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EFFECT OF COVER MANAGEMENT PRACTICES ON EROSION, SOIL PROPERTIES AND MAIZE PERFORMANCE UNDER NATURAL RAINFALL IN MAKURDI, BENUE STATE, NIGERIA

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ABSTRACT

A field experiment was conducted to assess the effect of cover management practices on erosion, soil properties and maize performance 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. The mechanical analysis of the study site indicated sandy loam texture with low values of soil nutrients, organic matter (0.86%) and soil pH (6.11) before the application of treatments. 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 effect of cover management practices on soil properties determined after harvest significantly ($p<0.05$) improved soil properties such as soil pH, O.M, N, P, exchangeable bases, EA, CEC, BS and porosity relative to the low values of nutrients obtained under bare fallow. ANOVA on yield parameters of maize such plant height and leaf area were significantly ($p<0.05$) different, while data on runoff, soil loss and grain yields showed significant ($p<0.01$) difference among the treatments. Lower values of runoff, soil loss, and higher values of soil properties and yield parameters of maize were obtained under 8 t/ha mulched maize management compared to bare fallow and unmulched maize treatments. Correlation analysis between grain yield and runoff, and soil loss showed significant negative correlation ($p<0.05$). Grain yield of maize decreased with increase in runoff and soil loss

Keywords: Cover management, erosion, soil properties, maize, yield

Introduction

In the Southern Guinea Savanna Agro ecological zone of Nigeria where Makurdi area of Benue State is located, the soil used predominantly for farming are alfisols characterized by their coarse texture and low/moderate organic matter content. They are equally moderate in CEC, with little mineral reserve, have moderate water holding capacity, moderate pH, high base saturation and unstable structure (Brady and Weil, 1999). Under natural vegetation cover, these soils maintain a close system because plant nutrients are derived from the natural vegetation and crop residue

when incorporated in the surface. Erosion is held in check by the canopy cover which dissipates rainfall energy, and by the plant residue cover on the floor which halts runoff and soil loss. With continuous accumulation of these plant residues, organic matter content of the soil is increased which invariably increases the CEC and hence soil fertility is maintained (Uwah and Iwo, 2011).

However, with the removal of vegetation, bush burning and subsequently cropping, fertility maintenance becomes a serious problem. The indicators are rapid decline of organic matter and soil nutrients, erosion which culminate in sharp decline in crop yields (Idoga and Ejembi, 2003). The numerous soil problems are further compounded by the seasonality and erratic distribution of rainfall which results in varying periods of drought separated by wet periods (Ajon *et al*., 2014). Such drought create problems in crop production in that crops are subjected to severe moisture stress which could lead to total crop failure if it coincide with critical growth periods (Uwah and Iwo, 2011). On the other hand, during periods of heavy rainfall, when field crops have not yet developed sufficient canopy to dissipate raindrop impact, erosion becomes a very serious problem. Furthermore, high temperature experienced in the area, encourage excessive evapotranspiration which ultimately leads to severe soil moisture stress.

Sustainable soil management systems must be developed to reduce further degradation, protect the soil against erosion during erosive storms and restore the productivity of the eroded land. Two soil conservation approaches, the barrier approach and the cover approach, have been developed and are in use worldwide to control soil loss by water erosion (Young, 1989; Hudson, 1984; Rodriguez, 1997; Tripathi and Singh, 1993). Between the two soil conservation approaches, surface cover management practice is found to be one of the most effective means of erosion control (Khurshid *et al*, 2006; Pervaiz *et al*., 2009; Mbah and Nneji, 2010; Uwah and Iwo, 2011; Ngome *et al*., 2011).

Studies carried out in and outside Nigeria have shown that cover management practices not only conserved soil moisture and prevent erosion they also increased soil fauna and flora activities and maintained high crop yields (Khurshid *et al*, 2006; Pervaiz *et al*., 2009; Mbah and Nneji, 2010; Uwah and Iwo, 2011; Ngome *et al*., 2011).

The present investigation was carried out to assess the effect of cover management practices on erosion, soil properties and maize performance in Makurdi area of Benue State, Nigeria.

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 7º46' – 7º50'N and longitude 8º36' – 8º40'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 – 35ºC. Vegetation is guinea savannah type. The major crops cultivated in the area are maize, cowpea, yam, cassava, rice, sorghum and millet.

