Engineering and Technology Journal e-ISSN: 2456-3358
Volume 08 Issue 01 January-2023, Page No.-1821-1829
DOI: 10.47191/etj/v8i1.06, I.F. – 6.484

Study of Soil Texture and Moisture Content Effect on Soil Compaction for Long-Year Tilled Farm Land

Yared Seifu[1], Simie Tola[1], Amana Wako[1], Ramachandran Jayaprakash[2]
[1]Department of Mechanical System and Vehicle Engineering, Adama science and technology university, Adama, Ethiopia
[2] Department of automobile engineering, Thiruvalluvar college of engineering and technology vandavasi Tamil nadu, India

ABSTRACT: Farm mechanization is the main indicator of modernizing the agriculture and use of farm machines that can take the place of human and animal power in agricultural processes. During field operation the weight of farm machinery compact the agricultural soil due to the contact with the tires or tracks of tractors. The aim of the article is to study the effects of soil texture and moisture content on soil compaction. During field experimental test 5 different depth (5, 10, 15, 20 and 25 cm) were selected for taking soil compaction data and soil samples at three depth range (0-10, 10-20 and 20-30 cm) from Kulumsa Agricultural research center farm land at two seasons. During compaction test 15 sample point data were taken from 0.6 ha farm land. The result of the study shows from average of all sample point the maximum and minimum value of soil compaction value where 3.73 Mpa and 3.032 Mpa during harvesting season and 1.37 Mpa and 1.19 Mpa during seeding season respectively. The laboratory result shows farm land soil is clay with 25.0% of sand, 51% of clay and 24 % silt during both experimental seasons. The maximum and minimum percentage of soil moisture value where 28.92% and 20.04% during harvesting season and 41.8% and 30.8% at 20 to 30 cm and 0 to 10 cm depth respectively.

KEYWORDS: Farm land, Soil compaction, Soil texture, Soil moisture

1. INTRODUCTION

Many soil scientists, agricultural engineers, and farmers are concerned about agricultural soil compaction. There is rising worry about the impact of soil compaction as agricultural tractors and field equipment become larger and heavier. In 2010, Ethiopia had an estimated 5,090 tractors in use, a huge increase from 2004 when there were only about 3,000. When "walking" or pedestrian tractors are included, the 2010 count rises to almost 6,000 [1]. In a mechanization system, farm machinery is employed for land preparation to harvesting processes by driving in agricultural land. Da Silva AP, et.al investigated the effects tillage, wheel traffic, soil texture, and organic matter concentration on dry bulk density [2]. The findings show that tillage intensity and wheel activity increase bulk density, but organic matter decreases bulk density. The weight of farm machinery compressed agricultural soil during field operations, resulting in an increase in soil bulk density and a decrease in soil porosity, particularly due to contact with tractor tires or tracks [3]. Compacted soil limits crops' access soil water and nutrients, and also reducing crop yields [4]. Soil compaction is affected by animal trampling as well as farm machinery. The risk of compaction is also dependent on the soil tillage and crop rotations, soil moisture and working depth [5].

The compacted soil is difficult to plow since it increases strength while compacted and the draft resistance also increases. Soil physical properties are crucial in determining a soil's appropriateness for agricultural, environmental, and engineering applications [6]. Soil strength can be measured traditionally using a hand operated soil cone penetrometer. Kumar V.et.al, 2019 designed and developed hydraulically operated mechanical soil cone penetrometer to measure soil resistance[7]. A literature review showed that penetration resistance measurements have been carried out with many types of cones. For instance, [8], [9], [10] and [11] used different types of cone shapes in their tests. Excessive compactness, is detrimental to maintaining a good root environment but it reduces penetration of water [12]. The value of the cone index varies depending on the depth of the soil, the textural parameters, the bulk density, and the moisture content [13]. Long-term land management has a significant impact on soil organic carbon (SOC) concentration, which are valued as climate-resilient systems. Soil physicochemical properties in Northeast Ethiopia were studied at soil depths of 0–15 cm and 15–30 cm in open grazing lands [14]. According to this study the effect of soil pH and exchangeable sodium percentage were investigated. The effects of reduced tillage and conventional tillage practices in row planting and broadcast planting methods on soil compaction are investigated [15]. The influences of soil texture, compaction, soil moisture and the resulting air-filled porosity on the gas permeability were researched by [16]. Effect of soil compaction have negative impact on physical properties of soil and plant growth [17]. The impact of textural and structural parameters on soil strength is moderated by SOC concentration[11].

