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Effect of crop and soil management practices on soil compatibility in maize and groundnut plots in a Paleustult in Southeastern Nigeria

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Abstract

Frequent occurrences of soil compaction damage resulting from high raindrop impact energy, and from human and animal trafficking during field operations pose a problem to farmers around the tropics. We studied the effect of some crop and soil management practices (manure, mulch, NPK applications, tillage and crop type) on some soil compactibility indices (dry bulk density, cone index, total soil porosity, gravimetric soil water content) in a Typic Paleustult in southeastern Nigeria. The study was carried out for three consecutive planting seasons using two tillage systems and four other soil management practices (poultry droppings + NPK, mulch + NPK, NPK alone and no amendment). These were laid out as split-plot in a RCB design replicated three times and using maize *(Zea mays* L.) and groundnut *(Arachis hypogea)* as test crops. Results indicate that the different soil management techniques adopted influenced dry bulk density, penetration resistance, total soil porosity and gravimetric soil water content at 44 and 66 days after planting (DAP) whereas only gravimetric soil water content was affected at 90 DAP. The dry bulk density of tilled maize and groundnut plots increased significantly ($P < 0.05$) by between 2 and 14% relative to no-till plots at 44 and 66 DAP. In both maize and groundnut plots, dry bulk density decreased significantly ($P < 0.05$) in plots amended with poultry droppings +NPK relative to the control plots by 3–10% at 44 and 66 DAP. Tilled maize and groundnut plots had 37–45% lower ($P < 0.05$) penetration resistance than their corresponding no-till plots at both 44 and 66 DAP. Penetration resistance measurements were lower by 16.5–25% in plots amended with poultry droppings + NPK relative to unamended plots at 44 and 66 DAP. Cumulative (1996, 1997, 1998) data indicate that gravimetric soil water content in maize and groundnut plots generally increased significantly ($P < 0.05$) in no-till plots relative to tilled plots by 18–27% at both 44 and 66 DAP. Plots amended with poultry droppings + NPK had between 24 and 111% increase ($P < 0.05$) in soil gravimetric soil water content at both 44 and 66 DAP. Results are indicative that all soil compactibility indices measured were not affected at 90 DAP except for soil gravimetric soil water content in 1996 and 1998. Results from this work demonstrate that some crop and soil management practices could be used to reduce soil compactibility problems thus increasing productivity of such soils.

Introduction

Soil compaction has been recognized as one of the greatest problems in terms of damage to soil resources around the world (Soane and van Ouwerkerk, 1998). Compaction, hardpans and crusting are three major causes of soil physical degradation (Steiner, 1996). Soil compaction is an increase in dry bulk density caused by external loading, leading to deterioration in root penetration, soil hydraulic conductivity and aeration (Chen, 1999). Gysi (2001) observed that soil compaction has become a problem of worldwide concern, especially under highly mechanized agricultural

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practices where severe structural degradation impedes plant growth. However, in partially mechanized and in unmechanised agricultural systems, inappropriate tillage practices and seedbed types, as well as frequent trafficking by humans and animals that work on the farm often cause soil compaction. Densification of surface soil could also be a result of raindrop impact energy or other natural factors. For example, the intense wetting and drying cycles that these soils are subjected to in this tropical climate create large ‘effective stresses’. In these systems, soil compatibility is influenced by soil organic matter content, soil water content during trafficking, initial dry bulk intensity, soil strength (cone index) and soil texture (Canillas and Salokhe, 2001; Gysi, 2001; Mogaddeghi et al., 2000). Crop and soil management practices impact on mass and energy movement in soils. It is logical that soil and cop management factors like tillage, crop type, incorporation of organic matter and mulching could influence soil compactability. For example, Mogaddeghi et al. (2000) found in central Iran that farmyard manure application at the rate of 50 Mg ha^{-1} increased the soil wetness trafficability range, thus reducing soil compactibility.

This work primarily aims at evaluating the effect of some crop and soil management practices on soil compactibility indices (dry bulk density, cone index, total soil porosity, gravimetric soil water content) on a Paleustult in southeastern Nigeria. The specific objective of this work was to determine the changes in various soil properties, which will help in developing appropriate technologies for remediation and management decisions in soils with compaction problems.