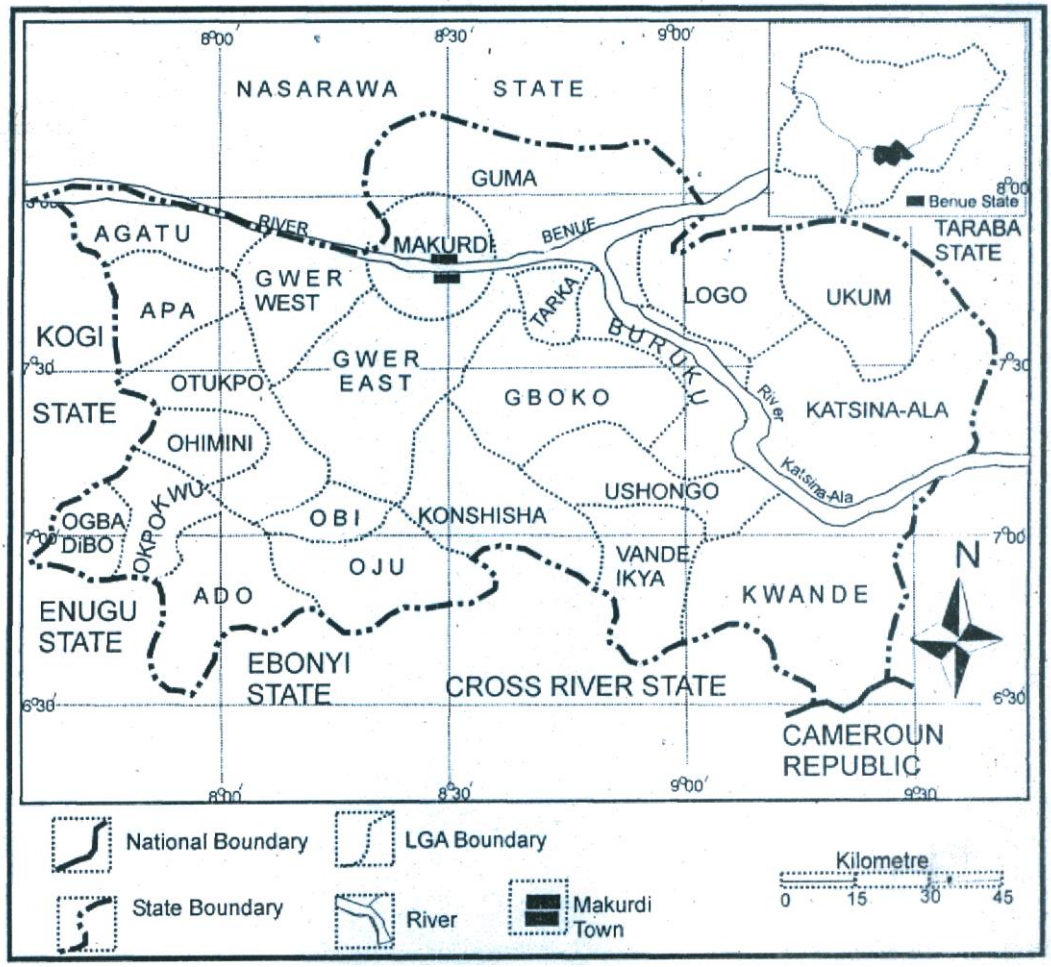

Fig. 1: Map of Benue State showing Makurdi
Source: Ministry of Land and Survey, Makurdi

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 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.

Soil samples were collected from the site at the depth of 0 – 30cm during the land preparation and after harvest and analyzed for physical and chemical properties using standard procedures (Udo *et al*., 2009).

Runoff and Soil Loss Collection

Runoff and soil loss 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.

Planting

Planting of maize and cowpea was done on the 7th July, 2015 and 5th July, 2016 cropping seasons. Planting was carried out by manually sowing the seeds on flat land into the soil. Two seeds of maize were sown per stand with a spacing of 0.25m x 0.75m and the seedlings were thinned to one per stand two weeks after planting (WAP) to give 328 stands per plot of 61.5m^2 (53,000 plants per hectare), and cowpea give 164 plants per plot of 61.5m^2 (27,000 plants per hectare) at spacing of 0.50m x 0.75m. The application of fertilizer was carried out one week after planting (1WAP). NPK 15:15:15 was applied at the rate of 200kg ha^{-1} (Agbede, 2009). Weed control was done manually in all the plots.

Crop data

Data on maize: Plant height and leaf area were collected at 3, 7 and 12WAP. In taking the plant height and leaf area, ten (10) plants in each plot were selected at random and tagged at 2WAP. Date of tasselling was taken 6WAP where more than 50% flowering was recorded in each plot. The grain yield was taken at harvest to evaluate the effect of cover management on maize performance.

