Colloquia SSSN 44 (2020) 552-557

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

Influence of different tillage practices on hydraulic properties of clay loam soil in semi arid Sokoto, Nigeria.

Khalid*[1]T. Khalid, Sauwa[2] MM, Yusif[2] SA, Aminu[2] ST, Okeke[1] GC, Aliyu[1] N, Gaya[1] MI, Abubakar[1] I

[1.1]National Agricultural Extension and Research Liaison Services, A.B.U., Zaria

[2]Department of Soil Science and Agric. Engineering, UsmanuDanfodiyo University, Sokoto, PMB 2346, Nigeria

Abstract

The experiment was carried out in farmer's farms around kwalkwalawa village in UsmanuDanfodiyo University Sokoto to investigate the influence of different land uses on hydraulic properties of clay loam soil. The experiment consists of three (3) treatments (conventional tillage: CT, reduce tillage: RT, and no-tillage: NT) replicated four times. Measurement of hydraulic properties such as infiltration characteristic (infiltration rate, cumulative infiltration rate, steady-state infiltration), saturated hydraulic conductivity, gravimetric moisture content, and water holding capacity was made at (0-20cm) and 20-40cm soil depths. Data obtained was analyzed using Statistix 9.0 analytical software, and means were separated using the least significant difference (LSD) at a 5% probability level. The result revealed that land-use systems significantly affect infiltration characteristic ($P \leq 0.05$) at both surface and sub-surface soil depths and water holding capacity at sub-surface (20-40cm) soil depth best improvement in the CT treatment. However, land-use systems have no significant ($p > 0.05$) effect on the other hydraulic properties of the soil (Ksat and θm). The results show that the CT treatment is the best soil management option around the experiment area for sustainable soil and water conservation and agricultural crop production. However, it is recommended that other conventional tillage systems such as animal traction and tractor plough should be tried to compare results.

Keywords: Conventional tillage; reduced tillage; no-tillage; infiltration; hydraulic conductivity

Corresponding Author's E-mail Address: tkhalid1991@yahoo.com : Phone: +2347035285441

https://doi.org/10.36265/colsssn.2020.4477

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

1.0 Introduction

Tillage is seen as mechanical manipulation of soil to modify soil conditions for crop production by providing a conducive environment for seed germinations and root development, suppressing weed, controlling soil erosion, increasing infiltration, and reducing evaporation soil moisture. Conventional tillage or intensive tillage system includes all tillage practices that leave < 15% of residues on the soil surface, while conservation tillage is a system that leaves > 30% of crop residue on the soil surface. Soil hydraulic properties include hydraulic conductivity as a function of soil water, pressure, soil water content, soil moisture retention relationships (Hillel,1998), and infiltration characteristic of soils (Sauwa*et al.,* 2013). Understanding the hydraulic properties of soils, such as hydraulic conductivity, moisture retention, and infiltration rate is essential for assessing soil quality, design of adequate soil, and land management practice (Lal, 1991). Likewise, water balance, irrigation, soil water transport processes, and soil erosion (Lucian *et al.,* 1991). Topography or slope gradient, pore-size distribution, pore continuity, and land use are among the primary soil and management factors that affect surface soil's hydraulic properties. Thus, knowledge of surface soil hydraulic properties concerning these soil and management factors is essential for efficient land and water management, particularly in arid and semi-arid environments where water remained a major limiting factor to agricultural crop production. Although several types of research had been conducted evaluating land uses system effects on soils' hydraulic properties (Azooz and Arshad, 1996; Sauwa*et al.,* 2013: Chiroma*et al.,* 2013), results do not apply to all soils, climate, and land uses. Information on the land-use system's effect on soils' hydraulic properties could help design proper soil and water conservation practices and sustainable agriculture policies.

The study's main objective is to evaluate the effect of different land uses on the soil's hydraulic properties. However, specific objectives include determining the effect of different land uses on:

i) Saturated Hydraulic conductivity of the soil.
ii) Water retention properties of the soil.
iii) Water retention properties of the soil.

2.0. Materials and methods

2.1Study Area
The experiment was conducted at the Agricultural chemical laboratory of UsmanuDanfodiyo University Sokoto. Sokoto State is located on latitude 13°N and longitude 15° E, 315m above sea level. The vegetation of Sokoto is characterized by scattered trees and grasses with the mono-model type of rainfall. The rainfall is erratic and scanty throughout the year (RAO 1983; Singh 1995), and it is between 400-700mm annually (Kowal and Kasim 1998).