The consequences of compaction of agricultural fields have been studied widely by [18]. Compaction results in reduced porosity, which implies limitations in oxygen and water supply with negative consequences for soil productivity [19]; [20]; [21]; [22]. Forest soils have been shown to recover more slowly than presumed previously [23]. Since ground pressure is known to correlate positively with soil compaction, many researchers have focused on analysing how well the choice of tires or bogie tracks and tire inflation pressure can lower soil compaction [24]; [25]; [26].

The goals of this study were to use statistical and geostatistical methods to determine the relationships between soil texture (clay content, silt content, sand content) and soil moisture content that affect soil penetration resistance in harvesting and seeding season, which was conventionally tilled farm land for a long time.

2. MATERIALS AND METHODS

2.1 Description of the study area

Farm sites selected for experiment in this research were Kulumsa agricultural research center farm land which is located at Oromia Region of Ethiopia's. This woreda's elevation varies between 1400 and 2500 meters above sea level [27].

During soil cone index measurement to study the effect of soil physiochemical property are shown in cause and effects of soil compaction flow chart of Figure 1

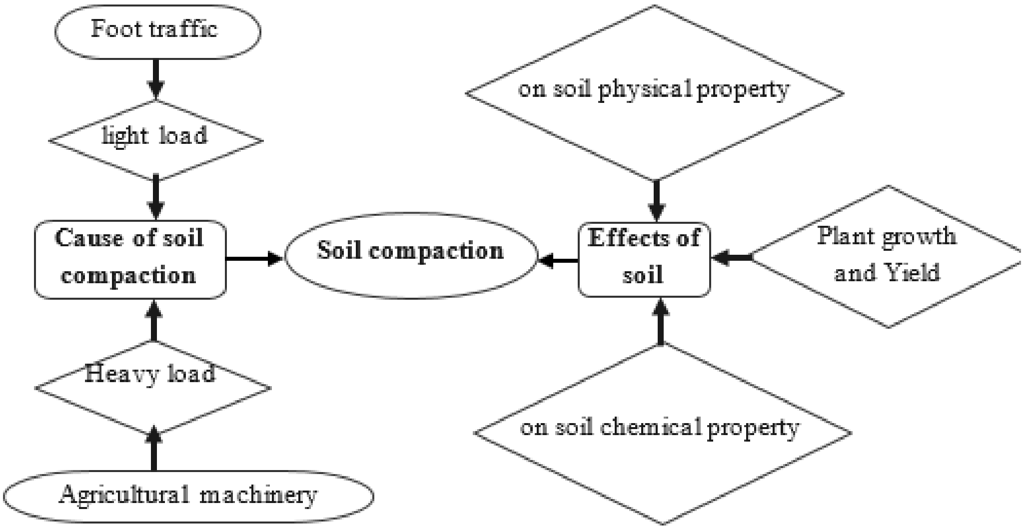


Fig. 1. Cause and effects of soil compaction

The experimental area selection criteria are based on the tractor density and availability of research center. The field under study had a size of 0.6ha and tilled since 1989.

2.2 Field Measurement Design and field Test

During field experimental test 5 different depth are selected for taking soil compaction data (5 cm, 10 cm, 15 cm, 20 cm and 25 cm). All the depth parameters were replicated fifteen times at farm field (point A to point O) shown in (Figure 2) or taking soil compaction data. The experimental design with fifteen number of replication and five treatment in experimental farm land with an area of 6000 m^2 (100 m ×60 m) is modeled in (Figure 2).

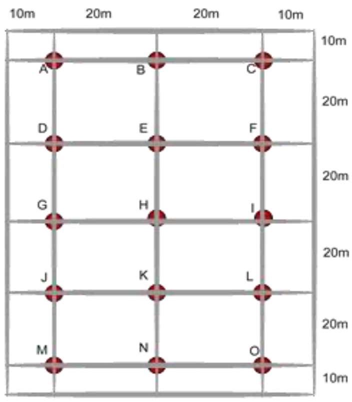


Fig. 2. Data sampling plot design and distribution of replication

The penetration resistance was measured in 10mm depth intervals using a SpotOn digital compaction meter. In total, 75 measurements were made in field. SpotOn digital soil compaction meter which meets ASABE S313.3 soil compaction standard and is equipped with a 12.8 mm steel cone diameter with 30° included angle is used in compaction measurement. For depth reference, the stainless-steel shaft is marked every 10 cm with a probe length of 76 cm, and when the probe is retrieved from the soil, it instantly displays the maximum compaction value. The Dimensions of the digital soil compaction meter is 89 cm long, 28 cm wide, and 7.6 cm in diameter.

