Assessment of Infiltration Characteristics of Soil at Faculty of Agriculture Demonstration Farm, Ifite-Ogwari, Anambra State, Nigeria

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ABSTRACT

Understanding the infiltration potentials of soils could provide valuable insights on the water use efficiency that is site specific for an informed decision on agricultural conservation practices. The study assessed the infiltration characteristics of soil at Faculty of Agriculture demonstration farm, Ifite Ogwari. Auger and core soil samples were randomly taken from a mapped-out area of the farm measuring 360 sq/m at 0–20 cm depth. The collected soil samples were used to determine the selected soil properties in the laboratory. A double ring Infiltrometer was used to assess the soil infiltration at intervals of 2, 5, 8, 12 and 15 minutes. Data obtained were subjected to descriptive analysis while variation in selected soil properties were determined using coefficient of variation and ranked according to known standards. Results showed that the soils belonged to sandy loam textural class; bulk density was 1.74 mgm^{-3}; total porosity was 34.51%, moisture content was 7.09%, saturated hydraulic conductivity (Ksat) was 0.14 cm/hr, organic carbon was 1.36% while organic matter was 2.34%. The study observed that as time increased the infiltration rate steadily decreased hence the studied area can be categorised as moderate to moderately slow soils.

INTRODUCTION

Soil infiltration refers to the process by which water enters the soil from the surface and moves through the soil profile while Infiltration rate is considered as an indispensable tool in defining and evaluating water movement, transmission and storage (Bamanga *et al.*, 2024). It describes the capacity of water to travel vertically down the soil profile (Amos-Uhegbu *et al.*, 2023). According to Angelaki *et al.*, (2013) and Ma *et al.*, (2015) infiltration rate is dynamic due to the effects of various factors like land use type, initial moisture content, biological matter and activities, degree of compactness, soil texture as well as porosity. Infiltration process may be quantified as a key factor in hydrologic, pedologic, hydrogeologic, and irrigation investigations (Kale and Sahoo, 2011; Mahapatra *et al.*, 2020). It remains the most essential process that affects the surface irrigation uniformity and efficiency because of its mechanism of transfer and distribution of water from surface to soil profile (Rashidi *et al.*, 2014) which allows the soil to temporarily store water, making it available for uptake by plants and soil organisms (Orji and Nwachukwu, 2021).

The infiltration properties of soils play a vital role in agricultural systems, significantly influencing the management of water resources, nutrient availability, and overall crop productivity (Jones *et al.*, 2011; Wang *et al*., 2012). The measurement of infiltration of water into the soil is an important indication concerning the efficiency of irrigation and drainage, optimizing the availability of water for plants growth and metabolism, improving the yield of crops and minimizing erosion (Adeniji *et al*., 2013). Demonstration farms essentially depends on rainfall and irrigation for their farming activities thus provides an excellent opportunity to study soil infiltration properties due to its diverse range of agricultural activities. Again, the unique land-use characteristics of the farms necessitate a focused investigation to gain a better understanding of soil infiltration and patterns of water distribution so as to provide site-specific data that can support informed decision-making in agricultural practice hence this study assessed infiltration characteristics of soil at Faculty of Agriculture demonstration farm in Ifite Ogwari, Anambra State, Nigeria.

MATERIALS AND METHODS

Study Area

The study was conducted at the Faculty of Agriculture demonstration farm of Nnamdi Azikiwe University located in Ifite Ogwari; Ayamelum Local Government of Anambra State. The farmland is located within latitude 6^0 36' 14" N and 6^0 38' 29" N and longitude 6^0 57' 2" E and 6^0 60' 39" E. The farm area is characterized by a wet season from April to October and a dry season from November to March (Ejikeme *et al.*, 2017) and falls within tropical savanna dominated by grasses and sparsely distributed trees. The soils are of Imo shale geologic formation (FDALR, 1990). The average annual rainfall in the area is about 1500mm while the average temperature and relative humidity of the area is 35ºC and 74% respectively. The farmland is usually used for arable crop production

