

EFFECTS OF MANURE INCORPORATION IN ALLEVIATING COMPACTION ON SATURATED HYDRAULIC CONDUCTIVITY OF SANDY LOAM SOIL IN MAIDUGURI, NIGERIA

¹Akwoga, J. A, ²John, W G, ¹Gisilanbe S. A., ¹Garpiya, B.T, And ¹Hashimu, S. A.

¹Department of Soil Science and Land Resource Management, Taraba State University, Jalingo

²Department of Soil Science, University of Maiduguri, Maiduguri

Corresponding Author's Email Address: wealthyjohnson@gmail.com

Received 18th July, November, 2022 Accepted 02nd December, 2022

ABSTRACT

Study on the effects of organic material incorporation in alleviating the effect of compaction on saturated hydraulic conductivity was conducted in the laboratory. Surface soil sample (0-15cm) at the University of Maiduguri Teaching and Research farm was collected and treated with 2.5kg each of poultry litters, groundnut haulm, and cow dung. Each of the soil organic mixed was subjected to four levels of compaction at 0, 10, 20 and 25 blows from Proctor hammer at 10% moisture content. The results showed that the control treatment (without organic material and compaction) had the highest saturated hydraulic conductivity with value 2.3×10^{-5} cm/s while groundnut haulm had the lowest value of about 3.2×10^{-5} cm/s. The saturated hydraulic conductivity in all the treatments decreased with increasing levels of compaction irrespective of the nature and type of organic material used. It was concluded that the addition of organic materials reduced the effect of compaction on saturated hydraulic conductivity at the highest levels of compaction (20 and 25 blows). Cow dung had the highest saturated hydraulic conductivity value than the other treatments, and it could be preferably used.

Keywords: Compaction; Saturated hydraulic conductivity; Organic materials; Sandy loam

INTRODUCTION

Traditional tools are no more in vogue for to perform agricultural production, and operations in most developing nations. Output from such tools is not often enough to meet with the food and fiber demands of a teeming population like Nigeria. However, increased use of farm machines for farm operations is thought to have adverse effects on crop production due to soil compaction problems (Upadhyayh and Davis, 1992). Soil Compaction influences many soil properties such as hydraulic properties, infiltration, soil water retention, soil water flow and hydrologic response (Klute, 1982; Oustand and Voorhee, 1987). It also influences surface water run-off, soil erosion, green house emission, eutrophication and reduced ground water recharge. Continuous use of heavy machines on agricultural lands, results especially destroy soil structure destruction (Sjoerd, 2005).

Saturated hydraulic conductivity is defined as the quantitative measure of a saturated soil's ability to transmit water when

subjected to hydraulic gradient. Saturated hydraulic is a function of both physical and chemical properties of the soil, land use and crop management (USDA, 2003). Saturated hydraulic conductivity is affected by several factors, some of which have direct influence while some indirect by their influence on soil properties (Six *et al.*, 2004). These soil properties include texture, structure, infiltration rate, organic matter content, clay mineral, cation exchange capacity, shear stress, bulk density, crust, slope and the crop cover, temperature, pressure and properties of soil fluid (USDA, 2003; Stibinger, 2014 and Zhang *et al.*, 2006). The subject of hydraulic conductivity is essential to the understanding of water flow through soils. It controls the drainage rate of soil. Also, its significant impact on geotechnical problems (retaining walls, slope, embankment, foundation, etc.).

The knowledge of saturated hydraulic conductivity is essential for irrigation and drainage management systems and can also be used for hydrological modeling (Dexter and Richard, 2009; Randellife and Rasmussen, 2002).

and Waynants *et al.*, 2009.), while tillage practices have significant influence on the different hydraulic properties under agricultural land use (Whahl *et al.*, 2003). To improve soil structure, stimulating soil biological activity by reducing tillage and increase inputs of organic matter is necessary (Kooisha and Boersma, 1994).

Low organic matter levels make the soil more susceptible to soil compaction organic residues on the soil surface have been shown the effects of soil compaction.