2.2 Soil Sample Collection and Preparation
The soil samples used for this experiment were collected from a low land area of Kwalkwalawa village, Usmanu-Danfodiyo University, Sokoto, using an auger. The samples were collected at 3 different points in each treatment plot (at 0-20 cm) and then air-dried, crushed, sieved through a 2 mm sieve, and used determination of the soil's textural composition. Also, two undisturbed core samples taken at (0-20cm) (surface) and 20-40cm (sub-surface) soil depths were used for the determination of hydraulic properties of the soil.

2.3 Treatments and Experiments Design
The experiment was laid out in randomized complete block design (RCBD) with3 tillage practices as factors; conventional tillage(CT), reduced tillage(RT), and No-tillage(NT), and replicated 4 times. The history of the 3 selected sites in terms of land uses was obtained and used in results and discussion. Plot under convectional tillage has been under continuous hand hoe cultivation for the past five (5) years. The dominant weed species in this site include vetiver grass, harkiya (*Digitarialongiflora*), Tunbulkiya, harwatsi (*Mitracarpusscaber). T*he commonly grown crops in this plot include Tomatoes, pepper, wheat, and sweet potatoes. Tillage practices in this treatment plot (land) involved 2-6 hand hoe cultivations per year, and cow dung manure is applied during land preparation, and urea fertilizer applied later as a top dressing (or supplement).
Reduce tillage is the land adjacent to the CT plot, not more than 3m away. This land has been under alternate cultivation and no cultivation practices. The land has never been cultivated continuously for more than 2 years. The fallow period between cultivation periods ranges from 6 months to 1 year. It is under no cultivation (fallow) at the sample time and represents the reduced tillage treatment (RT). The no-tillage treatment consisted of farmland opposite the CT farm (plot) under no-cultivation (fallow) for the past 5 years. The land is 2-3m away from the CT plot, and dominant weed species are the same as those in CT treatment (plot).

2.4 Determination of physical and hydraulic properties of the soil

The hydraulic properties of the soil were determined using standard methods.

2.5 Gravimetric Moisture Content (θM)

The gravimetric moisture content (**θ**m) would then be computed as:

$$\theta m = \left(\frac{Mm - Md}{md}\right) \times 100$$

Where:

Mm= mass of moist soil.

Md=mass of oven-dry soil.

2.6 Water holding capacity

The water holding capacity would then be computed as:

$$WHC\ (\%) = \left(\frac{Mw - Md}{md}\right) \times 100$$

Where:

Mw = mass of saturated soil.

Md = mass of oven-dry soil.

2.7 Saturated hydraulic conductivity (Ksat)

Saturated hydraulic conductivity computed as:

$$Ksat = -2.3\ \frac{aL}{At}\ Log\ \frac{Ho}{H1}$$

Where

Ho = Initial hydraulic head

H1 = final hydraulic head

a = cross-sectional area of the standing PVC pipe (πr^2)

L = length of the soil sample

A = cross-sectional area of the water (πr^2)

t = time (sec)

2.8 Infiltration rate (IR): The Infiltration rate (IR) of the Individual treatments (soil core samples) was determined using the single-ring infiltrometer method of Wu*let al.* (1999). Infiltration rate was then computed as the amount of water that enters the soil surface within the infiltration ring per time taken (cm/t). Steady-state infiltration rate (SSIR) and cumulative infiltration (CI) were deduced from the infiltration rate measurements and computations.

2.9 Particle Size Analysis (Texture)

The soil samples' particle size distribution was determined using the Bouyoucus hydrometer method (Gee and Bouder, 1986). Values obtained were then read using the USDA textural triangle to know the textural class of the soil.

2.9 Statistical Analysis

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

3.0. Results and Discussion

3.1Influence of different tillage practices on infiltration rate and steady-state infiltration rate.

