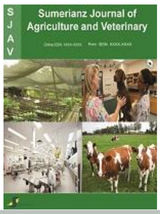
Sumerianz Journal of Agriculture and Veterinary, 2018, Vol. 1, No. 2, pp. 59-63
ISSN(e): 2617-3077, ISSN(p): 2617-3131
Website: https://www.sumerianz.com



Original Article Open Access

Effect of Soil Conservation Practices on Soil Chemical Properties and Growth of Maize in Makurdi, Southern Guinea Savanna Zone of Nigeria

Ali A.*
Department of Soil Science, College of Agronomy, University of Agriculture Makurdi, Nigeria

Agber P. I.
Department of Soil Science, College of Agronomy, University of Agriculture Makurdi, Nigeria

Adekeye A. S.
Department of Soil Science, College of Agronomy, University of Agriculture Makurdi, Nigeria

Abstract

This research was conducted at the Teaching and Research Farm of the University of Agriculture, Makurdi during 2013 and 2014 cropping seasons to assess the potentials of selected soil conservational practices on soil fertility and yield of maize. The experiment consisted of twelve treatments namely: zero tillage + soybean, zero tillage + cowpea, zero tillage + mulch, zero tillage + maize-only, surface-hoeing + soybean, surface-hoeing + cowpea, surface-hoeing +mulch, surface-hoeing + maize-only, manual ridging + soybean, manual ridging + cowpea, manual Ridging + mulch and manual Ridging + maize-only which were laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Composite soil samples were taken before cultivation and after harvest for physical and chemical soil properties determinations. Plant height, number of leaves, leaf area and seed yield were taken. Data collected were analysed using ANOVA and the significant means were separated using F-LSD. From the study it was observed that tillage and agronomic practices significantly affects soil chemical and physical properties, growth and yield of maize. Manual ridging and surface hoeing enhanced better crop growth and maize seed yield compared to zero tillage practice. Surface hoeing + Soybean produced the highest yield followed by manual ridging + soybean and surface hoeing + cowpea, with improved soil nutrient content. Zero tillage treated plots and surface hoeing +Mulch plot had the least values of maize plant height, number of leaves, leaf area and yield. For sustainable maize production, surface-hoeing and manual ridging tillage methods are hereby recommended. Soybean or cowpea should be inter-cropped with maize, the combination will ensure maintenance of soil fertility and increased yield of maize.
Keywords: Maize; Conservation practices; Makurdi; Tillage; Mulch; Cowpea.

1. Introduction

Soil is a key natural resource. Its productivity is the integrated effect of management that determines crop yield and sustainability [1]. The suitability of a soil for sustaining plant growth and biological activity is a function of its physical and chemical properties [2].

Conservation agriculture, defined as minimal soil disturbance (no - till) and permanent soil cover (mulch) combined with rotations was found to be more sustainable systems for the future than the conventional practices because conservation agriculture can recover soil functioning through improving water infiltration, reducing erosion, increasing soil organic matter content and improving soil surface aggregates [3].

A major staple crop grown widely in the Sub-Humid Guinea Savanna Zone of Nigeria is maize; its cultivation and utilization have increased due to greater demands for consumption and industrial purposes. Hence, more land is being opened up yearly to sustain increase demands. Poor choice of implements and soil management practices, inappropriate tillage systems, and seed bed types have identified as major constraints to maize crop production in the savanna agro-ecological zones of Nigeria [4]. Fertilization, irrigation, as well as modification of the soil nutrients optimize maize yield [4].

The objective of this study is to assess the effect of various soil conservation techniques on soil chemical properties, growth and seed yield of maize in Makurdi, Nigeria.