Good soil structure can withstand pressure from impacts of farm implements, raindrops and runoff waters. It can also enhance air penetration and circulation aeration and good root penetration, so that the soil can remain under favorable condition for plant growth (Braver *et al.*, 1990). Hamza and Anderson (2005) observed that incorporation of organic materials enhances the formation of stable aggregate and at the same time provides buffering actions in the soil. Although there are some published reports on soil organic materials on compaction and hydraulic properties of soils in Nigeria, this study was intended to deepen our knowledge of organic manure effects on soils of Borno State, Nigeria.

MATERIALS AND METHODS

Location and Sample Collection

This study was carried out in the laboratory section of the Soil Science Department at the University of Maiduguri, Borno State. Soil samples were collected from 0-15cm depth from the University Teaching and Research Farm. The soils had a sandy loam texture, with values of 65% sand, 18% silt and 17% clay according to Ibrahim *et al.* (2015).

Treatments

A total of 16 treatments comprising different levels of compaction and types of organic materials were used in the laboratory. The different levels of compaction were 0, 10, 20 and 25 blows, while the organic materials used were cow dung, poultry litter, and groundnut haulm. The combinations for the two factors namely, compaction levels (4 levels) and organic material types (4 types) which gave a 4x4 factorial or a total of sixteen treatments as shown below:

C0=Control (no organic material and no compaction)

C10=10 blows without organic material

C20=20 blows without organic material

C25=25 blows without organic material

CD0=Cow dung without compaction

CD10=Cow dung with 10 blows

CD20=Cow dung with 20 blows

CD25=Cow dung with 25 blows

PL0=poultry litter without compaction

PL10=poultry litter with 10 blows

PL20=Poultry litter with 20 blows

PL25=Poultry litter with 25 blows

GH0=Groundnut haulm without compaction

GH10=Groundnut haulm with 10 blows

GH25=Groundnut haulm with 25 blows

All the sixteen treatments were replicated 3 times to give a total of 48 sampling units.

Saturated hydraulic conductivity

The rate of water flow through a sample in the study soils was determined in the laboratory. A sample of soils was soaked in water for four days. After saturation the permeameter cell was connected to stand pipe and filled with water. The water was allowed to flow through the soil sample. Head drop were recorded at interval of 5 minutes and saturated hydraulic was computed using Darcy equation's

$$Q = -KA \frac{dh}{dl}$$

Where Q= is the rate of water flow

K= is the hydraulic conductivity

A= is the column cross section area

dh/dl = indicates hydraulic gradient.

Sample Preparation

Soil samples were collected according to standard procedure as described by FAO (2006). Two hundred (200kg) of soil was collected from the field and was divided into 4 equal parts of each 50kg. Each 50kg was mixed separately with cow dung, poultry litter and groundnut haulm. Prior to the mixing, the various organic materials were milled to finer particles to enhance proper mixing of the soil with the organic materials. About 5% organic materials were added to each 50kg soils, were thoroughly mixed, and the mixture subjected to the various compactive efforts and the soils are mixed with water until it is fully saturated.

RESULTS AND DISCUSSIONS

Saturated Hydraulic Conductivity

The laboratory result (fig1) showed that the control treatments had the highest saturated hydraulic conductivity with mean values of 2.3×10^{-5} cm/s. However, with increasing levels of compaction, the saturated hydraulic conductivity decreased, with the highest

compaction of 25 blows decreased by 27% to a value of 0.67×10^5 cm/s. The decrease in hydraulic conductivity with increasing level of compaction is thought to be due to the reduction in the number of macropores with increase in the level of compaction. The latter observation could have enhanced water accumulation instead of aiding its transmission. This result is in agreement with the observation by Hakansson and Lipiec (2000), that compaction decreases the rate of water transmission in soils as well as in their continuity. Similar observation was noted by Lipiec and Slepiewski (1995).

