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RESEARCH ARTICLE

Selected soil physical properties and maize yield influenced by tillage systems and fertilizer types in southwest Nigeria

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Abstract

Management practices can alter soil physical properties and maize (*Zea mays L.*) yield. The study examined the influence of tillage systems, nitrogen (N) fertilizer and cattle dung (CD) applications on selected soil physical properties and maize yield from 2018 to 2019 in southwest Nigeria. The soil at the site had a sandy loam texture with an annual mean air temperature of 27 °C and annual mean precipitation of 1214 mm. Tillage practices were zero tillage (ZT), minimum tillage (MT) and conventional tillage (CT); N fertilizer at the rate of 120, 90 and 0 kg N ha^{-1} (control); and CD was applied at the rate of 10, 5 and 0 t ha^{-1}(control). Soil bulk density, total porosity and saturated hydraulic conductivity were measured at the 0-15 cm depth after maize harvest. Bulk density was 7 % higher, but total porosity was 6 % lower for MT than CT at 5 t ha^{-1} of CD in 2019. Saturated hydraulic conductivity was 17 % higher for 10 compared with 5 t ha^{-1} of CD in 2018. Maize yield was 35-57 % higher for MT compared with CT or ZT at 0 and 120 kg N ha^{-1} in 2018 and 27-88 % higher for CT and MT compared with ZT at all N application rates in 2019. Soil bulk density was positive, but total porosity was negatively correlated in 2018. The MT with 120 kg N ha^{-1} or 5 t ha^{-1} of CD application enhanced bulk density, lowered total porosity and increased maize yield in southwest Nigeria.

Keywords: cultivation practices; maize yield; manuring; nitrogen application; soil properties

Introduction

Soil physical properties, such as soil temperature and water content, bulk density, total porosity and saturated hydraulic conductivity, are considered as some of the important components of soil health that have major implications for soil compaction, water and nutrient movements, root growth, crop yield and environmental quality (1, 2). Warm soils and adequate soil water content enhance root growth and crop yields compared to cold and dry soils (2). Increased bulk density can result in soil compaction that reduces porosity, limits water, gas and nutrient movements and decreases root growth and crop yields (3). Conversely, soils with greater total porosity favor rapid movement of gas, water and nutrients as well as root percolation and growth compared to soils with lower porosity (1). The water infiltration capacity of the soil, as determined by saturated hydraulic conductivity, is important for measuring soil water movement and retention that can directly affect root growth and crop yields (2, 4, 5).

Tillage can affect soil physical properties in numerous ways. Zero-tillage (ZT) can increase moisture content and reduce soil temperature compared with conventional tillage (CT) due to the intact condition of undisturbed soil and the mulching effect of the crop residue accumulated at the surface and subsurface of the soil (6). Some researchers reported that ZT increased soil bulk density and saturated hydraulic conductivity, but decreased total porosity compared with CT (7-9). Another previous research found that tillage did not affect soil bulk density even after 7 years of experimentation (10). In contrast, other studies showed that bulk density was higher for CT compared with ZT (11, 12). Several researchers demonstrated that minimal tillage (MT) and ZT reduced total porosity but increased capillary porosity compared with CT (8, 13). It was also found that soil macroporosity was greater for CT than MT (8). Saturated hydraulic conductivity was lower under ZT compared with MT and CT due to lower porosity (14). In contrast, ZT increased saturated hydraulic conductivity than CT after 28 years of experimentation (15).

Nitrogen fertilization and manure application can also affect soil physical properties due to enhanced root growth, above-ground biomass and the amount of crop residue returned to the soil compared with no application (16-18). Nitrogen fertilizer increased crop biomass production and reduced soil temperature and moisture content compared to no N fertilizer application due to increasing plant canopies with shade intensity and water uptake (19). It was also reported that ZT with N fertilization increased saturated hydraulic conductivity compared with CT with no N fertilization (20). Organic manure application improves soil properties by reducing soil bulk density, but increases saturated hydraulic conductivity compared to no manure application (21-24) . Soil water content and retention were greater with than without manure application (25). A combination of inorganic N, P and K fertilizers and organic manure application can decrease soil bulk density, but increase total porosity, water-holding capacity and saturated hydraulic conductivity compared to manure or fertilizer alone (26-28).

There is a variable effect of tillage on dryland maize yield. Studies have shown that ZT increased dryland maize yield compared with CT due to increased soil water conservation caused by undisturbed soil conditions and residue accumulation at the soil surface (29-31). Other researchers (27, 32) reported a low maize yield for ZT compared with CT (27, 32). On the other hand, tillage did not affect dryland maize yield (33). Increased N availability due to increasing N fertilizer or manure application has increased maize yield (34).

