Effects of Tillage and Leguminous Species on Selected Soil Physical Properties and Maize

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Abstract
Optimal use of management systems including tillage and legumes cover crops is recommended to improve soil physical properties and sustain agricultural production. Field study was carried out to evaluate the effects of tillage practices and cropping systems on soil physical properties in Ogbomoso, Southern Guinea savanna, Nigeria. The two tillage practices (as main plot) No-till (NT) and Tilled (T) were investigated under five cropping systems (CS) of sole maize (SM), sole *Mucuna* (SMu), sole *Pueraria*, maize+*Mucuna* and maize + *Pueraria* intercrop with three replications in 2013. In 2014, all the treatments were similar except *Canavalia gladiata* that replaced *Pueraria phaseolus.* Soil physical parameters determined were; bulk density, pore size distribution, saturated hydraulic conductivity (Ksat), soil available water (SAW), soil temperature. Also, maize plant height and grain yield were determined. Data collected were analyzed by analysis of variance. The result shows that Ksat was significantly ($P<0.05$) 54% higher on NT > T. SAW was 11% significantly increased on NT>T in 2014. A 1.5% increase was observed in SMu plots compared with SM plots in 2013, though the treatments were similar. Soil temperature was significantly affected by tillage and CS at 6 WAS in 2013, 6 and 8 WAS in 2014.The trend is NT >T while SM > other cropping systems. There was significant interaction of tillage and cropping systems on Ksat in 2014. Maize grain yield was 39% significantly higher on T > NT in 2013. It is apparent that long term tillage and cropping systems experiment would be required to detect changes in soil physical properties as a result of the soil management practices.
Keywords: Degradation, No-till, Tillage, Soil Physical Properties, Maize

1. Introduction

The teeming population of the world has led to the increasing demand for land resulting to intensive cultivation of available land with little or no fallow (Lal, 2000). This reduces soil fertility, destroys soil organic matter, increases soil acidification and accelerates desertification (Stockwell & Fisher, 1996). Land degradation is an issue of worldwide concern as it threatens global food security and environmental quality. Soil nutrients and physical status in small holder farms in south- western Nigeria are subjected to debilitating effects of continuous cropping without adequate efforts toward replenishment and conservation to ensure sustainability of soil resources (Ogoke *et al*., 2009).

Soil tillage, as a necessary practice in crop production, can affect the soil physical properties that are important for plant growth (Lampurlanes and Cantero-Martinez, 2006) improvements of root penetration and water infiltration. The most beneficial contribution of tillage to crop production among others are soil moisture storage, weed control, and supply of nutrients from rapid decomposition of organic matter (Gardner *et al*., 1999; Lampurlanes & Cantero-Martinez, 2003).The success of any tillage practices is directly related to the improvement of the soil physical properties which in turn may affect the growth and yield of crops due to different soil conditions created. In a review on the effect of tillage on soil physical properties, Strudley *et al*. (2008) reported that bulk density, porosity, hydraulic conductivity and infiltration rates were highly influenced by tillage. Therefore, the choice of tillage is imperative for maintenance of the soil physical properties necessary for growth (Lal, 1997a). However, the influence of tillage on soil physical properties is site specific depending on soil type, fertility status, and climatic conditions.

The impact of cover crops on soil physical properties is inconsistent (Folorunso *et al*., 1992; Keisling *et al*., 1994). Some studies have found significant changes in soil physical properties under cover crops. Samuel *et al*. (2015) on silt loam with corn (*Zea mays* L.)/soybean (*Glycine max*) rotation, observed a 3.5% decrease in bulk density in cover crop plots as compared with no cover plots. Similarly, on silt loam, rye and hairy vetch in no- till corn-soybean was found to increase total porosity, plant available water, reduced bulk density, but saturated hydraulic conductivity (Ksat) was unaffected compared with plots without cover crops after 4 year of management (Villamil *et al*., 2006).On a silt loam and loam, rye (*Secale cereale* L.) reduced bulk density and increased the Ksat after 17 year of management (Keisling et al., 1994).

