Colloquia Series

Available online at www.publishingrealtime.com

Publishing Real Time

Colloquia SSSN 44 (2020)

Proceedings of the 44th Conference of Soil Science Society of Nigeria on Climate-smart soil management, soil health/quality and land management: synergies for sustainable ecosystem services

Effect of different tillage systems on physical and chemical properties of a clay loam soil in semi arid Sokoto, Nigeria

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Abstract

The experiment was conducted in Usmanu Danfodiyo University, Sokoto peasant farmer's farms, to investigate the effect of different tillage systems on the physical and chemical properties of clay loam soil. The experiment consisted of three treatments (conventional tillage; CT, reduced tillage; RT and no-tillage; NT) arranged in a randomized complete block design (RCBD) replicated four times. Measurement of physical (such as Bd: bulk density; TP: total porosity) and chemical (such as OM: organic matter; OC: organic carbon; TN: total nitrogen; pH and CEC: cation exchange capacity) were made at 0-15cm and 15-30cm soil depths. Data obtained was analyzed using Statistix 9.0 analytical software. The result revealed that Bd and TP (physical) and PH, OC, OM, Ca and CEC (chemical) properties of the soil were significantly ($p \leq 0.05$) affected by the treatments while volumetric moisture (θv) and available phosphorus (AP), TN, Mg, Na, K were not significantly ($p \leq 0.05$) affected by the treatments at both surface and subsurface soil layers. Furthermore, CT and NT treatments gave better soil physical and chemical quality compared to RT treatment. Also, CT gave the highest Bd, TP, pH, AP, TN, exchangeable bases and CEC compared to other treatments (NT and RT) at both soil depths, as NT recorded highest (θv), OM, OC, compare to other treatments (CT and RT) at both soil depths. The result shows that conventional tillage practices (animal traction, Manual hoe usage plus cow dung and fertilizer application) are the best tillage option for crop production in the experimental area.

Keywords: Conventional tillage; reduced tillage; no-tillage; soil physical properties; soil chemical properties .

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https://doi.org/10.36265/colsssn.2020.4476

Peer-review under responsibility of 44th SSSN Conference LoC2020.

1.0. Introduction

Tillage is defined as the physical, chemical, or biological soil manipulation to optimize germination, seedling establishments, and crop growth (Lal,1983). Soil tillage is of fundamental significance in agriculture as it influences soil properties and crop yield (Khairul-Alam *et al.,*2014). Although tillage is done to create optimal soil conditions for crop production, tillage may exert undesirable effects on soil properties depending on the appropriateness or otherwise of the method used (Lal, 1993). This implies that tillage systems effects are not consistent across workers, soils, and climates.

For example, a study by Miriti *et al*. (2013) showed that conventional tillage (ox plough) system significantly reduced bulk density and improved total porosity compared to reduced tillage systems (subsoiling and ripping and tied ridge), while, Shirani*et al.* (2002) found no significant effect of conventional and reduced tillage on soil bulk density in a silt loam in Iran. In their study, Rahman et al. (2008) found increased pH in conventional tillage compared to conservation tillage systems. However, Lal (1997)reported a conservation tillage system having higher pH compared to the conventional system as Rasmussen (1999) observed no significant effect of tillage systems (conventional and conservation) on soil pH. Further, while Garcia *et al*. (2004) found conservation tillage to influence potential nitrogen mineralization due to surface accumulation of crop residue, Morris *et al.* (2010) reported that conservation tillage reduces mineral nitrogen as a result of the immobilized amount of nitrogen by undecomposed residue reducing its availability to wheat-fallow maize. Conversely, Spiegel *et al*. (2002) reported a high amount of nitrogen in conservation tillage due to plant cover throughout the year, which decreased the danger of nitrogen losses to the groundwater. Studies on tillage systems on exchangeable bases, available phosphorus (AP), and organic matter contents are also contradictory. As Rahman *et al*. (2008) reported higher exchangeable Ca, Mg and K in the surface soil under conservation tillage, Curtin *et al.* (2010) found conventional tillage soil having an appreciable amount of exchangeable bases, which was attributed to the addition of chemical fertilizer. A study by Ceyhum and Orhan (2008) reported a high accumulation of available phosphorus in conventional tillage, while Jitareanu *et al*. (2009) found high available phosphorous in conservation tillage compared to conventional tillage practice. On the other hand, Malecka *et al*. (2011) observed no significant tillage effect on available phosphorous. This was attributed to the high initial content of this element in the soil.

