

EVALUATION OF TILLAGE AND LAND MANAGEMENT PRACTICES IN SOUTHERN NIGERIA AS THEY AFFECT SOIL PROPERTIES AND WATER CONSERVATION

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Abstract

Agricultural production in Nigeria is generally rural based and presently suffers severe limitation arising from inappropriate land management practices. The slash and burn and clean tillage practices among the local farmers exposes the soil to accelerated soil erosion and rapid loss in productivity. To generate methods for conservation tillage options among the local farmers, a study was conducted to investigate the effects of different land management practices on soil erosion, soil physical properties and crop yield in the predominantly sandy loam soil in southeastern Nigeria. The study was carried out on runoff plots under different management practices in the University of Nigeria agricultural farm complex. The management practices included manually tilled and zero tilled treatments under groundnut and cocoyam as test crops. Other treatments included bare, grass and legume fallows. The study was carried out for two successive cropping seasons (1984 and 1985). Result showed that the average soil losses under the management practices were 0kg m⁻² under the legume/grass and zero tilled plots and 3.2 and 2.4kg m⁻² for bare and tilled plots respectively. The highest organic matter (OM) content of 1.05 %OM, was obtained under the grass and legume treatments while the least average value of 0.47% was recorded under the bare fallow treatment. Tillage practice had no significant effect ($p < 0.05$) on % soil OM and the measured soil physical properties namely - bulk density, air -filled porosity and hydraulic conductivity. From the stand point of energy input for grain and tuber crop production, conservation tillage has great prospects.

Key words : Nigeria, Management practice, Tillage, Sandy loam soil, Soil loss, Soil properties

INTRODUCTION

Tillage practice in the rural communities of southeastern Nigeria are more or less traditionally inherited cultures rather than products of research findings. The shifting cultivation cultures which characterised the agricultural practice of past decades were able to maintain the productivity and balance of the ecosystem. With very rapid population increase and the accompanying increasing pressure on the land, the practice of shifting cultivation is fast giving way to land rotation with shorter fallows and in many instances continuous cultivation. One of the greatest handicaps of the traditional tillage systems under continuous culture is the absence of a post- tillage management programme - a situation which according to FAO (1994) leads to irreversible land degradation.

Although several studies aimed at evolving post-tillage management practices have been conducted (Aina; et al 1997; Lal, et al 1978; Obi, 1982; Nweke, 1991), the adoption rate of the findings and recommendations is very low. In the predominantly acid sands of southeastern Nigeria where the major arable crops are tubers, roots and cereals, conservation tillage (zero-tillage) has been shown to compare favourably with the manual flat tillage and mounds (local conventional tillage) commonly practised in the area. Yield parameters of cassava which included roots, storage root number and dry root weight (t ha⁻¹) averaged over three years were found non-significant among four tillage treatments comprising two conservation tillage systems (ridge and zero-tillage) and two conventional tillage systems (flat-tilled and mounds (Okigbo,

1979). In terms of soil properties and erosion control, surface runoff and soil loss in a typical African rainfall event is frequently 10 - 25% and <6 to >250 t ha⁻¹ respectively (Fowler et al 2000). Several authors have acknowledged the positive influence of zero tillage and other cultural methods in the improvement of soil physico-chemical properties and erosion control (Nnabude 1986, Obi and Nnabude,1988 and 1990).

In spite of these efforts, conservation tillage and other recommended post-tillage management practices have not been widely tested under different soil types, agro-ecological regions and crop types. This presentation aims at highlighting the prospects of locally adapted conservation tillage and other cultured practices for sustained agricultural production in Southeastern Nigeria.

MATERIALS AND METHODS

Local Environment

The experiment was conducted at the university of Nigeria farm (06o 52 N and 07o 24 E) on runoff plots established in 1973. The site has been under continuous cover (*Panicum maximum*) prior to 1973 when the runoff plots were established. The annual rainfall for the area is about 1700mm. The distribution is bimodal with definite wet (April- October) and dry (November- March) seasons.

The runoff plots each 20 x 3m were established on a 5% slope. The soil of the area is deep porous and red in colour and derived from sandy deposits of false bedded sandstones and coastal plain sands. It is classified as a Typic Paleustult (USDA Soil Taxonomy, 1975) and Dystric Nitosol (FAO-UNESCO,1974).