Compaction affects the size, shape and continuity of pores in soil system which

influences many processes, in soils (Ringrose-Voase and Bullock, 1984). Similarly, treatments with organic materials also exhibited the same trend of behaviors in the saturated hydraulic conductivity of the soil. Among the organic material treated soils, cow dung treated soil had hydraulic conductivity of 6.7×10^5 cm/s at 0 level of compaction; while groundnut haulm treated soils had the lowest value of 3.2×10^5 cm/s. (Wortman and Jasa, 2003). The lower saturated hydraulic conductivity value in the control (uncompacted) without organic material compared to the organic material treated soils most have been due to the fact that the addition of organic material had improved the water holding capacity of the latter.

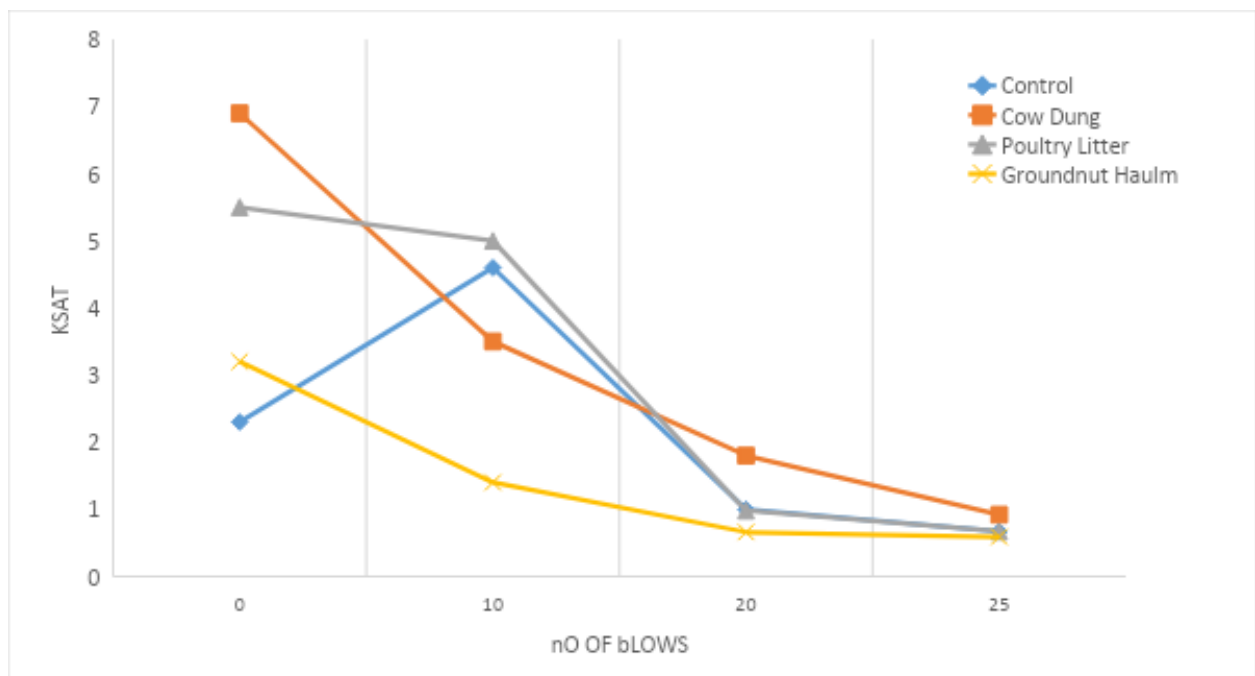


Figure 1: Effect of Compaction and Organic Materials on Saturated Hydraulic Conductivity of Sandy Loam Soils

This suggests that more water is being held in the matrix of organic matter treated soils compared to the control. Organic matter influence on the surface will cushion the effects of soil compaction. At the subsurface, the organic matters attached to soil particles might have helped to bind soil aggregates thereby reducing the compaction effects and increase water infiltration in the soils (Steven,2011). However, with increasing level of compaction, the hydraulic conductivity of all the organic material treated soils decreased irrespective of the nature and type of organic material used. The decreasing saturated hydraulic values with increase in compaction in agreement with Hillel (1988) and Horn (2015). In a similar study, Paggilai *et al.* (1988 and 1992), reported changes of micro and macro pore shapes and size distribution following compaction where they worked on sandy loam soils.

