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Assessment of Soil Infiltration Rate in Oye-Ekiti and Ikole-Ekiti of Nigeria

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ABSTRACT

Soil infiltration, the process by which water penetrates the soil's surface and flows downward, is a crucial hydrological factor affecting agricultural productivity, environmental sustainability, and water resource management. Despite their significance, Ekiti State lacks localized data on soil infiltration rates, which makes it difficult to develop sustainable land use and water management plans. This study evaluates infiltration behavior across four sites with diverse soil textures in Oye-Ekiti and Ikole-Ekiti, using field infiltration tests and laboratory geotechnical analyses. The research finding deduce that infiltration rates initially increase as the soil dries and becomes more receptive to water, reaching a peak as the soil begins to saturate, Peak infiltration rates ranged from 3.4 cm/hr to 6.9 cm/hr, with Site III having the maximum rate, Accumulated infiltration rates over 60 minutes varied from 22.6 cm to 63 cm, with Site IV showing the highest rate. Soil properties like specific gravity, moisture content, particle size distribution, and Atterberg limits were analysed and correlated with infiltration rates. The study concluded that infiltration rates significantly influence soil performance in Ekiti State.

Keywords: Soil, Index Properties, Soil Infiltration, Peak Infiltration Rate

1. INTRODUCTION

Soil infiltration, the process by which water penetrates the soil's surface and flows downward, is a crucial hydrological factor affecting agricultural productivity, environmental sustainability, and water resource management (Hillel, 2023). Accurate knowledge of infiltration rates is essential for forecasting water availability, designing efficient drainage systems, and managing flood risks (Foster et al., 2022). Ekiti State is located in southwest Nigeria, with a humid tropical climate with significant rainfall, especially during the wet season (June to September) and a relatively dry period (October to May) (Akinmoladun et al., 2023). Soil moisture levels and, in turn, infiltration rates are strongly influenced by the state's climate. Addressing regional issues with land use and water management requires an understanding of these dynamics (Brady and Weil 2022). The texture, composition, and structure of the soils in Ekiti State are greatly influenced by the underlying geology and land use practices (Iroko et al., 2022). There are different types of soil in Ekiti, from sandy to clayey, and each has distinct infiltration characteristics. Further altered soil properties and infiltration patterns caused by urbanization, agricultural practices, and deforestation lead to increased runoff and soil erosion (Oke et al., 2023). Given these variations, developing targeted management strategies requires a detailed analysis of the soil infiltration rates in different Ekiti State locations. Prior research on soil infiltration in Nigeria has mostly concentrated on larger regional scales or particular soil types, with little attention paid to the particular circumstances of Ekiti State (Ogunleye et al., 2021). Rainfall or irrigation water can either contribute to surface runoff or seep into the soil when it first reaches the soil's surface. When the rate of water application surpasses the soil's infiltration capacity, water flows overland instead of soaking into the soil, a phenomenon known as surface runoff (Dingman, 2015).

Soil infiltration rates are essential for efficient agriculture, infrastructure development, and water

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management. Water absorption, runoff, and soil erosion may be impacted by differences in soil types and climatic conditions in Ekiti State, Nigeria. Despite their significance, Ekiti State lacks localized data on soil infiltration rates, which makes it difficult to develop sustainable land use and water management plans. Planning infrastructure projects that take into account soil behaviour under various conditions, managing storm water effectively, and optimizing agricultural practices are all hampered by the lack of thorough, region-specific data. Based on this, this study assessed the infiltration rate performance of soils in Oye-Ekiti and Ikole Ekiti.

2. METHODOLOGY

2.1 Method

Based on land use, accessibility, and historical data, two towns were chosen from one senatorial district. The referenced town were Oye-Ekiti and Ikole Ekiti (Table 1). To ensure a variety of soil types and land uses, two locations were chosen from each town. Exploration Methods: Soil samples were collected at a depth of 600 mm using manual excavation and sampling techniques. The samples were packed in sacks and identified with identification marks. Index properties: specific gravity, moisture content, particle size distribution and atterberg limits were determined in accordance to BS EN ISO 17892-12 (2018) and BS 1377-2 (2022), while soil infiltration of the soils were measured using double-ring infiltrometer test method.

Table 1: Location of Site

SITE LOCATION		GPS LOCATION	
REGION	LOCATION NAME	LATITUDE	LONGI-TUDE
IKOLE EKITI	FUOYE, Ikole Campus (I)	7.807234°N	5.493282°E
	Ikole Local Governmtment Secretariat (II)	7.797336°N	5.468059°E
OYE EKITI	Post Gradu-ate School, FUOYE, Oy-eEkiti (III)	7.782036°N	5.31557°E
	FUOYE, Main Campus (IV)	7.782037°N	5.315576°E

3. RESULTS AND DISCUSSION

3.1 Specific Gravity and Moisture Content

The physical characteristics of soils in all the sites are compiled in Table 2, with an emphasis on average specific gravity and average moisture content. The information is essential for comprehending the properties of the soil, which might affect Infiltration Rate.

Site IV has the lowest specific gravity value at 2.03, while Site I has the highest specific gravity value at 2.35. The range of the value is lower to the findings by Oyelami (2017) and Olofinyo et al., (2019). High specific gravity is indicative of denser soil, which can limit the flow of water and lower infiltration rates. The average moisture content varies greatly, with Site III having the lowest moisture content at 6.7% and Site II having the greatest moisture content at 11.3%. Increased moisture content can cause infiltration rates to decrease because saturated soils are less able to hold on to water.

