International Journal of Plant & Soil Science
13(5): 1-12, 2016; Article no.IJPSS.25495
ISSN: 2320-7035

SCIENCEDOMAIN ***international***
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Soil Compaction under Three Different Land Use Systems within the Semi-deciduous Agro-ecological Zone of Ghana

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Authors' contributions

This work was carried out in collaboration between both authors. Author MDA designed the study, wrote the protocol and wrote the first draft of the manuscript. Author EFA managed the literature searches, analyses of the study, performed and managed the experimental process. Both authors read and approved the final manuscript.

Article Information

DOI: 10.9734/IJPSS/2016/25495
Editor(s):
(1) Artemi Cerda, Department of Geography, University of Valencia, Spain.
(2) Junhong Bai, School of Environment, Beijing Normal University, Beijing, China.
Reviewers:
(1) Philip Hegarty James, University of Maiduguri, Nigeria.
(2) Maria Joser Alves Bertalot and Eduardo Mendoza, Brazilian Association of Biodynamic Agriculture, Brazil.
Complete Peer Review History: http://www.sciencedomain.org/review-history/17323

Received 6th March 2016
Accepted 13th December 2016
Published 23rd December 2016

Original Research Article

ABSTRACT

Soil compaction due to land management systems has profound implications on soil physical properties with consequent effects on soil productivity. The paper at hand assesses soil compaction under three different land use systems (cultivated land, grassland and adjacent forest land). Soil samples were collected from the different land use types at 0-30 cm depth using the core sampler method and analyzed to determine soil texture, soil bulk density and soil porosity. The results showed variations in bulk density and porosity levels under the three different land use systems and also significant differences ($P<.05$) in soil texture with land use system and soil depth. Extreme levels of compaction were observed under the grassland (1.80 g/cm^3) and the cultivated land (1.76 g/cm^3) at 20-30 cm depth as compared to soils under the natural forest based on the Canarache's soil compaction index. The findings underpin the

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credence that conversion from natural forest to cultivated land or grassland decreases soil productivity. Therefore the need to consider soil compaction as a major area in land end-use planning.

Keywords: Land use systems; soil compaction; physical properties.

1. INTRODUCTION

Soil is of importance because it maintains biodiversity, ensures biofuels/energy security, regulates climate, provides ecosystem services, ensures food and water securities etc. [1,2]. Damages to these soils outweigh the bearing capacity of the soil as the magnitude of pressure forces applied is intensified by increasing anthropogenic activities such as agriculture [3] and animal grazing [4]. The result is seen in the inability of the affected soils to provide these importance services. It is therefore necessary to apply sustainable land management practices which is aimed at ameliorating these devastating soil conditions. As suggested by Brevik et al. [2], sustainable management should entail interdisciplinary approach which fosters holistic management. Therefore, the conditions of different land use types should be a point cut.

Soil quality decline due to soil compaction has become an important concern worldwide since it is becoming more increasingly severe. Most of these devastating soil quality degrading problems emanates from modern agriculture and forestry [5] particularly due to the overuse of machineries on farms [6-8] and overgrazing [4]. Soil ecosystem impacted by compaction often shows significant symptoms such as the reduction of pore spaces; decreasing water infiltration thereby increasing runoffs and erosion, restricting root growths [9] and a consequential effect on food security [1,2].

Agriculture is often cited as an important driver of soil system dynamics [10]. Conversion of forested lands to agriculture reduces its SOC [11], TOC and OMC [12]. Soil compaction reduces soil mesopores which increases the bulk densities [13]. Application of land cover management practices during crop production, however, are known to affect the severity of soil compaction. Zhang et al. [14] reported that changes in land use and land cover as well as its management activities (e.g. vegetation decline, long-term fertilization, herbicide applications etc.) have significant impaired the quality of soils. Continuous tillage practice induces soil compaction at varying depths [15-17] but no-tillage management practices appears not to effect soil physical factors markedly [13]. There are also some profound implications on soil fauna, particularly earthworm numbers as documented by Birkás and his colleagues in 2004.

Due to the importance of soil compaction, the phenomenon has received attention within the scientific communities. Several methods are therefore used to ascertain the severity of compacted soils. The core methods through laboratory and field surveys provided a good estimate of the impact of compaction on soil physical parameters, but some recent improvements soil parameters estimation provided by Reidy et al. [18] capitalized on their oversights and used pedotransfer functions to estimate bulk densities per horizon based on known soil parameters. Also, Udawatta et al. [19] used an interesting X-ray computed microtomography (CMT) method to analyze the influence of compaction on geometrical soil pore parameters. Their methodological approaches found that compaction significantly reduces soil pore properties which invariably affects hydraulic properties.