2. Materials and Methods

2.1. Experimental Site

The experiments were carried out at the Teaching and Research Farm of University of Agriculture, Makurdi, Benue state of Nigeria; during 2013 and 2014 cropping seasons. The site is located on Latitude 7^0 41^1N and Longitude 8^0 37^1E at an elevation of 97 m above mean sea level on a slope of 4%. The site has a mean annual rainfall of 1,250mm and mean temperature of 28^0C.The dominant vegetation at the site include guinea grass (*Panicum maximum*), gamba grass (*Andropogongayanus*) and elephant grass (*Pennisetumpurpurerum*). The site used for the experiment was fallowed for about 4 years.

*Corresponding Author

2.2. Experimental Treatments and Design

The experiment consist of twelve treatments, namely: Zero tillage + cowpea (ZT + CP), zero tillage + soybean (ZT + SBN), zero tillage + Mulch (ZT + M), Surface – hoeing + Soybean (SH + SBN), surface- hoeing + cowpea (SH+CP), surface - hoeing + mulch (SH + M), manual ridging + Cowpea (MR + CP), manual ridging + soybean (MR + SBN), manual ridging + mulch (MR + M), zero tillage + maize only, surface – hoeing + maize only, manual ridging + maize only. The treatments were laid out in a Randomized Complete Block Design (RCBD) and replicated three times. Individual plots have a dimension of 4m x 4m with an alley of 1m between blocks and 0.5m between plots giving a total land area of 756m$^{2..,}$

2.3. Land Preparation and Planting

The vegetation of the experimental field was manually cleared. No primary or secondary tillage operation was carried out on the zero tillage plots (ZT). Soil disturbance was limited to the manual clearing and opening of slots for seed placement during planting. Weed control was done by handpicking. The surface hoeing (SH) plots were done manually by turning the top 10cm of the soil with hoe while the manual ridging (MR) plots were ridged manually. Weed control for each of them was done by hoeing. Maize variety obtained from University of Agriculture Makurdi (QPM variety), was planted. The seeds were sown at three (3) seeds per hole at a spacing of 75cm apart and 50cm within rows and later thinned to two (2) plants per stand at two weeks after planting to give a plant density of 53,333 per ha. A week after maize germination, cowpea (UAM 09 – 1046 – 6 – 2 variety) and soybean (TGX – 1448 – 2E variety) were planted in their respective plots. Two (2) seeds of cowpea were planted between two maize stands, while soybean was drilled between two maize stands. Mulching materials were applied (4 t/ha,) [5] unto the appropriate plots at one week after maize germination.

2.4. Fertilizer Application

Maize received a uniform fertilizer application of 200kg/ha of NPK 15:15:15 in a split application. The first application was done two (2) weeks after planting, while the second application was done at six (6) weeks after planting.

2.5. Data Collection

Soil samples were collected from 0 – 15cm depth, using soil auger at the beginning of the experiment and after crop harvest, soil samples were taken for physical and chemical analysis. The Bouyoucos [6] was used to determine the particle size distribution of the samples. The Soil pH in water (1:1) was determined using the pH meter. The wet oxidation method of Walkely and Black [7] was used to determine the organic carbon content of the samples. Total nitrogen was determined by the macro-kjeldahl digestion method [8]. The CEC was determined by neutral, 1N ammonium acetate method. Phosphorus was determined according the method outlined by Bray and Kurtz [9]. The exchangeable cations were determined by atomic absorption spectrophotometer. Base Saturation was determined by dividing the sum of exchangeable bases by CEC and multiplying by 100.

At two weeks after germination of maize, leaf area index, plant height and number of branches of five tagged plants in each plot were taken. This was repeated at 4, 6, 8, 10 and 12 WAP. The three inner rows of each plot were harvested for seed yield determination. All data collected were subjected to analysis of variance using ANOVA and the significant means were separated using F-LSD.

