AGRICULTURAL SCIENCES

ISSN (Print): 24490954
ISSN (Online): 26364972

CATTLE TREADING EFFECTS ON SOIL PHYSICAL AND HYDRAULIC PROPERTIES IN ABEOKUTA, SOUTHWESTERN NIGERIA

[1]*Dada P. O. O., [2]Musa J. J., [1]Adewumi J. K., and [1]Ola I. A.

[1]Department of Agricultural and Bioresources Engineering,
Federal University of Agriculture, Abeokuta P.M.B.2240 Abeokuta. Ogun State. Nigeria.
[2]Department of Agricultural Engineering and Bioresources Engineering,
Federal University of Technology, P M B 65, Minna, Nigeria

**Corresponding Email:dadapoo@funaab.edu.ng*

Manuscript received: 19/11/2018 Accepted: 11/06/2019 Published: June 2019

ABSTRACT

Farmers face compaction problems due to its negative effect on soil structure, root development and water movement in soils. Hydraulic and physical soil properties are affected by compaction due to cattle treading. This research was carried out to study the effects of cattle treading on soil physical and hydraulic properties on a typical cattle farm in Abeokuta, southwestern Nigeria for two years. Treatments include within the paddock, a cattle trampled pathway and control. Soil physical properties such as bulk density, porosity, gravimetric moisture content and compaction characteristics were investigated using standard procedures. Hydraulic properties such as hydraulic conductivity, sorptivity, steady state flow and macroscopic capillary length were investigated with the CSIRO disc permeameter. Data were analyzed using a One way Analysis of Variance and mean differences were found using the Duncan Multiple Range Test at 0.05 level of significance. Mean bulk density at the 20-30 cm depth within paddock, on the trampled and control were 1.85, 1.83 and 1.65 gcm^{-3} respectively. Sorptivity values for within paddock, trampled pathway and control were 2.0, 142 and 47.1$cmhr^{-0.5}$ respectively. Hydraulic conductivity for paddock, trampled pathways and control were 4.9, 51.7 and 129.2 cm hr-1 respectively. Average steady state flow for control, trampled pathways and within paddock were 136.4, 123.9 and 5$cmhr^{-1}$ respectively. Mean pore sizes for control, trampled pathway and within paddock were 0.51, 1.06 and 0.18 cm respectively. Paddocks should be designed on sloppy lands to facilitate easy flow of waste into drainage systems and paddock floors should be sandy to facilitate infiltration.

Keywords: *Bulk density, Cattle treading, Hydraulic conductivity, Paddock, Sorptivity*

INTRODUCTION

Compaction has been shown to be a major challenge for many farmers especially those involved in crop production and agriculture(Asinyetogha and Josiah, 2016,Odey, 2018). It alters the structure of soils by increasing bulk density, reducing porosity and affecting pore spaces, aggregate shapes and size distribution (Pagliai *et al.,* 2003). Compaction due to animal treading often destroys soil structure by increasing bulk density, reducing the sizes of pore and decreasing infiltration rate leading to increase in surface ponding in depressed portions and surface runoff thereby increasing the vulnerability of soils in affected area to water erosion. Compaction from cattle has been reported to reduce the drainage capacity of soils by increasing soil bulk density (Cournane *et al.,* 2011; Houlbrooke *et al.,* 2008; McDowell *et al.,* 2003).

The effects of compaction from cattle treading cannot be ignored especially on agricultural lands where their negative effects on physical soil properties could be highly significant. In a report by Drewry *et al.,* 2000), cattle treading affects physical soil condition due to pugging especially when soils are wet causing major soil degradation. This process remolds the surface soil and destroys large pores in the soil. Studies have shown that cattle treading imposes a treading pressure of about 200-400KPa when considering static load which may increase with movement of the cattle (Thomas *et al.,* 1990) and increasing the grazing or stocking intensity will consequently increase the rate of compaction on many agricultural lands (Houlbrooke *et al.,* 2009). In a study by Singleton *et al.* (2000), grazing animals severely distorted the movement of water and drainage pathways by compacting the surface soil, resulting in increased bulk density and decreased macroporosity. This could result in a rigorous decrease of the infiltration rate of soils leading to high runoff volumes on the surface soil (Pietola *et al.,* 2005). This study was initiated to investigate the consequence of cattle treading on soil hydraulic and physical properties in a selected cattle paddock in Abeokuta, South western part of Nigeria.