Sandy soils under CT in the tropical conditions of Nigeria typically produce lower crop yields due to increased water and nutrient losses from surface runoff and leaching during intense precipitation events (>20 mm) than other soils (35–37). Proper management practices are needed to enhance the water and nutrient retention capacities of the soil to reduce their losses and increase crop yields and nutrient uptake. This study examined the influence of tillage systems, N fertilizer and cow dung (CD) application rate on selected soil physical properties (soil temperature and water content, bulk density, total porosity and saturated hydraulic conductivity) at 0-15 cm and maize yield and evaluated their relationships at two different growing seasons in 2018 to 2019 in southwest Nigeria. We hypothesized that ZT with 90 kg N ha^{-1} of N fertilization and 5 t ha^{-1} of CD application would reduce soil temperature and bulk density, but enhance soil water content, total porosity and saturated hydraulic conductivity as well as maize yield compared with other management practices. The objectives of this study were to determine: 1) the impact of tillage practices, N fertilizer rates and CD application rates on soil physical properties and maize yield in southwest Nigeria and 2) how soil physical properties correlate with maize yield.

Materials and Methods

Field studies and measurements

The studies were conducted at the Federal University of Agricultural Research Farm, Abeokuta, Nigeria (FUNAAB), from 2018 to 2019 growing seasons under tropical conditions in southwest Nigeria. The experimental site is located at 7°25' N, 3°45' E, 160 m altitude. The site had an annual mean (30-yr average) air temperature of 27 °C and annual mean precipitation of 1214 mm. Mean monthly air temperature during the 2018 cropping season was lower from July to September, but greater in October than the 30-yr average (Table 1). As a result, the 2018 cropping season air temperature was 1.7 °C lower than the 30-yr average. Mean monthly air temperature during the 2019 wet cropping season was greater in May, but lower from June to August than the 30-yr average. As a result, the 2019 cropping season air temperature was also 0.8 °C lower than the 30-yr average.

Monthly total precipitation was lower during the 2018 cropping season, but greater during the 2019 cropping season than the 30-yr average. As a result, the cropping season precipitation was 196 mm lower in 2018, but 826 mm greater in 2019 compared with the 30-yr average. The total annual precipitation in the 2018 cropping season accounted for 64 %, 56 % in 2019 and 54 % for the 30-yr average. The soil at the site was Plinthic Kandiudalf (FAO classification), before ploughing in 2018, the initial soil chemical properties of 11.3 g C kg^{-1} soil organic, 1.21 g N kg^{-1} soil total and 5.4 soil pH at the 0-15 cm depth were observed, with sandy loam texture of 814, 80 and 106 g kg^{-1} (sand, silt and clay content) respectively. Gamba grass (*Adropogon gayanus* L.) was the dominant weed at the study site and it was controlled with the glyphosate (N-[phosphonomethyl] glycine) application at the rate of 1.5 kg active ingredient ha^{-1} in 300 L water.

Table 1. Monthly average and maize growing season air temperature and total precipitation in 2018 and 2019 in southwest Nigeria

Month	Air temperature (°C)			Precipitation (mm)		
	2018	2019	30-yr average	2018	2019	30-yr average
January	31.4	31.2	26.7	1	13	8
February	29.2	30.2	28.3	36	41	23
March	29.2	30.1	28.3	37	46	46
April	29.2	31.2	28.3	20	57	89
May	28.2	28.2	27.2	68	261	132
June	24.2	25.2	26.1	106	496	188
July	23.2	23.2	25.6	146	336	175
August	23.2	24.2	25.0	114	393	165
September	23.2	24.5	25.6	165	303	211
October	26.2	23.2	26.1	70	569	140
November	29.2	27.2	27.2	13	146	28
December	31.2	30.2	26.7	1	13	10
July-October [a]	23.9	23.7	25.6	495	1601	691
May-August [b]	24.7	25.2	26.0	434	1486	660
January-December	27.3	27.4	26.8	777	2674	1214

[a] Wet maize growing season air temperature and precipitation. [b] Dry maize growing season air temperature and precipitation

The studies were a split-split plot factorial design arranged in a randomized complete block design with three replications. The main plot was three tillage (zero (ZT), minimum tillage (MT) and conventional tillage (CT)), subplot contained three nitrogen (N) fertilization rates of 0, 90 and 120 kg N ha^{-1}, while the sub-subplot contained three CD application rates of 0-, 5- and 10-ton ha^{-1} or 0, 150 and 300 kg N ha^{-1}. Each plot was 12 m × 4 m, which was separated by a 1.5 m border and margins of 15 m were left on both sides of the main plot for the tractor to maneuver without entering an adjacent plot.

The ZT was not tilled, MT plots were harrowed once to a depth of 15 cm, while the CT plots were ploughed twice with the aid of a moldboard plow to a depth of 30 cm, followed by harrowing to a depth of 15 cm. At seeding, N fertilizer from urea and CD at designated rates and P and K fertilizers were applied from triple super phosphate and muriate of potash, along with manure at 60 kg P ha^{-1} and 60 kg K ha^{-1}, respectively, were broadcast. All fertilizers and CD were incorporated into the soil through tillage in CT and MT and surface applied in ZT. The average N, P and K concentrations in the CD were 30 g N kg^{-1}, 19 g P kg^{-1} and 11 g K kg^{-1}, respectively.

On 12 July 2018 and 20 May 2019, maize (cv. SWAN1) was seeded at a spacing of 25 cm × 75 cm, 2 seeds were seeded per hole and thinned to one stand per hole 2 weeks after planting. Weeds were controlled by manual weeding with the aid of small hoe in CT and MT plots, while the use of herbicide (glyphosate) was adopted under ZT plots. The studies were terminated at 12 weeks after planting and maize was harvested by hand in both years of cropping.