2.3 Laboratory of soil physiochemical property test

The movement of air, water, and dissolved compounds through soil, as well as circumstances impacting germination, root growth, and erosion processes, are all examples of soil physical characteristics. In this study soil parameters like soil texture and soil moisture are determined in laboratory for the farm field soil.

One of the most difficult measures in agriculture is that of soil moisture [28], [29]. Soil moisture can be measured in a variety of ways, from feeling the soil to utilizing intricate electrical equipment that uses radioactive chemicals [16]. The ratio of the weight of water to the weight of solids in a particular mass of soil is known as soil moisture content. A non-corrodible container, a digital weight machine, and an electric oven are all essential equipment.

soil is grouped on the basis of the grain size of the particles that constitute the soil which is expressed as soil texture. Gravel is a term that describes coarse granular material, but sand is mostly used to describe finer granular material. In order to have a uniformly applicable terminology it has been agreed internationally to consider particles larger than 2 mm, but smaller than 63 mm as gravel. Sand is a substance made up of particles that are smaller than 2 mm but larger than 0.063 mm in diameter. Silt is defined as particles with a diameter of less than 0.063 mm but greater than 0.002 mm. Clay is soil that contains even smaller particles, less than 0.002 mm in size. [30]. Soil parameters like soil texture, soil pH, soil EC, soil organic content and soil cation exchange capacity [29] have significant influence on penetration resistance. Soil texture and moisture content derived from the farm field were used as spatial input variables for prediction of penetration resistance. The tillage practices and weight of tractor during tillage and harvesting are assumed to have the strongest influence on the penetration resistance.

3. RESULTS AND DISCUSSION

The result of this study covers the relation between soil compaction and the soil physical properties like soil texture and soil moisture content of farm field soil. The physical properties of soil were studied in soil laboratory to identify soil texture, and soil moisture content.

3.1. Soil compaction results and discussion

The soil compaction with respect to sampling point and depth are taken and plotted in (Figure 3). During compaction test 15 sample point data were taken from 0.6 ha farm land. The effect of season on soil compaction were clearly shown in (Figure 3a and 3b) for harvesting season and seeding season respectively. Based on the figures a soil compaction value during harvesting season were higher than seeding season due to the fact that the higher machinery and animal foot traffic is higher than seeding season. In addition, during harvesting season the moisture content of the soil is less which results the pore size between soil molecule decrease and increases the density of soil. The highest soil compaction value from the fifteen-sample point during harvesting and seeding season were 5.97 Mpa and 2.35 Mpa at sample point D and at depth of 15cm respectively.