Figure 1 shows the influence of different tillage practices of infiltration characteristic of the soil at 0-20cm- depth. The result revealed that tillage practices significantly ($p \leq 0.05$) affected the soil's infiltration rate (IR) at 2,6,10 and 50 minutes. On average the measurement period, the conventional tillage (CT) gives the highest IR, followed by the no-tillage (NT), while the reduced tillage (RT) is recorded the least. A similar trend was observed at the 20-40cm soil depth (figure 2) as the CT treatment recorded the highest IR, and the RT treatment gave the least. Land use system effect on steady-state infiltration rate of the soil was not significant ($P > 0.05$) as all treatments (CT, RT, and NT) gave the same steady-state infiltration rate (SSIR) 0.1 cm/hr after one (1) hour (Figures 1 and 2). The increased infiltration rate in the CT and NT treatments could be attributed to the lower bulk density (Bd) of these treatments compared to the RT treatments, which have the highest Bd at both surfaces (0-20cm) and sub-surface (20-40cm). Furthermore, Khalid (2016) attributed it to higher organic matter and organic carbon in the CT and NT treatments than the RT treatments. Organic matter is known to improve aggregation and aggregate stability (Tan *et al.,* 2007; Collins *et al.,* 1997), which invariably resulted in higher water transmission in CT and NT treatments than the RT treatment. The result revealed that the CT and NT treatments gave better water transmission compared to the RT treatment.

3.2 Influence of different tillage practices on cumulative infiltration rate (CIR.)

Figure 3 shows the influence of different tillage practices on the cumulative infiltration rate (CIR) of the soil at (0-20cm) soil depth. The result revealed that tillage practices ($P \leq 0.05$) significantly affected the soil's cumulative infiltration rate at 6, 10, 20, 50, and 70 minutes. On average, across the measurement period, CT treatment had the highest CIR, followed by NT and RT gave the least. A similar trend was observed at (20-40cm) soil depth (Figure 4) as the CT treatment recorded the highest CIR, and the RT treatment recorded the least. Generally, the cumulative infiltration rates were higher in sub-surface than in surface soil depth, increasing with time. However, the most significant increases were recorded in 10 minutes for CT treatment with a mean value of 29.08 cm/hr at the surface and sub-surface soil depth. The increased cumulative infiltration rate (CIR) in the CT and NT treatment could be attributed to a decreased bulk density compared to the RT treatment with the highest Bd at both surface and sub-surface soil depth. Khalid (2016), who carried out his experiment in the same experimental area, reported the higher organic matter and organic carbon in the CT and NT treatments compared to the RT Organic matter improves microbial activities, increase aggregate stability and decrease bulk density in CT and NT treatments at the surface (0-15cm) (Agbede, 2007) which invariably resulted in higher water transmission in CT and NT treatments compared to the RT treatment

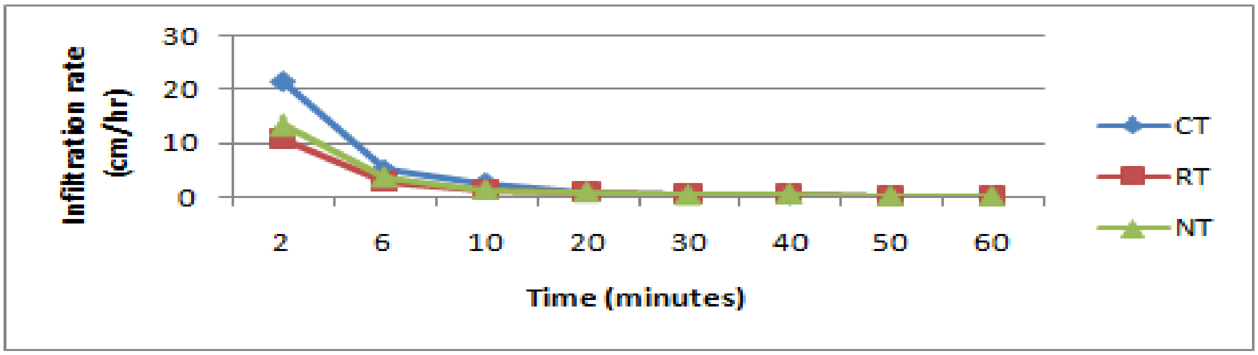

Figure1: infiltration rate of the soil as affected by different tillage practices at0-20cm soil depth.

