpea, yam, cassava, rice, sorghum and millet.

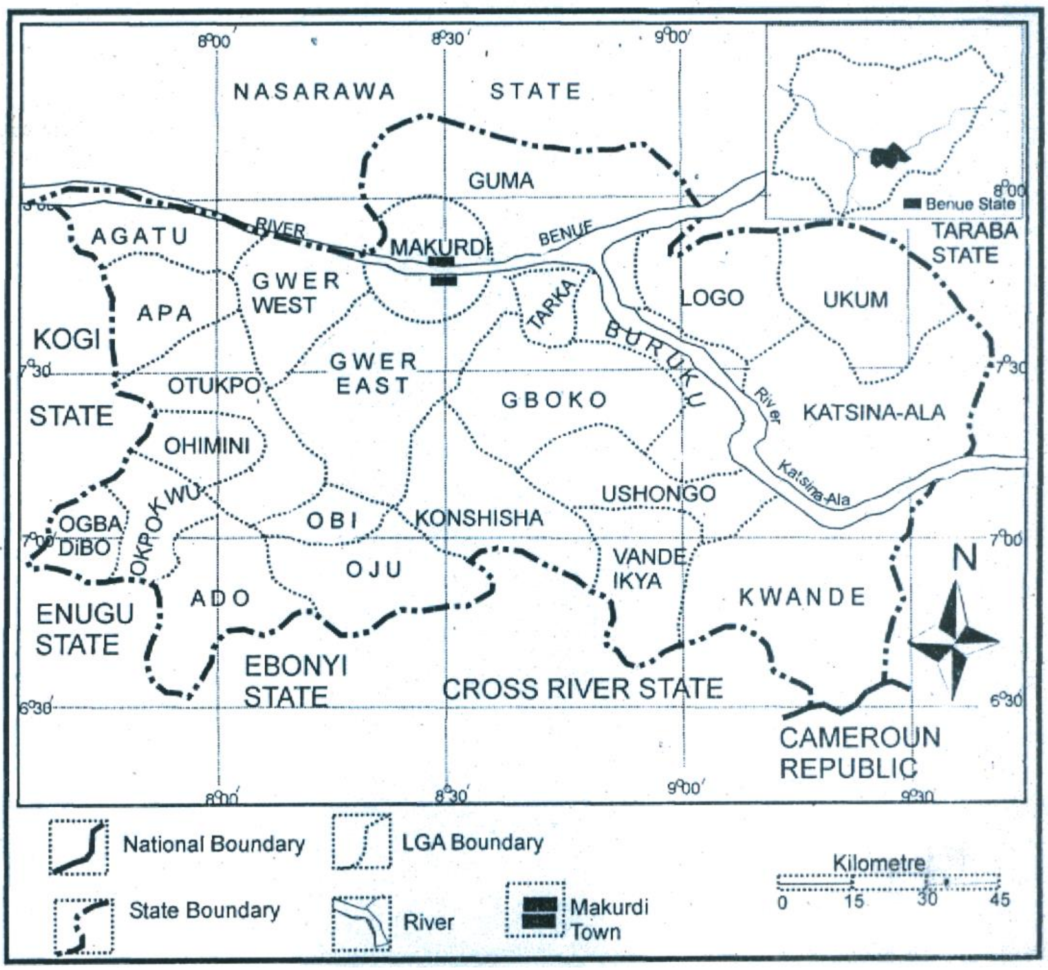

Fig. 1: Map of Benue State showing Makurdi

Source: Ministry of Land and Survey, Makurdi

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 downslope 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.

Rainfall Data, Runoff and Sediment Collection for Nutrients Loss 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 after each rainfall event. 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 (Udo *et al*., 2009). Total nitrogen was determined by micro-kjeldahl distillation method (Udo *et al*., 2009). Available phosphorus was determined by the method (Udo *et al*., 2009). The complexiometric titration method was used for the determination of calcium and magnesium (Udo *et al*., 2009). Sodium and potassium were extracted using 1N ammonium acetate (NH_4 OAC) solution and determined by Flame Photometry. Exchangeable acidity was extracted using the titrimetric method (Udo *et al*., 2009). The cation exchange capacity of the soil was obtained by summation of the exchangeable bases and exchangeable acidity (Udo *et al*., 2009).

