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Research Article

Investigation of Soil Physiochemical Properties Effects on Soil Compaction for a Long Year Tilled Farmland

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In many parts of the world, the earth has been heavily compacted as a result of large farm equipment. For soil compaction, the main constituent factors were soil physiochemical properties such as soil texture, moisture content, electrical conductivity, cation exchange capacity, total organic carbon, organic matter, total nitrogen, and soil pH directly and indirectly. This article addressed the causes and effects of soil compaction, operating parameters, and soil physicochemical properties in the Bishoftu long year tilled farmland of Ethiopia. For the experimental test, 5 different depths (5, 10, 15, 20, and 25 cm) and fifteen sample points were selected in 0.6 ha of 60 m by 100 m farmland for taking soil compaction data. Soil samples are taken from three depth ranges (0–10, 10–20, and 20–30 cm) from farmlands for investigation of soil physicochemical properties. The maximum and minimum values of the cone index of this study were 1918.133 kPa and 864.733 kPa, respectively, by taking the average of all sample points. The soil laboratory result shows that Bishoftu farmland soil is a mixture of loam, clay loam, and sandy clay loam with 47.33% of sand, 25.67% of clay, and 27% of silt. The maximum and minimum percentages of soil moisture values were 27.02 and 21.46 at 0–10 cm and 20–30 cm depth, respectively. Total organic carbon, organic matter, and total nitrogen exhibit positive relationships with depth and soil compaction. The correlation analysis indicates soil pH, electric conductivity, percentage of sand, cation exchange capacity, organic matter, and total nitrogen were among soil physiochemical parameters that are positively correlated with soil compaction. Furthermore, the percentage of clay, percentage of silt, and total organic carbon ($p \leq 0.05$) are negatively correlated with soil compaction in soil samples.

1. Introduction

In the agricultural mechanization system, physical properties of soil and plant growth are affected by soil compaction [1]. Many soil scientists, agricultural engineers, and farmers are concerned about agricultural soil compaction. In a mechanization system, farm machinery is employed for land preparation and harvesting processes by driving in agricultural land. Due to multi-functioning agricultural machinery, the problem related to soil compaction also increased as agricultural tractors and field equipment become larger and heavier [2]. 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 to soil water and nutrients, and also reduces crop yields [4].

Soil compaction is affected by animal trampling as well as farm machinery. The risk of compaction is also dependent on soil tillage and crop rotations, soil moisture, and working depth [5]. Soil tillage, crop rotations, soil moisture, and working depth have been continuously disregarded in the management of agricultural traffic, even though they are extremely relevant to maintaining the soil quality of different agroecosystems [6]. The effects of tillage, wheel traffic, soil texture, and organic matter concentration on dry bulk density were investigated [7]. The impact of textural and structural parameters on soil strength is moderated by soil organic carbon concentration [8].

Soil physical properties are crucial in determining soil's appropriateness for agricultural, environmental, and engineering applications. Excessive compactness is detrimental to maintaining a good root environment, reducing penetration of water, and increasing runoff and erosion [9]. The value of the cone index varies depending on the depth of the soil, the textural parameters, the bulk density, and the moisture content. The values of the cone index decrease with the increase in clay fraction and increase with the increase in sand and silt fractions of soil [10].

Physical attributes of the soil are intimately related to supporting capabilities, movement, retention, and availability of water and nutrients to plants [11]. Soil strength can be measured traditionally using a hand-operated soil cone penetrometer [12]. Kumar et al. designed and developed a hydraulically operated mechanical soil cone penetrometer to measure soil resistance [13]. The literature shows that penetration resistance measurements have been carried out with many types of cones. For instance, [8, 14] used different types of cone shapes in their tests. Measurements followed the ASAEBE S313.3 standards with the exception that the standard recommends a 30-degree cone. The tillage practices and weight of the tractor during tillage and harvesting are assumed to have the strongest influence on the penetration resistance.

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 [15]. One of the most difficult measures in agriculture is that of soil moisture [16]. Soil moisture is the ratio of the weight of water to the weight of solids in a particular mass of soil. A noncorrodible container, a digital weight machine, and an electric oven are all essential equipment [17].

Soil is grouped on the basis of the grain size of the particles that constitute soil, which is expressed as soil texture [18]. The pH of soil is a measure of its acidity or alkalinity [19]. Soil parameters like soil texture, soil pH, soil EC, soil organic content, and soil cation exchange capacity have significant influences on penetration resistance [20]. Soil quality can be assessed by combining biological, chemical, and physical soil parameters. Microbial activity shows the microbiological operations of soil microorganisms, which vary in proportion depending on the soil system [21]. According to [22], bacteria and fungi are the most common forms of microorganisms found in soil and play an important role in nutrient transformations and litter decomposition rates. Soil texture is one of the most important elements determining the structure of microbial communities, as are pH, cation exchange capacity, and organic matter concentration. These characteristics can directly alter microbial community structure by providing suitable habitat for specific microbes, resulting in a maximal degradation process. The interactions between soil organic matter, total nitrogen levels, and soil texture may have an impact on the microbial communities in soil and how well they perform in the process of degrading plant waste [23].