Land Use Characteristics

The experiment was carried out in the 1984 and 1985 cropping seasons with the following treatment and land use systems

	Treatments		Land use system for the past eleven years
i.	Bare fallow	(B)	continuous bare fallow
ii.	<i>Panicum maximum</i>	(G)	continuous cover
iii.	<i>Centrosema pubesens</i>	(L)	continuous cover
iv.	Groundnut- tilled plot	(GT)	continuous maize without mulch
v.	Groundnut (zero-tillage + mulch)	(GU)	continuous maize + mulch
vi.	Cocoyam(tilled plots)	(CT)	continuous maize + mulch
viii.	Cocoyam (zero-tillage + mulch)	(CU)	continuous maize and sweet potato rotation.

The no-tillage treatments (GU and CU) involved manual scrapping and removal of weeds. Thereafter, small holes were opened up and seeds were planted in these holes. Mulch was applied at the rate of 3t ha⁻¹ annually.

Runoff And Soil Loss Estimation

Rainfall data within the period of study were obtained from the meteorological station located near the university farm complex. At the lower end of each plot was a collecting tank measuring 65 litres in which both the runoff and eroded soil were collected. At the end of each erosive rain, the water in the collecting tank was agitated and three samples of one-litre size were taken, filtered and the residue dried to constant weight and weighed. Soil loss and total runoff were estimated according to the procedure described by (Jackson, 1964).

Laboratory Method

The Walkley-Black method as described by Allison (1965) was used in determining soil organic carbon. Undisturbed core samples were used to determine the bulk density, total porosity and pore size distribution.

The bulk density was determined using the core method. Porosity and pore size distribution were computed using the water retention data obtained with core samples.

The saturated hydraulic conductivity was determined using the modified Klute (1965) method. Cores of dimensions 7.6 x 7.6cm (height x diameter) were used. A pocket penetrometer was used to determine the penetrometer resistance of the soil surface.

RESULTS

1. Texture and organic matter content

The soil texture and organic matter content before the two-season experiment are presented in Table 1. The experimental site is dominated by the sand fraction. This could be attributed to the dominant influence of the parent material which in this case is false-bedded sandstone (Jungerius, 1964).

Organic matter content was highest under the *Centrosema pubescens* and *Panicum maximum* with values of 3.0 and 2.12 percent respectively. The least average value was obtained under the bare fallow treatments.

Table 1: Texture and organic matter content of the surface (0 - 10cm) soil at the start of the experiment in 1984

Management practice	Sand 2.0 - 0.02 mm (%)	Silt 0.02 - 0.002 mm (%)	Clay <0.002 mm (%)	Organic matter (%)
Bare fallow (B)	79	5	16	0.47
<i>Centrosema pubescens</i> (L)	80	5	15	3.00
<i>Panicum maximum</i> (G)	76	7	17	2.12
Groundnut, tilled (GT)	83	5	12	0.81
Groundnut, no tillage (GU)	76	5	19	0.59
Cocoyam, tilled (CT)	79	4	17	0.93
Cocoyam, no tillage (CU)	80	4	16	1.05

Table 2 shows that marginal increase in organic matter was obtained relative to the bare treatments and the tilled plots. On the other hand, thirteen years of permanent cover using *Panicum* and *Centrosema* brought about accumulation of soil organic matter. Continuous cultivation might have contributed to the depletion of organic matter in the tilled plots.

Table 2: Percent Organic matter content for the surface soil (0 - 10cm depth)

Management practice	Before cultivation	Percent Organic Matter		Mean (1984/85)
		1984	1985	
Bare fallow (B)	0.47	0.52	0.72	0.62
<i>Centrosema pubescens</i> (L)	3.0	2.64	3.36	3.00
<i>Panicum maximum</i> (G)	2.12	2.48	3.36	2.92
Groundnut, tilled (GT)	0.81	0.88	0.93	0.91
Groundnut, no tillage (GU)	0.59	1.03	1.12	1.08
Cocoyam, tilled (CT)	0.93	0.91	0.95	0.93
Cocoyam, no tillage (CU)	1.05	0.83	1.10	0.97

Bulk density, Total porosity and Air-filled porosity.

