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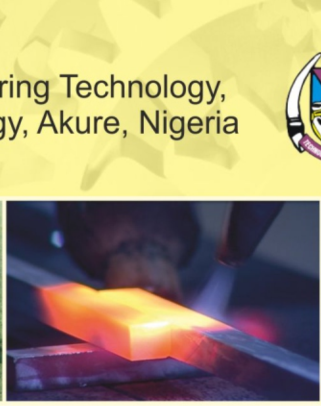


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Hydraulic and Compaction Characteristics of Soils in Grazed Land of Akure, Nigeria

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A B S T R A C T

Physical and hydraulic characteristics of soils of cattle grazed land in Akure was investigated in this research. Soil bulk density, total porosity, micro and macro porosities as well as the hydraulic conductivity of soils in a land under daily cattle grazing were determined following a 3 x 3 completely randomized design method. The grazed land of about 100 x 100 m^2 were divided into three sections i.e. Locations 1, 2 and 3. Three soil samples were collected per location using soil corers 4 x 5 cm^2 and the hydraulic conductivity determined insitu on the field using mini-disk infiltrometer. Results showed that the mean bulk density of the grazed land ranged between 0.80 (±0.49) and 0.86 (±0.65) g/cm^3, while the mean total porosities were 69.65 (±1.85), 69.95 (±0.99) and 67.57 (±2.54)% at depths 0 – 10, 10 – 20 and 20 – 30 cm, respectively. The soil moisture content were 10.99 (± 0.82), 8.38 (± 2.00) and 8.35 (± 0.30) % for sampling locations 1, 2 and 3, respectively. The hydraulic conductivity value of locations 1, 2 and 3 were 1.03 x 10-4, 1.47 x 10-4 and 6.60 x 10-5 cm s^{-1}. The result of the experiment indicated that the soil is over-grazed and thus should be put under conservation over some period to enable structural improvement of soil and better crop productivity.

1. Introduction

Soil is a natural body consisting of layers (soil horizons) of mineral constituents of variable thickness, which differ from the parent material in their morphology, physical, chemical and mineralogical characteristics (Devkota and Kumar, 2009). It is a mixture of mineral and organic constituents that are in solid, gaseous and aqueous state. Soils comprise of four basic constituent fractions- mineral matter, organic matter, soil water, and soil air (Obi, 2000). The makeups and proportions of these constituents considerably influence soil physical properties- soil texture, structure, porosity and the fraction of pore spaces in a soil. The structure of a soil, on the other hand, is the arrangement of the solid parts of the soil and of the pore spaces located between them (Marshall and Holmes, 1979). Brewer and Sleeman (1960) defined soil structure as the physical constitution of a solid mineral as expressed by the size, shape and arrangement of the solid particles and associated voids, including both the primary particle to form compound particles and the compound particles themselves. So a well-developed structure is essential for plant roots development, rate of infiltration, gas circulation, soil workability, biological activity and the strength property. The structure of soil depends on the type of parent material, the environmental conditions under which the soil was developed, the clay present, the organic matter content and the recent history of management. It often takes years of several biological, chemical and physical processes to form the structure of a soil, and these processes that influence the formation of the soil structure, decline overtime on the interaction of human and animal activities.

Several researches and studies have been conducted over the years on the changes that take place in soil structure. Most of these studies have focussed on the effects of human-induced processes such as tillage, reclamation and excavation on the soil structure, but very little have been done on the effects of animal trampling. A study conducted by Yong-Zhong *et al.*, (2005) shows that the most significant factor that leads to changes in grassland soil properties and thus structural degradation is animal trampling. Animal trampling led to changes in soil mechanical hydraulic properties on different scales, from disturbed soil to the structured bulk soil and single aggregate, (Reszkowska *et al.*, 2011), especially when grazing of livestock occurs at high water content, because the soil is most susceptible to compression and shear deformation and can under those conditions undergo serious modification of its structure (O'Sulivan and Simota, 1995). Roberson (1996) explained that cattle could weigh as much as 500 kg or more. The pressure exerted on the soil by these animals while moving was put to be between 1.7 - 4.2 kg cm^{-2} in comparison with tractors' 2.04 kg cm^{-2} (Ratliff, 1985; Abdel-Magid *et al.*, 1987; Drewry and Paton, 2005). In view of this, grazing animals (cattle) can be expected to cause a pronounce alteration in the arrangement of the soil aggregates. Animal trampling affects the soil by removal of the top vegetation thus exposing the soil to the actions of wind and water erosion,

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compaction of the surface leading to reduced infiltration rate, and decrease in the organic matter of the topsoil (Yong-Zhong *et al.*, 2005). The consequence of this is the role it plays in the mechanical strength (Krümmelbein *et al.*, 2006) and in the physical properties of the soil. Also, increase in soil bulk density, reduction in soil porosity, decrease in hydraulic and air conductivity, and increase in the resistance to the penetration of plant roots (Greenwood and Mackenzie, 2001; Horn, 1986) occur in the soil as a result of grazing of animals. This research was aimed at determining the effects of animal trampling on some physical and hydraulic properties of the soil.