MATERIALS AND METHODS

The research was carried out in a cattle paddock located in Abeokuta, Southwestern Nigeria (Latitude 7o 19'N and longitude 3o 34E). Vegetation around the paddock includes scattered shrubs, trees and grasses with some subsistent farms nearby for production of maize, cassava and pepper. The soil around the paddock is loamy sand based on particle size analysis using the hydrometer method (Gee and Or, 2002). The paddock has an area of 0.11ha (39.2m x 27m). A total of 92 cattle were stocked within the paddock and the average weight of cattle was 177kg. Heavy drainage problems were observed within the paddock during periods of rainfall (Plate 1).

Plate 1. Soil damage as a result of cattle treading within paddock on a farm in Abeokuta, southwestern Nigeria

Random soil samples were taken within the paddock, on the cattle pathways and a control site about 30m from the paddock for determination of soil physical and hydraulic properties at depths of 0-10, 10-20 and 20-30 cm for two consecutive years (2014-2015). Moisture content was determined gravimetrically. Bulk density was determined by the method of (Blake and Hartge, 1986) Porosity was determined from bulk density data assuming a particle density of 2.65 g cm^{-3}. Particle size distribution was carried out using hydrometer method (Gee and Or, 2002) and the textural triangle used to identify the textural class of soil at sample locations. Hydraulic soil properties such as cumulative infiltration, Hydraulic Conductivity, sorptivity, infiltration rate, macroscopic capillary length, mean pore size and steady state flow were investigated using the (CSIRO) disc permeameter (Clothier, 2001) which was installed on all sample points. Samples were taken from nine different points in each treatment for determination of the hydraulic parameters. Cumulative infiltration at any time t is the total amount of water that has gone into the soil at time t divided by the cross sectional area of the disc ring for the ponded flow. The cumulative infiltration is calculated by the relation proposed by Clothier, (2001).

$$\frac{Q}{\pi r^2} = \frac{SR - SR_1}{\pi r^2} \quad (RC) \quad \text{..........Equation 1}$$

Where SR is the scale reading at time of measurement, is the initial scale reading, and RC is the reservoir calibration.

The Wooding's equation (1968) was used to determine the soil hydraulic conductivity (K_o).

$$K_0 = \frac{q}{\pi r^2} - \frac{4bSo^2}{\pi ro(\theta o - \theta n)} \quad \text{............Equation 2}$$

Where r_0 is the radius of the ring , θ_0 is the volumetric moisture content at measurement potential ,θ_n is the volumetric moisture content at initial potential ,and b is approximately 0.55.

Sorptivity was estimated from the slope of the cumulative infiltration $\frac{q}{\pi r^2}$ and square root of time at the initial stage of the infiltration process. The steady flow rate $\frac{q}{\pi r^2}$ was determined by plotting the cumulative infiltration as a function of time at final stage of infiltration. The macroscopic capillary length ($\lambda_{c)}$ which simplifies the treatment multidimensional flow was investigated using the relationship below:

$$\lambda_c = \frac{bS_0^2}{(\theta_0 - \theta_n)K_0} \quad \text{Equation 3}$$

The mean pore size (λ_m) which identifies the pore sizes that are hydraulically functioning was determined from the Laplace's capillary rise equation proposed by (Phillip, 1987)

$$\lambda_m = {}^{7.4}/_{\lambda_c} \quad \text{..........Equation 4}$$

assuming pure water at 20^{o}C.

The characteristic time in relation to gravity or runoff initiation time (T_{grav}) was investigated using the relationship proposed by Phillip (1969) defined as:

$$T_{grav} = \left[\frac{S_0}{K_0}\right]^2 \quad \text{................Equation 5}$$

Analysis of results. The data obtained was analyzed using one way analysis of variance (ANOVA) at 5% level probability. Least significant difference (LSD) was applied by the Duncan test using Genstat Discovery Edition 3 software.

RESULTS AND DISCUSSION

The Soil Physical Properties are presented in Table 1 below.