The goals of this study were to determine the relationships between three variables, depth, soil penetration resistance, and soil physiochemical properties (water content, pH value, clay content, silt content, sand content, soil electric conductivity, cation exchange capacity, total organic carbon, organic matter, and total nitrogen), that affect soil penetration resistance in the study area, which was conventionally tilled farmland for a long time.

2. Materials and Methods

The methodology used in this work is primary experiment, involving soil compaction measurement in agricultural field and soil physiochemical property test in the laboratory level.

2.1. Description of the Study Area. Farm sites selected for this study include Bishoftu farm land, which is located in the Oromia Region of Ethiopia. This area is 1,920 meters above sea level and 47.9 kilometres southeast of Addis Ababa, with natural loam soil [24]. To achieve the goal of this study, the effect of soil physiochemical property on soil compaction is shown in the cause and effects form flowchart in Figure 1.

The experimental area selection criteria are based on the tractor density and availability of research center. The field under study had a size of 0.6 ha and had been tilled for more than 20 years.

2.2. Soil Sample Collection. During the field experimental test, 5 different depths are selected for taking soil compaction data (5 cm, 10 cm, 15 cm, 20 cm, and 25 cm). All the depth parameters will be replicated fifteen times at farm field (point A to point O), as 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 0.6 hectare $(100 \times 60\,\text{m})$ is modeled in Figure 2.

2.3. Soil Compaction Measurement. The soil compaction was measured using a SpotOn digital compaction meter which meets the ASABE S313.3 soil compaction standard. The measurement taken at 10 mm depth intervals using a SpotOn digital compaction meter equipped with a 12.8 mm steel cone diameter with a 30° included angle is used in compaction measurement. In total, 75 measurements were made in the field.

2.4. Soil Physiochemical Property Test. The physical, chemical, and biological properties of test soil were determined by the standard procedures. The soil particles like sand, silt, and clay contents were analysed with the use of different sieves and their settling rates in an aqueous solution using a hydrometer by the method given by [25]. Electric conductivity and pH were determined by a JENWAY 4310 conductivity meter and HI 2210 benchtop pH meter, respectively. The

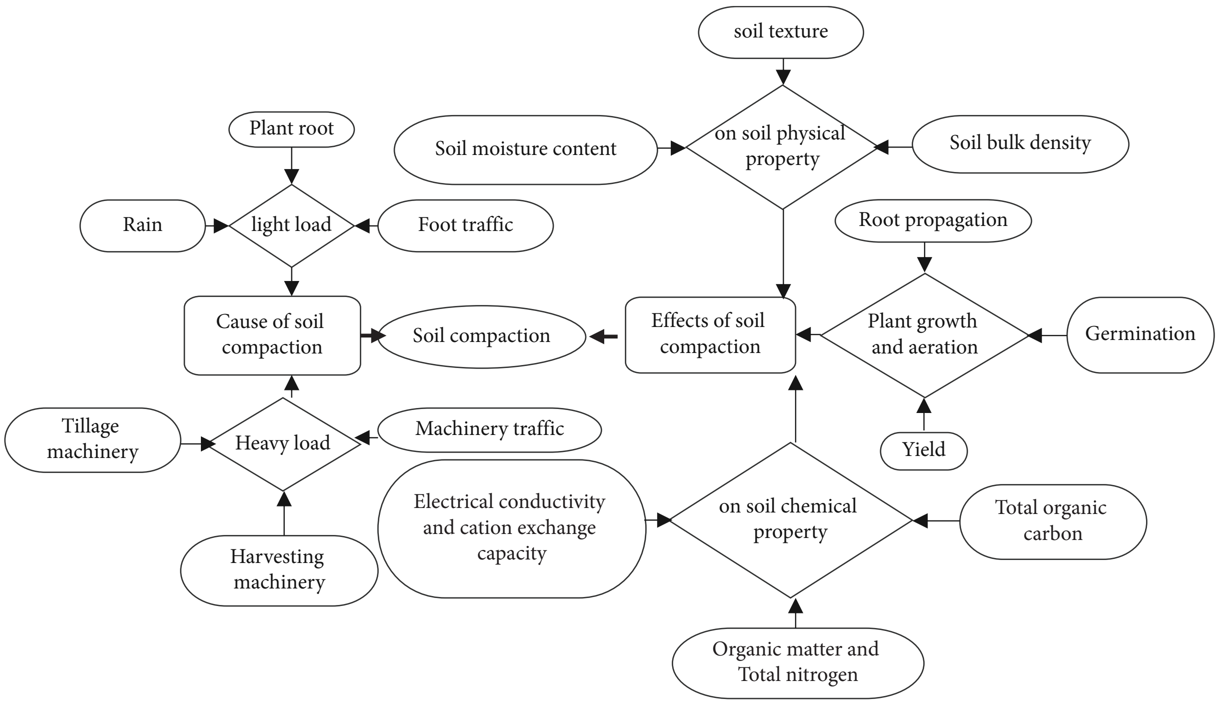


Figure 1: Cause and effects of soil compaction.