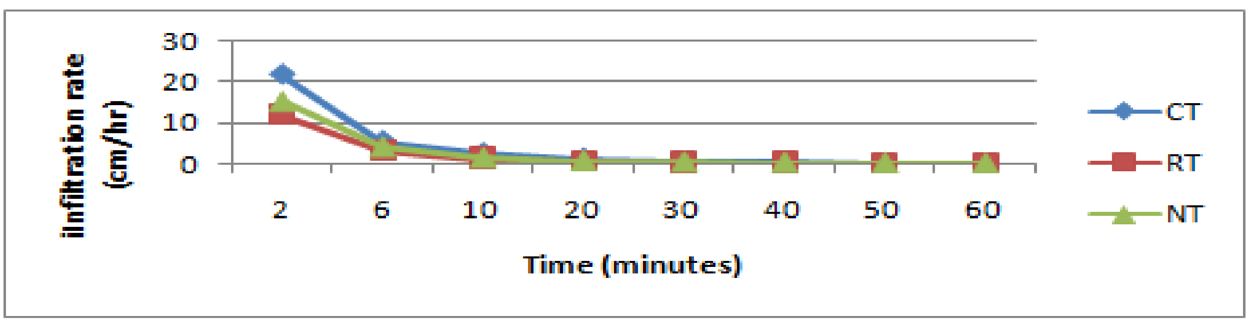

Figure 2: infiltration rate of the soil as affected by different tillage practices at 20-40cm soil depth

3.3 Influence of different tillage practices on gravimetric moisture content (GMC), water holding capacity, and saturated hydraulic conductivity (Ksat)

The gravimetric moisture content of the soil was also presented in Table 1. The result revealed no significant difference in moisture content ($P > 0.05$) in both surface and sub-surface soil depth. The mean value at the surface soil (0-20cm) was higher in CT (22.86%), followed by NT (22.81%) and RT had the least (17.78%). However, for sub-surface (20-40cm), the mean value was higher in NT (22.66%) followed by the treatment (19.62). On average, soil gravimetric moisture content generally decreases with soil depth across the 3 different land practices. However, it

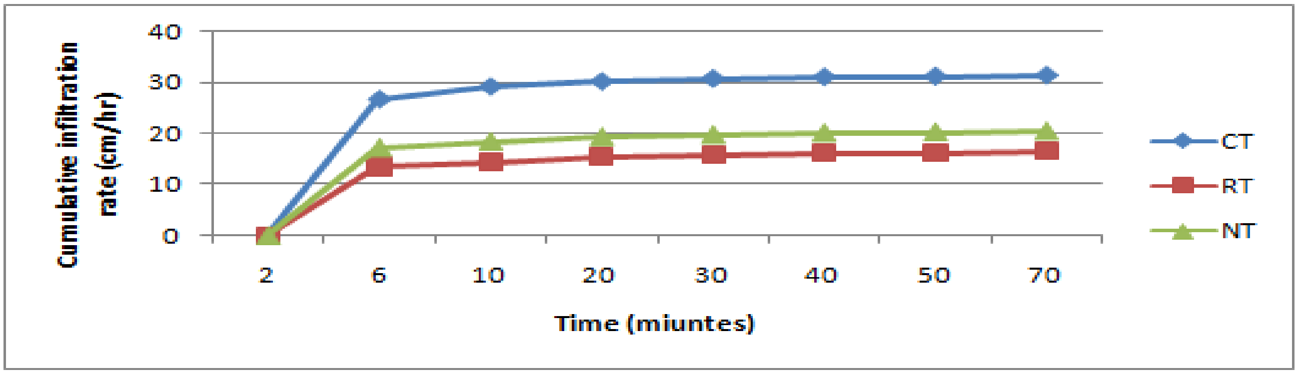

Figure 3: cumulative infiltration rate of the soil as affected by different tillage practices at 0-20cm soil depth.