Ghana, an agriculture dependent economy, has witnessed a significant population growth within the past two decades and is no exception to land use menaces. More productive lands (sometimes marginal lands) had to be cleared for agriculture production in an attempt to fight against food insecurity. This menace of rapid degradation of the quality of soils is both the cause and consequence of soil compaction which is manifested in increased bulk densities and reduced mesopore sizes [13]. This results in diminishing yield over time and productivity losses of the soil leading to poor farm output [3]. Again, due to land scarcity, famers are left with the dilemma on the management options to be applied to ensure sustained productivity. But empirical evidence to enable them make positive decision is lacking. From a comprehensive review, we found that most research work on soils in semi-deciduous forest zones of Ghana place little emphasis on soil compaction. A necessary step towards a guaranteed soil productivity is to be informed about the nexus of soil variables and anthropogenic influences. Quantifying the level of soil compaction under different land use systems is thus needed to enable local farmers put sustainable land management alternatives into practices. Ideally, farmers will know whether their management practices improve the soil or rather cause severe degradation of the soils structure.

The present paper aims 1) to find out if different land use systems affect the degree of compaction in soils at varying depths; 2) to compare the moisture content and level of porosity of the soil under the three different land use systems.

2. MATERIALS AND METHODS

2.1 The Study Area

The study area is Soil Research Institute (SRI) at Kwadaso, North West of Kumasi confined in Longitude 6°40’ 35.9" North and Latitude 1°40' 0.6" West (Fig. 1). The site has an elevation of 262 m above sea level and covers a total area of 214200 square meters. The study area has a mean annual rainfall of 1500 mm from June to August. It has an average monthly temperature ranging from 24-28°C while mean maximum and minimum temperature rises up to 34°C and 25°C respectively. Soils in the study area occur on gentle undulating topography (3-8% slopes) where susceptibility to erosion is relatively light to moderate under mechanical tillage and careful management. Narrow bands of very deep non-gravelly soils occur on gentle lower slopes (2-5%). Soils drainage classes ranges from a moderately well drain soil to a well drain soil. Water-holding capacity is moderate although surface layers are subject to dry season drought. Soils in the study area are sedentary in-situ develop which means that they are not transported during their formation. Soils are generally medium textured, highly or moderately gravelly with lots of quartz and higher amounts of acrisols which are clay-rich materials. Soils also have phyllite as parent material resulting from weathering of sedimentary and metamorphic rocks. Soils are heavily dark- reddish cracking clays. The clay content is very high amounting to 70% to 80%. Land use system in the area is dominated by Agricultural activities including Maize (*Zea mays*) and Beans (*Phaseolus vulgaris*) cultivation, Oil Palm (*Elaeis guineensis*) and Orange (*Citrus sinensis*) plantations, Livestock rearing and Forestry.

2.2 Materials

- Core Sampler, Core, Mallet, Gloves, Flat-bladed knife and an Earth chisel for sample extraction.
- Soil Pan and Rubber bags for sample collection.
- Measuring Tape for measuring.
- A Pair of Safety Boots for protection.
- Notebook, permanent marker and pen for recording.

2.3 Methods

2.3.1 Sampling design

The study was conducted on three sites having similar climatic conditions, namely; land subjected to maize (*Zea may*) cultivation for six years (land use site A), and grassland vegetation (land use site B). Additionally, undisturbed broadleaved forest (land use site C) was selected as control. The study employed stratified (grid) random sampling technique on each of the three land use options. Each site was first stratified into grids consisting of 10mx10m cells (subplots) to enable the selection of the sampling point. Three subplots were randomly selected from each field (land use site). Thus a total of 9 subplots were selected for the study. Within each subplot, three quadrants of size 1m x 1 m was constructed by measuring 1 m from the midpoint of the sides of the selected subplot for soil sampling. A total of twenty-seven (27) samples was used for the study (9 from each land use site). Samples were bagged and tagged for analysis to determine the variability of soil strength viz. particle size, dry bulk density, soil porosity and soil moisture content.

2.3.2 Soil physical parameters

2.3.2.1 Bulk density

Bulk density in the field at (0-30cm) was determined by the core method. The Penetration resistance of the soil was measured into 3 depths (0–10 cm, 10-20 cm, 20-30 cm) respectively using a manually improvised earth chisel. A cylindrical metal core sampler of 5cm diameter and 5cm long was used to sample undisturbed soil. The core was driven to a desired depth (0-10 cm, 10-20 cm, 20-30 cm) and the soil sample was carefully removed to preserve the known soil volume as existed in-situ.