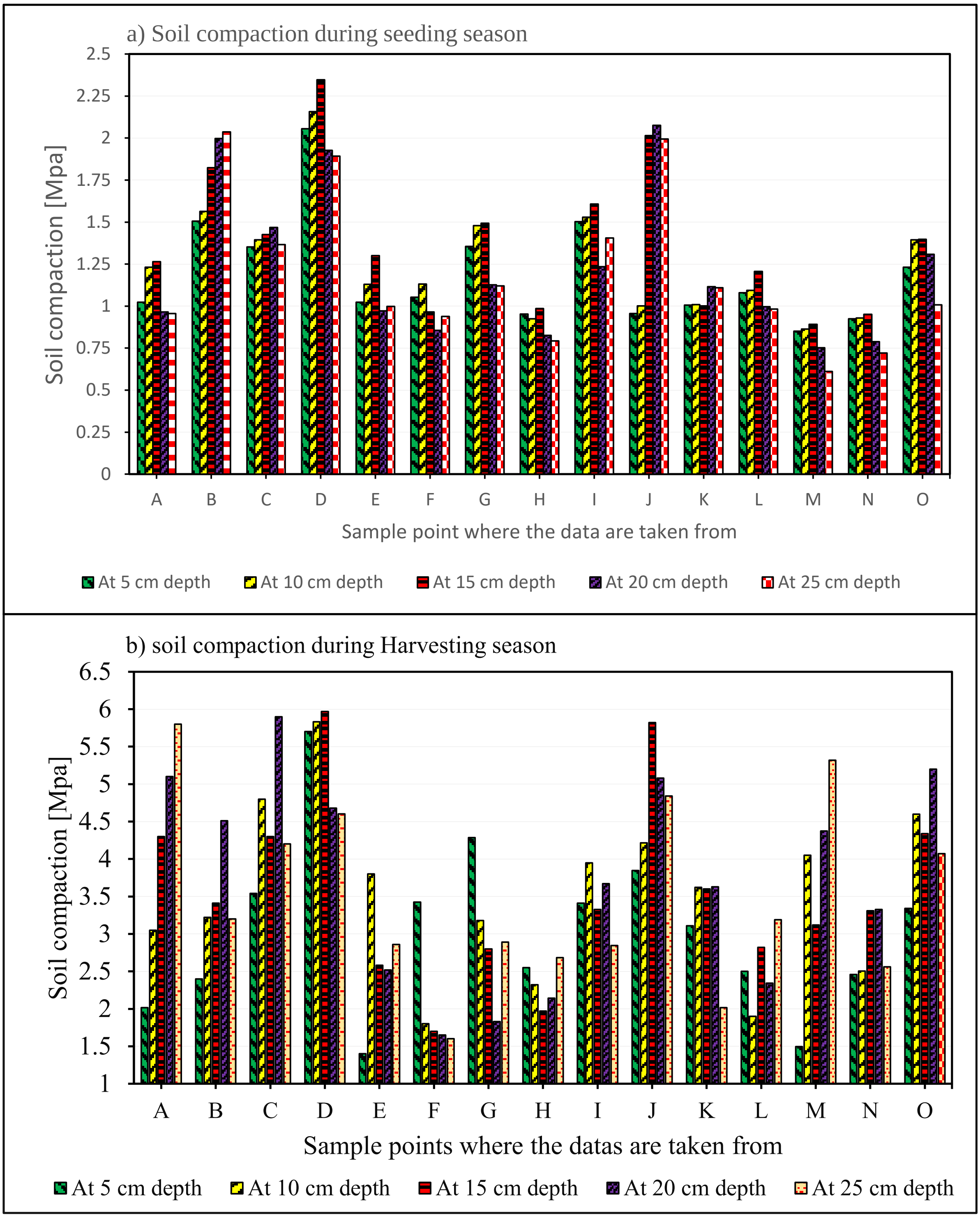


Fig. 3. Soil cone index of all sample points

The depth profiles of the mean penetration resistance were summarized in (Figure 4) for a farm field. The cone indices of experimental farm sites had a general tendency to increase with soil depth up to 20 cm and start to decrease after 20 cm during harvesting season. But for the seeding season the mean penetration resistance was increase with soil depth up to 15 cm and start to decrease after 15 cm. The result of the study shows from average of all sample point the maximum and minimum value of soil compaction value where 3.73 Mpa and 3.032 Mpa during harvesting season and 1.37 Mpa and 1.19 Mpa during seeding season at 15 cm and 5 cm respectively.

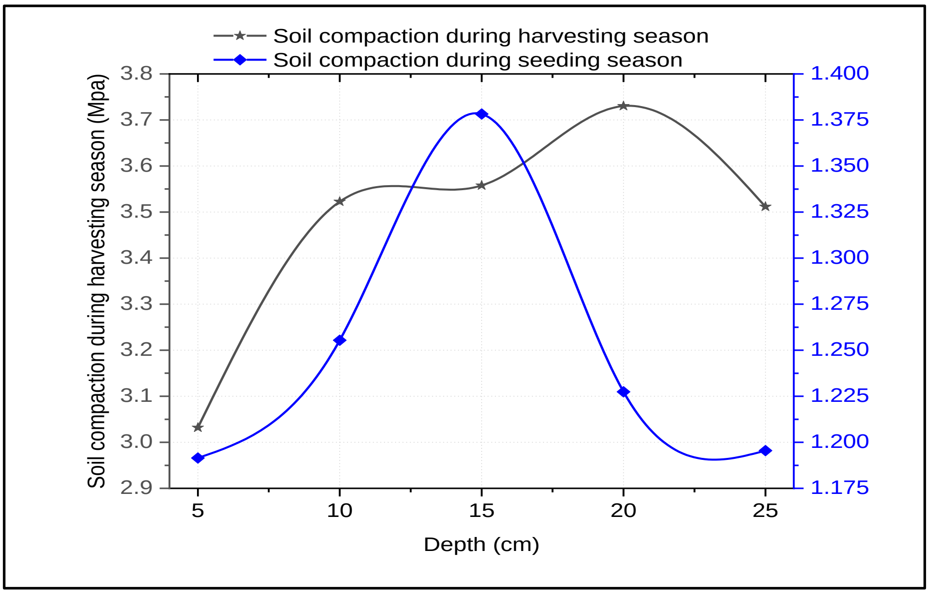


Fig. 4. Average value of all sample points soil cone index vs. depth

3.2. Soil compaction correlation of within experimental field sites

Correlation of soil compaction within Kulumsa experimental field sites of sampling point in field A to O indicates both positive and negative correlation (Table 1).