2.0 Methodology

2.1 *The Promax2100 Concept*

The study area is a Sango cattle grazing site located along Ado-Ekiti Road, Akure, Nigeria. The study was conducted in 2014 in a land that has been grazed for over 20 years with an approximately area of six hectares. It lies at latitude 07°17´00´´N and longitude 05°13´00´´E. The USDA textural classification of the soil is silt-loam and the relief of the area is rolling plain with some parts mountainous. It has humid tropical climate characterized by heavy rainfall occurring between the months of April and October, while the dry season occurs between the months of November and March. The mean annual rainfall of the area is between 1300 - 1600 mm with an average temperature of 27 ºC and an altitude of about 351 m. The relative humidity ranges between 85 and 100 % during the rainy season and less than 60% during the dry season period (Fasinmirin *et al.*, 2009).

Animal rearing takes place on the countryside of the town. This is so because majority of the land areas are still not inhabited and where there are settlements, the populations are still very scanty with lush vegetation thus permitting large scale rearing of animals. In recent years, there have been reported cases of increasing pastoral activities in these areas. This can be attributed to the ever increasing demand for meat. Also, the insecurity problems in the northern part of the country, where these animals are predominantly raise means that animals are brought down the Niger for rearing. The increasing number of animals grazed on the fringes of Akure is not without its attendant impacts.

2.2 *Sample Collection and Analysis*

This study adopted a random sampling method for the field measurement. A 100 x 100 m^2 portion of the grazed land was selected for the purpose of the research. Three sampling locations were chosen randomly for the collection of samples for the determination of soil bulk density, porosity, moisture content and hydraulic conductivities of cattle grazed site. The three points were spaced spatially.

2.3 *Parameters Investigated*

2.3.1 *Infiltration Rate*

The mini-disk infiltrometer was used for measuring the soil infiltration and consequently the hydraulic conductivity. The infiltrometer enabled the correct and accurate measurement of the hydraulic conductivity of the soil. The soil hydraulic conductivity was determined following the procedure described in Ale and Manuwa (2011) and Fasinmirin and Olorunfemi (2012).

2.3.2 *Bulk Density*

Soil samples were taken from soil core at three depths of 0 – 10 , 10 - 20 and 20 - 30 cm using ring cylinders with height 10 cm and diameter 4.8 cm. The samplers were driven vertically into the soil enough to fill the sampler, the sampler and its contents were carefully removed to preserve the natural structure and packing of the soil as best as possible. The soil extending beyond each end of the sample holder was trimmed to ensure soil is contained in exactly the volume of the cylinder and bulk density was determined using the method described by Black and Hartge (1986).

2.3.3 *Total Porosity*

Total porosity (% pore space) was calculated using the same soil samples collected for soil bulk density. To determine the total porosity, the bulk density was divided by the particle size density (which is a constant of 2.65 g cm^{-3}) and subtracted from one, then the result was multiplied by 100. The micro-porosity was calculated by subtracting the weight of the oven dried soil from the weight of the wet soil and the result divided by the volume of the soil in the cylinder. The outcome was multiplied by 100. The macro-porosity was obtained by subtracting the micro-porosity obtained from the total porosity. These were done following the equations described by Suzuki et al., (2004) and Adesigbin and Fasinmirin (2011):

$$P_t = \left[1 - \frac{B_d}{P_d}\right] \times 100 \quad (1)$$

$$Mic = \left[\frac{W_w - W_d}{V_c}\right] \times 100 \quad (2)$$

$$Mac = P_t - Mic \quad (3)$$

where:

Pt is total porosity (%), Mac and Mic are the soil macro- and micro-porosities in percentages (%) respectively, Bd and Pd are the soil bulk and particle densities (g cm^{-3}) respectively, Ww and Wd are wet and dry weights of samples in grams (g) respectively, and VC is the volume of soil in the ring cylinder (cm^{-3})