Table 1. Soil physical properties with respect to depth (Mean values for two years)

					PSD (%)			
Sample Points	**Depth (cm)**	**Porosity (%)**	**Bulk Density (g/cm³)**	**Moisture content (%)**	**Sand**	**Silt**	**Clay**	**Textural class**
Control	0-10	37.7	1.65	13.2	85.3	2.3	12.4	Loamy fine sand
	10-20	41.5	1.55	12.1	83.6	4.2	12.2	Loamy fine sand
	20-30	36.6	1.68	9.6	79.9	5.8	14.3	Sandy loam
Trampled pathway	0-10	30.9	1.83	8.9	85	2.6	12.4	Loamy sand
	10-20	26.4	1.95	4.6	83	4.7	12.1	Loamy sand
	20-30	38.9	1.62	5.1	81	4.7	14.3	Sandy Loam
Within Paddock	0-10	30.2	1.85	10.9	87.3	1.6	11.1	Loamy fine sand
	10-20	31.7	1.81	6.5	84.2	2.6	13.2	Loamy fine sand
	20-30	23.8	2.02	6.2	83.7	2.0	14.3	Sandy Loam

They reveal that particle size analysis within the paddock and the control site showed good similarities and the texture was predominantly loamy sand. Sand content was relatively high at all locations with values ranging from 77% - 87%, clay content was also high with values ranging from 11.2%-15.2% in both locations (Table 1) and the silt content was low with values ranging from 1.8%-8.8%, the porosity within the paddock was within the range of 23.8-41.5%, and ranged from 36.6 - 41.5% on the control plots showing the predominance of void spaces within the soil. At the 0-10cm depth, bulk density were higher in the paddock and on the trampled pathways but a reduction was observed on the control site with values of 1.85, 1.83 and 1.65 g cm^{-3} respectively. It was also observed that bulk density was higher both within the paddock and on the trampled pathways compared to the control further revealing the compactive effect of the cattle on the soil. This could be as a result of the clay content in the soil and the organic matter content. This observation was also reported by Hillel (1980) where bulk density increases by about 20% at the topsoil as a result of cattle treading and porosity decreases from about 17 to 7%. The porosity level was significantly higher at the control (37.7%) than within the paddock and on the trampled pathway which reveals that the cattle trampling caused a significant reduction in the pore spaces. It was also observed that moisture content decreased with depth increment in the soil in all the treatments though the it was not significantly different with respect to depth at the control site which further reveals that cattle trampling within the paddock reduced the pore sizes, prevented infiltrability causing considerable reduction of moisture with depth. This can be attributed to the reduction in organic matter content with depth. Similar reports were observed by Relf, (1997) and Betteridge *et al.,* (1999) where cattle treading prevented water from infiltrating into the soil causing wetted topsoil than subsoil.

The soil hydraulic properties give an indication of water flow movement within the soil with the aim of giving adequate information for proper soil management. Sorptivity rate which depicts the early flow of water into the soil without the influence of gravity was significantly low within the paddock (2.0 cm $hr^{-.05}$) compared to the values obtained on trampled pathways and control plots. This reveals the effect of high compaction rate within the paddock. Similarly, hydraulic conductivity for paddock, trampled pathways and control were 4.9, 51.7 and 129.2 cm hr^{-1} respectively ($P<0.05$). The very low saturated hydraulic conductivity could also be attributed to the high stocking rate per unit area and the level of compaction generated by the cattle. This has a direct effect on the rate of flow within the paddock causing enormous drainage challenges during periods of heavy rainfall. The steady state flow which gives an insight into the infiltration capacity of the soil was 5.0 cm/ hr within the paddock further revealing the minimal amount of water flow into the soil. This value was relatively low compared to many agricultural soils used for crop production. It was observed that there was no significant difference between the trampled pathways and the control sites in terms of steady state flow in the locations (P value 0.05). The mean pore sizes is the size of pores that are hydraulically functioning during the infiltration process and it was observed that fewer pores conducted water within the paddock and on the trampled pathways but no significant difference were noticed between the control and trampled pathways even though there were more pores conducting water through them on the trampled pathways than on the control site. The low pore sizes observed within the paddock further reveals that the macropores were significantly reduced by the pressure exerted by the cattle treading leading to inability of the pores to aid water percolation. The characteristic time in relation to gravity which is also an hydraulic soil property (time to ponding) shows when the gravity forces dominates the flow process and it further gives an indication of the time at which gravity and capillary forces are equal. The characteristic time in relation to gravity revealed that the time taken for water to flood within the paddock, on trampled pathways and control were very similar (8-9 minutes). This shows that during periods of light or short duration rainfall, the soil pores would be filled within a short period causing flooding. Generally, hydraulic conductivity, sorptivity and steady state flow were all significantly low under the trampled and control plots than within the paddock. This confirms the effect of the cattle treading on the soil which invariably affects the hydraulic soil properties.