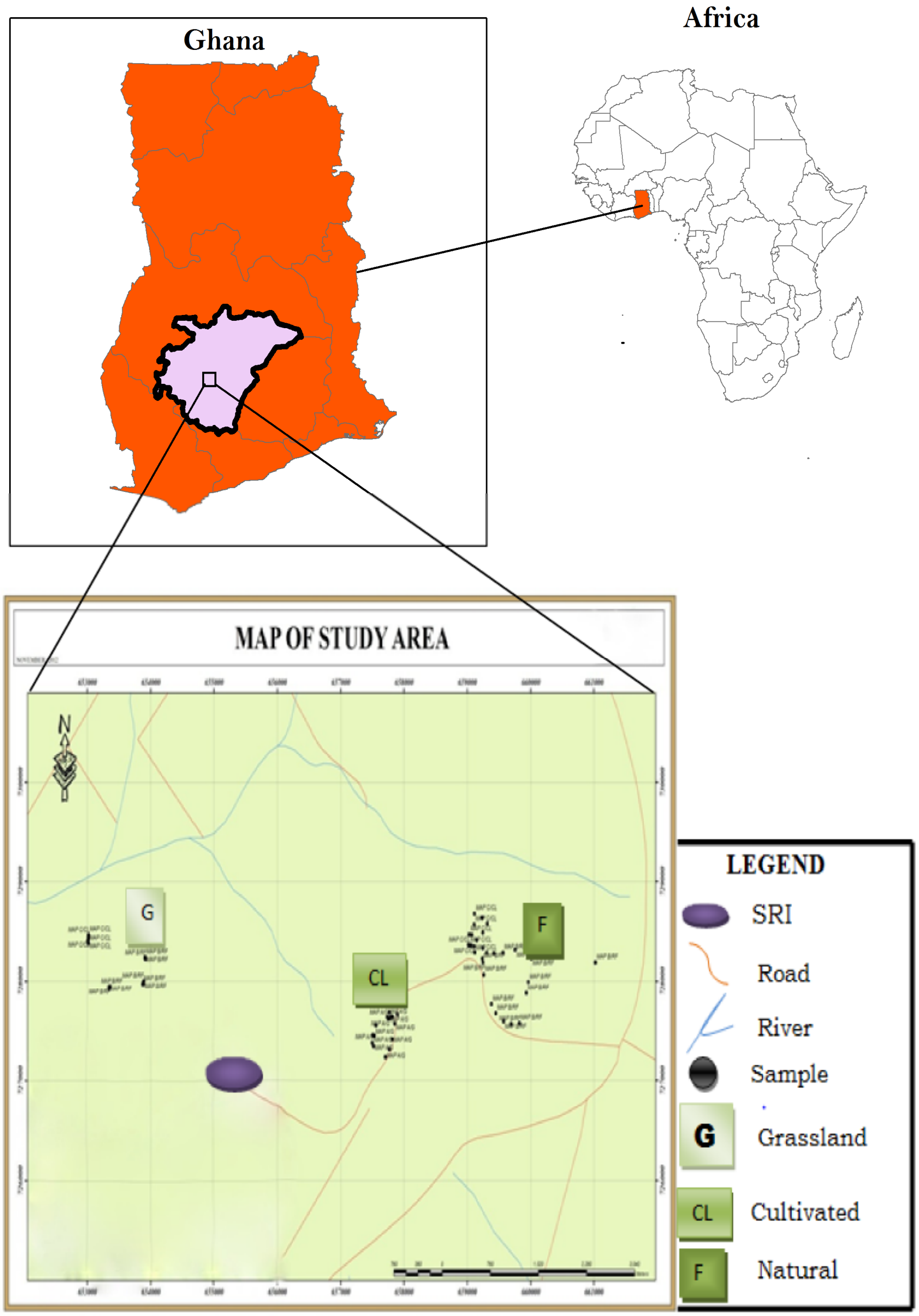

Fig. 1. Map of Ghana showing the location of the study sites

The soil was sent to the laboratory, weighed and dried in an oven at 105℃ for two days. The soil was reweighed and dry soil bulk density computed as;

$$\rho_b = \frac{M_s}{V_t}$$

Where:

ρb= soil bulk density (Mgm^{-3}); Ms = mass of oven dry soil (Mg); V_t =Total volume of soil (m^3)
Volume of the core was calculated using the expression below

$$A = \pi \left(\frac{d}{2}\right)^2 x\ h$$

Where:

π = 3.145; d = diameter; h = height

2.3.2.2 Soil texture

The Soil Texture was determined by the Hydrometer method. Approximately 50 g of soil was weighed into 250 ml beaker known weight. A100 ml of dispersing agent commonly known as calgon (sodium bicarbonate and sodium hexametaphosphate) was measured and added to the soil. It was then placed on a hot plate known as the Clifton heater and heated until boiling. The content in the beaker was washed completely into a shaking cup and then fitted to a shaking machine and shaken for 5 minutes. The Sample was sieved through a 50 microns sieve mesh into a 1.0 L cylinder to determine the clay content of the soil. The sand portion which is the particles that remained in the sieve was poured into the beaker and dried to get the weight of the sand particles. These were further separated into coarse, medium and fine sand. The 1.0 L cylinder containing the dispersed sample was placed on a vibrationless bench and then filled to the mark. It was allowed to stand for approximately 5hours where it was assumed to have obtained a stable temperature. The hydrometer is suspended into the cylinder containing the clay solution. The Hydrometer measures specific gravity or relative density of the clay solution. The mark that corresponds with the meniscus gives the reading of the clay content of the solution Silt and clay portions were then calculated. The various portions were expressed in percentage and using the textural triangle the texture was determined.