3. Results and Discussion

3.1. Soil Properties at the Start of the Experiment

Table 1 shows the results of the laboratory analysis of soil physical and chemical properties of the study area at the start of the experiment in 2013. The soil is loamy-sand and slightly acidic. It is low in total nitrogen, available phosphorus, soil organic matter and high bulk density. The exchangeable calcium, magnesium and potassium as well as the cation exchange capacity (CEC) were low. The insufficient levels of the major nutrients in the soil showed that it would not be able to meet the nutrional needs of the maize plants. Application of soil conservation practices are expected to improve the soil nutrional status and hence reduce its bulk density.

Table-1. Soil physical and chemical status in 2013 before treatment application

Parameters	Value
Bulk density (g/cm^3)	1.46
Sand (%)	77.6
Silt (%)	13.2
Clay (%)	9.2
Textural class	loamy-sand
pH in water	5.93
Porosity (%)	45
Organic carbon (%)	0.92
Organic matter (%)	1.59
Total Nitrogen (%)	0.06
Available phosphorus (ppm)	2.0
Exchangeable potassium (Cmol/Kg)	0.28
Exchangeable calcium (Cmol/Kg)	3.60
Exchangeable magnesium (Cmol/Kg)	1.52
Exchangeable sodium (Cmol/Kg)	0.55
Cation Exchange capacity (Cmol/Kg)	6.80
Base saturation (%)	87.5

3.2. Effect of Tillage and Agronomic Conservation Practices on Soil Chemical Properties

The results of tillage and soil conservation practices on soil chemical properties are presented in Tables 2 and 3 for 2013 and 2014 respectively. The effect of tillage and conservation practices show significant ($p< 0.05$) difference across all the chemical properties assessed for both 2013 and 2014 cropping seasons. The changes in pH level might be due to agronomic soil conservation effects of soybeans, cowpea and mulch materials in their respective plots. These crops and mulching materials might have decomposed and protected the soil surface from leaching of the plant nutrients. Also, the decomposition of the fallen leaves from soybean, cowpea and mulching materials might have released some plant nutrients which must have raised the pH thereby reducing soil acidity. Harpstead [10] stated that guinea savanna soils were less leached and hence have moderate to near neutral acid condition. The highest pH value from surface hoeing plot might be due to reduced tillage operation. The improvement in the organic matter content by the treatments is an indication of the enrichment potential of the crop biomass. Also the highest values of organic recorded from the surface hoeing plot might be as a result of minimum tillage carried out. This implies that tillage and agronomic soil conservation practices had positive effects on the soil organic matter content.

The plots treated with leguminous crops gave higher nitrogen contents than others. The nitrogen enrichment of the soil by legumes had been observed by some researchers. Peoples, *et al.* [11] attributed building soil nitrogen after legumes to the sparing of soil nitrogen by legumes due to their reliance on atmospheric nitrogen fixation and the release of nitrogen from the mineralization of their residues left on the field after harvest. Brophy and Heichel [12] also reported the release of N_2 from the breakdown of roots and nodules after the legume harvest. The nitrogen increment in the mulch treated plots could be as a result of decomposition of mulching materials through the action of bacteria and other soil organisms that feeds on the organic material and mineralize N. Very low nitrogen content of the sole maize plots could be due to lack of leguminous plants or organic materials which should have decomposed and raised the nitrogen level of the plots. The nitrogen uptake of growing maize crops might have also contributed to the very low level of nitrogen on these sole maize plots. The study showed that tillage and agronomic conservation practices influenced soil nitrogen content.

CEC values were also observed to be highest in the zero tillage treatment compared to other tillage treatments. This might be due to the low porosity and high bulk density and hence facilitated low water infiltration and low leaching of ions on these treated plots. The CEC values at the end of 2014 cropping season in most of the treated plots were seen to be higher than that of 2013 which might be due to the residual effects of nutrients from 2013 cropping season. The values of CEC from each treatment were proportional to the quantity of organic matter from each plot. Lal [4] observed that the higher the organic matter content of the soil, the higher the CEC. Lombin, *et al.* [13] also reported that organic matter content was a major contributor to the CEC of the soil. It was generally observed that zero tillage plots gave the highest values of CEC and exchangeable bases compared to other tillage methods