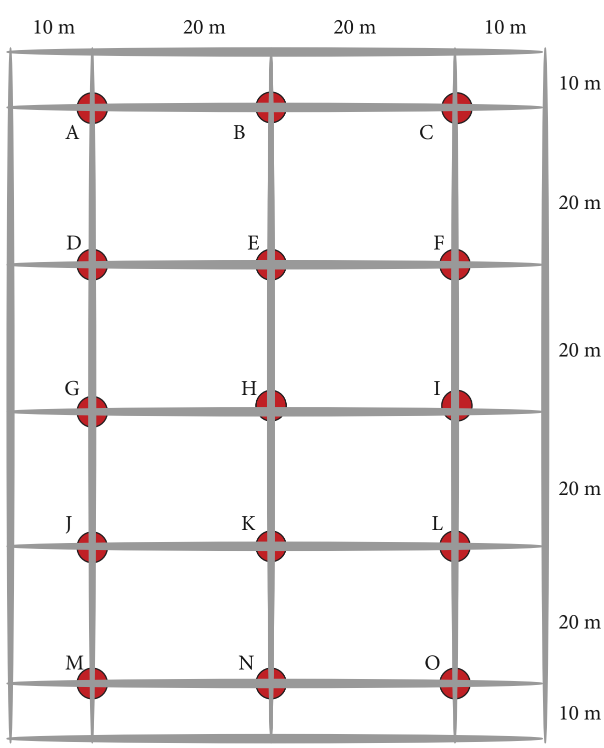


Figure 2: Data sampling, plot design, and distribution of replication.

cation exchange capacity (CEC) of soils was measured based on the NCR-13 Standard. The electrical conductivity of soil was determined in the filtrate of the water extract using a conductivity meter. Percent of total organic carbon (TOC) and total organic matter were determined by adopting the chromic acid wet digestion method and based on gravimetric weight change associated with high temperature oxidation of organic matter, respectively, as standard procedure of Walkley and Black. Available total nitrogen was estimated by the alkaline permanganate method. Whereas, soil moisture content was determined by the principle of weight difference of soil contain water and weight of dried soil in a particular mass.

2.5. Statistical Analysis. Data of soil chemical and physical parameters were tested using a one-way analysis of variance. A correlation coefficient was performed in order to detect the relationships between soil compaction, and the correlation between soil physiochemical properties was detected by IBM SPSS statistics 26.2.

3. Results and Discussion

The result of this study covers the effects of soil compaction on the physiochemical properties of farm field soil. The physical and chemical properties of soil were studied in the soil laboratory to identify soil texture, soil pH, EC, soil organic content, and cation exchange capacity (CEC).

3.1. Soil Compaction. The soil compaction with respect to depth for each sampling point and depth and the soil compaction measurements are taken and plotted in Figure 3.

Several countries have researched the effect of combined depth of tillage and regulated traffic on penetration resistance and its consequences for root growth. In the subsoil of

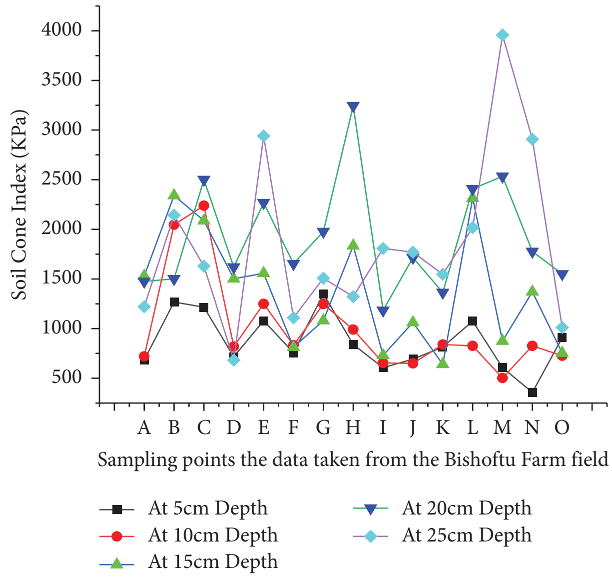


Figure 3: Soil cone index of all sample points vs. depth.

Table 1: Soil compaction correlation of within Bishoftu experimental field sites.