%SAND = Weight of beaker + sample – weight of beaker
%CLAY = hydrometer reading ×2
%SILT = 100− (%sand +%clay)

2.3.2.3 Moisture Content

- *Gravimetric moisture content (θ_m)*

The gravimetric method was used to determine the moisture content of the soil. Ten grams of soil was dried at 105℃ in an oven for 48 hours. After drying, the dry mass of the soil was taken and this was subtracted from the initial mass to give the percentage moisture content calculated as;

$$\%\theta_m = \frac{M_w}{M_s} x\ 100$$

Where:

$\%\theta_m$ = Mass of water loss /mass of oven dry soil ×100
M_w = mass of water loss (g)
M_s = mass of dry soil (g)

- *Volumetric water content (θ_v)*

This refers the volume of water associated with a unit volume of dry soil. Volumetric water content was calculated as;

$$\theta_v = \theta_m\ x \left(\frac{\rho_b}{\rho_w}\right)$$

Where

θ_m= gravimetric water content (m^3m^{-3})
ρ_b= dry bulk density (Mg m^{-3})
ρ_w= density of water (Mg m^{-3})

2.3.2.4 Porosity

Porosity of the core was determined using the expression below;

$$\%P = \left(1 - \frac{\rho_b}{\rho_s}\right) x\ 100$$

Where;

ρ_b= bulk density (Mg m^{-3})
P = total porosity (%)
ρ_s= particle density (2.65 Mg m^{-3})

2.4 Data Analysis

Data obtained was analyzed by SPSS (Statistical Package for the Social Scientist) and Minitab. Tukey's HSD Comparison test was used to compare treatment means ($P<.05$) and results presented in tables and graphs. Soil compaction categorization was conducted based on the Canarache's soil compaction indices [20].

3. RESULTS

3.1 Soil Texture Class

The dominant size classes of mineral particles comprise of sand, clay and silt expressed as percentage. There were significant differences in soil texture at ($P<.05$) as expressed in Table 1 with land use system and soil depth.

Comparatively, grassland soils had highest sand proportion at a depth of 20 – 30 cm with a mean value of 52.15% followed by cultivated land soils with a mean value of 29.10% and forest land soils recorded the least mean value of 27.39%. At 10 – 20 cm depth, mean values of 58.77%, 28.59% and 26.86% (Table 1) were recorded for grassland, cultivated land and forest lands respectively, and 56.57%, 29.94% and 28.61% mean values recorded for grassland, cultivated land and forest land soils at a depth of 0-10cm respectively. Although, different mean values were recorded for soils under cultivated land and forest land at three depths (0 – 10, 10 – 20 and 20 – 30 cm), statistically they are the same (P<.05). Thus there was no significant difference between the percent sand proportions of both the cultivated land and the forest land. By contrast, grassland soils were significantly different (P<.05) with respect to percent sand proportions at 0 – 10, 10 – 20 & 20 – 30 cm depths.

Percent clay proportions at 0-10 cm depth did not show any significant difference with respect to the three land use systems though mean values were different, statistically they are said to be the same (P<.05) (Table 1). Mean values recorded for cultivated land soils at 10-20 cm depth were no different from soils under the grassland (P<.05) and that of the forest land. However, soils under the grassland were significantly different in percent clay proportion from the forest land soils. Mean values of percent clay proportion 15.78%, 9.31% and 11.09% were obtained for cultivated land, grassland and forest land soils respectively. The values therefore showed no significant differences between soils under the cultivated land and the forest land and between grassland and forest land soils but there were significant differences (P<.05) between grassland and cultivated land soils.

Finally, for proportions of silt expressed as percentage, mean values obtained for forest land, grassland and cultivated land at 10-20 cm depth were 59.99%, 33.98% and 60.17% respectively, for 0-10 cm depth, the mean values were 61.10%, 37.68% and 56.37% for forest land, grassland and cultivated land respectively, and 60.88% 41.34% and 55.20% for forest land, grassland and cultivated land respectively at 20-30 cm depth (Table 1). At (P<.05), there was no significant difference in soils at the three different depth for both forest land and cultivated land soils. Statistically, they are the same though they had different mean values. By contrast, grassland soils were significantly different from the other two land-uses at the three different depths.