Other studies have found little or no effects of cover crops on soil physical properties. On a sandy loam, hairy vetch and winter wheat in no-till corn had no effect on bulk density, porosity, or Ksat after 3 years of management (Wagger & Denton, 1989).On a loam, rye and oat in no-till soybean did not affect bulk density during a 3- year study (Kaspar *et al*., 2001). Carof *et al.* (2007) also reported on a loam, with red fescue (*Festuca rubra* L.), bird's foot trefoil (*Lotus corniculatus* L.), and alfalfa (*Medicago sativa* L.) on no-till, after 2 year of management, had no effect on soil hydraulic conductivity although macroporosity was improved. In a 2 year study, Mubiru and Coyne (2009) found no differences in bulk density among four cover crops including [Mucuna (*Mucuna pruriens* (L.), Dolichos lablab (*Lablab vulgaris*), [Canavalia (*Canavalia ensiformis* L.)], and Crotolaria (*Crotolaria paulina* Schrank) when planted into fallow on degraded sandy clay, sandy loam, and loamy sand. Cover crop impact may depend on the type of cover crop, type of soil, tillage, management and climate.

In the light of an increasing world population and climatic change, there is need for sustainable management strategies to maintain, improve soil quality and enhance agricultural production. This study was therefore, conducted to (i) evaluate the effect of legume cover in improving soil physical properties under tillage and (ii) determine crop yield under sole/intercrop maize cover.

2. Materials and Methods

2.1 *Description of experimental site*

The field experiment was conducted on a soil under cultivation for more than 5 years at the Teaching and Research Farm, Ladoke Akintola University of Technology Ogbomoso, Nigeria between 2013 and 2014. Ogbomoso lies between latitude $8^0$10'N and longitude $4^0$10'E in the Southern guinea savanna ecological zone of Nigeria. The site has an altitude of 340 m above sea level. The rainfall pattern is bimodal and averages 1400 mm per annum. Rainfall peaks occur in June and September. There are two growing seasons; an early season runs from March/April to August and late season, from mid-August to October/November. Annual temperatures range from 29.8 to 19.7 ^oC. The soil of the area was Gambari series (Smith & Montgomery, 1962) derived from highly weathered metamorphic materials, typically referred to as basement complex rocks. The soil was classified as an Alfisol under the order Udic Paleustalf according to the USDA classification (Soil Survey Staff, 2006).

2.2 *Experimental design and Layout*

The trials were between 2013 and 2014 growing seasons. It was a split-plot laid out in a randomized complete block design (RCBD) with three replications and two factors; tillage as the main plot and cropping systems as subplots. The tillage practices were No- till (NT) and Tilled (T). In 2013, NT plots were slashed after which 1.1 kg ha^{-1} of glyphosate was applied to kill the vegetation. T plots were ploughed twice with a disc plough to a depth of 30 cm. The same land preparation for tillage treatments were repeated in 2014. The farmland size was 0.525 ha with a plot size of 125x5 m and sub-plot measuring 4 x 5 m ($20m^2$) with 1m border to separate each plot from another. The cropping systems used in 2013 were; sole maize, sole *Mucuna pruriens*, sole *Pueraria phaseolus*, maize+ *Mucuna pruriens* and maize + *Pueraria phaseolus*. However in 2014, *Pueraria* seeds were not available so that it was replaced with *Canavalia gladiata.* Therefore, the cropping systems consisted of sole maize, sole *Mucuna pruriens*; sole *Canavalia gladiata*, maize+*Mucuna pruriens* and maize+ *Canavalia gladiata* for both NT and T plots. The sole maize (*Zea mays L.*) was sown at a spacing of 0.75 x 0.25 m while legumes were established by sowing two weeks after maize were sown at a spacing of 100 x 50 cm.

2.3 *Soil sampling and field measurement*

In 2013 prior to sowing, soil samples were randomly collected from the soil surface (0-15 cm). This was thoroughly mixed to form a composite sample where sub-sample was taken for the determination of soil chemical properties. Also, soil samples were collected with a cylinder (125 cm^3) randomly at thirty one points from 0-15 cm depth before the experiment for selected physical properties. Similar sampling with the same cylinder was repeated on sub-plot basis at the end of the experiment, in 2013 and 2014 growing seasons, respectively.

Chemical properties

Sample were air-dried and ground to pass a 2 mm sieve before taken to the laboratory for routine analysis. Soil pH was determined in water using 1:1, Available P was determined in the soil using Bray P-1 method (Bray & Kurtz, 1945).Organic carbon was analyzed by dichromate wet oxidation method of Nelson & Sommers, (1982). Exchangeable K, Na, Ca, and Mg were extracted with 1 M NH_4OAc at pH 7, and determined by atomic absorption spectrophotometry. Effective Cation Exchange Capacity (ECEC) was calculated by summing up the exchangeable bases plus the exchangeable acidity. Cation Exchangeable Capacity (CEC) was determined by neutral, 1N Ammonium acetate method. Determination of Total Nitrogen was done by the Kjeldahl method as described by Bremner and Mulvaney (1982).