	BA	BB	BC	BD	BE	BF	BG	BH	BI	BJ	BK	BL	BM	BN	BO
BA	1														
BB	0.385	1													
BC	0.514	0.288	1												
BD	0.800	0.078	0.724	1											
BE	0.570	0.258	0.146	0.073	1										
BF	0.561	−0.266	0.567	0.537	0.641	1									
BG	0.302	−0.529	0.336	0.311	0.556	0.944*	1								
BH	0.780	−0.123	0.711	0.869	0.423	0.883*	0.729	1							
BI	0.421	0.219	−0.005	−0.111	0.983**	0.545	0.507	0.266	1						
BJ	0.715	0.110	0.266	0.325	0.953*	0.799	0.699	0.658	0.895*	1					
BK	0.284	−0.097	0.086	−0.087	0.907*	0.737	0.768	0.388	0.923*	0.870	1				
BL	0.980**	0.256	0.389	0.732	0.652	0.621	0.408	0.783	0.519	0.800	0.402	1			
BM	0.467	0.134	0.026	−0.032	0.987**	0.628	0.595	0.360	0.992**	0.934*	0.944*	0.575	1		
BN	0.605	0.444	0.162	0.069	0.979**	0.520	0.391	0.349	0.959**	0.903*	0.815	0.657	0.945*	1	
BO	0.454	−0.509	0.369	0.481	0.530	0.957*	0.975**	0.834	0.453	0.721	0.685	0.554	0.554	0.373	1

At the 0.05 level (2-tailed), the correlation is significant; ∗ ∗ at the 0.01 level, correlation is significant (2-tailed), "B" in first latter indicate Bishoftu farm site; A to O letters next to Bishoftu indicates sampling point in field; PC, personal correlation.

sandy soil with a water content of 0.03–0.09 kg/kg, a penetration resistance measured was 30–350 kPa [1]. The penetration resistance in sandy loam soil is between 3000 and 4500 kPa [26]. In the research area, the soil texture class was a combination of clay, clay loam, loam, and sandy clay loam. A penetration resistance value of 864.7–1838.3 kPa with a water content of 0.21–0.27 kg/kg was measured.

3.2. Statistical Analysis. Correlation of soil compaction within Bishoftu experimental field sites of sampling point in field A to O indicates both positive and negative correlations (Table 1).

Correlation of soil compaction within experimental field sites of sampling point in field A to O indicates both positive and negative correlations. Field points between G and F, H and F, J and E, J and I, K and E, K and I, M and J, M and K, N and J, N and M, and O and F have a strong positive connection that is statistically significant at the 0.05 level. Field points between I and E, L and A, M and E, M and I, N and E, N and I, and O and G have a strong positive connection that is statistically significant at the 0.01 level.

The correlations between physiochemical parameters and soil compaction are useful in farm mechanization as indicated in Table 2. Soil pH ($r = 0.49$), electric conductivity ($r = 0.999$), percentage of sand ($r = 0.965$), cation exchange capacity ($r = 0.47$), organic matter ($r = 0.767$), total nitrogen ($r = 0.257$) were among soil physiochemical parameters that are positively correlated with soil compaction. Furthermore, percentage of clay ($r = -87.5$), percentage of silt ($r = -1$), and total organic carbon ($r = -0.47$) at ($p \leq 0.05$) are negatively correlated with soil compaction in soil samples.

Table 2: The correlations between physiochemical parameters and soil compaction.

Parameters	Soil compaction	pH	EC	Sand	Clay	Silt	CEC	TOC	OM	TN	Moisture
Soil compaction	1	0.949	0.99*	0.96	−0.87	−1.0*	0.407	−0.47	0.767	0.257	0.996
pH		1	0.935	0.99*	−0.98	−0.94	0.097	−0.16	0.93	0.549	0.916
EC			1	0.954	−0.85	−1.0*	0.44	−0.50	0.74	0.218	0.99*
Sand				1	0.97	−0.96	0.15	−0.22	0.90	0.50	0.938
Clay					1	0.86	0.08	−0.02	−0.98	−0.69	−0.83
Silt						1	−0.42	0.48	−0.75	−0.240	−0.97*
CEC							1	−0.99*	−0.27	−0.77	0.48
TOC								1	0.20	0.73	−0.54
OM									1	0.81	0.70
TN										1	0.17
Moisture											1

*Correlation is significant at the 0.05 level.

Table 3: The physiochemical properties laboratory result for the farm field.

Field site	Depth	pH	EC (μS/cm)	Textural % sand	Textural % clay	Textural % silt	Textural class	CEC (meq/100 g soil)	% TOC	% OM	% TN	% moisture
Bishoftu	0–10	6.17	245	45	27	28	L, CL, and SCL	25.5	1.35	2.33	0.08	21.43
	10–20	6.46	251.2	48	25	27		21.3	1.53	2.43	0.12	23.87
	20–30	6.53	257.9	49	25	26		28.6	1.18	2.41	0.09	27.02
Mean		**6.4**	**251.4**	**47.3**	**25.7**	**27.0**		**25.1**	**1.4**	**2.4**	**0.1**	**24.1**

EC, electrical conductivity; CEC, cation exchange capacity; TOC, total organic carbon; OM, organic matter; TN, total nitrogen; C, clay; CL, clay loam; L, loam; SCL, sandy clay loam.

3.3. Soil Physiochemical Properties. Soil parameters like soil texture, soil pH, soil EC, soil organic content, and soil cation exchange capacity have significant influences on penetration resistance [20]. Thus, all information collected from the field are used as spatial input variables for the prediction of soil cone index at soil depth ranges of (0–10, 10–20 and 20–30) centimeters.