3.2 Bulk Density

Soil bulk density is an indicator of soil compaction. The direct effect of soil compaction is an increase in bulk density. Bulk density increased with increasing depth under the three different land uses. The mean values of bulk density at each depth of the different land uses were characterized. Higher values of bulk densities (g/cm^3) were observed for grassland soils with mean values of 1.51, 1.59 and 1.68 at depths of 0–10 cm, 10–20 cm and 20–30 cm respectively followed by the cultivated land and the natural forest. Mean values for cultivated land soils at depths of 0 – 10 cm, 10 – 20cm and 20 – 30 cm are 1.35 gcm^{-3}, 1.48 gcm^{-3} and 1.66gcm^{-3} respectively also showed an increasing trend in bulk densities with increasing depths. Mean bulk density values of 1.03 gcm^{-3}, 1.22 gcm^{-3} and 1.34 gcm^{-3} were observed for the natural forest at 0 – 10 cm, 10 – 20 cm and 20 – 30 cm respectively which shows increases with increasing depth as well. Mean values of soil bulk densities were not

Table 1. Soil particle size in relation to land use systems at various depths

Texture	Depth (cm)	CLD	GLD	FLD
Sand (%)	0 – 10	29.94 (2.13) ^{b}	56.57 (7.56) ^{a}	28.61 (3.40) ^{b}
	10 – 20	28.59 (3.30) ^{b}	58.77 (6.15) ^{a}	26.86 (3.12) ^{b}
	20 – 30	29.10 (4.49) ^{b}	52.16 (6.43) ^{a}	27.39 (3.13) ^{b}
Clay (%)	0 – 10	9.98 (6.52) ^{a}	5.84 (2.77) ^{a}	10.29 (5.31) ^{a}
	10 – 20	11.24 (4.69) ^{ab}	7.24 (2.57) ^{b}	12.93 (4.23) ^{a}
	20 – 30	15.78 (5.64) ^{a}	9.31 (3.31) ^{b}	11.09 (6.91) ^{ab}
Silt (%)	0 – 10	56.37 (11.24) ^{a}	37.68 (6.41) ^{b}	61.10 (6.03) ^{a}
	10 – 20	60.17 (4.01) ^{a}	33.98 (7.49) ^{b}	59.99 (5.26) ^{a}
	20 – 30	55.20 (6.15) ^{a}	41.34 (13.28) ^{b}	60.88 (6.13) ^{a}

CLD: Cultivated land; GLD: Grassland, FLD: Forestland. Different letter(s) within one row indicate significant differences (P<.05) by the Tukey's HSD Comparison test. Values with similar letter (s) within a row are not significantly different (P<.05). Values in parenthesis represent standard error (SE)

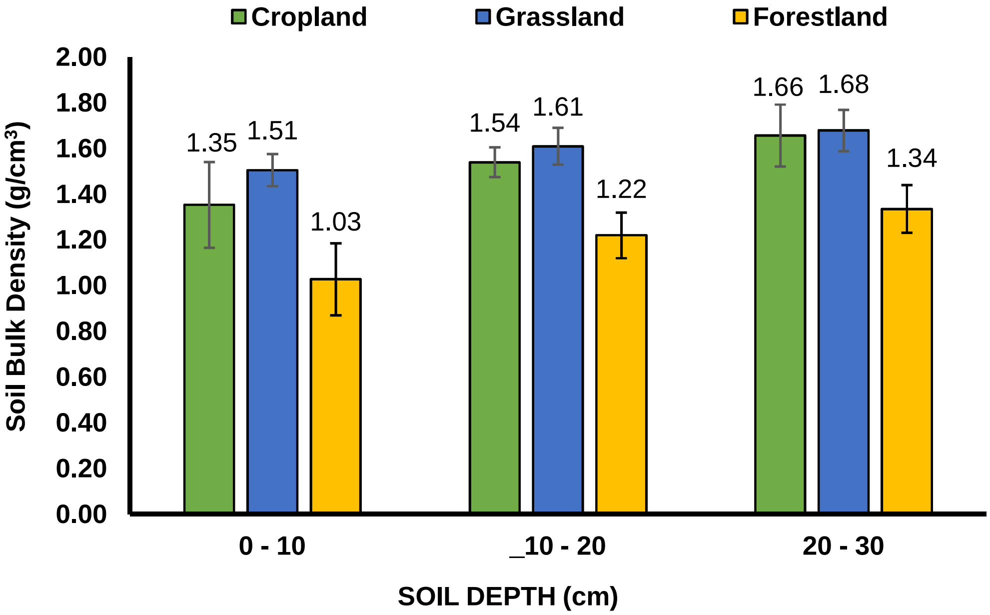

Fig. 2. Soil bulk density of three (3) land use systems at three depths (N=27; n=9)

significantly different at the three different depths for grassland and cultivated land soils whereas bulk densities of forestland soils were significantly different from both the cultivated land and grassland soils at 0 – 10, 10 – 20, 20 – 30 cm depths (Fig. 2). Statistically, there was no significant difference ($P<.05$) between bulk densities of grassland and cultivated land soils.

