EFFECT OF LAND MANAGEMENT USE ON SOIL HYDRAULIC CONDUCTIVITY IN GIDAN KWANO, NIGER STATE

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ABSTRACT

Hydraulic conductivity is one of the most important parameters for flow and transport related phenomena in soil and also a criterion for measuring soil ability to transfer water. There is concern arising from the suitability, efficiency and ease of the different measuring methods use under different land management practices. The purpose of this paper is to determine and evaluate soil hydraulic conductivity under different land management practices which include forest land (teak and Melina plantation), grass land and maize cultivated land using constant head method. The measurement is at different depth of 0-15cm, 15-25cm, 25-50cm, 50-75cm. The marginal means of each land use were used to compare the result obtained through statistical means. All tests were carried out using SPSS at significance level of 0.05. An ANOVA test was conducted to check if each of the land use is significantly different. The soil in forest zone (Teak plantation and Gmalina plantation) had significantly high bulk density as 1.7533cm^{-3} and 1.6967cm^{-3} respectively at depth 50-75cm compared to the low bulk density in grass, maize cultivated land as 1.5000cm^{-3} and 1.4833cm^{-3} respectively at depth 50-75cm. However, soil hydraulic conductivity was significantly high in the grass site or soil at the surface with 2.8833cmh^{-1}. Results obtained from the different land use serve as Knowledge of variability of soil that can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion, hydrological modeling and efficient planning of irrigation projects.

Keyword: soil hydraulic conductivity, bulk density, porosity and land management practices

1.0 INTRODUCTION

1.1 Background to the study

The hydraulic conductivity of soil is an important hydraulic property frequently used in hydrological modeling and water flow related studies in soils, such as irrigation and drainage system design and infiltration modeling, it is also a key parameters for the monitoring of soil and water management (Tayfun, 2005). Knowledge of the rate of water permeability through various soil types is essential for determining the type of plants to be grown, spacing, yield, managing soil

– water systems and erosion control. Many methods have been developed over time for field and laboratory measurement for hydraulic conductivity unfortunately, these methods often yield substantially dissimilar results, as hydraulic conductivity is extremely sensitive to sample size, flow geometry and soil characteristics (Sarki *et al*, 2014). Research has shown that regardless of the land management practices, a small portion of soil can be transported by a large portion of water flow, indicating that the spatial hydraulic characteristics of soils are highly variable (Ibrahim and Aliyu, 2016). Knowledge of variability of soil physical properties can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion, hydrological modeling and efficient planning of irrigation projects (Bagarello and Sgroi, 2004).

Several studies have been conducted on soil hydraulic properties in relation to tillage and the results were contradictory. Depending on cultivation history, climate zone, and soil management practices, saturated and unsaturated hydraulic conductivity under no-till or minimum tillage can either be greater or lower (Miller *et al*., 1998) than that under continuously tilled treatments, or not significantly different from that under continuously tilled treatments (Bodhinayake, 2003). Change in land use from natural forest to crop cultivation modified the hydraulic properties of the surface soil resulting in an increased runoff/infiltration ratio (Leduc *et al*., 2001). Land use change is a complex process shaped by human activity affected by ecological, economic, and social drivers, and capable of influencing a wide range of environmental and economic conditions (MacDonald, *et al*., 2000).

Understanding of soil hydraulic conductivity is also essential for sound land management. Therefore, there are no single value that represent soil hydraulic conductivity because it varies in a wide range of circumstances and for all soil types and some of the specific problems that instigate the need of this kind of study which may be due to lack of suitability of the soil hydraulic conductivity and their acceptability in the study locations. Information relating to hydraulic conductivity of the studied sites is dearth.

Based on the above statement, the major objective of this study is to determine hydraulic conductivity of soil under different land management practices and also compare various results obtained from the study areas.