Physical properties

Bulk density was estimated by dividing the oven-dried mass of the soil by the volume of the soil as described by Blake and Hartage (1986). This was computed by dividing the oven-dried mass of the soil by the volume of the core.

Bulk density (gcm^{-3}) = $\frac{\text{Mass of soil (oven dried)}}{\text{Total volume of soil}} = \frac{M_s}{V_T}$ ……… (1)

Volume of soil sample = volume of core (cylinder) = $\pi r^2 h$

Where h = height of the cylinder and r = internal radius of the cylinder.

Total porosity (TP) was calculated from the parameters of bulk density and particle density using an assumed value of $2.65 g/cm^3$ for particle density in the formula;

TP = 1- (Pb / Ps) x 100 …………………………………. (2)

Where Pb is the bulk density and Ps is the particle density.

Saturated hydraulic conductivity (Ksat) was determined by maintaining a constant head of water above undisturbed core (Klute, 1986). A flask of water was inverted above the core containing water in order to maintain constant head of water. The quantity of water (Q) drained in every 5 minutes was measured until equilibrium (constant volume of water) was reached.

Ksat = QL / [At (H+L)]…………………………….. (3)

Ksat = Saturated hydraulic conductivity

Q = volume of water passing through the soil column (cm^3).

L - Length of the soil column (cm)

A - Cross sectional area through which the flow takes place (cm^2)

(H + L) = Hydraulic head difference between the inlet and outlet ends of the column.

t = time (seconds)

Pore size distribution was calculated using the water retention data and capillary rise equation as described by Danielson and Sutherland (1986). Macropores (pores > 30µm), taken as drain pores were estimated at 10 kpa matric potential.

$Qw = \frac{Ww}{Vw}$ …………………………………………. (4)

Qw - macroporosity,

Ww - the difference between wet and oven dry soil,

Vw - Volume of the soil.

Microporosity of the soil was determined by subtracting macro porosity from the total porosity.

Soil temperature

Soil temperature was measured at 12 noon on each plot at 4, 6 and 8 weeks after sowing with the aid of soil thermometer in 2013. The thermometer was inserted into the soil at about 10 cm soil depth and left for 5 minutes after which the temperature change was recorded. The measurement was repeated in 2014.

Determination of maize plant height and grain yield

Maize plant heights were measured from 6 plants tagged on plot basis at 8 weeks after sowing. The maize grain yield was determined after harvest at maturity. Cobs were harvested from the field, dehusked and oven dried at 75 ^{O}C to constant weight of 13% moisture content. This was later shelled to calculate the grain yield in ton/ha.

2.5. Data analysis

Data analysis was done with analysis of variance (ANOVA) was used using SAS Package (2009). Means were separated using least significant difference (LSD) at 5% level of probability.

3. Result and Discussion

3.1 Soil physical properties

The physical and chemical properties of the soil prior to planting is as shown in Table1

Bulk density

Tillage practices had no significant influence on bulk densities in both 2013 and 2014 (Table 2). Although not significant, the average bulk density observed in 2013 was No-till < Tilled (T) while 2014 has similar value.. The high densities observed in T could be attributed to the second passes of soil manipulation (ploughing twice) compared to No-till plot. Non-significance of tillage effect on bulk density over time has also been observed in other studies by (Anken *et al*., 2004; Osunbitan *et al*., 2005; Jabro *et al*., 2009) due to different tillage practices. Agbede (2006) found high bulk densities in the ploughing plus harrowing plots and attributed that to tractor wheel traffic and implement passes and lower macroporosity. He observed that the plough layers get compacted as the tillage implement keeps passing the same depth season after season thus increasing the bulk density. Furthermore, Gomez *et al*. (2001) realized that it takes five years before changes in some of the soil physical properties (structure and aggregate stability which are indicators of bulk density) could be detected as a result of the soil management practices.

Cropping systems did not influence bulk density during the two years. However, sole *Mucuna* reduced bulk density than other cropping systems. The result is similar to Kaspar et al. (2001) who observed non-significance in bulk density after 3 year management with rye and oat in no-till soybean cover.