3.2.1 Bulk density index

Bulk density is an indirect measure of soil compaction and is dependent on soil texture. Soil compaction can further be characterized by the percentage clay criterion [15]. Based on this criterion, the cultivated land site and the grassland site are relatively more compacted with low compaction on the natural forest as evidence by the higher bulk density index (Table 2) by soil texture.

$$BDi = BD + 0.009\ CL \qquad (1)$$

Where BDi is bulk density index or soil packing density (g/cm^3), BD is bulk density (g/cm^3) and CL is percentage of clay or clay fractions.

By using equation (1), it is clearly shown that the degree of soil compaction is influenced by clay fractions in the soil. Thus there was more compaction on grassland and cultivated land soils as compared to the natural forest soils as evidence by increased BDi (Table 2).

3.3 Porosity

The mean values for percentage porosity at each depth under the different land uses. With increasing bulk densities at each depth, percentage porosity decreases with each depth under the three land use systems. Percentage mean values of porosity observed for forest land soils were 49.60, 53.80 and 61.21 at 20-30 cm, 10-20 cm and 0-10 cm depths respectively. Mean values such as 41.76%, 38.67% and 36.74% were also observed for porosity at depths of 0-10 cm, 10-20 cm and 20-30 cm under grassland soils. Cultivated land soils had 48.93%, 41.89% and 37.74% as percentage mean values at each depth (0-10 cm, 10-20 cm and 20-30 cm). The three land use systems were significantly different (Fig. 3) at 0-10 cm depth ($P<.05$). In contrast, both grassland and cultivated land at 10-20 cm & 20-30 cm depths were not significantly different in their porosity levels whiles forest land soils at the same depths was significantly different ($P<.05$) in porosity. Statistically, the level of soil porosity under the grassland and cultivated land are considered the same.

Table 2. Bulk density indices and soil compaction severity with land use and soil depth

Land use	Soil depth (cm)	BD (g/cm^3)	% clay	BDi (g/cm^3)	Degree of compaction
Grassland	0-10	1.51	5.84	1.56	Moderate
	10-20	1.61	7.24	1.68	Moderate
	20-30	1.68	9.31	1.76	Extreme
Cultivated land	0-10	1.35	9.98	1.44	Low
	10-20	1.54	11.24	1.64	Moderate
	20-30	1.66	15.78	1.80	Extreme
Natural forest	0-10	1.03	10.29	1.12	Low
	10-20	1.22	12.93	1.34	Low
	20-30	1.34	11.09	1.44	Low

BDi < 1.45 g/cm^3 – low compaction, 1.45 - 1.75 moderate and > 1.75 Extreme [20]

3.4 Volumetric Moisture Content

Moisture content of a soil is the property that has the greatest influence on the degree at which a soil will compact. Soil moisture acts as lubricate between soil particles against one another at lower stresses than would occur if little moisture was present. Soil moisture content decreases with increasing depth under the three land use systems. Mean values for volumetric moisture content of the three land use systems at different depth were analyzed. For cultivated land, mean values observed were 12.49 M/m^3, 8.96 M/m^3 and 8.04 M/m^3 at 0-10 cm, 10-20 cm and 20-30cm depths respectively.6.46 M/m^3, 4.56 M/m^3 and 3.50 M/m^3 are mean values of soil moisture observe for grassland soils under three land use systems at 0-10 cm, 10-20 cm and 20-30 cm depths respectively. Forest land soils had 8.54, 6.33 and 5.27 M/m^3 as mean values of soil moisture under three land use systems at depths 0-10 cm, 10-20 cm and 20-30 cm depths respectively. From Fig. 4, there were no significant differences in soil moisture content with the different land use systems at 0-10 cm depth. They are considered the same statistically. In contrast, for 20-30 and 10-20 cm depths soil moisture content were significantly different (P<.05).

4. DISCUSSION

4.1 Soil Texture

From the results, the soil textural class for grassland was sandy loam; silty loam was the soil textural class for both natural forest and cultivated land. Percentage (sand and silt) proportions of natural forest and cultivated land at the three depths after a t-test was conducted showed no significant differences (P<.05). This could be explained by them having the same textural class (Silty loam; a loam with higher proportions of silt than sand and clay. Grassland soils differed significantly at all depth in % (sand and silt) proportions and can be attributed to the soil textural class (sandy loam) with relative higher proportions of sand than silt and clay. Bulk density is dependent on soil texture. Thus clay fractions in the soil affect the degree of soil compaction [21]. Table 2 indicates the severity of compaction with percentage clay fractions.