Although the saturated hydraulic conductivity values decreased with increased levels of compaction, the addition of organic material, however, reduced this effect considerably (fig 1). This result is in agreement with the findings of Eusufzai and Fujii (2012) that organic matter generated as agricultural by-products could effectively be used to improve soil quality. That the addition of organic materials to soils reduces the effects of soil compaction and increases the saturated hydraulic conductivity. This affirms that organic matter tends to make the soils have larger, stronger and more stable aggregates that could resist compaction. From this study, it was evident that compaction had significant effects on the saturated hydraulic conductivity at ($P<0.05$) between the control and third and fourth level of compaction while the difference between C_2 and C_3 and C_4 were not statistically significant ($p \leq 0.05$)

At highest level of compaction (25 blow) the organic material appeared to have no tangible effect on the saturated hydraulic conductivity of the soil because all the macrospores responsible for infiltration and drainage characteristic had been closed up. However, there was no significant difference observed in the saturated hydraulic conductivity between 10 and 20 blows; but the higher level of compaction decreased the saturated conductivity by about 27% in the control, 13% in the cowdung, 11% in the poultry litter and 18% in groundnut haulm treated soil.

The result showed that cowdung treated soils had the highest Ksat value, followed by poultry litters and groundnut haulm. This observation might be attributed to the fact that cow dung had the highest organic binding agents with large surface area that could be involved in stabilizing the soil aggregates compared with both the poultry liter and groundnut haulms. This result is in agreement with results obtained by Hamza and Anderson (2005) that identified organic matter influences on soil structures and compactability by binding soil mineral particles which reduces its aggregate wettability and also influencing mechanical strength of the soil, by binding soil mineral particles, reducing aggregate wettability. Organic matter binds micro aggregate and macro aggregates in soil. Low organic matter levels make the soil more susceptible to compaction (Wortman and Jasa, 2003)

SUMMARY AND CONCLUSION

The results of the study revealed that soil compaction significantly ($p<0.05$) lowered the saturated hydraulic conductivity in soils while, the different types of organic materials treatments did have significant effect in improving the soil saturated hydraulic conductivity. Organic matter incorporation made the soil more permeable to water. This showed that incorporating organic matter in compacted soils could improve soil infiltration and drainage characteristics and makes the soils easy to manage and less susceptible to compaction by farm machineries but also provides good physical condition for crop growth. Comparatively, it could be deduced that cow dung has the highest saturated hydraulic conductivity value than the other organic materials, and could be preferably used.

REFERENCES

- B.S.1377.British Standard Specification for Methods of Soil Testing for Engineering purpose
- Batey.T.(2005).Soil compaction and soil amendment a review;soil use and management,12(12):335-345.
- Braver,L.D;Walter,L.D;Wilford, R. (1990).Soil physics.Fourth Edition, John Wiley and Sons Inc New York Pp87-98.
- Dexter,A.R. and Richard.G.(2009)The Saturated hydraulic conductivity of