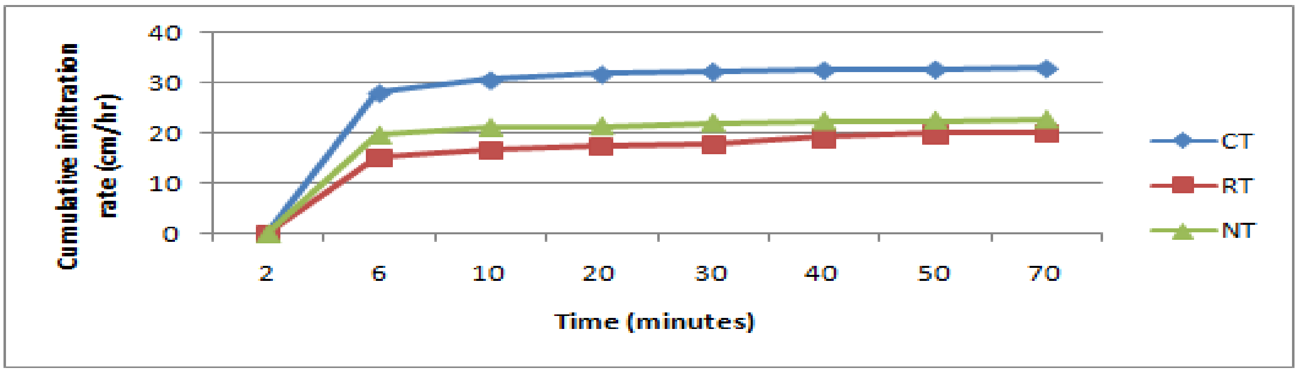

Figure 4: cumulative infiltration rate of the soil as affected by different tillage practices at 20-40cm soil depth.

is not clear why the CT treatment record the highest mean gravimetric moisture content compared to the NT treatment, although the NT had the least bulk density (Bd) at the subsurface (20-40cm) soil depth. However, this could be related to possibly better soil organism activities in the CT treatment at the surface soil layer, which have high resulted in the creation of bio pores. Biopores could have resulted in a preferential flow of water in CT treatment at the sub-surface layer and better water transmission despite moderate bulk density (Bd).

The influences of different tillage practices on the soil's water-holding capacity (WHC) were presented in table 1. The result shows that there were no significant differences (P>0.05) in both the treatments of surface and sub-surface depth, the highest mean WHC value at the surface (0-20cm) soil depth as recorded in CT (28.81%) followed by NT (25.54%) as the RT treatment had the least (25.01%). However, there were significant differences at the sub-surface (20-40cm); however, tillage treatment significantly ($P\leq 0.05$) affected the WHC of the soil. The NT treatment had the highest WHC (30.71%), while the RT treatment revealed the least (27.02%) in Table 1. The CT treatment had an intermediary value of 29.21%. The increase in water retention in the CT, and NT treatments could be related to higher organic matter (OM) and organic carbon content (Khalid, 2016). similar observation was made by Jabro *et al.* (2008), who reported no significant tillage system differences on water storage of sandy loam.

The increase in WHC in CT and CT and NT in surface and sub-surface can be attributed to the similar mesoporosity value in convectional (CT) and conservation tillage (NT). (Zhou et al., 1998). The inconsistent result of soil WHC under the different tillage practices may be related to the transitory nature if soil structure is affected by tillage and site history (Azooz and Arshad, 1996).

The results in Table 1 revealed that there were no significant differences ($P>0.05$) in Ksat of the soil among the 3 treatments both at the surface (0-20cm) and sub-surface (20-40cm). Soil Ksat was slightly influenced by tillage practices and varied from 2.17 cm/hr for RT and 2.38cm/hr for NT to 2.90cm/hr for CT. The highest mean value was recorded in CT treatment at both surface and sub-surface with a mean of (2.90cm/hr and 2.79cm/hr), followed by NT with a mean of (2.38 cm/hr and 2.15cm/hr) and then RT treatment (2.17cm/hr and 2.04cm/hr) respectively.

The slight increase of Ksat in CT treatment could be due to the lower bulk density in CT than NT and RT at both surface and subsurface soil depths. These findings agreed with the result reported by Chiroma *et al.* (2006) and Jabro *et al.* (2009). Higher bulk density (Bd) values obtained under RT, and NT systems are the indicators of soil compaction (Abu-Hameed, 2003) and might be the cause of low Ksat obtained in RT and NT treatments (Celik *et al.,*2010) at the surface (0 -20cm) and subsurface layer.

4.0 Conclusion and Recommendations

The study revealed that land-use systems significantly ($p\leq 0.05$) affected hydraulic properties of the soil except for Ksat and Θm, at both surface and subsurface soil depths, with the best improvement observed in the CT treatment compared to the NT and R.T. From the results, it can be concluded that, the CT treatment is the best soil management option for clay loam soil in semi-arid Sokoto, for sustainable soil and water conservation.