Materials and methods

Soil characterization

This study was carried out for three consecutive planting seasons (1996, 1997, 1998) on the University of Nigeria Teaching and Research Farm at Nsukka, Nigeria (latitude 06°, 52′ N; longitude 07° 24′ E; mean elevation 400 m above sea level) with an average annual rainfall of 1600 mm (Mbagwu, 1991). The soil is deep, porous and red to brownish red, derived from sandy deposits of false-bedded sandstone. It has an isohyperthermic soil temperature regime and is classified as Typic Paleustult (Nwadialor, 1989).

Field methods

A total land area of 64 m × 28.5 m (1824 m^2) was mapped out for the experiment at the Nsukka site. The experiment was carried out on the same plots in the 1996, 1997 and 1998 planting seasons. The field was divided into 3 blocks measuring 20.5 × 28.5 m (584 m^2) each and was demarcated by 1 m wide pathways. Each block was further divided into 8 experimental plots of 3 × 20 m (60 m^2) each with 0.5 m alleys between them.

The experimental design was split-plot on a randomized complete block (RCB) with two tillage treatments on the main plots and eight management practices on the sub-plots.

The tillage techniques were:

-TNO - no tillage
-T30 - 0.3m tillage on raised beds

The crop management practices were:

MF - Maize + NPK fertilizer
MFMA - Maize + Manure + NPK fertilizer
MFMU - Maize + Mulch + NPK fertilizer
MNF - Maize + no application
GF - Groundnut + NPK fertilizer
GFMA - Groundnut + Manure + NPK fertilizer
GFMU - Groundnut + mulch + NPK fertilizer
GNF - Groundnut + no application.

Weeds were manually removed with hand-held hoes in the ‘no till’ plots (TNO) and seed holes were made for planting. In the 0.3 m tilled (T30) plots, conventional tillage equipment (hand-held hoe) was manually used to prepare the soil to the specified depth.

The maize *(Zea mays* L.) variety used was *Oba* super II hybrid variety, whereas the groundnut *(Arachis hypogea)* variety used was the erect type (Virginia Cultivar ‘Nwakara’). Poultry droppings were used as a source of organic manure at a rate of 20 000 kg ha^{-1} (on dry matter basis). Grass mulch was used for the experiment and was applied to the surface at the rate of 3000 kg ha^{-1} (on dry matter basis). Fertilizer (NPK 15:15:15) was applied manually using a band application method at 0.05 m depth and 0.1–0.15 m radius at the rate of 300 kg ha^{-1}.

Maize and groundnut seeds were manually planted at 0.25 × 0.75 m spacing, 0.05 m deep, and two seeds per hole. They were thinned down to one seed per hole, one week after emergence, leaving 320 plants per plot or 53 000 plants ha^{-1}. Lost stands were replaced.

The mulch and organic manure (poultry droppings) were applied on the appropriate plots one week before planting. They were manually spread (by hand) on the surface.

The experimental area was kept relatively weed-free throughout the span of the experiment. This was done at a 3-week interval from planting date to harvest.

Observation and data collection

Six undisturbed soil core samples (for analysis of dry bulk density and total soil porosity) and six auger samples (for determination of gravimetric soil water content) were randomly collected from 0 to 0.1 m depth in each plot for laboratory analyses. The soil core samples, collected using 100 cm^3 cores, were analyzed separately and mean results used whereas the auger samples were mixed and a composite sub sample taken for analysis. Soil surface resistance to penetration measurements were also taken from six locations in each plot using a pocket penetrometer with 0.05 m in diameter 'blunt ended' tip (Model 06:01 from Eijkelkamp Agrisearch Equipment). The resistance to penetration measurement was made to the depth of 0.05 m at 90° angle. Measurements for dry bulk density, total soil porosity, penetration resistance and gravimetric soil water content were made at 44, 66 and 90 DAP (days after planting). Plant height was measured for maize and groundnuts at 44, 66 and 90 DAP whereas grain yield was measured at harvest (120 DAP). In each plot, 20 plants were randomly selected, tagged and sampled. Also the maize and groundnut grains were dried, threshed, weighed and yield data adjusted to 14% moisture content (by weight).