Table 1. Soil compaction correlation of within Kulumsa experimental field sites

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
A	1														
B	0.655	1													
C	0.476	0.933*	1												
D	-0.87	-0.589	-0.402	1											
E	0.306	0.328	0.546	0.011	1										
F	-0.80	-0.716	-0.700	0.481	-0.75	1									
G	-0.79	-0.97**	-0.88*	0.655	-0.42	0.84	1								
H	-.058	-0.568	-0.512	-0.212	-0.16	0.38	0.52	1							
I	-0.51	0.249	0.509	0.516	0.337	0.04	-0.09	-0.468	1						
J	0.668	0.585	0.355	-0.344	0.158	-0.7	-0.69	-0.68	-0.27	1					
K	-.413	0.347	0.451	0.523	0.110	-0.01	-0.20	-0.83	0.85	0.15	1				
L	0.577	-.128	-.422	-0.531	-0.324	-0.14	-0.04	0.29	-.98**	0.45	-0.74	1			
M	.849	.582	.597	-0.706	0.693	-0.86	-0.71	0.10	-0.21	0.35	-0.38	0.22	1		
N	.458	.770	.566	-0.296	-0.045	-0.48	-0.75	-0.85	0.09	0.85	0.5	0.1	0.13	1	
O	.526	.943*	.987**	-0.379	0.586	-0.78	-0.92*	-0.6	0.46	0.49	0.47	-0.35	0.62	0.64	1

* At the 0.05 level (2-tailed), the correlation is significant; ** at the 0.01 level, correlation is significant (2-tailed), 'A to O letters indicates sampling point in field.

Correlation of soil compaction within Kulumsa experimental field sites of sampling point in field A to O indicates both positive and negative correlation. Field points between O and B, C and B have strongly positive correlation significant at the 0.05 level. Field points between G and C, O and G have strongly negative correlation significant at the 0.05 level. Field points O and C have a substantial positive connection at the 0.01 level. Field points between L and I, G and B have strongly negative correlation significant at the 0.01 level.

3.3. Soil texture and moisture content results and discussion

soil parameters like soil texture have significant influence on penetration resistance [29]. Soil texture class based on laboratory result and soil texture triangle for farm field is clay with 24% silt, 51% clay and 25% sand (average values) during both experimental seasons as indicated in (Table 2) and (Figure 5).

Table 2. Soil texture, and moisture content for the farm field

Depth (mm)	% Sand		% Clay		% Silt		Textural class	% Moisture	
	Harvesting season	Seeding season	Harvesting season	Seeding season	Harvesting season	Seeding season		Harvesting season	Seeding season
0–10	25	24	51	50	24	26	**Clay**	20.04	30.82
10–20	27	25	54	55	19	20		24.13	36.45
20–30	23	25	48	49	29	26		28.92	41.83
Average	**25**	**24.7**	**51**	**51.3**	**24**	**24**		**24.36**	**36.4**

Soil texture triangle for farm field soil is drawn in (Figure 5) for identifying the soil texture class.

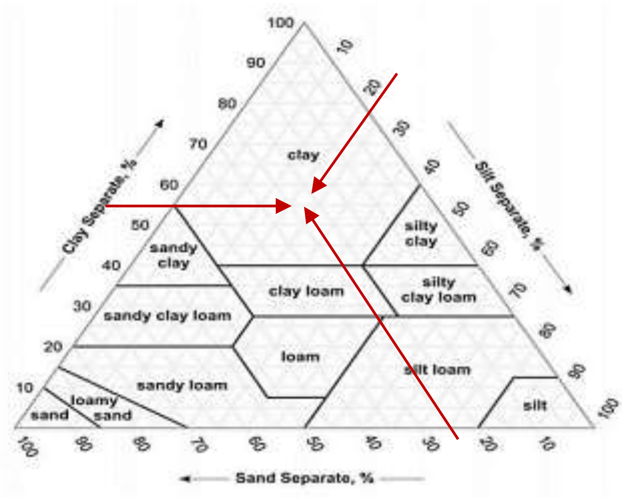
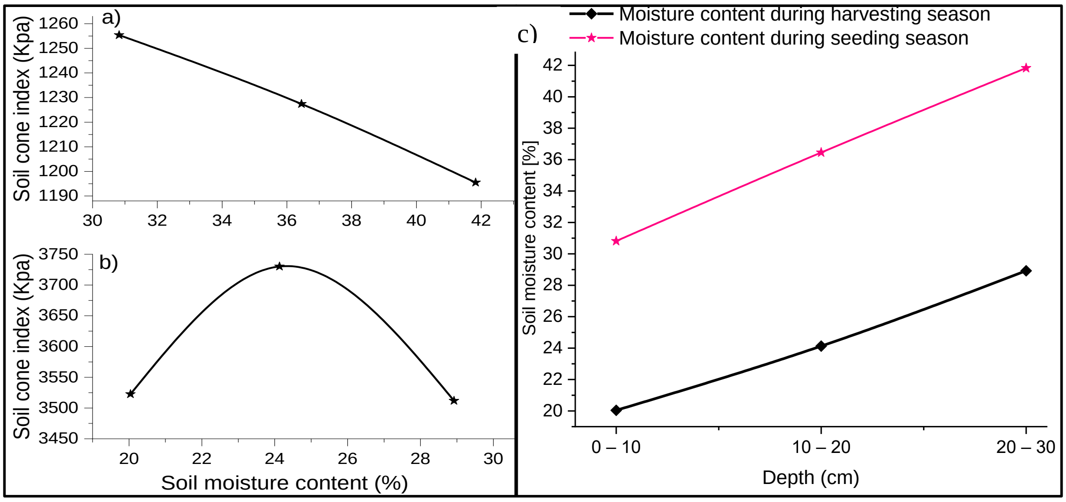