Bulk density (Table 3) and air-filled porosity (Table 5) were significantly influenced by the type of management imposed on the land. Legume and grass fallows with bulk densities 1.26 and 1.31 Mg m⁻³ respectively at 0-10cm depth contributed significantly to reduction in soil bulk density. Two years of zero-tillage did not significantly influence the soil bulk density. Also the adverse effects of conventional tillage without mulch compared well with bare fallow the treatment. Significant variation with depth occurred under the grass and legume covers. Again the top soil (0 - 10cm) bulk densities of 1.26 and 1.31 Mg m⁻³ for legume and grass covers respectively were significantly lower than the values at 10-20 and 20-30cm depth of the same treatments.

Table 3 Average bulk density (Mg m⁻³ at three depths under the management practices.

Management Practice	depth(cm)			Mean (A)
	0-10	10-20	20-30	
Bare fallow (B)	1.50	1.50	1.54	1.51
<i>Centrosema pubescens</i> (L)	1.26	1.39	1.49	1.38
<i>Panicum maximum</i> (G)	1.31	1.45	1.47	1.41
Groundnut, tilled (GT)	1.44	1.43	1.48	1.45
Groundnut, no tillage (GU)	1.41	1.49	1.49	1.46
Cocoyam, tilled (CT)	1.44	1.47	1.47	1.46
Cocoyam, no tillage (CU)	1.39	1.45	1.51	1.45
Mean (B)	1.39	1.45	1.49	
LSD (.05)				
Mgt. practice (A)	0.08			
Depth (B)	0.10			
A x B interaction	0.41			

Table 4: Total porosity (%) at three depths under different management practices

Management Practices	Depth(cm)			Mean (A)
	0-10	10-20	20-30	
Bare fallow (B)	42.25	44.00	39.65	41.97
<i>Centrosema pubescens</i> (L)	44.75	43.20	42.40	43.45
<i>Panicum maximum</i> (G)	44.00	44.80	43.75	44.18
Groundnut, tilled (GT)	45.15	43.00	41.10	43.08
Groundnut, no tillage (GU)	42.20	41.85	43.55	42.53
Cocoyam, tilled (CT)	43.50	42.30	41.30	42.37
Cocoyam, no tillage (CU)	74.55	43.10	41.40	43.02
Mean	43.77	43.18	41.88	
LSD(0.05)				
Management practice(A) NS				
Depth (B)	1.74			
A x B interaction	NS			

Total porosity (Table 4) was not significantly influenced by the management practices or the interaction with depth. Average values for the three depths showed that at 20-30 depth, total porosity (41.88 percent) was significantly lower than the top layers. On the other hand, air-filled porosity (Table 5) varied significantly with depth. Legume and grass fallows significantly increased the air-filled porosity

relative to other treatments at all depths. Two years of zero tillage did not improve the air-filled porosity over the conventional tillage and bare fallow treatments.

Hydraulic conductivity:

Table 6 shows the hydraulic conductivity of the soil as influenced by tillage and surface management practices. Variations in hydraulic conductivity was pronounced at the top soil (0 - 10cm) with values ranging from 12.83cm hr⁻¹ in bare fallow to 84.18cm hr⁻¹ under legume cover. Both the legume and grass covers maintained higher values at the lower depths 10-20 and 20-30cm but the variations were not significant. Hydraulic conductivity decreased generally with depth but the magnitude of the variation was highest under the legume and grass fallows. Values under the legume cover at 0 -10cm depth were 5 and 8 times those of 10-20 and 20-30cm depths respectively. This is in contrast to other treatments where values at 0 - 10cm depth were only 1 1/2 times the values at the other depths.

Table 5: Air-filled porosity at three depths under different management practices.