Laboratory methods

A composite soil sample (collected from six locations) from each plot was analyzed in the laboratory for N, P, K, Ca, Mg, Na, pH, organic carbon and CEC. Total nitrogen was determined by the macro Kjeldahl method (Bremmer, 1965). Available P was determined using Bray II method as outlined in Page et al. (1982) and organic carbon by the Walkley and Black method (Nelson and Sommers, 1982). Soil pH in potassium chloride was by the glass electrode pH meter (McLean, 1982). The exchangeable bases were determined by the method of the Association of Official Analytical Chemists (AOAC, 1970). Particle-size distribution was determined by the hydrometer method (Gee and Bauder, 1986). Dry bulk density was determined by the core method (Blake and Hartge, 1986). Total porosity was calculated from the dry bulk density data as the fraction of total volume not occupied by soil assuming a particle density of 2.65 Mg m^{-3}.

Available water capacity was determined using a pressure plate apparatus at 10 kPa (field capacity) and 1500 kPa (PWP- permanent wilting point) (Stolte, 1997).

Table 1. Some properties of the study soil

Sand (% kg^{-1})	65
Silt (% kg^{-1})	11
Clay (% kg^{-1})	24
pH in KC1	4.1
Organic matter (% kg^{-1})	1.2
CEC soil (cmol (+) kg^{-1})	7.7
Calcium (cmol (+) kg^{-1})	2.8
Magnesium (cmol (+) kg^{-1})	1.7
Potassium (cmol (+) kg^{-1})	0.004
Sodium (cmol (+) kg^{-1})	0.32
AWC (m^3 m^{-3})	0.14
Dry bulk density (Mg m^{-3})	1.33

Data analysis

The data collected from the experiments were analyzed using correlation and analysis of variance tests based on the split-plot design in a randomized complete block design (using F-LSD at $P < 0.05$) according to the procedures outlined by Steel and Torrie (1980).

Results and discussion

Soil properties

The soil of the study site is red in color with a shallow A horizon. The structure is granular to massive and the horizon boundaries are diffuse and irregular (Nwadialor, 1989). The lack of mottles indicates that they are well-drained soils. The physicochemical characteristics are presented in Table 1. The detailed physicochemical characteristics of this soil have been discussed earlier by Mbagwu (1992), Igwe et al. (1995) and by Anikwe and Obi (1999).

Table 2. Mean effect of two tillage practices on soil dry bulk density (Mg m^{-3}) in maize and groundnut plots

Days after planting	44			66			90		
Year	1996	1997	1998	1996	1997	1998	1996	1997	1998
Tilled Maize	1.22	1.34	1.27	1.42	1.38	1.43	1.45	1.46	1.45
No-Till Maize	1.39	1 42	1.31	1.47	1.45	1.46	1.52	1.54	1.49
Tilled Groundout	1.20	1.33	1.29	1.41	1.35	1.41	1.44	1.46	1.44
No - Till Groundnut	1.35	1.39	1.32	1.43	1.40	1.47	1.53	1.55	1.49
F-LSD ($P < 0.05$)	0.05	0.03	0.03	0.06	0.04	0 03	NS	NS	NS

NS – Not significant.

Table 3. Mean effect of crop and soil nanagement practices on soil dry bulk densitv (Mg m^{-3}) in maize and groundnut plots

Days after planting	44			66			90		
Year	1996	1997	1998	1996	1997	1998	1996	1997	1998
Management practice									
Maize+NPK	1 33	1.40	1.31	1.45	1.43	1.46	1.49	1.52	1.47
Maize + Manure +NPK	1.25	1 34	1.24	1.42	1.38	1.39	1.50	1.52	1.44
Maize + Mulch + NPK	1.29	1.36	1.30	1.43	1.41	1.43	1.48	1.49	1.46
Maize alone	1.35	1.43	1.34	1.47	1.45	1.49	1.47	1.50	1.49
Groundnut + NPK	1.30	1.32	1.33	1.44	1.38	1.47	1.45	1.46	1.48
Groundnut + Manure + NPK	1.21	1.28	1.26	1.38	1.34	1.39	1.43	1.53	1.44
Groundnut + Mulch + NPK	1.25	1.30	1.28	40	1.37	1.42	1.48	1.50	1.46
Groundnut alone	1.34	1.32	1.35	1.46	1.41	1.48	1.49	1.53	1.48
F - LSD ($P > 0.05$)	0.04	0.032	0.030	0.041	0.039	0.076	NS	NS	NS

NS – Not significant.