Table 1: Baseline physical and chemical properties of the experimental site at 0-15 cm depth of soil

Soil property	Values
Bulk density (g/cm^3)	1.61
Total porosity (%)	39.85
Microporosity (%)	16.39
Macroporosity (%)	23.48
Soil available water (cm^3/cm^3)	0.065
soil pH (H_2O)	7.30
Organic carbon (g/kg)	6.00
Total N (g/kg)	0.40
Mehlich (mg/kg)	7.50
Exchangeable bases (cmol/kg)	
Ca	1.84
Mg	0.38
Na	0.12
ECEC	2.65

Total porosity, Microporosity and Macroporosity

Total porosity was not affected by tillage in both 2013 and 2014 (Table 2). This result is in line with the observations of Karuma *et al*. (2014) report of non-significance of tillage practices and cropping systems on total porosity of soil. Similarly, cropping systems did not show significant influence on total porosity (Table 2). It follows similar trend as bulk density but sole *Canavalia* showed higher porosity values than other cropping systems in 2013 while sole maize had higher porosity in 2014 than the intercrop (Table 2). The observation in this study contradicts the results of Fan *et al*. (2006) who reported an increase in porosity after intercropping and attributed that to increased root biomass and stimulatory effects of the living roots on microbial activities that enhance organic matter decomposition.

Tillage practice had no significant effect on microporosity and macroporosity in 2013 and 2014 (Table 2). Similar trend of No-till > Tilled were observed in 2013 and 2014. This result could be attributed to the fact that under no tillage, the channels and pore spaces from root growth and activities of soil fauna in previous years are not disturbed by tillage process and was responsible for higher macroporosity of the reduced tillage. The higher macroporosity observed on No-till plot could be corroborated by the report of (Agbede, 2006) that in the ploughing plus harrowing plots, tractor wheel traffic and implement passes reduced macroporosity compared to Tilled plots. Micro and macroporosity was not affected by cropping systems (Table 2). Sole maize had higher microporosity while macroporosity was higher under maize + *Pueraria* than other cropping systems in 2013. However in 2014, higher microporosity and macroporosity were observed on sole maize than the intercrop. The reason for this inconsistency is not clear, but could be as a result of short term duration of the legumes which have not exerted their full influence on the soil. Similar observation was made by Gomez *et al*. (2001) that it takes five years before changes in some of the soil physical properties could be detected as a result of the soil management practices.

Saturated hydraulic conductivity

The tillage practices had significant effect on saturated hydraulic conductivity (Ksat) in 2014 (Table 2). No–till was 54% significantly higher than tilled plot. The higher Ksat in No-till could be attributed to preponderance of macropores which conferred high Ksat on No-till plot. The result is in agreement with Sharrat *et al*. (2006) that reported significant positive effect of zero-tillage on hydraulic conductivity due to either continuity of pores or water flow through very large pores. Bhattacharyya *et al*. (2006) compared the effects of no-tillage and conventional tillage practices in a four year study, and reported that the hydraulic conductivity values were higher in no-tillage than tilled soils. Osunbitan *et al.* (2005) studied for eight weeks four tillage practices: No-tillage (NT), Manual-tillage (MT), Plough-plough tillage (PP), and Plough-harrow (PH).They observed that saturated hydraulic conductivity decreased with increased intensity of soil manipulation by tillage. The highest conductivity was recorded under NT (7.2×10^{-3} cm/s) and the least under PH (6.1×10^{-3} cm/s).The NT plot consistently had the highest conductivity while the saturated hydraulic conductivity of the manually tilled soil (MT) did not differ significantly from that of PP.

Ksat was significantly affected by cropping systems (Table 2). Mean Ksat ranged from 15.33 to 39.50 cm/hr which were relatively high. Sole maize had higher Ksat values than the intercrop. The reason for this is not clear, but it may be attributed to short term effect of the period of study. Tillage and cropping systems had significant interaction on Ksat.

Soil available water

Soil available water (SAW) was significantly influenced by tillage only in 2014 growing season (Table 2), higher SAW was observed on No-till (0.125cm^3/cm^3) than tilled (0.111 cm^3/cm^3). The higher macroporosity which conferred high Ksat could have be attributed to higher infiltration which led to higher SAW under No-till.