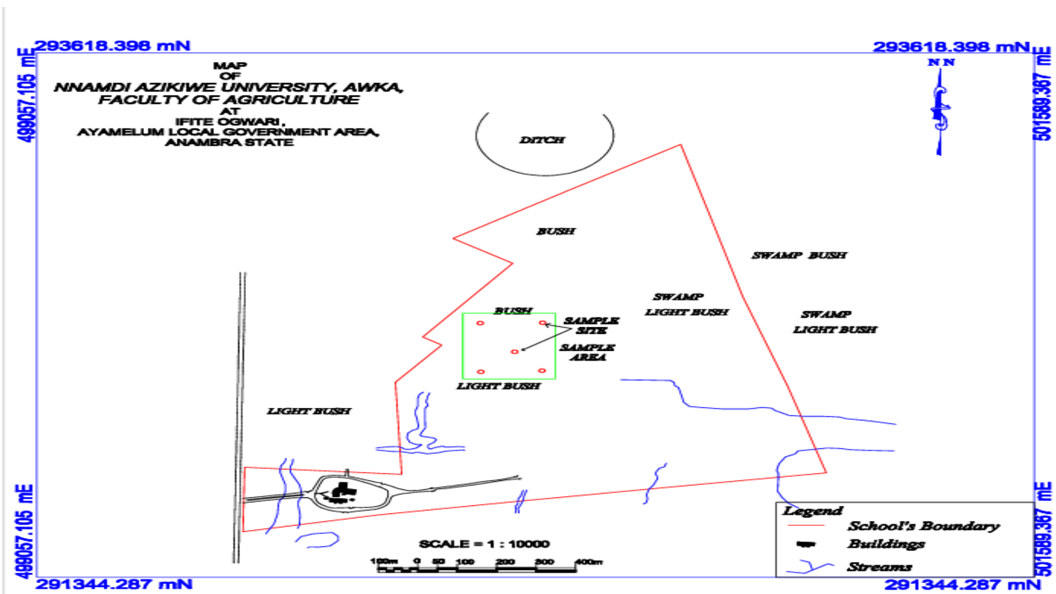

Fig. 1: Map of Faculty of Agriculture showing the sampled area; adapted from Onwuzuligbo (2023)

Soil Sample Collection

A land area measuring about 360sq/m was mapped out and used for the study. Soil samples were collected randomly at twenty (20) different points in a zigzag pattern from the farmland using auger and core samplers at 0-20cm depth. The collected auger soil samples were mixed thoroughly and a representative sample was used for soil chemical analysis while the collected soil samples with the core samplers were used for soil physical analysis. All the soil samples collected were labeled and bagged for laboratory analysis.

Laboratory Analysis

Soil Physical Properties

The hydrometer method as described by Gee and or (2002) was used to determine the particle size distribution of the samples, while the soil textures were determined using the USDA Textural triangle. The bulk density was determined by core method as described by Grossman and Reinsch (2002). Total Porosity was calculated from the bulk density as shown in this equation:

$$\text{Total Porosity (\%)} = 1 - \frac{\text{Bd}}{\text{pd}} \times 100 \quad \text{---------------} \ (1)$$

Where; Bd =Bulk density, Pd = Particle density (2.65g/cm^3). The Saturated hydraulic conductivity was determined by the constant head permeability procedure according to Young (2001) while Darcy's equation for vertical flow of liquid was used for the computation of K as shown in the equation:

$K_{sat} = \frac{QL}{AT\triangle H}$ ------- (2)

Where, Q is water discharge (cm), L is length of soil column, A is the interior cross-sectional area of the volume of soil not occupied by soil column (cm), H is the head pressure difference causing the flow and it is dimensionless, T is the time of flow measured in seconds. Gravimetric moisture content of the soil was determined by oven drying at a temperature of 105^{0}C and percentage of moisture in soil calculated mathematically as follows:

$\mathrm{GMC} = \frac{w_2 - w_3}{w_3 - w_1} \times 100$ --------------------- (3)

Where W_1=Weight of the can, W_2=Weight of wet sample + can, W_3=Weight of oven dried sample + Weight of the can. Soil organic carbon was determined using the wet dichromate oxidation method of Walkley and Black (1934) while organic matter was calculated by multiplying the value of organic carbon by a factor of 1.72 (Van Bemmelen factor).