From the preceding, the need for more research on tillage effect on soil properties in many regions of the world becomes necessary if tillage systems' effect on soil properties is to be well understood. Therefore, this aimed to evaluate the effect of different tillage systems on the physical and chemical properties of clay loam soil.

2.0. Materials and methods

2.1 The study area

The study was conducted on peasant farmers' farms in the kwalkwalawa village of Usmanu Danfodiyo University, Sokoto. Sokoto state is located on latitude 10^0N and longitude 13^0E. The vegetation of Sokoto is characterized by scattered trees and grasses with the mono-model type of rainfall. The rainfall is erratic and scanty (Rao, 1983; Singh, 1995). The area experiences two distinct seasons, which are wet and dry. The average annual minimum and maximum temperatures are 15^0C and 40^0C (Arnborg, 1988).

2.2Treatment and experimental design

The experiment was established as a randomized complete block design (RCBD) with 3 treatments (conventional tillage: CT, reduced tillage: RT, and no-tillage: NT) replicated four times. Each treatment plot was divided into four (4) segments representing replications and determination of the soil's physical and chemical properties in these segments for each treatment. The land-use history of the treatments plots (farms) is as follows:

2.3 PLOT 1: Cultivated Land (Conventional Tillage: CT)

This site consisted of a land that has been under continuous hand hoe cultivation for the past five (5) years. The dominant weed species in this site include vetiver grass, Striga species, *Pennisetum spp.* at the same time*,* the commonly grown crops in this plot include tomatoes, pepper, wheat, and sweet potatoes.

2.4 PLOT 2: Reduced Tillage (Alternate cultivation and no cultivation: RT)

This land had been under alternate cultivation and no cultivation practices for the past five years. The land had never been continuously cultivated for more than two years without fallow. The fallow period between cultivation periods ranged from 6-12 months. At the time of sampling, the land is under fallow for a year (1 year) and represents the reduced tillage treatment (RT). Dominant plant (weed) species, tillage, and manure application practices are the same as plot 1 (CT treatment).

2.5 PLOT 3: No Tillage (No Cultivation: NT)

The no-tillage treatment consisted of farmland opposite the CT farm under no cultivation (fallow) for the past five (5) years. The land is about 3 m away from the CT plot, and dominant weeds (plant) species found in this land are the same as those found in CT treatment (plot 1).The soil's physical and chemical properties were determined at two soil depths (0-15cm and 15-30cm).

2.6 Determination of physical and chemical properties of the soil

2.6.1 Physical properties

The physical properties of the soil were determined using standard methods, Texture by hydrometer method (Gee and Bauder, 1986), bulk density by core method (Blake and Hartge, 1986), volumetric moisture by the difference in masses of moist and oven-dry soil masses and total porosity by the following relations {(1- Bd/Pd) x 100}.

2.6.2 Chemical properties

Soil chemical properties were determined according to the methods of Page *et al.* (1982). Organic carbon by wet oxidation method, total nitrogen by Kjeldahl procedure, available phosphorus using Bray-1 method, Ph by Ph meter, electrical conductivity using conductivity meter, while cation exchange capacity (CEC) was determined using ammonium acetate saturation as exchangeable bases were extracted using 1N ammonium acetate.

2.7 Statistical analysis

Data obtained were subjected to the analysis of variance (ANOVA) using Statistix 9.0 analytical software. Means were separated using the least significance difference (LSD) test at a 5 % probability level.