Fabrizzi *et al*. (2005) reported an increase in soil moisture storage under conservation tillage due to decreased evaporation, increases in soil infiltration and the enhance soil protection from rainfall impact.

There was no significant effect on SAW due to the cropping systems in 2013 (Table 2). The trend observed was sole *Canavalia* higher (0.135 m^3/m^3) than other cropping systems. However in 2014, SAW was significantly influenced by cropping systems (Table 2). Sole maize showed higher SAW than the intercrop. In this study, reason for this result may not be clearly understood. The inconsistencies observed may be attributed to the short duration of the study which has not revealed the changes contributed to the soil by the cropping systems.

Table 2: Soil physical properties as affected by tillage, and cropping systems in 2013 and 2014 cropping seasons

Treatments	Bulk Density (g/cm^3)	TP (%)	Mic. (%)	Mac. (%)	SAW (cm^3/cm^3)	Bulk density (g/cm^3)	TP (%)	Mic. (%)	Mac. (%)	Ksat (cm/hr)	SAW (cm^3/cm^3)
	2013					2014					
Tillage											
No-till	1.45	39.86	22. 29	19.71	0.126	1.57	43.25	8.67	34.57	34.94	0.125
Tilled	1.53	40.69	21.72	16.12	0.122	1.57	41.59	7.79	33.79	16.08	0.111
LSD5%	ns	ns	ns	ns	0.12	ns	2.11	ns	ns	1.68	0.01
Cropping systems (CS)											
Sole maize	1.56	37.37	20.80	20.37	0.133	1.56	45.68	8.98	36.37	39.85	0.134
Sole *Mucuna*	1.57	37.02	16.28	21.97	0.111	1.58	41.50	8.68	32.80	25.99	0.119
Sole *Pueraria/ Canavalia*	1.54	39.23	17.03	22.18	0.135	1.53	41.18	7.90	33.33	15.33	0.101
Maize+ *Mucuna*	1.56	47.02	17.70	22.55	0.127	1.65	41.18	7.87	33.28	27.79	0.113
Maize+ *Pueraria/ Canavalia*	1.57	40.75	17.75	22.97	0.114	1.55	42.53	7.73	34.75	18.60	0.123
LSD5%	ns	ns	ns	ns	0.05	ns	3.68	ns	3.11	5.38	0.029
Tillage x CS	ns	ns	ns	ns	ns	ns	ns	ns	ns	<.0001	ns

TP- Total porosity, Mic- Microporosity, Ksat- Saturated hydraulic conductivity, SAW- Soil available water
LSD- Least significant difference, ns- not significant

Soil temperature

Soil temperature was significantly influenced by tillage 6 weeks after sowing (WAS) in 2013 and 4, 6 and 8 weeks after sowing in 2014 (Table 3). The result clearly depicts that No –till had relatively higher soil temperature compared to Tilled plots. The consistent higher soil temperature observed under No–till could be due to higher macroporosity which allowed more heat transfer into the soil. This would have consequently heated up the soil thereby resulting into higher soil temperature when compare to tilled plots. The observation in this study is in contrast with (Tenge *et al*., 1998; Wang *et al*., 2009), they reported that soils under conventional tillage management exhibited higher soil temperatures than No-till.

Soil temperature was significantly influenced by cropping system at 6 WAS and 4, 6, 8 respectively in 2013 and 2014 season (Table 3). In 2013, the intercrop of maize plus *Pueraria* show higher soil temperature than other treatments. However, in 2014, sole maize consistently had higher soil temperature than 4, 6, and 8 WAS than the intercrop at 6 and 8WAS, respectively. This might be due to a surface difference: the soil surface is partially covered by the legumes causing the soil to absorb less solar radiation.

3.3. *Maize growth and yield*

Maize height was significantly affected by tillage practices in 2014 (Table 4). Tilled treatment produced taller maize plants than No–till. The results could be due to the loosening effect on tilled plot that increased infiltration of water which led to increased growth. Iwuafor and Kang (1993), evaluated some tillage systems (strips, zero, minimum and conventional) and reported that at all growth stages, plant height was significantly higher under conventional than other tillage systems and attributed this to higher weed density under zero tillage, resulting in increased moisture and nutrient competitions with the crops. In Nigeria, Lal (1997b) noted that in the second season (Late August to early November) of the first year, when maize suffered from a prolonged drought, plant were generally taller on the zero tillage plots than on ploughed plots.