MATERIALS AND METHODS

2.1 Materials

2.1.1 Study Region

The host community of Federal University of Technology Minna Gidan Kwano is located along Minna - Bida road and is approximately 12 km from the state capital, Minna. Gidan Kwano lies between Latitudes 9°31'N and Longitudes 6°26'E with an estimated land mass of about eighteen thousand nine hundred hectares (18,900 ha). Teak plantation and Gmelina land is at latitudes and longitudes 9°31'1"N, 6°27'30"E and 9°30'55"N, 6°27'28"E respectively while Grass land and Maize cultivated land is at 9°31'55"N, 6°27'23"E, 9°31'55"N, 6°27'39"E respectively. The site is bounded Northwards by the Western rail line from Lagos to the northern part of the country and the eastern side by the Minna – Bida Road and to the North – West by the Dagga hill and river Dagga (Musa, *et al.,* 2013). Four locations were selected to perform the experiment, which include forest sites (Teak and Gmelina plantations), grass land (fallow) and maize cultivated land. Measurement of soil hydraulic conductivity was determined at four depths of 0-15cm, 15-25cm, 25-50cm and 50-75cm for each of the study locations.

2.1.2 Laboratory Analysis

Particle size analyses were determined by hydrometer method according to the procedure of Gee and Or, 2002) using sodium hexameta phosphate (calgon) as dispersant. Soil bulk densities were determined using core method described by (Fasinmirin and Adesigbin, 2011). Soil samples were taken from soil core at depths 0-15cm, 15-25cm, 25-50cm and 50-75cm on each location of the land use using ring cylinders with height 5.1cm and diameter 5cm (Gabriel and Cornelis, 2008). Porosity was determined for each sample collected from the study area (Knutsson and Morfeldt, 2002). Porosity of the soil was calculated from bulk density and particle density was assumed to be 2.65 mg/m^3(Suzuki *et al.,*2004). The hydraulic conductivity of soil was carryout according to the guideline of Akanegbu, (2013).

2.2.3 Statistical analysis

To compare various results obtained from different land management practices for the study areas, statistical test was carried out using SPSS and tests are conducted at significance level of 0.05. For each of the location or different land management practices, the mean and standard deviation were calculated. Statistical test was conducted to check if each of the locations is significantly different. Marginal means of hydraulic conductivity, bulk density and porosity was use to compare the land use through multiple comparison.

3.0 RESULTS AND DISCUSSIONS

3.1 Results of soil aggregate

The soil aggregate for the various study locations were determined and the result presented in Table 1. It was observed that there was a gradual increment of sand particle for 0-15cm depth to 50-75cm depth which could be as a result of the decaying plant properties as this is within the root zone of crops.

Sandy soil is the most predominant soil in the study areas and these are easily detached but hard to transport while clayey soil is hard to detach but easily transported if finally detached. This reveals that the actual percentage of sand in any soil sample determines to a great extent the saturated hydraulic conductivity of that particular soil (Odumeke, 2014).

Table 1: soil textural classification of the forest (Teak and Gmalinaplantation) land, Grass land and Maize cultivated land

Study location	Depth (cm)	Sand (%)	Silt (%)	Clay (%)	USDA Textural class
Teak plantation					
	0-15	60	12	28	sandy clay loam
	15-25	50	8	42	sandy clay
	25-50	65	10	25	sandy clay loam
	50-75	68	12	20	sandy loam
Gmalina plantation	0-15	72	10	18	sandy loam
	15-25	62	18	20	sandy clay loam
	25-50	72	8	20	sandy clay loam
	50-75	65	17	18	sandy clay
Grass land	0-15	65	15	20	sandy clay loam
	15-25	60	22	18	sandy loam
	25-50	58	20	22	sandy loam
	50-75	55	23	22	sandy clay loam
Maize cultivated land	0-15	72	17	11	sandy loam
	15-25	70	17	13	sandy loam
	25-50	65	22	13	sandy loam
	50-75	60	18	22	sandy clay loam