The soil temperature and moisture content at 0–15 cm were measured once a month, right after seeding until maize harvest. Soil temperature was measured using a probe at five random places within a plot. Gravimetric soil moisture content was determined by collecting soil cores with a soil probe (2.5 cm diameter) at five places within a plot and measuring water content by weighing the core before and after oven drying at 105 ˚C for 24 hr. After maize harvest, soil bulk density at 0-15 cm was determined by collecting soil cores randomly from five places within a plot using a cylindrical tube (2.5 cm diameter), which was calculated by dividing the weight of the oven-dried soil core by the volume of the core. Total porosity was calculated as:

$$\text{Total porosity (\%)} = (1 - \text{bulk density}/\text{particle density}) \times 100 \quad \text{(Eqn. 1)}$$

The particle density of the soil was considered as 2.65 Mg m^{-3} for the calculation of the total porosity. Values for soil temperature and water content at a sampling date, bulk density and total porosity within a plot were averaged to reduce spatial heterogeneity and the average value was used for a treatment for data analysis. Saturated hydraulic conductivity at 0-15 cm at two places within a plot was measured by using the two-ponding head method by examining the water flow rate (38). As with other parameters, values for saturated hydraulic conduction from two places within a plot were averaged and the average value was used for data analysis.

Statistical analysis of data

Because of the variations in air temperature and precipitation between two maize growing seasons in various years, data for each parameter were analyzed separately by year. Data for soil temperature and water content were analyzed using the MIXED model of SAS (39). For this, tillage, N fertilizer, CD and their interactions were considered as the fixed effect, date of measurement as the repeated measure variable and replication as the random effect. Soil bulk density, total porosity and saturated hydraulic conductivity, as well as maize yield, were analyzed using the MIXED model of SAS, where fixed effects were tillage, N fertilizer and CD and their interactions and random effects were replication. Means and interactions were separated by using the least square mean test when significant (39). Pearson's correlation analysis was used to explore the relationship between soil physical properties and maize yield for average values across replications (n = 27).

Results

Selected soil physical properties

Soil temperature and water moisture

Soil temperature and moisture were significantly affected by measurement dates during the 2018 and 2019 cropping seasons. The interactions between tillage and measurement date, N fertilization rate and measurement date and CD application rate and measurement date were significant in 2018 (Table 2). In 2018, soil temperature remained mostly stable at all measurement dates. It was observed that across N fertilizer and CD application rates, soil temperature was higher under MT compared with ZT in early July but was higher under ZT compared with CT in September and early October (Fig. 1A). Soil temperature, across tillage and CD rates, was also higher under 0 and 90 compared with 120 kg N ha^{-1} in early July but was greater under 90 and 120 compared with 0 kg N ha^{-1} in early August (Fig. 1B). Similarly, soil temperature, averaged across tillage practices and N fertilizer rates, was higher under 10 compared with 5-ton ha^{-1} of CD application from early August to early September, but

Table 2. Analysis of variance for soil temperature and water content with sources of variance as tillage (T), N fertilization rate (F), manure application rate (M) and date of measurement (D) in 2018 and 2019 Bold values denote significant *P* values

Source	Soil temperature		Soil water content	
	2018	2019	2018	2019
	***P* values**			
T	0.846	0.454	0.074	0.159
F	0.501	0.298	0.543	0.898
T × F	0.078	0.410	0.738	0.950
M	0.060	0.218	0.244	0.858
T × M	0.940	0.457	0.070	0.478
F × M	0.434	0.382	0.576	0.901
T × F × M	0.054	0.310	0.268	0.716
D	**<0.001**	**<0.001**	**<0.001**	**<0.001**
T × D	**0.016**	0.225	**0.001**	0.937
F × D	**0.015**	0.360	**0.025**	0.849
T × F × D	0.215	0.876	0.300	0.956
M × D	**0.003**	0.461	**0.002**	0.996
T × M × D	0.280	0.648	0.438	0.998
F × M × D	0.839	0.291	0.589	0.981
T × F × M × D	0.350	0.461	0.853	0.998

was higher under 0 than 10-ton ha^{-1} in early October (Fig. 1C). In 2019, soil temperature decreased from early May to early July and increased in early August for all treatments (Fig. 2D, 2E & 2F). Soil temperature did not vary with any treatment at all measurement dates. Average soil temperature across sampling dates was not correlated to maize yield in 2018 and 2019 (Table 3).

Averaged among N fertilizer and CD application rates, soil moisture content was higher under ZT than MT in early July and September, but was higher under ZT than CT and MT in early October 2018 (Fig. 2A). Averaged among tillage practices and CD application rates, moisture content was higher under 90 and 120 than 0 kg N ha^{-1} in early July (Fig. 2B). Averaged among tillage practices and N fertilizer rates, moisture content was higher under 5 and 10 than 0-ton ha^{-1} of CD application in early July, but was higher for 0 than 5-ton ha^{-1} of manure application in early September (Fig. 2C). In 2019, moisture content increased from early May to early July, but decreased in early August for all treatments (Fig. 2C, 2D, 2E). As with soil temperature, moisture content did not vary with any treatment at all measurement dates. The average soil moisture content across sampling dates was not correlated with maize yield in 2018 but was negatively correlated in 2019 (Table 3).