Cropping systems showed significant influence on maize height only in 2014 .The order of growth were maize + Canavalia > maize + Mucuna> sole maize with respective values of 153.9, 141.9 and 139.3 cm.

Grain yield of maize was significantly affected by tillage practice in 2013 (Table 4). In 2014, although not significant, till has consistently increased maize grain yield. The trend observed in both 2013 and 2014 were similar. Tilled plot produced 39% significant higher grain yield over No-till in 2013. The result of tilled plot producing greater yield than No–till has been reported by many researchers. This result is in line with Albuquerque *et al.* (2001), who concluded that weight and numbers of grains per ear were reduced with no tillage as compared with conventional tillage. Khan *et al.,* (2007), also reported that tillage (both conventional and deep tillage) produced significantly taller plants with greater total dry-matter (45 %) and grain (30 %) yields of corn than no tillage.

Cropping system had significant effect on maize grain yield in 2013 (Table 4). Sole maize consistently produced greater yield than the intercrop in both 2013 and 2014 although, 2014 did not show any significance. This result revealed that there was competition among the intercrop which has led to decrease in growth and finally reduction in yield among the intercrop.

Interaction of tillage and cropping systems

Generally, there were no on tillage and cropping systems did not show any significant interaction on the physical properties during the 2013 and 2014 cropping seasons. However, in 2014 there was significant tillage x cropping systems interaction on Ksat.

Table 3: Soil temperature as influenced by tillage and cropping systems at 4, 6 and 8 weeks after sowing (WAS) in 2013 and 2014 cropping seasons

Treatments	4	6	8	4	6	8
	--------------WAS--------- 2013			------------WAS---------------- 2014		
Tillage (T)						
No till	36.27	37.60	37.07	29.33	29.60	25.20
Till	35.40	36.87	36.52	28.66	27.27	24.53
LSD 5%	ns	0.64	ns	0.87	0.94	0.68
Cropping systems (CS)						
Sole maize	34.83	37.33	37.17	30.14	29.00	25.50
Sole Mucuna	35.83	36.50	36.17	29.33	27.50	24.33
Sole Pueraria/Canavalia	35.67	37.17	36.00	29.33	27.83	24.83
Maize+ Mucuna	36.17	37.67	37.83	29.00	28.83	25.17
Maize + Pueraria/Canavalia	36.67	37.50	36.83	28.67	29.00	24.83
LSD 5%	ns	1.01	ns	ns	1.75	0.46
T x CS	ns	ns	ns	ns	ns	ns

LSD- Least significant difference, ns-not significant

Table 4: Tillage and cropping systems influence on maize height at 8 weeks after sowing and grain yield in 2013 and 2014 cropping seasons

Treatment	Plant height (cm)	Grain yield (ton/ha)	Plant height (cm)	Grain yield (ton/ha)
	---------------2013----------		------------ 2014------------	
Tillage (T)				
No-Till	126.60	1.58	133.69	2.32
Till	123.50	2.63	155.07	3.58
LSD 5%	ns	0.97	17.6	ns
Cropping systems (CS)				
Sole maize	126.90	2.97	139.30	2.98
Maize +Mucuna	126.20	1.58	141.90	2.63
Maize+Pueraria/ Canavalia	122.00	1.77	151.90	1.48
LSD 5%	ns	1.19	ns	ns
T x CS	ns	ns	ns	ns

LSD- Least significant difference, T- Tillage, CS- Cropping systems, ns- not significant

Conclusion

Generally, tillage and cropping systems effects on soil physical properties did not follow a consistent trend in 2013 and 2014 cropping seasons. However, No-till improved some of the physical properties such as bulk density, total porosity, macroporosity, and SAW in both years compared to Tilled plots. Soil temperature was reduced with no-till > tilled. In contrast, maize grain yield was increased with tillage compared with no-till for the two years. In 2013, bulk density, total porosity, macroporosity and SAW were improved under intercrop compared to sole maize, but the differences in the parameters were similar. Bulk density amid the soil physical properties was improved by cropping system in 2014. Also, cropping systems reduced soil temperature compared to sole maize in either year. On the contrary, sole maize produced taller plants and higher maize grain yield than the intercrops. Based on the soil physical properties measured in this study, it suggests that long term tillage under similar environmental and soil conditions will be required to detect changes in soil physical properties as a result of management practices. The long term studies will thus provide site-specific recommendations of the appropriate tillage and cropping systems for adoption in this region.

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