Cation exchange capacity, measured in milliequivalents (meq) per 100 g of soil, is a measure of a soil's ability to store a specific group of nutrients such as calcium, magnesium, potassium, ammonium, hydrogen, and sodium. The quantity of clay in the soil and the amount of organic matter in the particles have a net negative charge [27]. In this research, the cation exchange capacity mean result of farm soil was 25.1 meq/100 g as indicated in Table 3.

The soil texture classes based on soil texture triangle for the field were a combination of loam, clay loam, and sand clay loam as shown in Figure 4, with a mean value of 47.33% of sand, 25.67% of clay, and 27% of silt. In this study, the higher soil class was sand (47.33%) and the soil electric conductivity (251 μS/cm), and the pH values ranged from a moderately acidic character (pH = 6.4). The moisture level and EC are affected by soil texture. The soil can store water particles in a variety of areas depending on the size of the soil particles. Because of its low surface contact, sand cannot store moisture very well and has a lower electrical conductivity (EC) value, whereas silt is wet with a medium EC value. Clay-rich soil has a higher electrical conductivity (EC) value due to its texture, which can hold a lot of water and result in a high moisture level [28]. Based on past studies, the results of studied soil were in a moderate range since it contains all soil types in it. Soil pH is an important soil attribute because it influences a variety of chemical and biological processes in the soil, such as nutrient availability and microbial activity [29]. Temperature, the quantity of fertilizers used, the type of soil, salinity, moisture content, and irrigation are a few significant factors that influence the EC value of soil [28]. The results were in conformity with the past studies, and moisture level aids in releasing the ions so that EC values may be read easily.

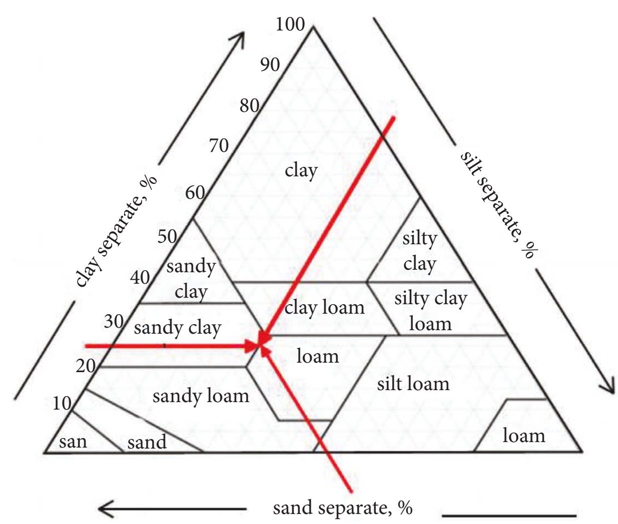


Figure 4: Soil texture triangle [17].

The percentage of moisture content is studied in the soil laboratory and the mean result of the study indicates 24.1%.

Soil compaction constituent factors with respect to depth are plotted in Figures 5 to 8 and the impacts of soil physical and chemical properties on soil penetration resistance are

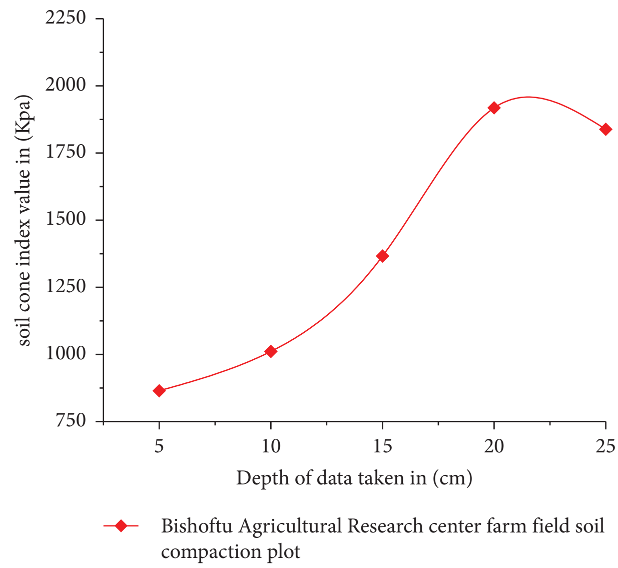


Figure 5: Average value of all sample points soil cone index vs. depth.