Soil bulk density and total porosity

There was a significant effect of tillage practices on soil bulk density (BD) in 2018, with a significant tillage × CD application rate interaction in the year 2019 (Table 4). In 2018, BD averaged among N fertilizer and CD application rates was 2-6 % higher under MT compared with CT and ZT and 3 % higher under CT compared with ZT (Table 5). In 2019, BD averaged across N fertilizer rates was 7 % higher under MT compared with CT at 5 t ha^{-1} of CD application. The BD was also 7 % higher under 5 compared with 0 t ha^{-1} of CD application in MT. Nitrogen fertilizer rate did not affect BD. Bulk density was positively correlated with maize yield in 2018 (Table 3).

There was a significant effect of tillage on soil total porosity (TP) in 2018, with a significant tillage × CD application rate interaction in the year 2019 (Table 4). Averaged among N fertilizer and CD application rates, total porosity was 3-6 % higher under ZT compared with CT and MT and 2 % higher under CT compared with MT in the year 2018 (Table 6). In 2019, total porosity averaged across N fertilization rates was 6 % higher under CT compared with MT at 5 t ha^{-1} of CD application. Total porosity was also 7 % higher under 0 compared with 5 t ha^{-1} of CD application in MT. Nitrogen fertilization rate did not affect total porosity. In contrast to bulk density, total porosity was negatively correlated with maize yield in 2018 (Table 3).

Saturated hydraulic conductivity

Cow dung application significantly affects saturated hydraulic conductivity in the 2018 and 2019 cropping seasons (Table 4). Averaged among tillage practices and N fertilizer rates, hydraulic conductivity was 24 % higher under 10 t ha^{-1} compared with 0 t ha^{-1} of CD application in 2018, but was 16-19 % higher under 0 and 5 compared with 10 t ha^{-1} in the year 2019 (Table 7). Tillage and N fertilization rate did not affect hydraulic conductivity. Averaged across treatments, hydraulic conductivity was higher in 2019 than in 2018. Hydraulic conductivity did not correlate with maize yield in 2018 and 2019 (Table 3).