Table 2. Effects of cattle treading on hydraulic soil properties under different treatments (Mean values for two consecutive years)

Locations	**Initial Moisture Content (%)**	**Final moisture content (%)**	**Sorptivity (cmhr$^{-0.5}$)**	**Hydraulic conductivity (cm hr^{-1})**	**Steady state flow (cm hr^{-1})**	**Mean pore size (cm)**	**Macroscopic capillary length (cm)**	**Characteristic time in relation to gravity (hr)**
Control	18.56	46.55	55.75	149.65	157.42	0.41	1.81	0.14
	19.17	36.9	54.96	145	156	0.67	1.11	0.14
	17.79	48.76	32.32	120.17	122.54	0.27	2.74	0.07
	17.65	42.7	47.97	135.84	141.38	0.32	2.3	0.13
	23.8	52.81	48.29	151.61	157.24	0.29	2.54	0.1
	16.68	43.02	102.86	198.27	226.4	1.11	0.66	0.23
	34.88	77.63	48.6	131.14	135	0.23	3.19	0.14
	42	80.22	23.02	65.98	66.95	0.29	2.55	0.35
	24.75	49.1	41.07	127.98	132.83	1.19	0.62	0.1
	40.05	76.48	14.57	66.71	67.78	0.35	2.13	0.05
Mean	**25.5**	**55.4**	**47.0**	**129.2**	**136.4**	**0.51**	**1.97**	**0.15**

Trampled pathways	9.1	16.1	38.21	7.02	37.72	0.14	5.16	0.04
	9.92	26.2	168.93	55.17	155.83	0.66	1.12	0.13
	11.91	26.39	43.83	7.08	43.59	0.44	1.69	0.02
	9.91	24.7	274.5	129.12	195.58	3.18	0.23	0.44
	5.63	20.62	358.05	124.71	292.03	3.68	0.2	0.18
	7.5	28.63	116.33	36.19	120.66	0.29	2.52	0.09
	9.9	26.21	135.28	48.28	127.56	0.48	1.55	0.14
	11.63	27.67	29.15	4.32	29.07	0.2	3.7	0.02
	21.13	38.18	140.77	54.23	128.7	0.78	0.95	0.18
	13.41	30.95	118.49	51.32	107.977	0.77	0.97	0.23
Mean	**11.0**	**26.6**	**142.0**	**51.7**	**123.9**	**1.06**	**1.81**	**0.15**
Within Paddock	7.52	10.56	1.75	4.06	4.12	0.14	5.418	0.19
	6.83	9.25	4.14	10.51	11	0.37	2	0.16
	3.45	6.13	1.79	4.46	4.54	0.15	5.05	0.16
	5.22	7.8	1.1	5.63	5.63	0.15	5	0.04
	7.88	13.4	1.74	3.84	3.86	0.32	2.24	0.21
	7.13	12.07	0.88	5.75	5.76	0.15	4.93	0.02
	4.6	10.24	0.88	2.46	2.48	0.15	5.1	0.18
	7.48	12.02	1.49	3.63	3.65	0.16	4.74	0.168
	8.2	13.9	0.64	5.28	5.37	0.15	5.07	0.015
	4.78	7.68	1.37	3.37	3.412	0.11	6.99	0.166
Mean	**6.3**	**10.3**	**2.0**	**4.9**	**5.00**	**0.18**	**4.65**	**0.13**
LSD<0.05	**5.71**	**9.26**	**57.1**	**31.51**	**48.93**	**0.70**	**1.24**	**0.09**

CONCLUSION

This study has confirmed adequately the negative effects of cattle compaction by treading in a selected paddock in the Southwestern part of Nigeria by critically expatiating on physical and hydraulic soil properties that are affected by cattle treading in selected paddocks for two consecutive years. Bulk density was very high within the paddock and water flow into the soil was drastically impeded with the very low sorptivity observed. Similar results were observed in the hydraulic conductivity and characteristic time in relation to gravity that had low values. Based on this research work, It is recommended that stocking rates should be standardized by strategically managing the animals not only within their paddocks but on the trampled pathways. Cattle treading paths should be changed either yearly or in two years and such paths can be used for agricultural purposes thereafter by proper and sustainable tillage activities. Furthermore, paddock floors should be critically constructed on well aerated sandy soils having adequate drainage system and not soils prone to compaction. Paddocks can also be designed on sloppy lands to facilitate or aid drainage of wastes such as water and cattle dung.

ACKNOWLEDGEMENT

The authors wish to acknowledge the cattle rearers in the locality for giving us access to their paddocks while their cattle were taken out for grazing. The Departments of Civil and Agricultural Engineering soil laboratory where most of the soil physical analysis were carried out. Professor F.K. Salako, who provided the disc permeameter (CSIRO) that was used in the field to monitor hydraulic soil properties.