Table 1. Effect of different tillage practices on water retention properties of the soil at Sokoto, Nigeria.

Treatments	Depth (cm)	ϴm (%)	WHC (%)	Ksat(cm/hr)
	0-20			
CT		22.86[a]	28.81[a]	2.90[a]
RT.		17.78[a]	25.01[a]	2.17[a]
NT		22.81[a]	25.54[a]	2.38[a]
LSD 0.05		5.11	13.69	0.86
SE (±)		2.08	5.59	0.35
	20-40			
CT		19.62[a]	29.21[a]	2.79[a]
RT.		18.78[a]	27.02[a]	2.04[a]
NT		22.66[a]	30.71[a]	2.15[a]
LSD. (0.05)		9.79	2.69	0.99
SE (±)		4.00	1.10	0.40

Means fallowed by the same letters in the same column are not significantly different at a 5% level of probability. ***θ***m-gravimetric moisture content, WHC – water holding capacity, Ksat- saturated hydraulic land activity.

5.0 Recommendations

According to the findings of the research, the following recommendations were made:

1. Adoption of conventional tillage practice around the experimental area should be encouraged.

2. another conventional tillage method such as animal traction and tractor plough should be tried to compare results.

3. Similar research should be extended to other soil types to compare results.

References

Abu-Hamdeh N. H. (2003). Soil compaction and root distribution for okra as affected by tillage and vehicle parameters. *Soil and Till. Res.,* 74:25-35.

Agbede, T.M., (2007). Effect of zero tillage on cassava

Table 2 . Effect of Different Land Uses on Bulk Density of the Soil at 0-20cm and 20-40cm soil depths.

Treatment	Depths (cm)	Bulk density (g/cm^3)
	0-20	
CT.		1.55[a]
RT.		1.71[a]
NT.		1.65[a]
SE (±)		0.24
	20-40	
CT.		1.39[a]
RT.		1.66[a]
NT.		1.52[a]
SE (±)		0.14

Table 3. Cumulative Infiltration Rate (CIR) in cm/hr as affected by Different Land Uses in Sokoto, Nigeria.

Treatments	Depth cm	2	6	10	20	30	40	50	70
	0-20								
CT		0	26.50[a]	29.08[a]	30.10[a]	30.65[a]	30.98[a]	31.10[a]	31.30[a]
RT.		0	13.50[b]	14.85[b]	15.32[b]	15.93[b]	16.23[b]	16.36[b]	16.56[b]
		0	17.25[b]	18.45[b]	19.35[b]	19.78[b]	20.15[b]	20.27[b]	20.47[b]
NT									
SE (±)		-	2.49	2.72	2.89	2.87	2.88	2.88	2.88
	20-40								
CT		0	28.00[a]	30.53[a]	31.07[a]	32.25[a]	32.54[a]	32.68[a]	32.88[a]
RT.		0	15.25[b]	16.67[b]	17.38[b]	17.75[b]	19.05[b]	19.82[b]	19.90[b]
NT		0	19.50[ab]	21.00[ab]	21.56[b]	21.91[b]	22.29[ab]	22.41[b]	22.60[b]
SE (±)		-	3.92	4.11	4.07	4.06	4.51	4.06	4.07

Table 4. Effect 0f Different Land Uses on Infiltration Rate and Steady State Infiltration Rate of the Soil at 0-20cm and 20-40cm soil depth

Treatments	Depth cm	2	6	10	20	30	40	50	70
	0-20								
CT		21.50[a]	5.10[a]	2.57[a]	1.02[a]	0.55[a]	0.32[a]	0.12[b]	0.1
RT.		10.75[b]	2.75[b]	1.20[b]	0.90[a]	0.35[a]	0.30[a]	0.12[b]	0.1
NT		13.50[b]	3.75[ab]	1.35[b]	0.90[a]	0.40[a]	0.60[a]	0.16[a]	0.1
SE (±)		2.34	0.68	0.43	0.15	0.09	0.09	0.01	---
	20-40								
CT		21.75[a]	5.50[a]	2.53[a]	1.18[a]	0.55[a]	0.45[a]	0.15[a]	0.1
RT.		12.00[b]	3.25[b]	1.35[b]	0.71[b]	0.35[a]	0.30[a]	0.15[a]	0.1
NT		15.38[ab]	4.13[ab]	1.43[b]	0.70[b]	0.38[a]	0.30[a]	0.15[a]	0.1
SE(±)		3.16	0.73	0.34	0.16	0.09	0.10	0.02	---

(*ManihotesculantusCrantz*) in southwest Nigeria.*Nig. J. Soil Sci.*, 17: 81-86.