Fig. 5. Soil texture triangle

Soil moisture content: The maximum and minimum percentage of soil moisture value where 28.92% and 20.04% during harvesting season and 41.8% and 30.8% during seeding season at 20 to 30 cm and 0 to 10 cm depth respectively.

The relation between soil moisture content and depth is plotted in (Figure 6c) shows as depth increases percent of soil moisture content also increases for both experimental seasons



.

Fig. 6. soil cone index vs. a) Soil moisture during seeding season b) harvesting season, c) soil moisture content vs. depth

As illustrated on (Figure 6a) as soil moisture increases, soil compaction decreases for the seeding season. In case of harvesting season as the soil moisture increases up to certain 24% the soil compaction also increased, but after the 24% moisture content the compaction value starts to decline as indicated in (figure 6b).

Soil texture: As illustrated in the (Figure 7) as the depth increases up 20 cm percent of sand and clay increased and percent of silt decreased. After 20 cm percent of sand and clay decreased and percent of silt increased.

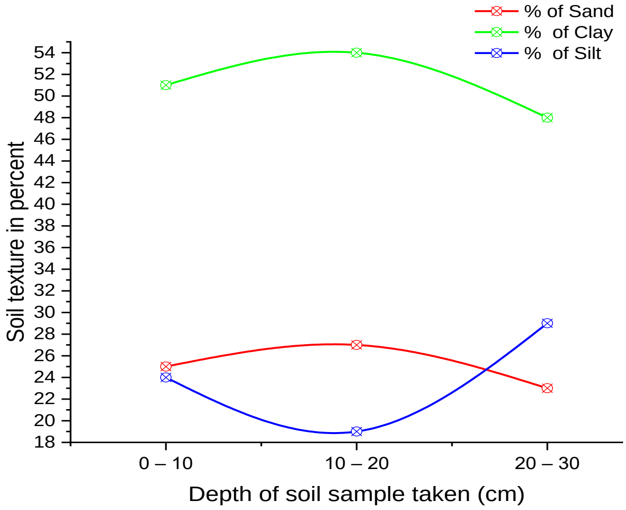


Fig. 7. Sand soil, Clay soil and Silt soil percent vs depth

As illustrated in the soil texture triangle (Figure 5) the experimental field soil where under clay so, as illustrated in the (Figure 8b) the relationship between soil compaction and soil clay percentage shows as soil clay percentage increases, soil compaction also increased for the fharvesting season. In case of seeding season as the soil clay percentage increases up to certain 52% the soil compaction also increased, but after the 52% soil clay percentage the compaction value starts to decline little bet as indicated in (figure 8).