4.2 Bulk Density

As shown in the results, soil bulk density (bulk density index) differed significantly among the three land use systems. Comparatively, higher bulk density (bulk density index) observed at the subsurface soil (20-30 cm) of the cultivated land can be attributed to crop and land use management practices which reduce organic matter, soil structure and porosity [6]. The higher bulk density observed can also be as a result of continuous cultivation without rotation at constant depth and the amount of clay fractions in the soil and this is in line with Biro et al. [15], who looked at the effect of different land use types on soil compaction attributed soil texture, tillage operations at constant depth and animal trampling as the main factors increasing the hazards of soil compaction. Higher bulk density observed at the subsurface layer (20-30 cm) of the grassland can be attributed to the soil textural class and animal trampling. Olebile and Oagile, [21] also observed similar findings while working on compaction of agriculture soils. The soil textural class of the grassland as revealed in the results was sandy loam which is one of the typical textural classes with relatively higher proportions of sand than silt and clay and has lower levels of organic matter, poor soil structure due to less aggregation of soil particles. A study conducted by Brady & Weil [13]; and Hamza &

Anderson [6] also revealed that the soils which has limited aggregation of structure are susceptible and prone to compaction. Low bulk density exhibited in the natural forest can be attributed to higher organic matter residues on the soil surface; adequate pore space [18] and improved soil structure and drainage [15] as well as limited human impacts. In contrast, Islam and Weil [19] observed higher bulk density in a natural forest attributing it to land use changes, especially cultivation of deforested land rapidly diminishing soil quality leading to reduction of land productivity. Therefore, higher bulk densities will eventually reduce crop yield and restrict root penetration [13,22].

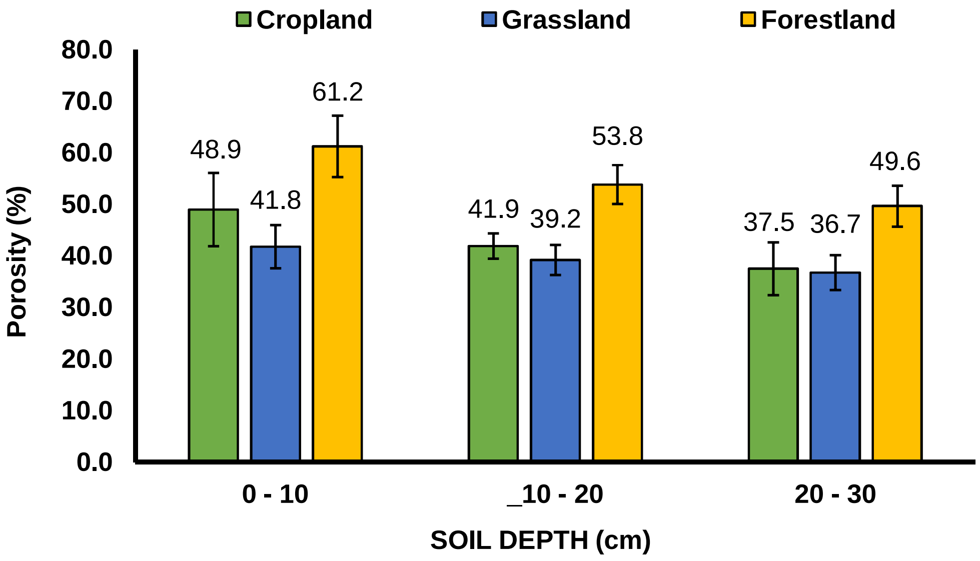

Fig. 3. Porosity of three (3) land use systems at three depths
(N = 27; n = 9)

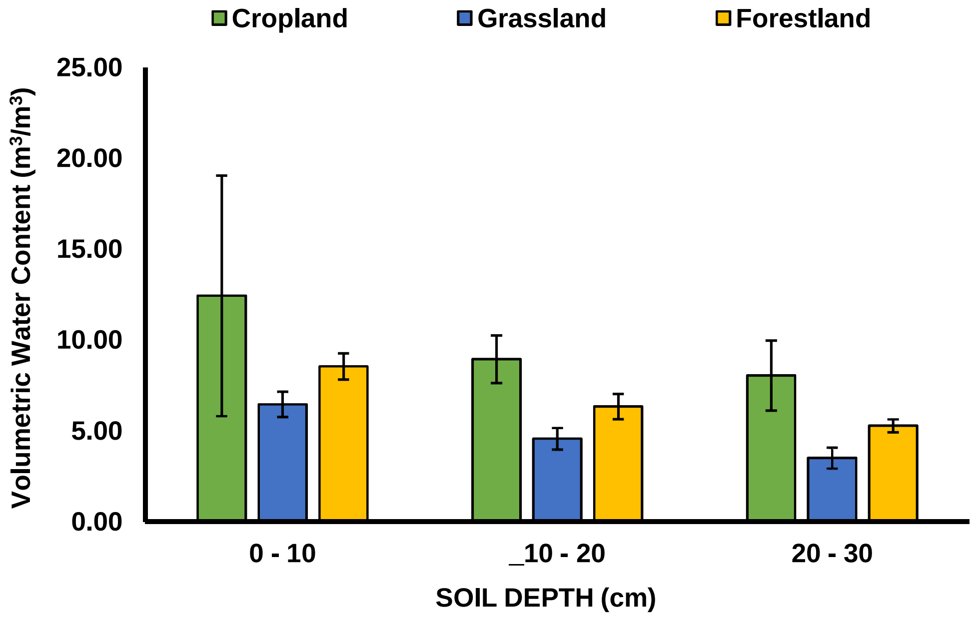

Fig. 4. Volumetric soil moisture of three (3) land use systems at three depths
(N = 27; n = 9)