Azooz, R.H., and Arshad, M.A.(1996). Soil infiltration and hydraulic conductivity under long-term no-tillage and conventional tillage systems. *Can. J. Soil Sci.,* 76:143-152.

Celik I, Gunal, H., Budak, M. andAkpinar, C. (2010).Effect of long-term organic and mineral fertilizers on bulk density and penetration resistance in semi-arid Mediterranean soil condition.*Geoderma,* 160(2): 236-243.

Chiroma, A.M., Foloronso, O.A., Alhassan, A.B.(2006). The effect of land configuration and wood-shavings mulch on the properties of sandy loam soil in northeast Nigeria.2. Changes in physical properties. *Tropicultura,* 24(1):33-38.

Collins, H, P., Poul, E. A., Paulstian, K. and Elliot, E.T. (1997).Characteristic of soil organic carbon relative to its stability and turnover.*In:* Paul, E.A., Paulstaian, K., Elliot, E. T., Cole C.V., (Eds). Soil organic matter in temperature agro-ecosystems: long term experiments in North America. CRC Press, Boca Raton, FL. Pp. 51-72.

Gee, G.W. and Bouder, J.W. (1986). Particle Size Analysis: In Klute, A. (ed) method of soil analysis part 1. Physical and mineralogical properties, Agronomy monograph 9, ASA, Madison Wisconsin, Pp. 303-411.

Hillel, D. (1971). *Soil Water: physical principles and processes.* Academy press Inc. California. Pp 69-157.

Jabro, J.D., Sainju, U.M., Steaves, W.B., Lenssen, A.W., Evans, R.G.(2008). Long-term tillage frequency effects on dryland soil physical and hydraulic properties. Inter soil conserve. Org. conf. Proc. May 15-23, 2008, Budapest, Hungary. Pp 1-4.

Khalid, T.K. (2016). Effect of tillage systems on physical and chemical properties of clay loam in semi-aridSokoto, Nigeria. A research project was submitted to the Department of Soil science and Agric. Engr., Faculty of Agriculture, UDU. Sokoto.

Kowal, J.N. and Kassam, AH (1998).*Agricultural Ecology of savannah*. A study of West Africa, Oxford University Press. P.67.

Lal, R., Mahboubi, A.A. and Fausey, N.R. (1994). Long-term tillage and rotation effect on properties of a central Ohio soil. *Soil Sci. Soc. Am. J.,* 58:517-522.

Lucian, S., Serge, B. and Christian, P. (1991). An Approach to the development of Sustaining Farming System in Columbia, R.E. (ed) Evaluation for sustainable land management in developing world vol. 2, Technical paper, Bangkok, Thailand.

Rao, N.N.P. (1983). Preliminary results of the study on the Agro-climatology of Sokoto State. A seminar paper presented at faculty of agriculture, University of Sokoto.

Sauwa, M.M., Waniyo, U.U., Ngala, AL, Yakubu, M. and Noma, S.S. (2013). Influence of Tillage practices on physical properties of sandy loam in a semi-arid region. *Bayero J. Pure and Appl. Sci.,* 6(2): 76-8 -3.

Statistix 9.0 (2005).Version 2005, statistix for windows analytical software, USA.

Tan, Z., Lal, R., Owens, L. and Izaurralde, R. C. (2007). Distribution of light and a heavy fraction of organic carbon as related to land use and tillage practice. Soil & Tillage Res., 92: 53-59.

Wu, L., Pan, L., Mitchell, J. and Sanden, B. (1999). Measuring saturated hydraulic conductivity using a generalized solution for single ring Infiltrometers.*Soil Sci. .Soc. Am. J.,* 63: 788-792.

Zhou, Z., Zhang, J., Lai, D.J. and Jiang, G. (2012). Effect of conventional tillage practices on winter wheat water use efficiency and crop yield on the Loess Plateau, China. Agricultural water management. 87, 307-314.