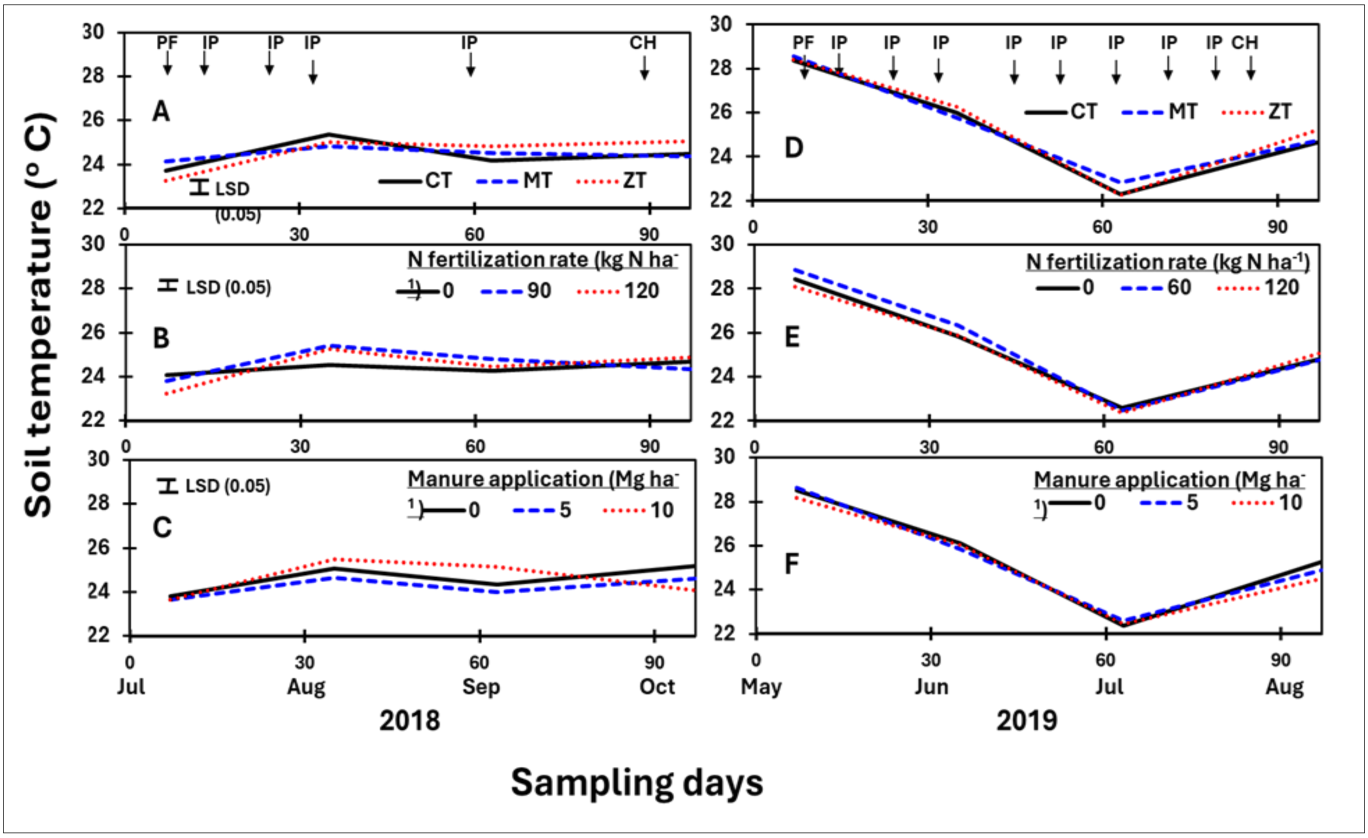

Fig. 1. Soil temperature at the 0–15 cm depth as affected by tillage, N fertilization rate and manure (CD) application rate from July to early October 2018 and May to early August 2019. Tillage practices are CT- conventional tillage; MT- minimum tillage and ZT- no-tillage. PF denotes planting and fertilization; IP- intense precipitation (≥20 mm) and CH- crop harvest.

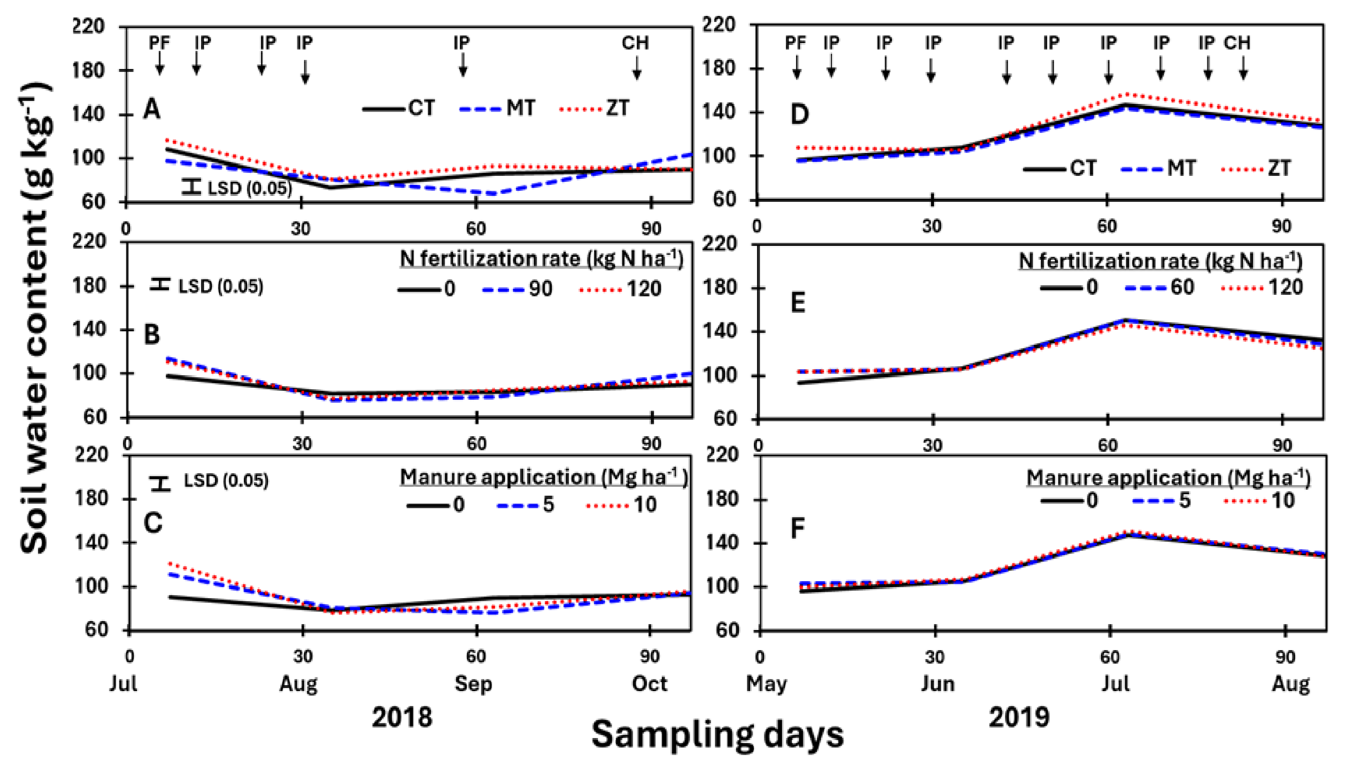

Fig. 2. Soil water content at the 0-15 cm depth as affected by tillage, N fertilization rate and manure (CD) application rate from July to early October 2018 and May to early August 2019. Tillage practices are CT- conventional tillage; MT- minimum tillage and ZT- no-tillage. PF denotes planting and fertilization; IP - intense precipitation (≥20 mm) and CH - crop harvest.