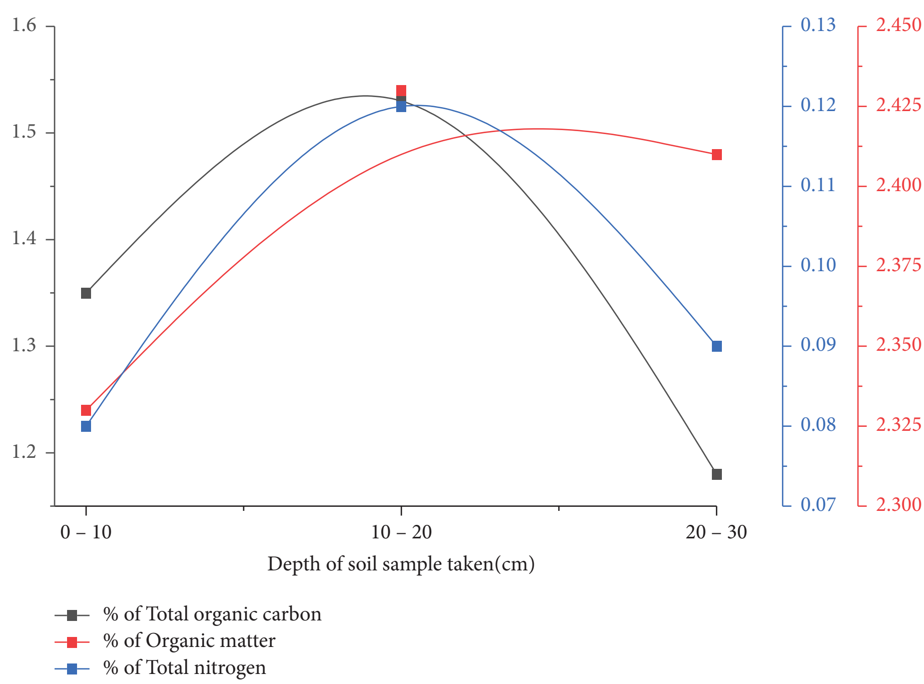
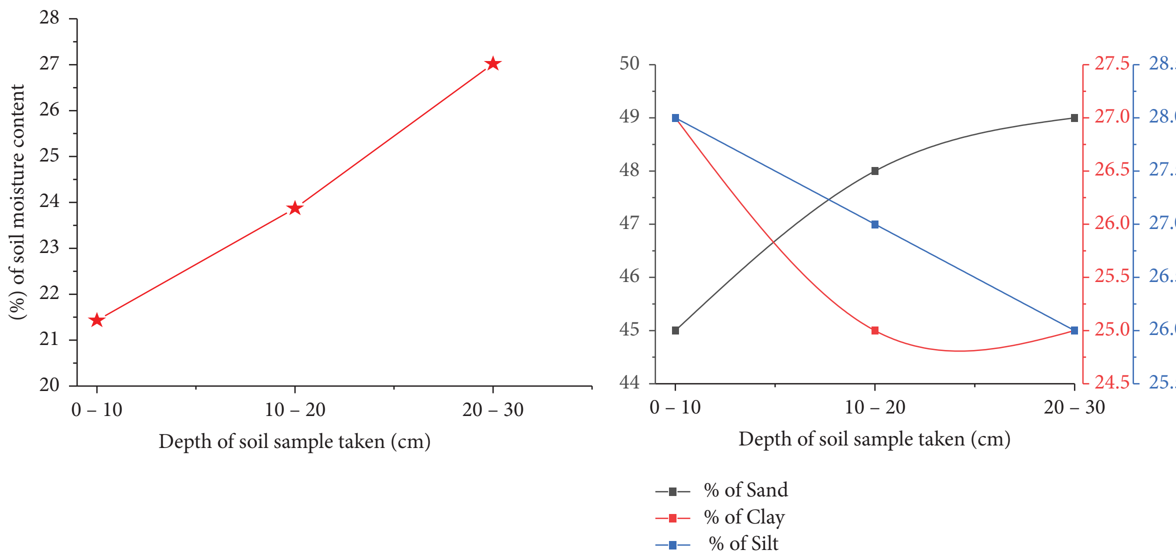


Figure 6: Total organic carbon percent, organic matter percent, and total nitrogen percent vs. depth.

indicated. The depth profiles of the mean penetration resistance were summarized in Figure 5, for selected farm field. The cone indices of experimental farm sites had a general tendency to increase with soil depth. The relation between soil moisture content and depth is plotted in Figure 7(a), which shows as depth increases, percent of soil moisture content also increases. As indicated in Figure 5, soil compaction is increasing as depth increases. So, based on Figures 5 and 7(a), as soil depth increases, so do soil compaction and moisture content. The maximum and minimum percentages of soil moisture values were 27.02 and 21.43% at 0–10 cm and 20–30 cm depth, respectively. As illustrated in Figure 7(b), as the depth increases up 20 cm, percent of sand and clay increases and the percent of silt decreases. After 20 cm, percent of sand and clay decreased and the percent of silt increased. The relationship between soil compaction and soil texture in



(a) (b)

Figure 7: (a) Soil moisture content vs. depth. (b) Soil types percent vs. depth.