Table 1 above shows the result of particle size composition of the collected soil samples. Teak plantation land shows a little variation in the percentages of sand, silt, and clay among the collected soil samples. According to the USDA classification system, the soil samples collected at the 0-15cm, 25-50cm depth of teak plantation land are predominantly Sandy clay loam while those of 15-25cm and 50-75cm depth are sandy clay and sandy loam. The highest value of sand is 68% at depth 50-75cm it also have the lowest percentage of clay at the same depth of 50-75cm and this is in line with research work on manure teak plantation by Fernández-Moya *et al*., (2013). Results from table 1 was observed also from gmalina plantation that at depth 0-15cm and 25cm-50cm there is same percentage of sand content which was also observed in the studying of Fernández-Moya *et al*., (2013). From the results obtained from grass land it shows that sand contents has the highest value of 65% of sand at depth 0-15cm and it has the lowest value of silt content as 15% in the study area of grass plantation. At depth 25-50cm and 50-75cm of grass land the clay content remain the same. The results obtained from maize cultivated land shows that at depth 0-15cm, 15-25cm, and 25-50 the soil samples collected are predominantly sandy loam while that of depth 50-75cm are sandy clay loam. The results obtained from soil textural classification throughout the land use are predominantly having high percentage of sand particles which is similar to the works of Olorunfemi and Fasinmirin, (2011) and also recorded a high percentage of sand particles throughout their study but the values obtained from their study were observed to be lower when compare with values from this study location. This could be linked to the fact that there study location is in the forest zone where they experience high amount of rainfall compared to this study location.

3.2 Statistical results of bulk density, porosity and soil hydraulic conductivity

From the table 2 it shows that soil bulk density value for teak plantation land was observed to be highest at depth 50-75cm with little porosity of 22.96% which means the soil is too compacted and there is no record of soil hydraulic conductivity at the depth. Also the lowest soil bulk density is at the surface i.e depth 0-15cm which is almost in line with Ajibola *et al.,* (2018) and it has the highest hydraulic conductivity at same depth. It was also observed that soil hydraulic conductivity decreases from the surface to the bottom i.e from 0-15cm to 50-75cm. These values from teak plantation site in table were much lower than those found by Rubio *et al*., (2005).

Table: 2 selected physical properties of the various study locations with their mean and deviation

Location		ρ_b **(gcm^{-3})**	P **(%)**	K_{sat} **(cmh^{-1})**
Teak plantation				
	0-15	1.4067±0.01528	46.92±0.576	0.0006±0.00003
	15-25	1.5000±0.02000	43.40±0.755	0.0001±0.00002
	25-50	1.6200±0.02646	38.87±0.996	0.0005±0.00004
	50-75	1.7533±0.02517	33.84±0.951	0.000±0.00000
Gmalina plantation				
	0-15	1.5667±0.06658	42.39±0.785	0.0014±0.00040
	15-25	1.5867±0.10693	42.01±0.433	0.0014±0.00010
	25-50	1.6067±0.06658	39.24±1.000	0.0003±0.00004
	50-75	1.6967±0.06506	36.48±0.951	0.0000±0.00000
Grass land				
	0-15	1.3000±0.01732	50.94±0.652	2.8833±0.02082

	15-25	1.3533±0.02082	48.93±0.785	1.4767±0.03215
	25-50	1.3533±0.03055	48.93±1.155	1.5033±0.01528
	50-75	1.5000±0.02000	43.40±0.755	1.3833±0.02082
Maize cultivated land				
	0-15	1.2967±0.03786	51.07±1.433	1.2200±0.02000
	15-25	1.3533±0.01155	48.93±0.433	1.1533±0.02887
	25-50	1.3533±0.03055	48.93±1.155	1.1133±0.02517
	50-75	1.4833±0.02082	44.03±0.787	0.9767±0.07767

Where ρ_b= soil bulk density, P = porosity, K_{sat} = soil hydraulic conductivity.