Determination of Soil Infiltration rate

The measurement of soil infiltration was done using the double-ring infiltrometer method described by Anderson Ingram (1994) as seen in plate 1. The double-ring infiltrometer measuring about 60cm and 30cm in diameter consists of two concentric rings which was hammered into the soil to a depth of 10 cm using 2×4 wood. About 30 cm plastic ruler was vertically placed into the inner ring for measuring the amount of water that infiltrated while the rate of water infiltration was measured by recording the time taken for a certain amount of water to infiltrate using a stop watch. Water was poured quickly into both the outer and inner rings at a constant height of 15 cm above the ground surface ensuring that a jute cloth was placed inside the inner ring to protect the soil surface when pouring water. The water in the outer ring was to prevent the lateral spread of water from the infiltrometer. Readings in drop of water was taken at 2mins, 5mins, 8mins and 12mins and 15mins. Following Horton (1974)'s idea which states that 'the water infiltrating into the soil starts at a constant rate (i.e. the depth of water initially enters the soil from the surface), and this water will start to decrease exponentially with time (t), and likewise, after some time when the soil saturation zone reaches a certain value, the rate of infiltration will level off or terminated as a steady stage and further calculated using the formula:

I = Q/t ----------------------- (4)

where I= Infiltration rate (cm/hr); Q= volume of water entering the soil; t= time of Infiltration. The rate of infiltration was further plotted in a graph (Fig 2)

Plate 1: Double ring infiltrometer in the field

Statistical Analysis

Data collected were subjected to descriptive analysis. Variation of soil properties were determined using coefficient of variation and was further ranked according to the procedure of Wilding *et al.,* (1994) where CV ≤ 15 % represents low variation (LV), > 15 CV ≤ 35 % is moderate variation (MV) and > 35 % is high variation (HV).

RESULTS AND DISCUSSION

From the results obtained, the particle size distribution showed 652 g/kg of sand, 180 g/kg of silt and 168 g/kg of clay. Other results showed a bulk density value of 1.74 mgm$^{-3,}$ total porosity of 34.51%, moisture content of 7.09%, saturated hydraulic conductivity (Ksat) of 0.14 cm/hr, organic carbon content of 1.36% and organic matter content of 2.34%. The dominance of sand fraction in relation to silt and clay fractions could be ascribed to the geological materials of soils of the area as reported by Nnabuihe *et al*. (2023) and Nwosu *et al*., (2021) and may equally indicate well aerated soils capable of supporting crop root penetration (Nweke and Nsoanya 2012). Based on textural class, the studied area could be classified as sandy loam. Sand, silt and clay particles respectively had low variation (CV= 10.92%, 8.33% and 0.27%). The observed bulk density value of 1.74 mgm^{-3} falls within the recommended limit range of 1.75 mgm^{-3} to 1.85 mgm^{-3}for root penetration based on the report of SSS (2010) however the report of Marshall *et al.* (1999) observed a strong negative relationship between high bulk density and infiltration rate. Total porosity had moderate variation (CV= 34.51%). Soil moisture content affects soil consistency, compatibility as well as swelling; the observed 7.09% value in this study suggests low moisture content and dryness which reduces cohesiveness among soil particles.

Moisture content had moderate variation (CV= 24.57%). The Ksat value of 0.14cm/hr obtained in this study was low; this contradicts the submission of Brady and Weil (2002) who considered sandy soils to have higher Ksat values due to its macropores characteristics that helps in conducting water. Ksat had higher variation (CV= 37.43%). Bhadha *et al.* (2017) reported that high organic carbon content can increase the soil's ability to store water however the low organic carbon content (1.36%) and the textural characteristics as observed in this study could have affected the water storing capacity of the soil. Furthermore, Emeh and Igwe (2018) suggested that organic matter content of < 2% could lead to decline in soil structural stability and could affect water movement however the value of organic matter content (2.34%) in this study was slightly above the suggested limit.