Management practices	Depth (cm)			Mean (A)
	0-10	20-30	30-40	
Bare fallow (B)	11.20	12.95	12.45	12.20
<i>Centrosema pubescens</i> (L)	16.20	17.70	15.20	16.37
<i>Panicum maximum</i> (G)	19.90	17.35	17.35	18.20
Groundnut, tilled (GT)	12.00	16.80	13.65	14.15
Groundnut, no tillage (GU)	12.80	13.90	18.30	15.00
Cocoyam, tilled (CT)	12.70	14.65	14.30	13.88
Cocoyam, no tillage (CU)	12.45	14.40	14.75	13.85
Mean (B)	13.89	15.39	15.14	
LSD (0.05)				
Management Practice (A)	5.30			
Depth (B)		Ns		
A x B interaction		6.7		

Table 6: Hydraulic conductivity K(cm hr⁻¹) at three depths under different management practices

Management Practices	Depth (cm)			Mean
	0 - 10	10 - 20	20 - 30	
Bare fallow (B)	12.83	13.55	8.08	11.49
<i>Centrosema pubescens</i> (L)	84.18	18.71	10.22	37.70
<i>Panicum maximum</i> (G)	61.58	19.30	14.35	31.74
Groundnut, tilled (GT)	26.63	12.65	12.60	17.29
Groundnut, no tillage (GU)	22.34	14.38	16.42	17.23
Cocoyam, tilled (CT)	22.52	14.71	14.45	17.23
Cocoyam, no tillage (CU)	33.07	13.00	10.79	18.95
Mean B	37.59	15.19	12.42	
LSD (0.05)				
Management Practice (A)		26.00		
Depth (B)		18.96		
A x B interaction		40.76		

Penetrometer Resistance

The surface resistance to penetration is shown in Tables 7 and 8 for the 1984 and 1985 cropping seasons respectively.

The bare fallow consistently gave highest values with means of 1.95 and 2.25 kg m⁻² for the 1984 and 1985 seasons respectively. Legume fallow with an average of 0.57kg m⁻² gave the lowest value followed by the grass fallow with a two year average value of 0.92kg m⁻². The lower values obtained under the tilled plots relative to the untilled plots could be a reflection of the moisture condition of the soil which imparts soft consistence to the cultivated loose soil.

Soil and water conservation

The distribution of runoff (mm) and soil loss (kg m⁻²) for the cropping seasons is shown in Tables 9,10,11. In 1984, total runoff expressed as a percentage of total rain fall was highest under the bare fallow (10.1%) followed by the GT (5.8%) and CT (3.4%). Soil loss followed the same trend with 2.8, 1.0 and 0.5kg m⁻² for the respective treatments.

The zero-till + much treatments (GU and CU) resulted in little or no loss in soil and water. Similar results were obtained for 1985 seasons (Table 10). Table 11 showed that both grass and legume fallows gave 100% reduction in soil and water loss relative to the bare fallow. Groudnut under zero tillage + mulch gave substantial reduction in soil and water loss. On the hand the bare fallow and conventional tillage practices seriously pre-disposed the plots to erosional losses.

Table 7: Mean penetrometer resistance (kg m⁻²) at given sampling periods (1984)

Sampling period	Treatments							
	B	L	G	GT	GU	CT	CU	
30/5	0.97	0.32	0.43	0.72	1.27	0.63	1.00	
11/6	1.67	0.42	0.70	0.98	1.00	0.55	0.93	
27/6	1.27	0.61	0.55	1.23	1.32	1.22	0.72	
6/7	1.78	0.42	0.58	1.39	1.58	1.15	1.35	
11/7	2.31	0.55	0.83	1.85	2.15	1.67	1.89	
24/7	2.43	0.55	0.75	1.80	2.00	2.02	2.15	
2/8	2.00	0.60	0.95	1.73	1.90	1.40	1.90	
9/8	2.20	0.70	1.04	1.66	1.85	1.60	1.70	
16/8	2.75	0.54	1.20	2.38	2.00	2.46	2.29	
30/8	2.04	0.71	1.00	1.58	1.58	1.54	1.08	
6/9	1.83	0.45	0.66	1.54	1.25	1.33	1.33	
14/9	2.00	0.75	0.83	1.71	1.83	1.38	1.42	
21/9	2.08	0.58	0.75	1.38	1.71	1.46	1.54	
Mean	1.95	0.56	0.79	1.53	1.65	1.42	1.48	

Table 8: Mean Penetrometer resistance (kg m⁻²) at given sampling periods (1985)