Statistical Analysis

The data collected on nutrient losses were analyzed using analysis of variance test based on randomized complete block design (RCBD) using GenStat Release 10.3DE. The mean values of the nutrients losses were compared among the different treatments as influenced by cover management practices.

RESULTS AND DISCUSSION

Seasonal Rainfall

The total monthly rainfall recorded at the study site during the time of the experiment in 2015 were 1991.4, 145.4, 92.8 and 15.6 mm during July, August, September and October respectively. In 2016, the total monthly rainfall recorded were 58, 75.7, 155.8 and 59.2 mm during July, August, September and October respectively.

Nutrient Losses by Runoff and Soil Loss

The total values of nutrients concentration in the runoff and soil loss are given in Tables 1, 2, 3 and 4 during the two cropping seasons. The combined total nutrients concentration in runoff and soil loss is given in Tables 5 and 6 for 2015 and 2016 respectively. Higher nutrients concentration were obtained under the bare fallow plots followed by unmulched maize, maize + cowpea, 4 t/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; Ajon *et al*., 2017). In this study, the ‘critical period’ was considered in July and August. During these 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 (Ajon *et al*., 2017). In October 2015, nutrients concentration in runoff were not observed under 4 t/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 (Ajon *et al*., 2017).

In contrast, no runoff and soil loss were observed under all the treatments in July, 2016 (Ajon *et al*., 2017). 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 loss. 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 (Ajon *et al*., 2017). 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 (Ajon *et al*., 2017). Appreciable amount of N and K determined in runoff and sediment suggest their 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 (Ajon *et al*., 2017).

In this study, the nutrients loss through runoff and soil loss were not very high at each rainfall event; nevertheless, the 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 economic 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.

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 were 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; Ajon *et al*., 2017). In this study, crops were planted during the first week of July (5^{th} July, 2015 and 7^{th} July, 2016) (Ajon *et al*., 2017). Therefore, the critical period for the 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.

Table 1. Total Nutrient Loss by Runoff under Different Soil Management Practices in Makurdi (2015)

Treatment	**N (%)**	**P (mg/kg)**	**K**	**Na**	**Mg**	**Ca**	**EA**
			←		(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 + Cowpea	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

Source: Ajon *et al*. (2017)

Table 2. Total Nutrient Loss by Soil Loss under Different Soil Management Practices in Makurdi (2015)

Treatment	**OM (%)**	**N (%)**	**P (mg/kg)**	**K**	**Na**	**Mg**	**Ca**	**EA**	**CEC**
				←		(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 + Cowpea	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

Source: Ajon *et al*. (2017)

Table 3. Total Nutrient Loss by Runoff under Different Soil Management Practices in Makurdi (2016)

Treatment	**N (%)**	**P (mg/kg)**	**K**	**Na**	**Mg**	**Ca**	**EA**
			←		(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 + Cowpea	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

Source: Ajon *et al*. (2017)

Table 4. Total Nutrient Loss by Soil Loss under Different Soil Management Practices in Makurdi (2016)

Treatment	OM (%)	N (%)	P (mg/g)	K	Na	Mg	Ca	EA	CEC
				←		(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

Source: Ajon *et al*. (2017)

Table 5. Combined Total Nutrient Loss by Soil Loss + Runoff in 2015

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

Source: Ajon *et al*. (2017)

Table 6. Combined Total Nutrient Loss by Soil Loss + Runoff in 2016

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

Source: Ajon *et al*. (2017)

CONCLUSION

The review work quantified the variation in nutrients loss through runoff and soil loss from an agricultural field under rainfed conditions for two cropping seasons. The findings of the study will aid in estimation of nutrients conservation potential for sustainable soil management systems. The nutrients losses were dependent on total soil loss and runoff. Nutrients losses from agricultural land may have in-situ environmental impacts on decline in soil productivity. Rainfall extreme events or erosive events are important for runoff and soil losses even if they occur rarely or meagerly.

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