The rate of water infiltration in soil of the farmland over time is shown in table 2 while fig 2 showed the infiltration graph. Generally, the study observed that as time increased, the infiltration rate decreased (fig 2). For instance, highest infiltration rate was observed at 2mins while the lowest was observed at 15mins. Similar observation was made by Adindu *et al*., (2013) who reported higher infiltration rate at earliest time in selected soils of Aba, southeast Nigeria. This showed that as the soil becomes more saturated with water over time, its ability to absorb additional water diminishes, resulting in a lower infiltration rate. Again, as time increased the infiltration rate steadily decreased indicating that the soil is nearing saturation and can only absorb water at a much slower rate. The slower rate of water infiltration over time increase could be suggestive of sub surface compaction. Based on Landon (1991) classification of soil infiltration capacity where class 1= very slow (0.1), class 2 = slow (0.1-0.5), class 3 = moderately slow (0.5-2.0), class 4 = moderate (2.0-6.0), class 5 =moderately rapid (6.0-12.5), class 6 = Rapid (12.5-25.0) , class 7 = very rapid (>25) ; the soil could be categorized as moderate to moderately slow soils probably due to low organic carbon content obtained. However, the study of Gregory *et al*., (2005) opined that infiltration rate of coarse soil group is much higher than medium to fine soil groups.

Table 1: The Mean, Standard deviation and Coefficient of Variation of selected hydro-physical properties of the studied area

	Sand	Silt	Clay	TC	BD	MC	TP	Ksat	OC	OM
		g/kg			mgm^{-3}	(%)	(%)	(cm/hr)	(%)	(%)
Mean	652	180	168	SL	1.74	7.09	34.51	0.14	1.36	2.34
Sd	3.30	2.89	0.52		3.24	4.96	4.46	6.12	2.01	1.91
Cv	10.92	8.33	0.27		10.49	24.57	19.91	37.43	4.06	3.65

KEY: TC = textural class, SL = sandy loam, BD = bulk density, MC = moisture content, TP = total porosity, Ksat = saturated hydraulic conductivity, OM = Organic matter, sd = standard deviation, cv =coefficient of variation

Table 2: Infiltration rate of the farmland

Time (mins)	Time (hr)	Depth (cm)	Infiltration rate(cm/hr)
2	0.03	9.5	4.8
5	0.08	9.9	2.0
8	0.13	9.8	1.2
12	0.20	9.5	0.8
15	0.25	9.1	0.6

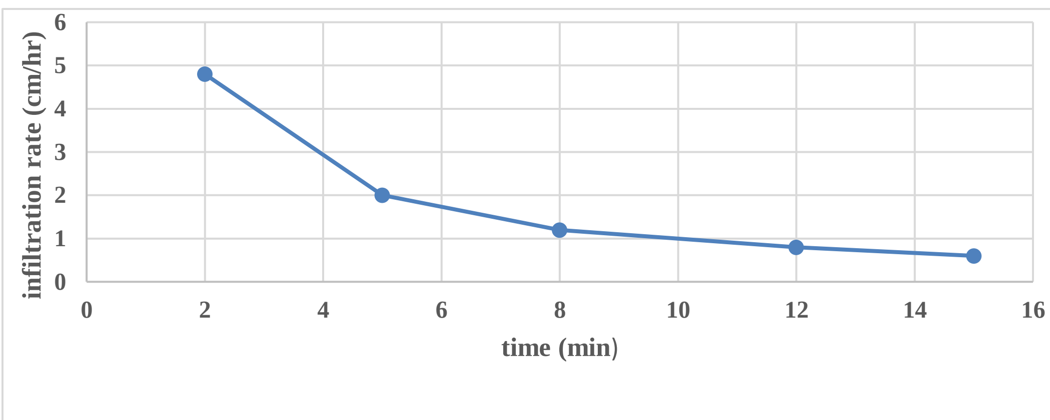

Fig 2: Infiltration Rate Graph

CONCLUSION

The study observed that as the soil becomes more saturated with water over time its ability to absorb additional water diminishes, resulting in a lower infiltration rate which was evidenced in the reduced infiltration rate at 15mins interval. Soils of the studied area can be categorized in the range of moderate to moderately slow hence the need to increase water movement into the soil through organic matter management, soil cover with residue, reduced tillage within the farmland is encouraged.

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