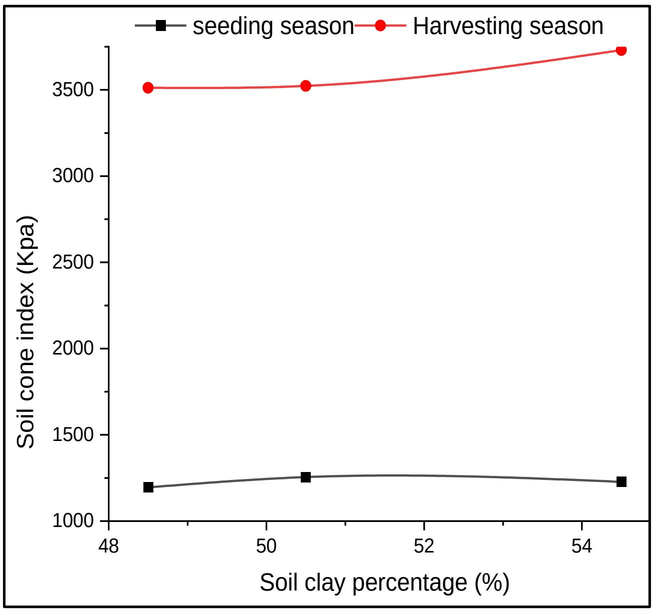


Fig. 8. Soil cone index vs. Clay soil percent

4. CONCLUSIONS

The result of this study covers the effects of soil compaction moisture content and soil texture at different depth and farming season. The result of study taken from fifteen sample point indicates the highest soil compaction value from the fifteen-sample point during harvesting and seeding season were 5.97 Mpa and 2.35 Mpa at sample point D and at depth of 20cm respectively. From average of all sample point the maximum and minimum value of soil compaction value where 3.73 Mpa and 3.032 Mpa during harvesting season and 1.37 Mpa and 1.19 Mpa during seeding season at 20 cm and 5 cm respectively. Soil texture class based on laboratory result and soil texture triangle for farm field is clay with 24% silt, 51% clay and 25% sand (average values) during both experimental seasons. Soil compaction and soil moisture content both rise as soil depth increases. The highest clay percentage of soil has the highest value of soil compaction value in general. As soil clay percentage increases, soil compaction also increased for the harvesting season. In case of seeding season as the soil clay percentage increases up to certain 52% the soil compaction also increased, but after the 52% soil clay percentage the compaction value starts to decline little bet

5. ACKNOWLEDGMENT

This research work is sponsored by the Dire Dawa University under Ethiopian ministry higher education institute. The authors would like to thank the Kulumsa agricultural research center for allowing the field farm, field test instruments and laboratory. Thank adama science and technology university for their support in a form of lab facility and facilitating PhD scholar for the student.