- soils with n- modal pore size distributions, *Geoderma*, 154:76-85
- Eusufzai, M and Fujii, K. (2012). Effect of organic matter amendment on hydraulic and pore characteristics of a clay loam soil. *Open Journal of Soil Science*, Vol. 2, No. 4, pp. 372-381.
- Håkansson, I and Liepiec, J. (2000). A review of usefulness of relative bulk density values in studies of soil structure and compaction. *Soil and Tillage Research*, 53, 7-83.
- Hamza, M.A and Anderson, W.K. (2005). Soil compaction in cropping systems: a review of the nature, causes and possible solutions. *Soil and Tillage Research* Vol 82, 2, 121-145.
- Hillel, D. (1988). The green house effect and its effect regarding global agriculture. *Research bulletin. agris. fao.org*.
- Horn, R. (2015). Soil compaction and consequences of soil deformation on changes in soil function. In: Northcliff, S. (ed): *Task Force-solutions under fort catena verlag, reiskichan*, pp 28-32
- Ibrahim, B.G., Hassan, M.A., Ismail, A., Jacob, M and Paul, J. (2015). Enhanced Nematicidal effect of cowdung soil amendment by Neeem (*Azadirachta indica*). *Open Access Library journal*, 02, 1-4
- Klute, A. (1982). Tillage effects on the hydraulic properties of soil; A review. In: D.M. Kral and S. Hawins (Editors), *Predicting Tillage on soil physical properties and process*. Am. Soc. Agron. Madison, WI, U.S.A., APEC. Pub I. 44. Pp-29-41.
- Kooistra, M.J and Boersma, O.H. (1994). Subsoil compaction in Dutch marine sandy loams. loosening practices and effects. *Soil tillage research* 29:237-247.
- Liepiec, J. and Slepiewski, W. (1995). Effect of soil compaction and tillage systems on uptake and losses of nutrients. *Soil and tillage research*, 35, 37-52
- Onstad, C.A and Voorhes, W.B. (1987). Hydraulic Soil Parameters affected by tillage. In: A.J. Logen, J.M. Davidson, Baker and M.R. Overcash (Editors) *Soil parameters affected by tillage on Grounds Water Quality. Nitrates and Pesticides*. Lewis, M.I, U.S.A, Pp. 92-112
- Pagliai, M. (1988). Soil porosity aspects. *International Agrophysics*, 4, 215-232.
- Pagliai, M., Fabo, P., Lucamante (1992). Effetti del compattamento provocato da differenti tipi di pneumatici su porosità e struttura del terreno. *Rivista di Ingegneria Agraria*, 3, 168-176
- Pagliai, M., Rousseva, S., Vignozzi, N., Piovenelli, C., Pellegrini, S., Miclaus, N. (1988). Tillage e impact on soil quality. In *Soil porosity and related physical properties*. Italian Journal of agronomy (in press)
- Rahel, A.G. (2016). How to reduce the compaction and soil erosion by reduced tillage. *Ferdowsi university of mashhad*.
- Redcliffe, D.E. and Rasmussen, T.C. (2002). Physical Properties of primary Particles. In: A. Warrick. (Ed). *Soil physical composition*. (CRP Press New York) PP 85-126.
- Rigose-vaise, A. J and Bullock, P. (1984). The automatic recognition and management of soil pores type by image analysis and computer programs. *J. Soil Science*, 35, 673-684
- Sjoerd, M.D. (2005). Effect of compaction. *Pennstate extension collage of agricultural sciences*.
- Six, J., Bossuyt, H., Degryze, S., and Daniel, K. (2004). A history of research on the link between (Micro) aggregates, soil biota, and soil organic matter dynamics. *Soil and Tillage Research*, 76(1), 7-31
- Steven, P. (2011). Increasing organic matter can reduce soil compaction in sugarbeet. *Michigan State University extension*.
- Stibinger, J. (2014). Examples of determining the hydraulic conductivity of soils: Theory and Applications of selected basic methods (University Hand Book on Soil compaction on Hydraulic). Published by Faculty of Environment, an Evangelista University in Uste n. Labem.
- Upadhyay, S.K. and Davis, U.C. (1992). Determining compaction of soil by heavy machinery, *California Agriculture*, 46(4):19-20.

USDA(United State Department of Agriculture)(2003).Saturated hydraulic conductivity:water movement concept and class history(Soil Survey Technical Note 6,US Govt.Printing office.

Wahl.N.A.;Buczko,U.;Bens .O;Huttl,(2003).Infiltration Capacity and Macroporosity of Silty loamy Soil under Different Tillage Systems EGS-AGU-EU.G Joint Assembly. Abstracts from Meeting held in Nice,France,6-11 April,2003,Abstract,5326.

Waynants,M; Vereecken,H; Javaux.M.(2009).Revisiting Vereeckenpedotransfer functions; Introducing a closed form hydraulic model.Vadose Zone J.8.86-95.

Wortman,C, and Japa,P (2003).Managenent to minimize and Reduce soil compation(G8996)University of Nabraka

Zhang Sh.H., Grip,H,L and Lovdahl,(2006b) Effects of soil compaction on hydraulic properties two loess Soils in China, Soil Till. Res ,90,117-125.