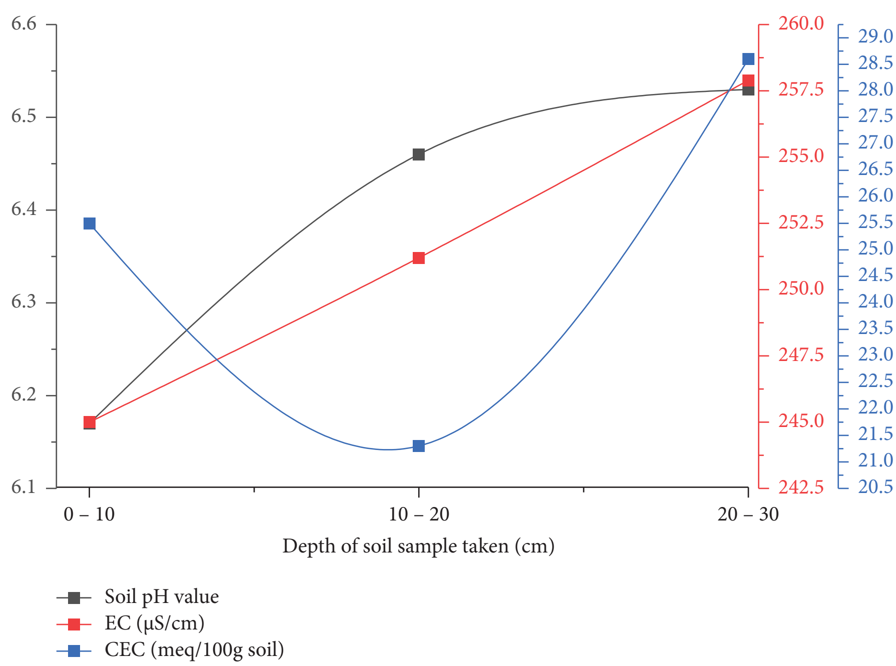


Figure 8: Soil pH value, soil EC, and soil citation exchange capacity vs. depth.

Figures 5 and 7(b) shows the largest sand and clay percentage of soil has the highest value of soil compaction value and vice versa.

Soil pH value and soil EC increases when depth increases, as shown in Figure 8. Soil citation exchange capacity decrease for the first 20 cm depth. After 20 cm depth, soil citation exchange capacity increases with dept. The soil compaction exhibited a linear relation with soil pH value and soil EC. Soil citation exchange capacity has inverse relation with soil compaction for the first 20 cm and after 20 cm depth have linear relation as indicated in Figures 5 and 8.

Total organic carbon, organic matter, and total nitrogen exhibit positive relationships with depth and soil compaction. Both soil compaction and amounts of total organic carbon, organic matter, and total nitrogen start decrease after 20 cm depth as shown in Figures 5 and 6.

4. Conclusions

The result of this study covers the effects of soil compaction on soil physical and chemical properties like moisture content, soil texture, soil pH, EC, soil organic content, and

CEC at different depths. The result of the study taken from fifteen sample points indicates the highest soil compaction value of Bishoftu farm field at 3958 kPa and the minimum was 358 kPa at M and N sample points of depth of 25 cm and 5 cm of depth, respectively. From the average of all sample points, the maximum and minimum values of soil compaction value were 1918.13 kPa and 864.73 kPa at 20 cm and 5 cm depths, respectively. Soil compaction increased with soil depth at the experimental farm under study. The laboratory result shows the farm soil is a mixture a combination of loam, clay loam, and sand clay loam. The other predicting variable for soil compaction is soil texture (sand, clay, and silt). The average result of soil texture shows 47.33% of sand, 25.67% of clay, and 27% silt. Soil compaction and soil moisture content both rise as soil depth increases. The soil with the highest sand and clay percentage has the highest value of soil compaction value and vice versa. The cation exchange capacity of the laboratory result indicates Bishoftu farm soil is 25.1 meq/100 g of soil, taking average values for all depth samples. Total organic carbon, organic matter, and total nitrogen exhibit positive relationships with depth and soil compaction. Both soil compaction and amounts of total organic carbon, organic matter, and total nitrogen start to decrease after 20 cm of depth.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

Acknowledgments

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References

[1] D. Mada, S. Ibrahim, and I. Hussaini, "The effect of soil compaction on soil physical properties southern Adamawa State agricultural soils," *International Journal of Engineering Science*, vol. 2, no. 9, pp. 70–74, 2013.

[2] Food and Agriculture Organization of the United Nations, *Agricultural Engineering in Development: Guidelines for Mechanization Systems and Machinery Rehabilitation Programmes*, Food and Agriculture Organization of the United Nations, Rome, Italy, 1990.

[3] N. Ungureanu, Şt. Croitoru, S.-S. Biris et al., "Agricultural soil compaction under the action of agricultural machinery," in *Proceedings of the Actual Tasks on Agricultural Engineering*, Opatija, Croatia, 2015.

[4] H. Liu, T. Colombi, O. Jack, T. Keller, and M. Weih, "Effects of soil compaction on grain yield of wheat depend on weather conditions," *Science of the Total Environment*, vol. 807, no. Pt 1, Article ID 150763, 2022.

[5] R. S. Bertonha, F. C. E. Angeli, V. F. A. Silva, and D. L. Wright, "Tractor performance and corn crop development as a function of furrow opener and working depth," *Australian Journal of Crop Science*, vol. 9, no. 9, pp. 812–818, 2015.

[6] W. D. S. Guimaraes Junnyor, E. Diserens, I. C. De Maria, C. F. Araujo-Junior, C. V. V. Farhate, and Z. M. de Souza, "Prediction of soil stresses and compaction due to agricultural machines in sugarcane cultivation systems with and without crop rotation," *Science of the Total Environment*, vol. 681, pp. 424–434, 2019.