3.0. Results and Discussion

3.1 Influence of tillage systems on bulk density (Bd) and total porosity (TP)

The result of the effect of different tillage systems on bulk density (Bd) and total porosity (TP) of the soil are presented in Table 1. Tillage systems significantly ($p \leq 0.05$) affected Bd and TP of the soil at both surfaces (0-15cm) and sub-surface (15-30cm) soil depths. The conventional tillage (CT) recorded the least Bd and highest TP, while the no-tillage (NT) treatment gave the highest Bd and lowest TPat 0-15 cm soil depth. However, at 15-30 cm depth, the NT treatment gave the least Bd and the highest TP as the CT treatment recorded the highest Bd and lowest TP. The decreased BDobserved in the CT treatments at the surface (0-15cm) soil depth could be attributed to the loosening effects of tillage implements used, while the highest Bd in conservation tillage systems (reduced; RT and no-tillage; NT) could be attributed to minimal and lack of soil disturbance respectively. A similar result was reported by (Malecka *et al*. 2012).

3.2 The volumetric moisture content of the soil

The tillage system effect on the volumetric moisture content of the soil is also presented in Table 1. No significant (p≥o.o5) effect of the tillage system on volumetric moisture of the soil was observed at both depths. However, comparing the means at both surface and sub-surface soil depths, the no-tillage (NT) and conventional tillage (CT) gave higher volumetric moisture compared to the reduced tillage (RT) treatment. Also, moisture content decreased with depth. The high moisture content observed in the CT and NT treatment compared to the RT treatments could be due to the higher organic matter (OM) and organic carbon (OC) content of the treatments relative to the RT treatment. Also, lack of soil disturbance in the NT could have resulted in vegetation growth, which upon decomposition adds OM to the soil. Further, the CT treatments through pulverization could have helped mix up the soil and organic constituents add by farmers, these might have resulted in higher organic matter (Table 2), and volumetric moisture content observed in these treatments. Similar observations were made by (Miriti et al. 2013) who reported higher moisture content in NT treatment than the reduced tillage system.

3.3 Soil pH

Results of the effect of tillage systems on soil pH are presented in Table 2. Tillage systems (conventional; CT, reduced; RT and no-tillage; NT) significantly ($p \leq 0.05$) affect soil pH at both surface (0-15cm) and sub-surface (15-30cm) soil depths. CT and NT treatments gave the highest and lowest pH at both surfaces, respectively. The increased pH in CT treatment could be associated with applying manure and fertilizer, which in turn result in high exchangeable bases Table 2. The lowest pH in NT treatments could be due to the dominant grasses' consumption of available exchangeable bases. A similar observation was made by Rahman *et al*. (2008).

3.4 Organic matter (OM) and organic carbon (OC)

Tillage systems significantly ($p \leq 0.05$) affected the OM and OC content of the soil at both surfaces (0-15cm) and sub-surface (15-30 cm) depths. The higher OC and OM contents observed in the NT treatments at both soil surfaces could be attributed to plant residues' long-term addition and reduced leaching into deeper horizons, likewise reducing OM's erosion. A similar observation wasmade by Jitareaunu *et al.(*2009). Also, the relatively higher OC and OM content of the CT treatment compare to the RT treatment could be due to continuous mixing of organic matter added with the soil and its constituents, resulting in better accumulation and mineralization of the manure than in the RT treatment where short fallows between cultivation periods break the mixing action of cultivation. This is in accord with Jitareaunu et al. (2009), finding higher OC and OM in conventional tillage than in reduced tillage.

3.5 Available phosphorous (AP) and total nitrogen (TN)

Effect of tillage on available phosphorous and total nitrogen at the surface (0-15cm) and sub-surface (15-30cm) soil depths are also presented in Table 2. No significant (p≥o.o5) treatment effect on AP and TN of the soil was observed at both soil surfaces. However, comparing the means, the CT and NT treatment had higher AP and TN content than the RT treatment. The relative improvement in AP and TN concentrations in the CT and NT treatment compared to the RT could be attributed to higher organic carbon (OC) and organic matter (OM) of these treatments. Organic matter, upon decomposition, releases minerals elements into the soil (Agbede, 2007). Also, applying chemical fertilizer in the CT treatment could have resulted in the higher AP and TN content compared to the NT and RT treatment, which agrees with finding Ceyhum and Orhan (2008).