2.3.4 *Soil Moisture*

The soil moisture was determined using samples collected for bulk density measurement. The soil moisture content (dry basis) was determined using gravimetric method. This was done using the relationship given in equation 4.

$$M_{db} = \left[\frac{W_w - W_d}{W_d}\right] \times 100 \quad (4)$$

where:

Mdb is the moisture content on dry basis expressed in percentage,

Ww is the weight of wet soil in grams,

Wd is the weight of oven dried soil in grams

2.3.5 *Soil Texture*

The soil texture was determined using samples of soil collected from the site at depths 0 – 15 cm. The soil was air-dried to reduce the moisture content after which it was taken to the laboratory where the soil texture class was determined using the method described by Schlichting *et al.* (1995) and samples were classified following the FAO/USDA soil textural classification system.

2.4 Statistical Analysis

Field data obtained were subjected to statistical analysis such as mean, standard deviation and analysis of variance (ANOVA). The means of bulk density, penetration resistance and soil moisture content at the various depths were compared using LSD test (p = 0.05).

3 Results and Discussion

3.1 Soil Texture

The USDA textural classification of soils of the three sample locations showed identically silty loam class (Table 1). The soil of the sampled site is averagely 36.95 % by Sand, 56.65% by Silt and 6.01% by Clay, and is m ostly underlain by gravels, laterite and hardpans at the soil sub-surface layer.

3.2 Bulk Density

The mean bulk densities of the cattle grazing land were 0.80 (± 0.49), 0.80 (± 0.25) and 0.86 (± 0.65) g cm-3 for sample locations 1, 2 and 3, respectively (Table 2). The difference in mean bulk density between the sample locations 1 and 2, and 1 and 3 are not significant (0.87ns) and (0.19ns), respectively at the P = 0.05 (LSD) (Table 3). Similarly, there was no significant difference (0.15ns) (Table 3) in mean bulk density (P = 0.05) between sample locations 2 and 3. This result implies that soil trampling by animals causes more compaction than detachment and consequently increased bulk density. Similar observation was made by Fasinmirin and Adesigbin (2012), who reported increase in bulk density from a tilled plot to a plot subjected to 15 vehicular passes (compacted plot). Similar results were reported by Cassel *et al.* (1995) who found an increase in soil bulk density for tracked inter-row areas of a controlled traffic area.

3.3 Porosity

From Table 4, sample location 2 which is far removed from the regular treading by animals had on the average the highest total porosity of 70.13%, while the compacted sample locations 1 and 3 have mean total porosities of 69.2 and 67.85% respectively. Maximum micro-porosity of 9.5% was obtained at sample location 3 but decreased to 5.3% in location 2. Maximum macro-porosity of 64.53% was observed in sample location 2 and the lowest, 57.23% in location 3, a situation that can be attributed to the re-distribution of the soil pores by continuous trampling by animals. The effects of compaction were very pronounced in the top 10 cm depth of the soil at the three sample locations than in the 10-20 and 20-30 cm depths. Similar observations were made by Kim *et al.*, (2010) who reported, for a compacted soil, a decrease in the number of pores by 71%, the number of macro-pores (>1000 mm diameter) by 69% and coarse meso-pores (200–1000 mm diameter) by 75%, with the most pronounced effect in the upper 10 cm of the soil layer.

3.4 Moisture content

The mean moisture contents of the cattle grazing field were 10.99 (± 0.82), 8.38 (± 2.00) and 8.35 (± 0.30) % for soil sampling points 1, 2 and 3, respectively (Table 5). The difference in mean soil moisture content between the sample locations 1 and 2 was significant (0.04*) at the P = 0.05 (LSD) (Table 6). Similarly, the difference in mean soil moisture content between sample locations 1 and 3 was significant (0.04*) at P = 0.05 (LSD) (Table 6). The significantly higher moisture content value in location 1, which leads to the cattle paddock after all grazing on the field, must have been caused by cattle movement and the eventual compaction of the soil on the superficial layer, which reduces infiltration rate of the soil. However, there was no significant difference (0.97 ns) (Table 6) in mean soil moisture content (P = 0.05) between sample locations 2 and 3 and this must have resulted from less repeated loading of the soil by animal trampling, which enhances the process of moisture evaporation from the soil.