Table-2. Soil chemical properties as affected by tillage and soil conservation practices (2013)

Treatment	pH	OC (%)	OM (%)	N (%)	P (ppm)	K	Ca	Mg (Cmol/Kg)	Na	CEC	BS (%)
Zero tillage + soybean	6.00	0.88	1.52	0.08	1.75	0.26	3.70	1.46	0.50	6.30	93.90
Zero tillage + cowpea	6.55	0.68	1.17	0.10	2.75	0.26	3.51	1.40	0.55	6.20	93.20
Zero tillage + mulch	6.05	1.38	2.39	0.08	2.50	0.20	3.16	1.42	0.40	5.80	89.50
Zero tillage + Maize Only	6.02	0.94	1.62	0.08	2.25	0.22	2.57	1.33	0.42	5.30	85.70
surface hoeing + soybean	6.01	1.48	2.55	0.08	2.75	0.21	2.32	1.36	0.40	6.20	85.80
surface hoeing + cowpea	6.60	0.48	0.83	0.07	1.75	0.23	3.12	1.39	0.45	6.10	86.70
surface hoeing + mulch	6.10	1.40	2.41	0.07	2.75	0.26	2.93	1.41	0.60	6.00	86.70
surface hoeing + Maize Only	6.46	1.24	2.14	0.08	2.00	0.25	2.97	1.46	0.64	6.00	88.70
manual ridging + soybean	6.31	1.52	2.62	0.07	2.25	0.23	2.90	1.45	0.51	5.60	90.90
manual ridging + cowpea	6.59	1.68	2.90	0.08	2.00	0.24	2.83	1.30	0.40	5.50	86.70
manual ridging + mulch	6.57	1.22	2.10	0.07	2.25	0.24	3.51	1.49	0.47	6.40	89.20
manual ridging + Maize only	6.48	0.86	1.48	0.07	1.50	0.25	3.45	1.37	0.43	5.80	94.80
LSD 0.05	0.17	0.27	0.17	0.04	0.16	0.15	0.36	0.16	0.17	0.17	0.15

Table-3. Soil chemical properties as affected by tillage and soil conservation practices (2014)

Treatment	pH	OC (%)	OM (%)	N (%)	P (ppm)	K	Ca	Mg (Cmol/Kg)	Na	CEC	BS (%)
Zero tillage + soybean	6.15	1.58	2.72	0.10	2.00	0.28	4.06	1.65	0.44	7.10	90.6
Zero tillage + cowpea	6.22	1.34	2.31	0.11	3.25	0.27	3.85	1.44	0.48	6.65	90.8
Zero tillage + mulch	6.50	0.74	1.28	0.10	2.75	0.26	3.42	1.50	0.55	6.45	88.8
Zero tillage + Maize Only	6.15	0.80	1.38	0.10	2.75	0.22	3.01	1.55	0.50	6.25	84.5
surface hoeing + soybean	6.10	1.58	2.72	0.11	3.00	0.22	2.84	1.36	0.50	6.65	87.9
surface hoeing + cowpea	5.92	1.82	3.14	0.10	2.50	0.26	3.56	1.50	0.60	6.45	91.8
surface hoeing + mulch	5.98	0.58	1.00	0.08	2.75	0.25	3.41	1.44	0.55	6.30	89.7
surface hoeing + Maize Only	5.83	1.20	2.07	0.10	2.75	0.27	3.38	1.55	0.55	6.50	88.5
manual ridging + soybean	6.00	1.00	1.72	0.10	3.25	0.26	3.45	1.44	0.50	6.45	87.6
manual ridging + cowpea	6.35	1.16	2.00	0.11	2.75	0.25	3.20	1.48	0.55	6.15	89.1
manual ridging + mulch	6.00	0.88	1.52	0.10	2.75	0.28	3.80	1.41	0.66	6.10	95.9
manual ridging + Maize only	5.82	1.38	2.38	0.08	2.50	0.24	3.07	1.28	0.50	5.90	86.3
LSD 0.05	0.17	0.16	0.17	0.07	0.17	0.17	0.17	0.20	0.17	0.16	0.82