Table 3. Correlation (r) between maize yield and soil physical properties in 2018 and 2019 (n = 27) (Bold values denote significant *P* values)

Soil physical properties	Maize yield			
	2018		2019	
	R	*P* value	r	*P* value
Soil temperature	-0.06	0.78	-0.09	0.65
Soil water content	0.06	0.78	**-0.51**	**0.01**
Bulk density	**0.45**	**0.02**	0.08	0.68
Total porosity	**-0.44**	**0.02**	-0.09	0.66
Saturated hydraulic conductivity	0.28	0.16	-0.14	0.48

Maize yield

Table 4 shows that tillage practices and N fertilizer rates had significant influence on maize yield in the years 2018 and 2019 and by CD application in 2018. A significant tillage × N fertilization rate interaction occurred in both years. In 2018, maize yield averaged among the manure application rates was 46-57 % higher under MT compared to CT and ZT at 0 kg N ha^{-1} of N fertilization and 13-35 % higher under MT compared with ZT at 120 kg N ha^{-1} (Table 8). At 90 kg N ha^{-1}, maize yield was 23% higher for CT compared with ZT. Maize yield was also 42-82 % higher under 120 compared with 0 kg N ha^{-1} for CT, MT and ZT. In 2019, maize yield was 27-88 % higher for CT and MT than ZT at all N fertilization rates. Similarly, maize yield was 18-75 % higher under 120 compared with 0 kg N ha^{-1} for all tillage practices. Averaged among tillage practices and N fertilization rates, maize yield was 17 % higher under 10 compared with 0 t ha^{-1} of CD application in 2018 (Table 7). Averaged among treatments, maize yield was 33 % higher in 2019 compared with in year 2018.

Table 4. Analysis of variance for soil bulk density, total porosity, saturated hydraulic conductivity and maize yield with sources of variance as tillage (T), N fertilization rate (F) and manure application rate (M) in 2018 and 2019. Bold values denote significant *P* values

Source	Soil bulk density		Total porosity		Saturated hydraulic conductivity		Maize yield	
	2018	2019	2018	2019	2018	2019	2018	2019
	P values-							
T	**<0.001**	0.566	**<0.001**	0.560	0.825	0.169	**<0.001**	**<0.001**
F	0.134	0.367	0.090	0.314	0.939	0.597	**<0.001**	**<0.001**
T × F	0.857	0.679	0.801	0.638	0.204	0.911	**0.045**	**0.037**
M	0.532	0.269	0.497	0.258	**0.030**	**0.045**	**0.042**	0.290
T × M	0.965	**0.048**	0.974	**0.047**	0.907	0.135	0.772	0.440
F ×M	0.858	0.602	0.952	0.640	0.362	0.221	0.124	0.111
T × F × M	0.770	0.980	0.699	0.989	0.691	0.962	0.193	0.393

Table 5. Interaction between tillage and manure application rate on soil bulk density in 2018 and 2019

Manure application rate (Mg ha^{-1})	Soil bulk density (Mg m^{-3})							
	2018				2019			
	CT[a]	MT[a]	ZT[a]	Mean	CT	MT	ZT	Mean
0	1.34	1.36	1.29	1.33	1.27	1.25b[b]	1.26	1.26
5	1.34	1.37	1.28	1.37	1.25B	1.34aA[c]	1.27AB	1.29
10	1.34	1.37	1.30	1.34	1.29	1.27ab	1.27	1.28
Mean	1.34B	1.37A	1.29C		1.27	1.29	1.27	

[a] CT denotes conventional tillage, MT- minimal tillage, and ZT- no-tillage; [b] Numbers followed by different lowercase letters in a row are significantly different at $P \leq 0.05$ by the least square means test; [c] Numbers followed by different uppercase letters in a column are significantly different at $P \leq 0.05$ by the least square means test

Table 6. Interaction between tillage and manure application rate on soil total porosity in 2018 and 2019

Manure application rate (ton ha^{-1})	Soil total porosity (%)							
	2018				2019			
	CT[a]	MT[a]	ZT[a]	Mean	CT	MT	ZT	Mean
0	49.4	48.4	51.1	49.7	52.0	53.0a	50.4	52.5
5	50.0	48.4	51.7	50.0	52.5A	49.4 bB	52.1AB	51.4
10	49.4	48.2	51.1	49.6	51.2	52.1ab	52.0	51.8
Mean	49.6B	48.4C	51.3A		52.0	51.5	52.2	

[a] CT denotes conventional tillage, MT- minimal tillage and ZT- no-tillage; [b] Numbers followed by different lowercase letters in a row are significantly different at $P \leq 0.05$ by the least square means test; [c] Numbers followed by different uppercase letters in a column are significantly different at $P \leq 0.05$ by the least square means test

Table 7. Effect of manure application rate on soil saturated hydraulic conductivity and maize yield in 2018 and 2019

Manure application rate (ton ha^{-1})	Saturated hydraulic conductivity (cm h^{-1})		Maize yield (Mg ha^{-1})	
	2018	2019	2018	2019
0	13.6b[a]	18.0a	1.56b	2.18
5	15.3ab	18.5a	1.66ab	2.32
10	16.9a	15.5b	1.82a	2.22

[b] Numbers followed by different lowercase letters in a row are significantly different at $P \leq 0.05$ by the least square means test

Table 8. Interaction between tillage and N fertilization rate on maize yield in 2018 and 2019