Statistical analysis

The data collected on soil properties, growth parameters and grain yield of maize were subjected to analysis of variance test based on randomized complete block design (RCBD) using GenStat Release 10.3DE (Rothamsted Experimental Station, 2011). Correlation analyses using the IBM SPSS version 20 was performed to show the relationships between grain yield of maize and runoff, and soil loss.

RESULTS AND DISCUSSION

Effect of Cover Management Practices on Soil Properties under Natural Rainfall

In this study, effect of cover management practices on soil properties was investigated. The result of the soil properties in the study site at the start of the experiment shown in Table 1 revealed that, the soil was low in nutrients including N, P, and K. The soil represents a typical tropical soil which has been continuously and intensively cultivated in the previous seasons. In the present study, cover management practices significantly ($p<0.05$) improved soil properties both in 2015 and 2016 cropping seasons (Tables 2 and 3). The values of nutrients in the bare fallow plots were significantly reduced followed by unmulched maize plots compared to the cover managements treated plots. Higher nutrients values were observed under 8 t/ha mulched maize followed by maize + cowpea and 4 t/ha mulched maize managements.

Effect of cover management practices on soil properties showed no significant difference among the cover treatments, but there was significant different ($p<0.05$) between cover treatments and unmulched maize, and bare fallow (Table 2 and 3). Low values of soil bulk density 1.22g/cm^3 and high porosity 54% were obtained under 8 t/ha mulched maize in 2015 and 2016. These results are in agreement with those of Khurshid *et al*. (2006); Mbah and Nneji, (2001); Pervaiz *et al*. (2009); Uwah and Iwo, (2011) and Ngome *et al*. (2011), who concluded that increasing

mulch level at 8 t/ha significantly improved soil properties and reduce soil erosion. Reports also indicate that, as compared to bare soils, mulched soils have greater porosity (Suwadjo and Abujamin, 1983); increased water holding capacity (Unger and Wiese. 1979; Unger and Jones, 1981; Edwards *et al*., 2000), higher infiltration rate (Bonsu,1983), increased amount of percolation, less runoff and water erosion (Suwadjo and Abujamin, 1983) and less evaporation (Unger and Jones, 1981).

The results of poor values of soil properties under the bare fallow and unmulched maize plots suggested that soil organic carbon or soil organic matter is greatly affected by soil erosion and is related with productivity. Depletion of soil organic matter by erosion is accompanied by the removal of plant nutrients, deterioration of soil structure, and diminishing soil workability (Mandal *et al*., 2012; Lal and Mishra, 2015). Depletion of soil organic matter and erosion are spirally cyclic since a decrease in organic matter increase the susceptibility of soil to erosion, thereby increasing the rate of depletion of soil organic carbon (Pierce and Lal, 1994; Mandal *et al*., 2012).

Table 1 Physical and Chemical Properties of the Soil of the Study Site at the Start of the Experiment in 2015

Soil properties	Values
Sand (%)	72.8
Silt (%)	10.0
Clay (%)	17.2
Textural class	Sandy Loam
pH (H_2O)	6.11
Organic Carbon (%)	0.50
Organic Matter (%)	0.86
Nitrogen (%)	0.29
Phosphorus (mg/kg)	2.5
Potassium (Cmol/kg)	0.23
Sodium (Cmol/kg)	0.21

Magnesium (Cmol/kg)	2.6
Calcium (Cmol/kg)	2.9
Total Exchangeable Bases (Cmol/kg)	5.94
Exchangeable Acidity (Cmol/kg)	1.10
Cation Exchange Capacity (Cmol/kg)	7.04
Base Saturation (%)	84.38
Bulk Density (g/cm^3)	1.40
Porosity (%)	47
Available water content (AWC) (g/g)	23.8