3.3. Effect of Tillage and Agronomic Soil Conservation Practices on Maize Growth and Yield

There were significant increases in plant height, number of leaves, leaf area and yield of maize among the treated plots in 2013 and 2014 cropping seasons. it was observed that surface hoeing + soybean treated plots showed highest level of plant height, number of leaves, leaf area and yield compared with other treated plots. This was followed by manual ridging + soybean, surface hoeing +cowpea, manual ridging + soybean. Zero tillage treated plots had the least values of maize height, number of leaves, leaf area and yield (Tables 4, 5 and 6).The lower bulk density and higher porosity values observed in surface hoeing and manual ridging plots of soybean and cowpea might have facilitated good root penetration, water infiltration which might have resulted to increased nutrient uptake of maize in those plots and eventually leads to better performance compared with zero tillage plots. Agbede and Ojeniyi [14] reported that heaping and ridging raised total porosity and reduced soil bulk density when compared with zero tillage. Findings of this work is therefore consistent with that of Ojeniyi [15] who compared the effects of manual tillage with hoe and no-tillage on nutrient availability and maize yield and found that tillage with hoe increased maize yield significantly.

The biomass of soybean and cowpea produced during the first cropping season in 2013 might have decomposed and increased the organic matter content of the soil which the crops made use of in 2014. That might have facilitated high values of maize yield parameters which later transformed to higher yields in surface hoeing and manual ridging plots. Moreover, soybeans and cowpea are leguminous crops which have ability to enrich the soil with nitrogen through the effort of nitrogen fixing bacteria living in their root nodules. This might have also led to the outstanding performance of surface hoeing plots of soybeans and cowpea in the area of plant height, number of leaves, leaf area which later transformed to higher yield, compared to other treatment plots where nitrogen fixation process may not have taken place.

Table-4. Effect of tillage and soil conservation practice on the growth parameters of maize (2013)

Treatment	Plant Height (Cm)			Number Of Leaf			Leaf Area (Cm^2)		
	8 WKS	10 WKS	12 WKS	8 WKS	10 WKS	12 WKS	8 WKS	10 WKS	12 WKS
Zero tillage + Soybean	156.5	175.3	194.1	13.13	13.47	13.27	630.0	642.0	664.0
Zero tillage +cowpea	136.9	176.7	181.0	11.47	11.93	12.20	459.0	542.0	565.0
Zero tillage + mulch	144.3	172.7	173.0	12.20	13.20	12.60	502.7	578.0	517.0
Zero tillage + sole- maize	128.7	158.3	163.7	11.73	12.27	12.73	546.0	547.0	548.0
Surface hoeing + soybean	194.1	208.0	208.3	13.53	14.57	14.80	648.0	675.0T	703.0
Surface hoeing + cowpea	164.5	194.8	195.1	12.53	13.47	12.73	602.0	648.0	672.0
Surface hoeing +mulch	148.5	163.1	172.1	12.53	13.13	13.27	541.0	522.0	541.0
Surface hoeing + sole-maize	131.0	181.7	183.0	12.00	13.00	13.00	533.0	580.0	557.0
Manual ridging + soybean	162.1	193.6	198.6	12.87	13.40	13.85	645.0	631.0	703.0
Manual ridging + cowpea	136.2	181.7	192.5	12.00	12.80	13.07	544.0	561.0	593.0
Manual ridging + mulch	138.3	176.1	177.9	12.47	13.33	13.40	420.0	546.0	561.0
Manual ridging + sole-maize	155.3	178.8	182.1	12.93	14.07	13.67	515.4	568.0	560.0
LSD 0.05	0.17	0.17	0.17	0.17	0.17	0.16	39.71	0.17	0.16