Effect of crop and soil management practices on soil dry bulk density (Mg m^{-3}) of maize and groundnut plots

Results of the study show that the different management techniques adopted influenced the soil dry bulk density at 44 and 66 DAP, whereas at 90 DAP there were no significant treatment differences (Tables 2 and 3). Dry bulk density of tilled maize plots increased ($P < 0.05$) by 3 – 14% relative to 'no-till' plots at 44 DAP for the 1996, 199, and 1998 planting seasons. At 66 DAP, dry bulk density increased ($P < 0.05$) by 2–5% for the three seasons, whereas at 90 DAP no significant increase in dry bulk density was found.

In groundnut plots, soil dry bulk density increased ($P < 0.05$) in no-till plots relative to tilled plots by 2 – 13% at 44 DAP for the three seasons, whereas at 66 DAP there was an increase ($P < 0.05$) of 4% for the 1997 and 1998 seasons. No significant increase in dry bulk density was found between the tilled and no-till groundnut plots at 90 DAP.

The results show that there were no significant differences in dry bulk density between corresponding rnaize and groundnut plots (i.e., tilled maize *versus* tilled groundnut and no-tilled maize *versus* no-till groundnut plots) at 44 and 66 DAP. No significant ($P < 0.05$) dry bulk density treatment effect was found between the different plots at 90 DAP. This may be because dry bulk density increases with time after tillage as a result of trafficking during field operations and other natural factors like the alternate wetting and drying cycles that cause large 'effective stresses', in a tropical climate. Dry bulk density is a soil physical parameter used extensively to quantify soil compactness and has a very influential effect on root growth and proliferation which are both 'indicators', of soil productivity (Alvaro et al., 1998). Charrau and Nicou (1971) noted that a 0.1 Mg m^{-3} decrease in dry bulk density had a significant beneficial effect on root development and yield of sorghum and groundnut.

The results showed that the other soil management practices (manure, NPK, mulch, no application) significantly affected the soil dry bulk density of maize and groundnut plots at 44 and 66 DAP, whereas at 90 DAP there were no significant treatment differences (Table 3). In both maize and groundnut plots, the trend in decreasing dry bulk density is manure + NPK < mulch + NPK < NPK alone < control. The result shows that the lowest ($P < 0.05$) soil dry bulk density was recorded in groundnut plots amended with manure + NPK. These plots had soil dry bulk densities of 1.21, 1.28 and 1.26 Mg m^{-3} at 44 DAP and 1.38, 1.34 and 1.39 Mg m^{-3} at 66 DAP for the 1996, 1997 and 1998 planting seasons, respectively. These were higher ($P < 0.05$) than the control (groundnut alone) by 3 – 10% at 44 DAP and by 5 – 6% at 66 DAP, whereas no significant treatment difference in dry bulk density was found at 90 DAP. Similarly, dry bulk density in corresponding maize plots was lower ($P < 0.05$) by 4 – 7% and 7 – 8% relative to the control. The dry bulk density of plots amended with manure + NPK were higher ($P < 0.05$) by 3 – 5% at both 44 and 66 DAP in maize plots relative to groundnut plots except for the 1998 season where there was no significant difference between them. The dry bulk density of other maize plots (Maize + NPK, Maize + mulch + NPK and Maize alone) were statistically comparable to that of corresponding maize plots. Significant differences in soil dry bulk density were not found in both maize and groundnut plots at 90 DAP.

Groundnut plots amended with Manure + NPK had lower ($P < 0.05$) soil dry bulk density than corresponding maize plots at both 44 and 66 DAP for 1996 and 1997 seasons. This suggests that planting groundnut in a particular year will increase soil productivity relative to planting maize by helping to reduce soil dry bulk density. Groundnut plants cover the soil surface and may consequently reduce raindrop impact and degree of erodibility, which are factors that increase soil dry bulk density. Maize is a row crop and does not achieve as much ground cover as groundnut.

Finally, these assertions were further supported by the fact that a significant correlation was achieved between grain yield of groundnut and soil dry bulk density of groundout plots, $r = 0.61$ ($P < 0.036$) at 44 DAP and $r = 0.59$ ($P < 0.045$) at 66 DAP. Similarly, a positive correlation of $r = 0.61$ ($P < 0.037$) at 44 DAP and $r = 0.79$ ($P < 0.002$) at 66 DAP was achieved between seed yield of maize and soil dry bulk density of maize plots (Table 4).