Gmelina plantation shows that soil bulk density increases from the surface to the bottom i.e from 0-15cm to 50-75cm. This is an indication that the soil is compacted down the soil profile for the study area. At 0-15 and 15-25cm depth the bulk density is almost the same with a recorded porosity of 42.26 and 41.87% respectively. This is almost in line with Ajibola *et al.,* (2018). The bulk density value obtained almost same with one found by Uloma *et al.,* (2013). The grass land in table 2 shows that the bulk density at 50-75cm depth was 1.50gcm^{-3} and it's in line with a research work carried out by Uloma *et al.,* (2013). The result obtained from the grass land show some variation down the profile and these changes down the profile is also in line with the work of Rubio *et al*., (2005) due to these variations of soil bulk density, It can stated that soil bulk density is one of the major soil property that affect soil hydraulic conductivity. Soil hydraulic conductivity at 0-15cm record the highest value due to low soil bulk density at the profile. The results from maize cultivated land in table 2 indicates that the soil bulk density at 15-25cm and 25-50cm is same and the soil hydraulic conductivity at that depth varies by small value. At depth 50-75cm the soil hydraulic conductivity was lowest this could be as a result of high bulk density at the region. The highest value of soil hydraulic conductivity from maize cultivated land in table 2 was recorded at 0-15cm depth.

The saturated hydraulic conductivity varied at different locations. This confirms spatial variation of hydraulic conductivity as reported by other researchers (Rubio *et al*., 2005). This variation was also further confirmed by the statistical difference shown by other properties of soil determined which include porosity and bulk density. It was also noted that locations with same soil textural class had different values of soil hydraulic conductivity. This is in line with report of Ritzema, (2006) that soils of identical texture may have different soil hydraulic conductivity values due to differences in structure.

Table 3 shows the comparative levels of significance of the various physical properties for the various study location

Location		Mean bulk density	Mean hydraulic conductivity	Mean porosity
TP				
	GP	-0.0192ns	-0.0005ns	0.73ns
	GS	0.1933*	-0.0192*	-7.29*
	MS	0.1983*	-1.1155*	-0.748*
GP				
	TP	0.0192ns	0.0005ns	0.73ns
	GS	0.2125*	-1.8109*	-8.02*
	MS	0.2175*	-1.1151*	-8.21*
GS				
	TP	-0.1933*	1.8114*	7.29*
	GP	-0.2125*	1.8109*	8.02*
	MS	0.005ns	0.6958*	-0.19ns
MS				
	TP	-0.1983*	1.1155*	7.48*
	GP	-0.2175*	1.1151*	8.21*
	GS	-0.005ns	-0.6958*	0.19ns

* = The mean difference is significant at the .05 level, ns = the mean difference not significant at the 0.05 level

Where TP = Teak plantation site, GP = Gmelina plantation site, GS = Grass site, MS = cultivated land

The subjected result to statistical analysis test in table 3 shows that the hydraulic conductivity, bulk density and porosity of teak plantation site shows that there is no significant difference between the teak plantation site and gmelina plantation site at 0.05 level but there is significant difference between teak plantation site and (grass, maize site), which means that bulk density, porosity and hydraulic conductivity has no effect on teak plantation and gmelina plantation site. Table 3 also shows that there is no significant difference between grass and maize cultivated land for bulk density and porosity but has significant difference on teak and gmelina plantation site.

4.0 CONCLUSIONS

The results obtained have shown that saturated hydraulic conductivity varied at different locations. This variation was also further confirmed by the statistical difference shown by other properties of soil determined which include porosity and bulk density. It was also noted that locations with same soil textural class had different values of soil hydraulic conductivity.

The study further reveals the significant differences in the soil of four land uses in Gidan Kwono, Minna Nigeria. The soil hydraulic conductivity is strongly compared to bulk density and porosity. The soil in forest zone (Teak plantation and Gmalina plantation) had significantly high bulk density as compared to the low bulk density in grass, maize, beans and yam sites. However, soil hydraulic conductivity was significantly high in the grass site or soil. Soil hydraulic conductivity is highly dependent on soil texture, soil bulk density and porosity. Results shows that soil bulk density and porosity, affect soil hydraulic conductivity of soils of the study areas. Results obtained from the different land use serve as Knowledge of variability of soil that can assist in defining the best strategies for a sustainable soil management through the provision of vital information for estimating soil susceptibility to erosion, hydrological modeling and efficient planning of irrigation projects. Finally, results of the experiment revealed that soil hydraulic conductivity vary considerably among land uses. Saturated hydraulic conductivity was higher in grasslands than other land use. Improvement on this study could be done through expansion of area of studied and increasing the number of samples and measurements since a soil are highly heterogeneous and tends to vary from point to point even at the same layer.

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