REFERENCES

1. Guimaraes Junnyor WDS, Diserens E, De Maria IC, Araujo-Junior CF, Farhate CVV, and de Souza ZM, "Prediction of soil stresses and compaction due to agricultural machines in sugarcane cultivation systems with and without crop rotation," *Sci Total Environ,* vol. 681, pp. 424-434, Sep 1 2019.
2. da Silva AP, Kay B, and Perfect E, "Management versus inherent soil properties effects on bulk density and relative compaction," *Soil and Tillage Research,* vol. 44, no. 1-2, pp. 81-93, 1997.
3. Ungureanu N *et al.*, "agricultural soil compaction under the action of agricultural machinery," *Conference Paper Simpozij Aktualni Zadaci Mehanizacije Poljoprivrede* 2015.
4. Liu H, Colombi T, Jack O, Keller T, and Weih M, "Effects of soil compaction on grain yield of wheat depend on weather conditions," *Sci Total Environ,* vol. 807, no. Pt 1, p. 150763, Oct 5 2021.
5. Bertonha RS, Furlani CEA, Silva VFA, and Wright DL, "Tractor performance and corn crop development as a function of furrow opener and working depth," *AJCS* vol. 9, no. 9, pp. 812-818, 2015.
6. Phogat VK, Tomar VS, and Dahiya R, "Soil Physical Properties," 2015.
7. Kumar V, Kumar P, Sahni RK, and Thomas E, "Design of tractor mounted hydraulically operated soil compaction measurement system," *Central Institute of Agricultural Engineering, Bhopal,* vol. VIII, no. XXVIII, 2019.
8. Ayers P and Perumpral J, "Moisture and density effect on cone index," *Transactions of the ASAE,* vol. 25, no. 5, pp. 1169-1172, 1982.
9. Busscher W, "Adjustment of flat-tipped penetrometer resistance data to a common water content," *Transactions of the ASAE,* vol. 33, no. 2, pp. 519-0524, 1990.
10. [Canarache A, "PENETR—a generalized semi-empirical model estimating soil resistance to penetration," *Soil and Tillage Research,* vol. 16, no. 1-2, pp. 51-70, 1990.
11. Smith CW, Johnston MA, and Lorentz S, "The effect of soil compaction and soil physical properties on the mechanical resistance of South African forestry soils," *Geoderma,* vol. 78, pp. 93-111, 1997.
12. Mudarisov S, Gainullin I, Gabitov I, Hasanov E, and Farhutdinov I, "Soil compaction management Reduce soil compactionusing a chain-track tractor," *Journal of Terramechanics,* vol. 89, pp. 1-12, 2020.
13. Kumar A, Chen Y, Sadek MA-A, and Rahman S, "Soil cone index in relation to soil texture, moisture content, and bulk density for no-tillage and conventional tillage," *Agricultural Engineering International: CIGR Journal,* vol. 14, no. 1, pp. 26-37, 2012.
14. Shiferaw W, Demissew S, Bekele T, Aynekulu E, and Pitroff W, "Invasion of Prosopis juliflora and its effects on soil physicochemical properties in Afar region, Northeast Ethiopia," *International Soil and Water Conservation Research,* vol. 9, no. 4, pp. 631-638, 2021.
15. Mihretie FA *et al.*, "Tillage and crop management impacts on soil loss and crop yields in northwestern Ethiopia," *International Soil and Water Conservation Research,* 2021.
16. van Verseveld CJW and Gebert J, "Effect of compaction and soil moisture on the effective permeability of sands for use in methane oxidation systems," *Waste Manag,* vol. 107, pp. 44-53, Apr 15 2020.
17. Mada D, Ibrahim S, and Hussaini I, "The effect of soil compaction on soil physical properties southern Adamawa State agricultural soils," *The International Journal of Engineering and Science (IJES),* vol. 2, no. 9, pp. 70-74, 2013.
18. Alakukku L *et al.*, "Prevention strategies for field traffic-induced subsoil compaction: a review: Part 1. Machine/soil interactions," *Soil and tillage research,* vol. 73, no. 1-2, pp. 145-160, 2003.
19. Murphy G, Brownlie R, Kimberley M, and Beets P, "Impacts of forest harvesting related soil disturbance on end-of-rotation wood quality and quantity in a New Zealand radiata pine forest," *Silva Fenn,* vol. 43, pp. 147-160, 2009.
20. Ampoorter E, Van Nevel L, De Vos B, Hermy M, and Verheyen K, "Assessing the effects of initial soil characteristics, machine mass and traffic intensity on forest soil compaction," *Forest Ecology and Management,* vol. 260, no. 10, pp. 1664-1676, 2010.
21. Goutal N, Renault P, and Ranger J, "Forwarder traffic impacted over at least four years soil air composition of two forest soils in northeast France," *Geoderma,* vol. 193, pp. 29-40, 2013.
22. Cambi M, Certini G, Neri F, and Marchi E, "The impact of heavy traffic on forest soils: A review," *Forest ecology and management,* vol. 338, pp. 124-138, 2015.
23. Labelle ER and Jaeger D, "Soil compaction caused by cut-to-length forest operations and possible short-term natural rehabilitation of soil density,"

Soil Science Society of America Journal, vol. 75, no. 6, pp. 2314-2329, 2011.

24. Bygdén G, Eliasson L, and Wästerlund I, "Rut depth, soil compaction and rolling resistance when using bogie tracks," *Journal of Terramechanics*, vol. 40, no. 3, pp. 179-190, 2003.
25. Eliasson L, "Effects of forwarder tyre pressure on rut formation and soil compaction," *Silva Fennica*, vol. 39, no. 4, p. 549, 2005.
26. Sakai H, Nordfjell T, Suadicani K, Talbot B, and Bøllehuus E, "Soil compaction on forest soils from different kinds of tires and tracks and possibility of accurate estimate," *Croatian Journal of Forest Engineering: Journal for Theory and Application of Forestry Engineering*, vol. 29, no. 1, pp. 15-27, 2008.
27. Ham J-Pvd, "Dodota Spate Irrigation System Ethiopia A case study of Spate Irrigation Management and Livelihood options," 2008.
28. Ganiyu SA, Olurin OT, Oladunjoye MA, and Badmus BS, "Investigation of soil moisture content over a cultivated farmland in Abeokuta Nigeria using electrical resistivity methods and soil analysis," *Journal of King Saud University - Science*, vol. 32, no. 1, pp. 811-821, 2020.
29. Puissant J, Villenave C, Chauvin C, Plassard C, Blanchart E, and Trap J, "Quantification of the global impact of agricultural practices on soil nematodes: A meta-analysis," *Soil Biology and Biochemistry*, vol. 161, p. 108383, 2021/10/01/ 2021.
30. Li H *et al.*, "Soil texture strongly controls exogenous organic matter mineralization indirectly via moisture upon progressive drying — Evidence from incubation experiments," *Soil Biology and Biochemistry*, vol. 151, 2020.