Effect of crop and soil management practices on surface soil resistance to penetration (kg cm^2) in maize and groundnut plots

The surface soil resistance to penetration was affected by the different crop and soil management practices adopted (Tables 5 and 6). Tilled maize plots had 45 and 37% lower ($P < 0.05$) resistance to penetration than no-till maize plots at 44 and 66 DAP, respectively. In groundnut plots, there was a significant decrease of 48% (at 44 DAP) and 41% (at 66 DAP) in surface resistance to penetration in tilled plots when compared to no-till plots (Tables 5 and 6). No statistical treatment difference in surface resistance to penetration was found at 90 DAP in both maize and groundnut plots. This corroborates the work of Ehlers et al. (1983) who found that while root growth was severely limited at a penetration resistance of 3.6 MPa in conventionally tilled soil, the corresponding limit in untilled soil was higher at about 5 MPa. There, the roots avoided resistant barriers by using continuous channels left by earthworms and decayed roots that were not preserved in tilled soil.

Lower measures of resistance to penetration were obtained in plots treated with manure + NPK. In maize plots, a penetration resistance value of 1.15 kg cm^{-2} was obtained in plots amended with manure + NPK. This was 16.5% lower ($P < 0.05$) at 44 DAP and 25% lower ($P < 0.05$) at 66 DAP relative to plots where no applications were made. In groundnut plots, the trend in decreasing surface resistance to penetration was manure +NPK < mulch + NPK < NPK alone < no application. Although Busscher et al. (1998) stated that field variation in water content could mask treatment differences in surface resistance to penetration, cumulative data from this study show that manure + NPK application led to significantly lower ($P < 0.05$) penetration resistance values in maize and groundnut plots. Stelluti et al. (1998) noted that the penetrometer is the most widely used instrument at present for assessing *in situ* soil strength, one of the extrinsic factors affecting plant growth and crop productivity.

Effect of crop and soil management practices on gravimetric soil water content of maize and groundnut plots

The results showed that gravimetric soii water content was affected by the different treatment applications at 44 and 66 DAP in both maize and groundnut plots (Tables 7 and 8). However, no significant treatment

Table 4. Relationship between grain yield (Y) and some independent soil parameters (X) for maize and groundnut

Dependent Parameter (Yield)	Maize		Groundnut	
	Correlation coefficient (r)	P-value	Correlation coefficient (r)	P-value
Dry bulk density (Mg m^{-3}) 44 DAP	–0.61	0.037	–0.61*	0.036
Dry bulk density (Mg m^{-3}) 66 DAP	–0.79**	0.002	–0.59*	0.045
Penetration resistance (kg cm^{-2}) 44 DAP	–0.07^{ns}	0.835	–0.27^{ns}	0.393
Penetration resistance (kg cm^{-2}) 66 DAP	–0.35^{ns}	0.263	–0.39^{ns}	0.208
Gravimetric water content (%kg kg^{-1}) 44 DAP	0.38^{ns}	0.222	0.22^{ns}	0.501
Gravimetric water content (% kg kg^{-1}) 66 DAP	0.45^{ns}	0.136	0.54^{ns}	0 069

* Significant at $P = 0.05$.
** Significant at $P = 0.01$.
ns not significant.

Table 5. Mean effect of two tillage practices on surface soil resistance to penetration (kg cm^{-2})in maize and groundnut plots

Days After Planting	44			66			90		
Year	1996	1997	1998	1996	1997	1998	1996	1997	1998
Tillage Practice									
Tilled Maize	0.76	1.66	0.66	1.74	2.55	0.95	2.8	3.0	1.08
No-Till Maize	1.21	1.93	1.34	2.30	2.95	1.92	3.0	3.2	I.98
Tilled Groundnut	0.65	1.61	0.76	1.71	2.35	O.99	2.8	3.0	1.08
No-Till Groundnut	1.19	1.98	1.3	2.31	2.89	1.91	3.1	3.3	1.98
F- LSD ($P < 0.05$)	0.31	0.22	0.46	0.32	0.26	0.27	NS	NS	NS

NS – Not significant.