N fertilization rate (kg N ha^{-1})	Maize yield (Mg ha^{-1})							
	2018				2019			
	CT[a]	MT[a]	ZT[a]	Mean	CT	MT	ZT	Mean
0	1.13c[b]B[c]	1.77bA	1.21bB	1.37c	2.29bA	2.33bA	1.24cB	1.95c
90	1.79bA	1.67bAB	1.45abB	1.64b	2.42abA	2.63abA	1.76bB	2.27b
120	2.06aAB	2.32aA	1.72aB	2.03a	2.60aA	2.75aA	2.17aB	2.51a
Mean	1.66AB	1.92A	1.46B		2.44A	2.57A	1.72B	

[a] CT- conventional tillage, MT- minimal tillage and ZT- no-tillage; [b] Numbers followed by different lowercase letters in a row are significantly different at $P \leq 0.05$ by the least square means test; [c] Numbers followed by different uppercase letters in a column are significantly different at $P \leq 0.05$ by the least square means test

Discussions

Soil physical properties

Soil temperature and water content

Intense precipitation (>20 mm day^{-1}) events did not alter soil temperature throughout the maize cropping season (July-October) in 2018 (Fig. 1A-C) because the cropping season precipitation was lower compared with the 30-yr average (Table 1). However, greater cropping season precipitation (May-August) than the 30-yr average, as well as heavier precipitation events in 2019, reduced soil temperature from early May to early July, after which soil temperature increased until early August (Fig. 2A-C). Exposure of soil caused by intensive tillage activities may have led to increased soil temperature under MT compared with ZT at planting in early July 2018 (Fig. 1A). Our results are similar to those observed by other studies (6, 10) that reported higher soil temperature for reduced tillage than CT in semiarid and subtropical regions. Conversely, the greater soil temperature under ZT compared with CT and MT from early September to early October was probably due to accumulated crop residues at the soil surface that acted as insulation for maintaining soil temperature.

The reasons for lower soil temperature under 120 than 90 and 0 kg N ha^{-1} in early July 2018 were not clear (Fig. 1B). However, greater soil water uptake by plants from increased growth due to N fertilizer may have increased soil temperature under 90 and 120 compared with 0 kg N ha^{-1} from early August to early September 2018. Although insignificant, soil water content was lower under 90 and 120 compared with 0 kg N ha (Fig. 2B). Soil temperature usually increases when soil water content is low (19, 27). Similarly, the greater soil temperature under 10 compared with 0 and 5 t ha^{-1} of CD application from early August to early September (Fig. 1C) was likely due to increased water uptake from higher maize yield (Table 7). In contrast, a lower shading effect due to reduced biomass growth from non-manure application may have increased soil temperature under 0 compared with 5 and 10 t ha^{-1} of CD application in early October 2018. Greater than normal precipitation likely nullified the effect of treatments on soil temperature in 2019.

Lower than average growing season precipitation in 2018 also resulted in a limited variation in soil water content from early July to early October (Table 1 & Fig. 2A-C). However, increased precipitation increased soil water content from early May to early July, after which it slightly declined until early October 2019 (Fig. 2D-F). Conservation of soil water by crop residue accumulation at the soil surface may have increased soil water content for ZT than the MT in early July and early September 2018 (Fig. 2A). Zero tillage increased soil water content compared with MT or CT due to unruffled soil condition and accumulated crop residue at the soil surface that acted as a mulch (27). This may also be true for greater soil water content under MT compared with CT in early October 2018.

Increased water absorption by N fertilizer or manure at planting may have increased soil water content under 90 and 120 compared with 0 kg N ha^{-1} of N fertilization or greater under 5 and 10 compared with 0 t ha^{-1} of CD application in early July 2018 (Fig. 2B, 2C). Several researchers have reported that applying organic manure increased soil water content compared with no application (25, 27). However, lower water extraction by maize due to reduced yield may have increased soil water content under 0 compared with 5 and 10 t ha^{-1}of CD application in early September 2018. Greater than average precipitation may have resulted in a limited effect of treatments on soil water content in 2019, a case similar to that observed for soil temperature.

Variability in soil temperature and moisture content among treatments during the maize cropping season probably resulted in a non-significant correlation between soil temperature, moisture content and maize yield in 2018 (Table 3). Although trends among treatments for soil temperature and moisture content were similar from planting to harvest (Fig. 1, 2), a significant correlation between soil moisture content and maize yield rather than between soil temperature and maize yield in 2019 demonstrates that soil moisture content is much important than soil temperature for affecting maize growth in the tropical condition of Nigeria. The negative correlation between soil moisture content and maize yield in 2019 probably resulted from increased nutrient loss due to leaching and surface runoff in sandy soil due to excessive precipitation, as growing season precipitation in 2019 was more than twice the 30-year average.

Soil bulk density and total porosity

Greater soil compaction from tillage equipment used for plowing probably increased soil bulk density under CT and MT compared with ZT in 2018 (Table 5). This reduced total porosity under CT and MT compared with ZT in 2018 (Table 6). Our results agree with those reported by other researchers who observed that soil bulk density was greater under CT compared with ZT (11,12). In contrast, others found that bulk density was higher for ZT compared with CT (7-9). Increased soil compaction can increase bulk density at the initiation of ZT, but enhanced root growth can reduce bulk density later in ZT compared with CT (11,12). Similarly, our results of lower total porosity under CT compared with MT and ZT in 2018 are similar to those reported by many researchers (8, 13).