Table 2 Effect of Cover Management on Soil Properties after Harvest in 2015

Treatment	pH (H_2O)	O.M (%)	N (%)	P (mg/kg)	K	Na	Mg	Ca	EA	CEC	BS (%)	BD (g/cm^3)	Porosity (%)	AWC (g/g)
					← (Cmol kg^{-1}) →									
(T1) Bare Fallow	6.06	0.71	0.13	1.80	0.14	0.16	1.97	2.13	0.97	5.38	81.90	1.40	47.30	19.10
(T2) 4 t/ha Mulch + Maize	6.19	1.52	0.35	3.00	0.27	0.24	2.87	3.07	1.03	7.47	86.10	1.27	53.07	18.10
(T3) 8 t/ha Mulch + Maize	6.26	3.05	0.38	3.25	0.27	0.25	2.93	3.20	1.07	7.72	86.13	1.22	53.84	17.00
(T4) Maize + Cowpea	6.21	1.26	0.37	3.24	0.29	0.27	2.93	3.10	1.04	7.64	86.73	1.31	50.69	19.57
(T5) Maize	6.14	1.16	0.26	2.16	0.30	0.28	2.73	2.93	1.00	7.25	85.50	1.34	49.56	18.30
LSD ($p<0.05$)	0.125	0.499	0.053	0.217	0.027	0.033	0.408	0.411	0.067	0.826	1.535	0.065	2.47	NS

Table 3 Effect of Cover Management on Soil Properties after Harvest in 2016

Treatment	pH (H_2O)	O.M (%)	N (%)	P (Mg/kg)	K	Na	Mg	Ca	EA	CEC	BS (%)	BD (g/cm^3)	Porosity (%)	AWC (g/g)
					← (Cmol kg^{-1}) →									
(T1) Bare Fallow	6.63	0.87	0.17	1.87	0.17	0.15	1.83	2.07	1.17	5.39	78.37	1.46	45.03	16.50
(T2) 4 t/ha Mulch + Maize	6.80	1.85	0.38	3.00	0.28	0.23	2.90	3.07	1.08	7.56	85.67	1.28	51.82	19.97
(T3) 8 t/ha Mulch + Maize	6.87	3.30	0.43	3.17	0.31	0.24	3.03	3.23	1.07	7.88	86.43	1.22	54.09	23.00
(T4) Maize + Cowpea	6.83	1.57	0.42	3.07	0.28	0.24	2.83	3.07	1.21	7.63	84.13	1.29	51.19	19.97
(T5) Maize	6.70	1.17	0.28	2.70	0.25	0.23	2.53	2.77	1.04	6.82	84.80	1.33	49.94	18.30
LSD ($p<0.05$)	0.124	0.233	0.019	0.144	0.024	0.046	0.267	0.239	NS	0.504	2.954	0.041	1.557	0.790

Effect of Cover Management Practices on Maize Performance and Erosion

The effect of cover management on growth of maize was assessed (Tables 4 and 5). The results showed a significant ($p<0.05$) response in the growth parameters of crop. The use of cover management was beneficial in improving the growth and grain yield of maize.

The higher values of plant height and leaf area were obtained under 8 t/ha mulched maize management followed by 4 t/ha mulched maize and maize + cowpea treatments compared to unmulched maize treatment. Pervaiz *et al*. (2009); Khurshid *et al*. (2006); Mbah and Nenji, (2011); Uwah and Iwo, (2011) and Ngome *et al*. (2011) observed the same results that plant

height and leaf area increases by increasing level of mulched. This may be due to the fact that mulched develops suitable environment for root growth penetration by maintaining moisture content, reduce erosion, increase plant nutrients, improve soil structure and enhance biological activities.

The maximum values of weight of grain yield, 1000 – grain yield and grain yield were obtained under 8t/ha mulched maize management followed by 4t/ha mulched maize and maize + cowpea managements compared to unmulched maize treated plot. These results are in agreement with

those of Pervaiz *et al*. (2009); Khurshid *et al*. (2006); Mba and Nneji, (2011) and Uwah and Iwo, (2011), who concluded that cover management practice improve the ecological environment of the soil, increased soil temperature and soil water contents, promoted the growth and maturation of maize and increased crop yield.

Surface runoff and soil loss under the various soil management practices are given in Tables 4 and 5. The values of runoff varied from 15.26 to 88.79 mm in 2015 and 1.4 to 127.02 mm in 2016, while soil loss from 2.62 to 31.8 t/ha/yr in 2015 and 0 to 13.9 t/ha/yr during 2016 cropping season. The results indicated that the mean runoff and soil loss collected at the bare fallow were significantly higher than those from cover management practices ($p>0.01$). The high soil loss (31.8 t/ha/yr) and moderate soil loss (13.9 t/ha/yr) under the bare fallow plots in 2015 and 2016 respectively are beyond the soil loss tolerance limit of 12.5 t/ha/yr as reported by Smith, (2013). This implies that cover management practices reduced runoff and soil loss significantly as compared to the bare fallow plots. The lowest values of runoff and soil loss were obtained under 8 t/ha mulched maize management.