Table 6. Mean effect of crop and soil management practices on surface soil resistance to penetration (kg cm^{-2}) in maize and groundnut plots

Days After Planting	44			66			90		
Year	1996	1997	1998	1996	1997	1998	1996	1997	1998
Managment									
Maize + NPK	1.06	1.9	1.01	2.25	2.9	1.61	3.0	3.2	1.7
Maize + Manure + NPK	0.84	1.6	1.01	1.84	2.5	0.97	2.9	2.8	1.02
Maize + Mulch + NPK	1.00	1.8	0.91	1.92	2.7	1.52	2.9	2.9	1.60
Maize alone	1.05	1.9	1.07	2.07	2.9	1.65	3.0	3 0	1.75
Groundnut+NPK	1.00	1.90	1.12	2.13	2.77	1.62	3.0	3.2	1.80
Groundnut + Manure+NPK	0.79	1.40	0.95	1.78	2.36	1.11	2.80	3.05	1.15
Groundnut + Mulch + NPK	0.09	1.70	1.04	1.93	2.55	1.49	2.90	3.14	1.51
Groundnut alone	1.12	2.0	1.15	2.20	2.80	1.58	2.90	3.21	1.65
F- LSD ($P < 0.05$)	0.13	0.22	0.12	0.28	0.31	0.16	NS	NS	NS

NS –Not significant.

difference in gravimetric soil water content was found at 90 DAP. Higher gravimetric soil water content was found in no-till plots relative to tilled plots in both maize and groundnut plots.

Cumulative data (1996, 1997, and 1998) indicate that gravimetric soil water content in maize plots increased ($P < 0.05$) in the no-till plots by 27 and 21% relative to tilled plots at 44 and 66 DAP, respectively, except at 66 DAP in the 1998 season. In plots where groundnut was planted, increases ($P < 0.05$) in gravimetric soil water content of between 18 and 27% were observed in no-till plots relative to tilled plots up to

Table 7. Mean effect of two tillage practices on graviimetric soil water content (kg kg^{-1}) in maize and groundnut plots

Days After Planting	44			66			90		
Year	1996	1997	1998	1996	1997	1998	1996	1997	1998
Tillage Practices									
Tilled Maize	22.2	18.2	18.6	26.7	16.0	31.9	34.3	16.2	28.8
No-Till Maize	34.6	23.2	22.9	40.3	20.4	33.6	37 2	20.5	29.9
Tilled Groundnut	25.3	20.3	15.0	28.9	18.9	35.2	36.8	19.1	32.5
No-Till Groundnut	38.1	24.9	19.1	43.3	21.4	36.5	40.0	23.5	33.8
F- LSD ($P < 0.05$)	6.6	2.5	3.0	6.7	3.5	1.5	NS	NS	NS

NS – Not significant.

Table 8. Mean effect of crop and soil managment practices on gravimetric soil water content (kg kg^{-1}) in maize and groundnut plots

Days After Planting	44			66			90		
Year	1996	1997	1998	1996	1997	1998	1996	1997	1998
Management Practice									
Maize +NPK	26.3	19.4	13.5	30.2	14.5	27.8	31.4	18.5	25.0
Maize+Manure+NPK	34.1	25.3	19.1	44.7	19.7	377	48.2	22.2	35.0
Maize+Mulch+NPK	29.8	21.7	17.5	6.2	17.8	32.4	39.1	18.6	29.8
Maize alone	23.4	16.5	13.8	22.8	12.1	24.4	34.3	16.2	21.5
Groundnut+NPK	28.7	21.3	14.25	31.4	15.8	32.5	35.6	20.1	30.0
Groundnut + Manure + NPK	38.8	28.0	19.8	46.5	27.9	49.9	47.3	25.4	37.3
Groundnut + Mulch + NPK	34.7	23.5	18.4	40.7	28.5	37.3	41.3	22.6	34.9
Groundnut alone	24.6	17.6	15.9	25.8	13.2	33.6	29.4	17.2	25.5
F- LSD ($P < 0.05$)	6.41	5.1	1.5	12.0	5.1	4.2	13.1	NS	3.2

NS – Not significant.

66 DAP. Statistical differences in gravimetric soil water content were not found at 90 DAP in both maize and groundnut plots. This result is corroborated by the work of Lyon et al. (1999) who found that water storage was higher with a no-till system relative to a tilled system in the Central Great Plains, USA.