Table 1. Classification of Sango cattle market soils

Site	Location	Sand (%)	Silt (%)	Clay (%)	USDA
Sango Market Area,	1	37.04	56.46	6.50	Silt loam
Akure	2	36.80	57.27	5.93	Silt loam
	3	37.02	56.50	6.48	Silt loam

Table 2: Mean (STD) of the soil bulk density of the grazed site

Sample Location	Replicate	Mean (g cm^{-3})
1	3	0.80 (± 0.49)
2	3	0.80 (± 0.25)
3	3	0.86 (± 0.65)

Table 3: Multiple comparison of soil bulk densities in grazed land (LSD Test), P=0.05

Location (i)	Location (j)	Mean difference (i-j)	Significant
1	2	0.01 (± 0.04)	0.87^{ns}
	3	-0.06 (± 0.04)	0.19^{ns}
2	3	-0.07 (± 0.04)	0.15^{ns}

Table 4: Total porosity, micro- and macro-porosities of soil under grazing

Porosity	Depth (cm)	Location 1	Location 2	Location 3	Mean (STD)
Total Porosity (%)	0 -10	70.99	70.43	67.54	69.65 (±1.85)
	10 – 20	69.02	69.84	70.99	69.95 (±0.99)
	20 – 30	67.59	70.11	65.02	67.57 (±2.54)
Micro-porosity (%)	0 -10	9.06	7.96	9.50	8.84 (±0.79)
	10 – 20	6.52	5.30	8.12	6.64 (±1.41)
	20 – 30	7.40	6.35	7.79	7.18 (±0.74)
Macro-porosity (%)	0 -10	61.93	62.47	58.03	60.81 (±2.42)
	10 – 20	62.50	64.53	62.87	63.30 (±1.08)
	20 – 30	60.19	63.76	57.23	60.39 (±3.27)

Table 5. Descriptive of the means (STD) of the soil moisture content of the grazed site

Sample location	Replicate	Mean (%)
1	3	10.99 (± 0.82)
2	3	8.38 (± 2.00)
3	3	8.35 (± 0.30)

Table 6: Comparison of mean soil moisture content in grazed land (LSD Test), P = 0.05

Location (i)	Location (j)	Mean difference (i-j)	Significant
1	2	2.61 (±1.03)	0.04*
	3	2.65 (±1.03)	0.04*
2	3	0.04 (±1.03)	0.97^{ns}

*significant at P = 0.05, ns – not significant at P = 0.05

Table 7:

	Location 1	Location 2	Location 3
Replicate 1	3.87×10^{-5}	1.14×10^{-4}	9.53×10^{-5}
Replicate 2	9.46×10^{-5}	3.62×10^{-5}	2.44×10^{-5}
Replicate 3	1.77×10^{-4}	2.92×10^{-4}	7.82×10^{-5}
Mean	1.03×10^{-4}	1.47×10^{-4}	6.60×10^{-5}

3.5 *Hydraulic Conductivity*

The highest mean hydraulic conductivity of soil at suction of 2 cm in the three sample locations chosen for experimentation was obtained at location 2, (1.47×10^{-4} cm s^{-1}) (Table 6) and the lowest ((6.60×10^{-5}cm s^{-1} at location 3 (Table 7). The very low hydraulic conductivity measured in location 3 must have been caused by the relatively high bulk density when compared to other sampling locations. The hydraulic conductivity of soil is influenced by bulk density, which is a function of micro and macroporosity as well as moisture availability within the soil system. The highest hydraulic conductivity in location 1 must have been caused by high soil total porosity, an indication of the infiltration rate of water into soil. Similar observation was made by Rauzi (1966) who attributed his observed hydraulic conductivity differences, in part, to differences in bulk density resulting from cattle grazing. Great losses of porosity also result to reduction of hydraulic conductivity in forest soils when overgrazed.

4. Conclusions

The soil bulk density of the site varied with depths and locations due to the level of compaction by animal trampling. Similarly, there was re-distribution of the soil pores in the site, which created differences in the soil moisture characteristics and distributions and consequently varied rate of infiltrations and hydraulic conductivities in the grazed land. The implication of this is that an increase in soil compaction showed by the low infiltration rate and hydraulic conductivity, high water content, low porosity and high bulk density will result to reduced root length, concentration of roots on the uppermost layer of the soil (creeping root), surface ponding, and over land flow. Controlled grazing should be practiced as this will ensure that only rangelands are grazed, living other land ungrazed. The result of this therefore, will be that the productivity of land required for planting is conserved. This, when taken into consideration, will also help to checkmate soil erosion.

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