Sampling Period	Treatments							
	B	L	G	GT	GU	CT	CU	
2/4	2.00	0.50	1.00	1.00	1.90	1.30	2.00	
27/4	2.80	0.60	1.10	1.50	2.30	1.60	2.30	
4/5	2.50	0.50	1.30	1.80	2.00	1.30	1.80	
11/5	1.80	0.50	1.00	1.00	1.70	1.00	1.50	
18/5	2.00	0.60	1.40	1.20	1.50	1.00	1.60	
25/5	1.60	0.60	1.00	0.90	1.90	0.60	1.70	

1/6	1.80	0.50	0.70	0.80	1.60	0.70	1.80
8/6	2.50	0.50	1.30	0.90	2.00	1.10	2.20
15/6	2.40	0.90	0.90	1.50	2.00	0.90	1.90
22/6	2.90	0.50	1.20	1.10	2.00	1.00	1.60
29/6	2.20	0.70	1.30	1.30	2.20	1.30	2.80
6/7	2.30	1.00	1.30	1.50	1.80	1.20	1.50
13/7	2.20	0.50	0.80	0.40	1.50	0.90	1.50
20/7	2.20	0.70	1.00	0.90	1.70	1.00	1.50
27/7	2.00	0.50	0.90	1.00	1.50	1.00	1.40
3/8	2.80	0.70	0.80	1.30	1.30	0.80	1.50
Mean	2.25	0.58	1.06	1.13	1.81	1.04	1.79

Table 9: Runoff and soil loss under different land management practices (1984)

Month	Soil loss (kg m ⁻²) Rainfall (mm)	Runoff (mm)					
		B	GT	CT	B	GT	CT
May	124.30	18.51	8.42	2.02	0.6	0.1	0.0
June	202.80	19.46	10.14	1.19	0.3	0.0	0.0
July	372.70	59.40	42.59	13.64	0.9	0.6	0.3
August	291.40	16.04	12.51	12.19	0.4	0.2	0.2
September	256.90	18.70	6.13	8.35	0.4	0.1	0.0
October	126.00	7.25	0.15	9.18	0.2	0.0	0.0
Total	1374.10	139.36	79.94	46.57	2.8	1.0	0.5
* Runoff Ratio (%)	10.14	5.82	3.39				

* (Runoff under given management/ Total rainfall) 100

B = bare fallow, GT = Groundnut on tilled plot; CT = cocoyam on tilled plot

Table 10, Runoff and Soil loss under different land management practices (1985)

Month	Soil loss(Kg m ⁻²) Rainfall (mm)	Runoff (mm)					
		B	GT	CT	B	GT	CT
April	55.00	3.10	0.30	0.30	0.1	0.0	0.0
May	260.00	34.80	22.90	19.0	0.4	0.1	0.2
June	110.00	5.70	1.70	2.30	0.2	0.1	0.2
July	270.00	30.50	6.80	15.40	0.4	0.2	0.3
August	170.00	11.90	4.40	5.60	0.2	0.2	0.1
Sept.	250.00	28.80	10.30	10.50	0.3	0.2	0.2
Total	1115.00	114.80	46.40	53.10	1.6	0.8	1.0
* Runoff ratio (%)	10.30	4.16	4.76				

Table 11: Percentage reduction in soil and runoff under different management practices relative to the bare soil treatment

Year/ Month	Management practices							
	<i>Centrosema pubescens</i> (L)		<i>Panicum maximum</i> (G)		Groundnut tilled (GT)		Groundnut- no - tillage + mulch	
	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss	Runoff	Soil loss
1984								
May	100	100	100	100	63	75	91	96
June	100	100	100	100	52	71	100	100
July	100	100	100	100	26	67	74	93
August	100	100	100	100	32	50	97	98
Sept.	100	100	100	100	75	74	100	100
Oct.	100	100	100	100	80	83	100	100
1985								
April	100	100	100	100	76	85	100	100
May	100	100	100	100	40	38	72	75
June	100	100	100	100	75	83	100	100
July	100	100	100	100	79	82	100	100
AUG.	100	100	100	100	54	54	91	100
Sept.	100	100	100	100	66	70	100	100
Oct.	100	100	100	100	55	87	100	100

Discussion:

The sustainability of any agricultural production system is a function of several variables. Such variables include organic matter and other soil physical properties. The soils of the area are derived from sandy deposits of false-bedded sandstones and coastal plain sands. Investigations by Obi and Asiegbu (1980), showed that in soils of similar parent material, the texture is predominantly sandy regardless of the farming system. Organic matter content under the grass and legumes were 2.02 and 3.00 respectively (Table 2). The build up of organic matter content under the legume and grass cover particularly at 0 - 10cm depth is an indication that a rotational arrangement in combination with conservation tillage practices can reduce organic matter depletion and thereby enhance sustainable agricultural production. On the other hand, the mean organic matter content of 1.08 and 0.97 percent under the GU and CU treatments respectively (Table 2) did not represent a significant addition relative to the bare fallow and tilled plots. The implication is that short term remedial measures cannot compensate for the damages caused by long term poor soil management practices. Continuous cultivation has been proved to be a major factor in organic matter destruction. Table 3 shows that two years of conservation tillage (zero-tillage) did not significantly reduce the bulk density relative to the conventional tillage. Osuji and Babola (1982) obtained similar results for a sandy Alfisol in Southwestern Nigerian. Nevertheless the marginal reduction under the GU (1.41Mg m⁻³) point to the potentials of zero-tillage to ultimately bring a substantial reduction in soil bulk density. Similar prospects exist for the total and air filled porosity both of which are directly related to the bulk density. The higher values obtained for air -filled porosity at the 10cm depth under the legume (16.20%) and grass (19.90%) covers could be associated with the high organic matter content of the soil (Table 2) .

Table 6 showed a significant increase in hydratic conductivity in legume and grass covers over the rest of the treatments. Values at the 0-10cm depth were 84.18 and 61.58 cm hr⁻¹ respectively compared with 22.34

and 33.07cm hr⁻¹ obtained under GU and CU treatments respectively. The high organic matter accumulation with the expected improvement in soil structure in the legume and grass covers as well as the noted difference in air-filled porosity could contribute immensely to the observations. Tillage did not significantly influence hydraulic conductivity. This is consistent with the result of other physical properties obtained under the zero and conventionally tilled plots.

Although two years of zero - tillage (GU and CU) failed to alter significantly the soil physical properties, its impact on soil and water conservation was highly pronounced (Tables 9, 10 and 11). Expectedly, runoff and soil loss were most devastating under the bare fallow treatment. This could be attributed to the impact of the high intensity rainfall and resulting soil surface sealing, crusting and reducing infiltration. With total rainfall of 1374.10mm in the 1984 cropping season, the total runoff under the B, GT and CT treatments were 139.36, 79.94 and 46.57mm representing 10.14, 5.82 and 3.39 percent of the rainfall respectively. The corresponding soil losses were 2.8, 1.0 and 0.5kg m⁻² respectively. Obi (1982) found a mean value of 10% for runoff as a percentage of rainfall in the bare fallow plots of the same soil for two consecutive years and an average soil loss value of 4.5kg m⁻². In the zero tillage + mulch treatments, the mulch effectively checked runoff and soil loss during the cropping season. Similar findings have been reported in earlier research conducted in Nigeria (Obi, 1982; Obi and Nnabude 1990).

Table 10 showed that the result for 1985 were essentially the same. Runoff losses were 114.80, 46.40 and 53.10mm representing 10.30, 4.16 and 4.76 percent of the total rainfall under the B, CT and CT treatments respectively. The corresponding soil losses were 1.6, 0.8 and 1.0 Kg m⁻² respectively. Averaged over the two cropping seasons, the soil losses were 2.2, 0.9 and 0.75kg m⁻² or 22.0, 9.0 and 7.5 t ha⁻¹ under the B, GT and CT treatments respectively. Although the values for GT and CT fall within the tolerance limits of 10 t ha⁻¹ for soil of the area (Obi, 1982), prolonged continuous cropping without cover would lead to drastic loss in productivity.

The percentage reduction in runoff and soil loss relative to the bare fallow is presented in Table 11. The result highlighted the relative impact of mulch and conservation tillage in checking soil and water losses. Much of the sheet and severe gully erosion afflicting the agro-ecological region could be minimized if conservation tillage practices in combination with post - tillage management practices such as mulching is practised.

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