REFERENCES

Asinyetogha, H.I. and Josiah, M.A. (2016). Maize yield response to induced compaction in a sandy-loam soil. *Sustainable Agriculture Research. Volume 5. No. 2.* Canadian Center of Science and Education

Betteridge K, Mackay AD, Barker DJ, Shepherd TG, Budding PJ, Devantier BP, Costall, DA (1999). Effect of cattle and sheep treading on surface configuration of a sedimentary hill soil. *Australian Journal of Soil Research, 37:* 743–760.

Blake, G. R. and Hartge, K. H. (1986).Bulk density. In: A. Klute (Ed.) Methods of soil analysis. Part 1 Physical and mineralogical methods.2nd Edition. *American Society of Agronomy,* Madison, Winscosin, 363-375.

Cournane, F.C., McDowell. R., Littlejohn, R, Condron L (2011) Effects of cattle, sheep and deer grazing on soil physical quality and losses of phosphorus and suspended sediment losses in surface runoff. Agriculture, *Ecosystems & Environment 140*, 264-272.

Clothier, B. E. (2001). Infiltration. In: Smith, K.A., Mullins, C.E. (Eds.), Soil and Environmental Analysis; Physical methods. 2nd Edition. Marcel Dekker, New York. pp. 239-280.

Drewry, J.J., Littlejohn, R.P., Paton R.J., (2000). A survey of soil physical properties on sheep and dairy farms in southern New Zealand. *New Zealand Journal of Agricultural Research 43,* 251-258.

Gee, G. W. and Or, D. (2002). Particle size analysis. In J. H. Dane and G.C. Topp.(Ed). Methods of Soil Analysis. Part 4, Physical Methods. *Soil Society America Book Series.255-295* pp.

GenStat11 (2008) GenStat for Windows. (VSN International Ltd: Oxford).

Houlbrooke, D.J., Littlejohn R.P., Morton, J.D., Paton, R.J. (2008) Effect of irrigation and grazing animals on soil quality measurements in the North Otago Rolling Downlands of New Zealand. Soil Use and Management 24, 416-423.

Houlbrooke, D.J., Paton, R.J., Morton, J.D., Littlejohn, R.P. (2009) Soil quality and plant yield under dryland and irrigated winter forage crops grazed by sheep or cattle. *Australian Journal of Soil Research 47*, 470-477.

McDowell, R.W., Drewry, J.J., Paton, R.J., Carey, P.L., Monaghan, R.M., Condron, L.M. (2003) Influence of soil treading on sediment and phosphorus losses in overland flow. *Australian Journal of Soil Research 41*, 949-961.

Odey, Simon Ogbeche (2018) Tractor traffic influences of soil properties, growth and yield of maize in Obubra. Nigeria. *International Journal of Engineering Inventions. Volume 7.* Issue 1. P ISSN: 2319-6491.

Pagliai, M., Marsili, A., Servadio, P., Vignozzi, N., Pellegrini, S. (2003). Changes in some physical properties of a clay soil in central Italy following the passage of rubber tracked and wheeled tractors of medium power. *Soil and Tillage Research*. 73: 119–129.

Phillip, J.R. (1969) Theory of Infiltration. Advances in Hydrosciences 5:215-305.

Phillip, J. R. (1987). The infiltration joining problem. *Water Resources. Research. 23*:2239–2245.

Pietola, L., Horn, R., Yli-Halla, M., (2005) Effects of treading by cattle on the hydraulic and mechanical properties of soil. *Soil and Tillage Research 82*, 99-108.

Relf, D. (1997). Managing Compacted and Heavy Soils. The Virginia Newsletter, 8 (6).

Singleton, P.L., Boyes, M., Addison, B., (2000) Effect of treading by dairy cattle on topsoil physical conditions for six contrasting soil types in Waikato and Northland, New Zealand, with implications for monitoring. New *Zealand Journal of Agricultural Research 43*, 559-567.

Thomas, R.F., Mew, G., Baker, P.R., (1990) Effect of different drainage systems on bearing resistance of some West coast, south island soils. *New Zealand Journal of Agricultural Research 33*: 479-488.

Tuffour, H.O., Bonsu, M., Khalid, A.A. (2014) Assessment of soil degradation due to compaction resulting from cattle grazing using infiltration parameters. *International Journal of Scientific Research in Environmental Sciences, 2 (4),* pp. 139-149.

Wooding, R.A. (1968) Steady infiltration from a shallow circular pond. *Water Resources Research 4:* 1259-1273.