3.6 Exchangeable bases and cation exchange capacity (CEC)

Results on tillage systems that affect exchangeable bases (calcium: Ca, magnesium: Mg, sodium: Na, and potassium: K) are presented in Table 2. No significant (p≥o.o5) effect of tillage systems was observed on exchangeable bases except Ca at the surface (0-15cm) soil depth. The CT and NT treatment gave higher Ca content compare to the RT treatment (Table 2). Similarly, tillage effect on cation exchange capacity (CEC) was not significant (p≥o.o5) except at surface (0-15cm) soil depth, where CT treatment gave the highest CEC (8.95cmol/kg) followed by the NT treatment (8.30cmol/kg) as RT treatment recorded the least (7.03cmol/kg) Table 2.In general, the higher exchangeable bases and CEC in the CT and NT treatment than RT treatment could also be associated with higher organic matter (OM) content of these treatments which upon decomposition add mineral element (exchangeable bases) to the soil which invariably results in higher CEC and exchangeable bases. This is in accord with the observation made by Agbede (2007).

However, it is striking that the CT treatments recorded higher exchangeable bases despite the highest OC and OM in the NT treatment. However, it could be a result of better decomposition conditions (lower Bd, higher TP) in the surface soil layer combined with the relatively high OM content in the CT treatment, which resulted in better microbial activities and decomposition of OM releasing element to the soil.

Table 1: Effect of different tillage systems on physical properties of the soil

Treatment	Soil depth (cm)	Bd (gcm-1)	TP (%)	Ɵv (%)
CT	0-15	1.36[b]	48.95[a]	17.11[a]
RT		1.54[ab]	41.00[b]	15.17[a]
NT		1.58[a]	40.73[b]	18.23[a]
LSD(0.05)		0.19	6.78	5.11
CT	15-30	1.72[a]	35.11[a]	15.67[a]
RT		1.56[ab]	41.25[b]	14.45[a]
NT		1.43[b]	46.10[b]	17.82[a]
LSD(0.05)		0.27	10.42	8.17

1. by the same letter(s) in the same column are not significantly different at 5% level of probability
2. 2. NT- no tillage, RT- reduced tillage, CT- conventional tillage, Bd- Bulk density, TP- total porosity, Θv-volumetric moisture content

Table 2: Effect of Different Tillage Systems on Chemical Properties of the Soil

treatments	Soil depth	PH	OC	OM	TN	AP	Ca	Mg	Na	K	C.E.C
CT	0-15 cm	6.69[a]	1.02[b]	1.76[b]	034[a]	0.83[a]	0.77[a]	0.21[a]	0.89[a]	1.21[a]	8.95[a]
RT		5.80[b]	0.60[b]	0.60[b]	0.06[a]	0.69[a]	0.64[b]	0.07[a]	0.83[a]	1.10[a]	7.03[b]
NT		5.47[b]	1.92a	1.92[a]	0.22[a]	0.77[a]	0.73[a]	0.17[a]	0.76[a]	1.10[a]	8.30[ab]
LSD(0.05)		0.49	0.89	1.54	0.51	0.38	0.08	0.18	0.18	0.45	1.41
CT	15-30 cm	6.56[a]	0.82[b]	1.42[b]	0.07[a]	0.78[a]	0.76[a]	0.20[a]	0.20[a]	0.98[a]	8.45[a]
RT		6.21[ab]	0.61[b]	1.06[b]	0.06[a]	0.74[a]	0.68[a]	0.12[a]	0.12[a]	0.92[a]	7.20[a]
NT		5.85[b]	1.72[a]	2.97[a]	0.06[a]	0.84[a]	0.75[a]	0.15[a]	0.15[a]	1.01[a]	9.90[a]
LSD(0.05)		0.51	0.55	0.95	0.05	0.45	0.27	0.17	0.17	0.59	4.01

1. *Means followed by the same letter(s) in the same column are not significantly different at the 5% probability level.*
2. *2. OC- organic matter, OM- organic matter, AP- available phosphorous, TN- total nitrogen, Ca, Mg, Na, K- CEC.*

4.0 Conclusion

The study revealed that conventional tillage (CT) and no-tillage (NT) treatments gave better soil physical and chemical quality compared to the reduced tillage (RT) treatments. However, the best improvement was observed in the CT treatment. From the result, it could be concluded that CT treatment is the best management option for the soil of the experimental area. However, similar research should be conducted on different soil types to compare results.

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