[7] A. P. da Silva, B. Kay, and E. Perfect, "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.

[8] C. W. Smith, M. A. Johnston, and S. Lorentz, "The effect of soil compaction and soil physical properties on the mechanical resistance of South African forestry soils," *Geoderma*, vol. 78, no. 1-2, pp. 93–111, 1997.

[9] S. Mudarisov, I. Gainullin, I. Gabitov, E. Hasanov, and I. Farhutdinov, "Soil compaction management Reduce soil compactionusing a chain-track tractor," *Journal of Terramechanics*, vol. 89, pp. 1–12, 2020.

[10] A. Kumar, Y. Chen, M. A. A. Sadek, and S. Rahman, "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.

[11] V. K. Phogat, V. S. Tomar, and R. Dahiya, "Soil physical properties," *The Nation That Destroys Its Soil Destroys Itself*, New Statesman, London, UK, 2015.

[12] J. E. Herrick and T. L. Jones, "A dynamic cone penetrometer for measuring soil penetration resistance," *Soil Science Society of America Journal*, vol. 66, no. 4, pp. 1320–1324, 2002.

[13] V. Kumar, P. Kumar, R. K. Sahni, and E. V. Thomas, "Design of tractor mounted hydraulically operated soil compaction measurement system," *Central Institute of Agricultural Engineering*, vol. VIII, no. XXVIII, 2019.

[14] A. Canarache, "PENETR—a generalized semi-empirical model estimating soil resistance to penetration," *Soil and Tillage Research*, vol. 16, no. 1-2, pp. 51–70, 1990.

[15] M. L. Jat, B. Singh, C. M. Stirling et al., "Chapter four - soil processes and wheat cropping under emerging climate change scenarios in south Asia," in *Advances in Agronomy*, D. L. Sparks, Ed., pp. 111–171, Academic Press, Cambridge, MA, USA, 2018.

[16] S. A. Ganiyu, O. Olurin, M. Oladunjoye, and B. Badmus, "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.

[17] G. Estefan, *Methods of Soil, Plant, and Water Analysis: A Manual for the West Asia and North Africa Region*, International Center for Agricultural Research in the Dry Areas (ICARDA), Beirut, Lebanon, 2013.

[18] H. Li, J. Van den Bulcke, X. Wang 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, Article ID 108051, 2020.

[19] W. Ejigu, Y. G.Selassie, E. Elias, and M. Damte, "Integrated fertilizer application improves soil properties and maize (*Zea mays* L.) yield on Nitisols in Northwestern Ethiopia," *Heliyon*, vol. 7, no. 2, Article ID e06074, 2021.
[20] J. Puissant, C. Villenave, C. Chauvin, C. Plassard, E. Blanchart, and J. Trap, "Quantification of the global impact of agricultural practices on soil nematodes: a meta-analysis," *Soil Biology and Biochemistry*, vol. 161, Article ID 108383, 2021.
[21] G. Chen, H. Zhu, and Y. Zhang, "Soil microbial activities and carbon and nitrogen fixation," *Research in Microbiology*, vol. 154, no. 6, pp. 393–398, 2003.
[22] D. R. Zak, D. Tilman, R. R. Parmenter et al., "Plant production and soil microorganisms in late-successional ecosystems: a continental-scale study," *Ecology*, vol. 75, no. 8, pp. 2333–2347, 1994.
[23] N. H. Hamarashid, M. A. Othman, and M.-A. Hussain, "Effects of soil texture on chemical compositions, microbial populations and carbon mineralization in soil," *Egyptian Society of Experimental Biology*, vol. 6, no. 1, pp. 59–64, 2010.
[24] A. A. Kebede, D. D. Olani, T. Getahun, and Y. T. Damtew, "Heavy metal Content and physico chemical Properties of soil around solid waste disposal sites," *American Journal of Scientific and Industrial Research*, vol. 7, no. 5, pp. 129–136, 2016.
[25] M. J. S. S. Alexander, "Introduction to soil microbiology," *Soil Science*, vol. 125, no. 5, p. 331, 1978.
[26] S. Kukal and G. J. S. Aggarwal, "Puddling depth and intensity effects in rice–wheat system on a sandy loam soil I. Development of subsurface compaction," *Soil and Tillage Research*, vol. 72, no. 1, pp. 1–8, 2003.
[27] K. Peverill, L. Sparrow, and D. J. Reuter, *Soil Analysis: An Interpretation Manual*, CSIRO publishing, Clayton, Australia, 1999.
[28] N. C. Othaman, M. N. Md Isa, R. C. Ismail, M. I. Ahmad, and C. K. Hui, "Factors that affect soil electrical conductivity (EC) based system for smart farming application," in *AIP Conference Proceedings,* AIP Publishing LLC, Melville, NY, USA, 2020.
[29] F. G. Fernández and R. G. Hoeft, "Managing soil pH and crop nutrients," *Illinois Agronomy Handbook*, vol. 24, pp. 91–112, 2009.