Table 4 Effect of Cover Management Practices on Maize Performance in 2015

Treatment	Plant height (cm) 3WAP	Leaf area (cm^2) 3WAP	Plant height (cm) 7 WAP	Leaf area (cm^2) 7 WAP	Plant height (cm) 12 WAP	Leaf area (cm^2) 12 WAP	Weight of grain / cob (g)	Weight of 1000 grain / plot (g)	Grain yield (t/ha)	Total Runoff (mm)	Soil Loss (t/ha/yr)
(T1) Bare Fallow	-	-	-	-	-	-	-	-	-	88.79	31.80
(T2) 4 t/ha Mulch + Maize	26.97	304.3	88.8	525.0	224.6	713.0	114.4	274.1	1.90	18.30	4.25
(T3) 8 t/ha Mulch + Maize	28.87	355.9	100.9	639.0	256.2	797.0	151.4	297.0	2.55	15.26	2.62
(T4) Maize + Cowpea	23.82	277.6	85.1	518.0	228.2	720.0	109.1	271.9	1.72	26.40	4.60
(T5) Maize	22.20	300.0	72.1	565.0	192.1	614.0	86.9	240.4	1.45	37.48	9.19
LSD (P<0.05)	4.648	58.43	12.69	NS	22.93	101.8	10.25	13.32	0.247	1.461	3.870

Table 5 Effect of Cover Management Practices on Maize Performance in 2016

Treatment	Plant height (cm) 3WAP	Leaf area (cm^2) 3 WAP	Plant height (cm) 7 WAP	Leaf area (cm^2) 7 WAP	Plant height (cm) 12 WAP	Leaf area (cm^2) 12 WAP	Weight of grain / cob (g)	Weight of 1000 grain / plot (g)	Grain yield (t/ha)	Total Runoff (mm)	Soil Loss (t/ha/yr)
(T1) Bare Fallow	-	-	-	-	-	-	-	-	-	127.02	13.90
(T2) 4 t/ha Mulch + Maize	37.43	312.5	166.0	719.0	232.8	746.0	128.4	288.3	2.39	6.54	0.12
(T3) 8 t/ha Mulch + Maize	40.80	397.3	176.7	774.0	253.4	811.0	154.0	304.2	3.06	1.40	0.00
(T4) Maize + Cowpea	35.12	285.3	166.2	739.0	251.3	760.0	114.8	267.4	2.06	14.00	0.49
(T5) Maize	34.58	308.2	145.0	719.0	212.2	650.0	93.6	241.3	1.57	48.43	1.83
LSD (P<0.05)	5.491	65.28	27.27	NS	20.55	94.9	10.87	12.66	0.314	2.864	2.913

Relationships between Grain Yield of Maize and Erosion Parameters

Correlation between grain yield of maize and runoff, and soil loss showed high significant negative correlation ($p<0.01$) (Table 6). These relationships indicated that the grain yield of maize decreased with increase in runoff and soil loss (and vice versa) with good negative correlation (Table 6). The high correlation coefficient indicate that the improvements observed in the reduction/control of runoff and soil loss as a result of the use of cover management practices contributed to the higher grain yield obtained under mulched and legume amended plots relative to the unmulched maize plot. These results are in agreement with those of Mandal *et al*. (2012); Khurshid *et al*. (2006); Mbah and Nenji, (2011) and Ngome *et al*. (2011) who obtained more grain yield of maize when mulch and legume cover was tested in their various studies. In Kentucky, corn yield reduction of 1.25 t/ha has been reported due to moderate erosion (Mbagwu *et al*., 1984).

Table 6 Correlation Coefficient (r) and p-values between Grain Yield of Maize and Runoff and Soil Loss.

Relationships	Corr. Coeff. (r)	p-values
2015		
Grain yield vs Runoff	- 0.976*	0.004
Grain yield vs Soil Loss	- 0.959**	0.010
2016		
Grain yield vs Runoff	- 0.971**	0.006
Grain yield vs Soil Loss	- 0.924*	0.025

CONCLUSION

The present study quantified the variation in runoff, soil loss, soil nutrients, and growth and yield parameters of maize from an agricultural field under natural rainfall conditions for two cropping seasons. The cover management practices greatly improved soil properties and reduced runoff and soil loss as well as nutrient losses which their values were lower for good canopy coverage. The lowest values of runoff and soil loss, higher soil properties and yields of maize were obtained under 8 t/ha mulched maize management.

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