4.3 Total Porosity

The per cent porosity of grassland differed markedly from cultivated land at depth (0-10 cm). But soil porosity under grassland was not statistically different from cultivated land soils at 10-20 & 20-30 cm depth. Changes in soil porosity can be attributed to altered land management systems as well as their respective individual textural classes. Sandy loams have lower organic matter level, higher bulk density resulting in low levels of porosity as observed in the grassland soils. However, silt loams have lower bulk density if adequate organic matter is present then there will be high pore space [6] but since higher bulk density values were observed at 10-20 and 20-30 cm depths on the cultivated land, total porosity reduces. Costa et al. [13] also observed that uninterrupted agriculture significantly affects porosity. Generally, soils with higher proportions of pore space to solid have lower bulk density than those with compacted layer and have less pore space. Total porosity of soils was higher for natural forest at all depths as compared with the grassland and the cultivated land at the three different depths; this can be attributed to low levels of soil compaction observed on the natural forest and higher levels of compaction under the cultivated land and the grassland [22]. Increased bulk density (or bulk density index) would generally result in reduction of total porosity due to the compaction of soil particles and consequently constricted space that the water and air can occupy [21]. Dörner et al. [23], reported that the pores most easily affected in this way are the larger channels or macro pores through which air and water movement is normally unrestricted and rapid, and which generally provide a good environment for root growth. These qualities can be changed when compaction reduces this large pore space. Result of this study indicating high significant differences (P<.05) in levels of porosity in the natural forest at all depths is consistent with what is widely reported by various authors including [11,16,18,24,25] and together contradicts a study conducted by Brady and Weil [22] on the impact of degraded forest land on soil compaction which showed lower levels of porosity ascertaining the fact that compaction in a degraded forest increases the possibility of serious erosion and runoff due to total pore space destruction.

4.4 Volumetric Moisture Content

From the results, the soil moisture content did not differ significantly at (0-10 cm) depth and this can be due to the slope, climate and rainfall patterns of the landscape [26] and the soils drainage class. The cultivated land and the grassland soils occurs on a middle slope and are moderately well drained soils whereas the natural forest falls within an upper slope and is a well-drained soil. According to Sys et al. [27], the type of crop grown can also be a contributing factor. Maize is tolerant to a wide range of environmental conditions. The rainfall should be 500-1200 mm in a growing cycle to become an optimum water supply. Biro et al. [15] also reported the influence of different land use types on soil compaction. From his results, the land use types differed significantly at (10-20 cm) depth but were not significantly different at 0-10cm depth. He attributed this to environmental and climatic conditions beyond man's control. A t-test conducted showed significant differences (P<.05) among the three land use systems at depths (10-20 cm) and (20-30 cm) in relation to moisture content. This can be attributed to high bulk density and reduced porosity for water entry resulting in slow movement of nutrient and water into the soil.

5. CONCLUSION

The study assessed the level of soil compaction under three different land use systems. Compaction affects the soil physical properties severely. It increases the soil bulk density, decreases porosity with increasing depth because of less aggregation of soil particles and macro pores destruction. Soil texture also plays a contributing factor in a soils susceptibility to compaction. However, soils moisture content suffered reduction with increases in bulk density and reduction in total pore space of the soil. The effect of different land use systems on soil compaction cannot be left out. The grassland and the cultivated land indicated more effects of compaction than the natural forest. This conclusively suggests that all changes in land use systems can lead to the decline of soil productivity with subsequent reduction in crop production.

First, the study gives credence to the assertion that, different land use systems influence the degree of soil compaction. Again, the study can be used as basis to understand the potential of soil compaction on the physical properties of the soil, and the extent of degradation to the soil. Furthermore, this could be used by farmers as a control options for land use and for practicing sustainable soil use by adapting compaction tolerant crops to extreme compaction areas and/or limit the use of machineries.

From the results of the study, it is recommended that long–term research into the effect of land use management systems on soil compaction and crop yield at the study area should include physical, biological and chemical soil properties. Government policies or programs to support or enhance agricultural production should be designed so as to ensure that soil degradation (soil compaction) from management systems and farmlands are minimized. For the future, issues such as the determination of density-moisture relationships for different types of soils be modelled and guidelines for quick hand determinations of critical moisture contents would help farmers to know when to operate their land. Further studies should focus on developing an overall model for soil compaction which would allow a farmer to estimate the effects of cropping and land use systems on compaction under varying moisture content. This could be a very useful tool for planning management systems.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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