Table-5. Effect of tillage and soil conservation practices on maize growth parameters (2014)

Treatment	Plant height(cm)						Number of leaf						Leaf area (cm^2)					
	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP	2 WAP	4 WAP	6 WAP	8 WAP	10 WAP	12 WAP
Zero tillage + soybean	14.93	39.9	71.3	151.5	170.3	189.1	4.80	7.00	10.33	11.13	11.47	11.27	27.3	151.6	388.0	620.0	632.0	654.0
Zero tillage + cowpea	14.00	38.3	60.5	131.9	171.7	176.0	4.07	7.00	9.13	9.47	9.93	10.20	21.3	112.8	190.0	449.0	532.0	555.0
Zero tillage +mulch	14.47	33.9	71.8	139.3	167.7	168.0	4.83	6.60	9.07	10.20	11.20	10.60	25.6	136.2	346.0	526.0	568.0	507.0
Zero tillage + Maize Only	14.07	36.7	68.6	123.7	153.3	158.7	4.47	6.87	9.60	9.73	10.27	10.73	22.6	127.9	314.0	536.0	537.0	538.0
surface hoeing + soybean	16.53	57.1	103.1	189.1	203.0	203.3	4.93	8.60	11.47	11.53	12.53	12.80	39.1	277.4	560.0	638.0	665.0	693.0
surface hoeing + cowpea	14.67	37.1	72.3	159.5	189.8	190.1	4.33	7.00	10.07	10.53	11.47	10.73	27.6	150.9	407.0	592.0	638.0	662.0
surface hoeing + mulch	14.07	37.9	72.9	143.8	158.1	167.1	4.40	6.53	9.13	10.53	11.27	11.13	23.0	145.3	389.0	531.0	512.0	531.0
Surface hoeing + Maize Only	14.47	37.1	66.3	126.0	176.7	178.0	4.40	6.60	9.00	10.00	11.00	11.00	20.1	131.9	332.0	523.0	570.0	547.0
manual ridging + soybean	17.40	44.6	85.4	157.1	188.6	196.5	4.73	7.73	10.87	10.87	11.40	11.87	34.9	211.0	446.0	635.0	621.0	693.0
manual ridging + cowpea	14.27	37.1	65.1	131.2	176.7	187.5	4.47	7.07	9.20	10.00	10.80	11.07	24.8	131.9	328.0	534.0	551.0	583.0
manual ridging + mulch	13.00	37.1	73.6	133.3	171.1	172.9	4.20	6.93	9.20	10.47	11.33	11.40	22.6	129.3	360.0	410.0	536.0	551.0
manual ridging + Maize only	14.67	42.0	88.9	150.3	173.8	177.1	4.53	7.80	10.73	10.93	12.07	11.67	29.8	193.1	473.0	572.0	558.0	550.0
LSD(0.05)	NS	11.64	16.87	27.61	21.56	20.31	NS	1.01	1.51	NS	1.07	0.88	10.53	73.09	146.0	NS	NS	119.1

Key: WAP = weeks after planting

Table- 6. Effect of tillage and conservation practices on the yield and yield parameters of maize (2013 and 2014)

2013		**2014**
Treatment	Grain Yield (t/ha)	Grain yield (t/ha)
Zero tillage + Soybean	1.46	1.51
Zero tillage +cowpea	1.60	1.65
Zero tillage + mulch	1.51	1.56
Zero tillage + Maize Only	1.52	1.57
Surface hoeing + soybean	2.76	2.81
Surface hoeing + cowpea	2.20	2.25
Surface hoeing +mulch	1.37	1.42
Surface hoeing+ maize only	1.48	1.53
Manual ridging + soybean	2.47	2.52
Manual ridging + cowpea	1.70	1.75
Manual ridging + mulch	1.68	1.73
Manual ridging+maize only	1.51	1.56
LSD 0.05	0.02	0.17

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