Incorporation of manure into the soil through intensive tillage probably reduced bulk density under CT compared with MT at 5 t ha^{-1}of CD application in 2019 (Table 5), as manure is less dense than soil (27). This resulted in increased porosity for CT compared with MT in 2019 (Table 6). Numerous researchers have demonstrated that manure application reduced soil bulk density and increased soil total porosity than no application (22-24, 27, 43). However, the reasons for greater bulk density or lower total porosity under 5 than 0 t ha^{-1} of CD application in MT were not known. The lower soil bulk density or increased soil total porosity for all treatments in 2019 than in 2018 (Table 5, 6) was probably due to increased root growth, as maize yield was greater in 2019 (Table 8). The positive correlation between soil bulk density and maize yield or the negative correlation between total porosity and maize yield in 2018 (Table 4) suggests that slight compaction of sandy soil that reduced porosity may favor maize yield during the below-average precipitation in 2018 by holding more soil water. This may not be the case in 2019 when precipitation was above the normal and soil was saturated with water.

Saturated hydraulic conductivity

Increased maize yield and root growth due to enhanced nutrient availability likely increased saturated hydraulic conductivity with an increasing rate of manure application in 2018 when the cropping season precipitation was below the average (Table 1, 7). Our results are similar to those reported by numerous researchers who found that manure application increased saturated hydraulic conductivity compared to no application during the year with below-average precipitation (21-24, 40). However, this was not the case in 2019 when an increased amount of water held by manure during excessive precipitation may have reduced saturated hydraulic conductivity under 10 compared with 0 and 5 t ha^{-1} of CD application. Saturated hydraulic conductivity did not correlate with maize yield in 2018 and 2019 (27, 41). It may be possible that water permeability in the sandy soil has a limited effect on maize yield.

Maize yield

Enhanced N mineralization from soil organic matter due to intensity tillage may have increased N availability, leading to increased maize yield for MT compared with ZT at 0 and 120 kg N ha^{-1} in 2018 and for CT and MT than ZT at all N fertilizer application rates in 2019 (Table 8). This is similar to the studies reported by many researchers who found greater dryland maize yield for CT compared with ZT (32,42). This was In contrast to those reports by numerous researchers who observed greater maize yield for ZT than CT in semiarid and subhumid regions (42-45). In areas with limited precipitation in the semiarid region, ZT increased soil moisture content due to undisturbed soil conditions and enhanced dryland maize yield compared with CT (42, 43, 46). This may not be the case for the humid tropical conditions of Nigeria, where precipitation is abundant and CT and MT enhanced maize yield compared with ZT. Increased N availability likely increased maize yield with increasing N fertilization rate for all tillage practices in 2018 and 2019. Similarly, increased nutrient availability may have increased maize yield with increasing manure application rate in 2018 (Table 7). Greater precipitation also likely increased maize yield in 2019 compared with 2018. The results suggest that MT with 120 kg N ha^{-1} can sustain maize yield in the sandy soil of southwest Nigeria.

The results of this study showed that overall maize yield was < 3 t ha^{-1}, regardless of treatments, which is lower than those observed in other regions of Nigeria (18, 38). This was probably due to increased N loss to the environment because of leaching, surface runoff, volatilization, denitrification and gaseous emissions stemming from higher precipitation in sandy soils, which reduced N availability and maize yield. Total annual precipitation was below the 30-yr average in 2018 but was more than twice the normal precipitation in 2019 (Table 1). Maize yield may be sustained and nitrogen loss to the environment can be reduced through split application of N fertilizer to synchronize N availability with crop N demand during its growth instead of applying basal dose of N fertilizers at planting, as is the case in this study.

Conclusion

Tillage, N fertilizer rate and CD rate variably affected the soil physical properties and maize yield. Soil temperature and moisture content varied with treatments at various measurement dates during the below-average growing season precipitation in 2018, but not in 2019 when the growing season precipitation was above average. The CT increased soil bulk density but decreased total porosity compared with MT and ZT in 2018. In contrast, MT increased bulk density but decreased total porosity compared with CT at 5 t ha^{-1} of CD application in 2019. Saturated hydraulic conductivity increased with increasing manure application rate in 2018, but decreased in 2019. Maize yield was significantly higher under CT and MT compared with ZT at most N fertilization rates and greater with increasing N fertilization and manure application rates, regardless of tillage practices. Soil physical properties were inconsistently correlated with maize yield. Results showed that MT with 5 t ha^{-1} of manure application or 120 kg N ha^{-1} of N fertilization may sustain soil physical properties and maize yield in the tropical conditions of southwest Nigeria.

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Authors' contributions

SYA carried out the conceptualization, data curation, formal analysis, investigation, methodology, validation, visualization and writing of the original draft. UMS contributed to data curation, investigation, project administration, resources and validation. MBA was involved in data curation, investigation and project administration. FKS participated in data curation, investigation, methodology and supervision. TOI handled data curation, investigation, methodology, project administration and supervision. OHO helped with data curation, investigation and resources. IK contributed to data curation, formal analysis, investigation, project administration and supervision. OKA carried out the data curation, formal analysis, investigation, project administration and supervision. SKB participated in data curation, formal analysis, investigation, project administration and supervision. All authors were involved in writing, reviewing and editing and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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