Results show no statistical difference in gravimetric soil water content between tilled maize *versus* tilled groundnut and no-till maize *versus* no-till groundnut plots. This implies that the tillage system influences gravimetric soil water content more than does the type of crop grown. According to Meilke and Welhelm (1999), the soil physical environment influences the amount of water entering the soil and the microenvironment influences soil biological processes important to plant response.

Results show that plots amended with manure + NPK had between 24 and 59% increase ($P < 0.05$) in gravimetric soil water content relative to control plots (i.e., plots where no applications were made) at 44 DAP and 49 – 111% at 66 DAP in both maize and groundnut plots. Plots amended with mulch + NPK also increased statistically relative to the control plots in both maize and groundnut plots. There was no statistical difference in gravimetric soil water content between maize plots and corresponding groundnut plots at 44, 66 and 90 DAP. This implies that soil management practices like manure, fertilizer and mulch application rather than the type of crop have a more pronounced effect on soil water storage.

This shows that under the different crop and soil management practices, groundnut plots would have the same gravimetric soil water content as corresponding maize plots. Wilhelm (1999) elucidated that crop management practices (i.e., tillage, residue management, fertilization, etc.) define the soil environmental conditions to which crops are exposed and through which crop growth is controlled.

Table 9. Effect of crop and soil management practice on grain yield (Kg ha^{-1}) of maize and groundnut during the 1996, 1997 and 1998 planting season

Crop	Management Practice	Seed yield (Kg ha^{-1})		
		1996	1997	1998
Maize				
	NPK	1270	1194	1124
	Manure +NPK	4600	5344	6200
	Mulch+NPK	1440	1386	1328
	Control	730	680	620
	FLSD ($P = 0.05$)	171.7	69.7	66.69
Groundnut				
	NPK	640	608	580
	Manure+NPK	990	1181	1400
	Mulch + NPK	603	670	760
	Control	590	610	544
	FSLD ($P = 0.05$)	48.06	45.53	20.10

Effect of crop and soil management practices on grain yeild of maize and groundnut

The results show that tillage did not significantly influence grain yield of maize and groundnut in the three seasons. Grain yield of maize and groundnut were significantly affected by four other soil management practices (Table 9). Cumulative results show that maize plots amended with manure + NPK had an over 8-fold increase in grain yield relative to the control. Other treatments (mulch + NPK and NPK alone) did not statistically affect grain yield of maize relative to the control (unamended plots). In groundnut plots amended with manure + NPK, cumulative data show that grain yield also increased ($P < 0.05$) by 123% relative to the control.

Cumulative results indicate that plants in plots amended with manure + NPK had higher grain yield than plants in plots treated with mulch + NPK, NPK alone and the control. Apart from supplying large quantities of nutrients, manure + NPK treatment may improve the soil physical properties, which translated to higher yields. Upawansa (1997) elucidated that improvement in soil fertility exceeded expectations in an integrated system probably because of the combined effect of soil conservation, nutrient enrichment, enhancement of biological activities and improvement in soil water retention capacity. This is further supported by the fact that a positive correlation ($P < 0.05$) was obtained between seed yield and measured individual soil parameters except for penetration resistance and gravimetric soil water content in maize and groundnut plots.

Conclusion

The results of this study showed that the use of different crop and soil management practices significantly affected soil compactibility indices (dry bulk density, total soil porosity, gravimetric soil water content and surface resistance to penetration) in a Typic Paleustult in southeastern Nigeria at 44 and 66 DAP for three consecutive planting seasons. However, none of the compactibility indices studied were affected at 90 DAP except for gravimetric soil water content in 1996 and 1998 seasons.

In both maize and groundnut plots, soil dry bulk density and surface resistance to penetration were reduced in tilled plots relative to no-till plots whereas total soil porosity and gravimetric soil water content increased significantly at 44 and 66 DAP when compared to the control plots. Similarly, maize and groundnut plots amended with poultry droppings + NPK had significantly lower dry bulk density and resistance to penetration and higher total soil porosity and gravimetric soil water content relative to the control plots. The results of the study show that soil and crop management practices that reduce soil compactibility also appear to lead to higher grain yield of maize and groundnut. Appropriate soil and crop management practices could be used to reduce soil compactibility problems, thus improving the productivity of such soils.

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