Increased specific gravity is frequently associated with increased soil compaction, which can hinder water flow and reduce infiltration rates. Reduced pore spaces in compacted soils cause slower water absorption and more runoff. Moisture Levels: Because of saturation, higher moisture content soils may show reduced rates of infiltration. Soils that are saturated lose some of their capacity to hold on to water, which can cause surface ponding.

The pace at which soil penetrates is greatly impacted by variations in specific gravity. The denser soils are generally indicated by higher specific gravities, which can hinder water movement and diminish pore space size. As a result, infiltration rates will reduce because water will find it difficult to permeate dense or compacted soils. On the other hand, soils with a lower specific gravity tend to be less thick, which makes more pore space available for faster water absorption and higher infiltration rates (Folorunso and Aribisala, 2018; Oluwakuse et al., 2020; Ahmed, et al., 2024). Because it affects the dynamics of surface runoff and groundwater recharge, this relationship is significant to hydrology. Comprehending these fluctuations facilitates efficient land administration and farming methods, guaranteeing maximum water retention and utilization.

Table 2: Specific Gravity and Moisture Content of Soil

Site Location	I	II	III	IV
Average Specific Gravity	2.35	2.1	2.23	2.03
Average Moisture Content (%)	11.1	11.3	6.7	11.26

3.2 Particle size distribution

Table 3 shows the soil composition from the four site locations, focusing on the percentages of gravel, sand

and silt and clay, as well as their classification according to the Unified Soil Classification System.

Table 3: Particle Size Distribution

Site Location	I	II	III	IV
Gravel (%)	32.5	10.7	10.9	27.7
Sand (%)	39.3	51.7	27.5	50.1
Silt (%)	27.7	36.4	59.1	21.3
Clay (%)	0.5	1.2	2.5	0.9
UCSC Classification	GC	SM	SW	CL

From table 3, in accordance to the Unified Soil Classification system, two site location (II and III) were classified as SM (Silty Sand), locations I was classified as GC (Gravelly Clay) while location IV was classified as CL (Clay). FUOYE, Ikole Campus (I). From Table 3, across the entire site, the gravel content varies from 10.7 to 32.5%. The minimum gravel content was recorded at site II (Ikole Local Governmtment Secretariat) with 10.7%, with a maximum of 32.5% observed at Site I (FUOYE, Ikole Campus). Sand which constitutes the largest part of the soil components have the least percentage of 27.5% at site III (FUOYE Post Graduate School), peaking at 51.7% in site II (Ikole Local Governmtment Secretariat). The silt content across all sites varies from 21.3 to 59.1%. The average percentage of silt content is 35.29%, with site III (Post Graduate School, FUOYE, Oye-Ekiti) showing the highest silt percentage of 59.1%. Lastly, clay has the lowest percentage with clay content range of 0.5 to 2.5%.

3.3 Atterberg Limit

The Table 4 examines the different site locations' liquid limit, plastic limit, and plasticity index. The liquid limit values range from 23.8% (Site III) to 44.8% (Site II). Higher liquid limits indicate soils with more clay content, which can restrict water movement and reduce infiltration rates. Plastic limit values vary from 26.0% (Site IV) to 28.0% (Site II). Soils with higher plastic limits tend to have more clay content, potentially leading to lower infiltration rates. And plasticity index ranges from 1.4% (Site III) to 17.2% (Site I). Higher plasticity index values suggest soils with more clay content and higher potential for swelling, which can impede water movement and reduce infiltration rates (Oluwakuse et al., 2020).

Table 4: Atterberg Limit of Soil

Site Location	I	II	III	IV
Liquid Limit (%)	43.3	44.8	23.8	38.3
Plastic Limit (%)	26.1	28.0	26.9	26.0
Plastic Index (%)	17.2	16.8	1.4	7.8
Plasticity	High		Low	Low

3.4 Infiltration Rate

Figures 1 to 4 shows the plot of infiltration and accumulated infiltration rate for each selected site in Ekiti State. It is observed at all site that the infiltration rate increases as the time increases until a peak value is reached and then the infiltration reduces slightly and remain steady. As the peak is reach, the soil begins to saturate. This peak value occurs because dry soil has more open pores, allowing rapid water entry. As the time progresses, the soil becomes more saturated, leading to a decrease in infiltration rate as the soil's capacity to absorb water diminishes. Eventually, the infiltration rate stabilizes at a lower level, reflecting the soil's saturated

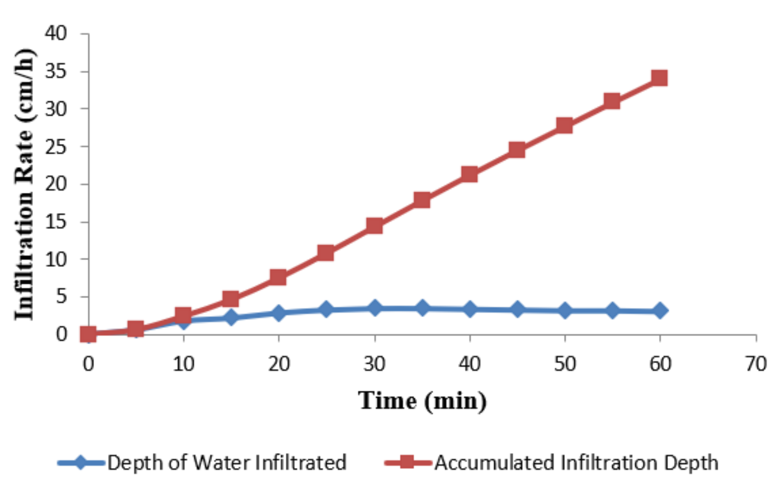

Figure 1: Plot of Infiltation Rate and Accumulated Infiltration Rate for Fuoye Ikole (Site 1)

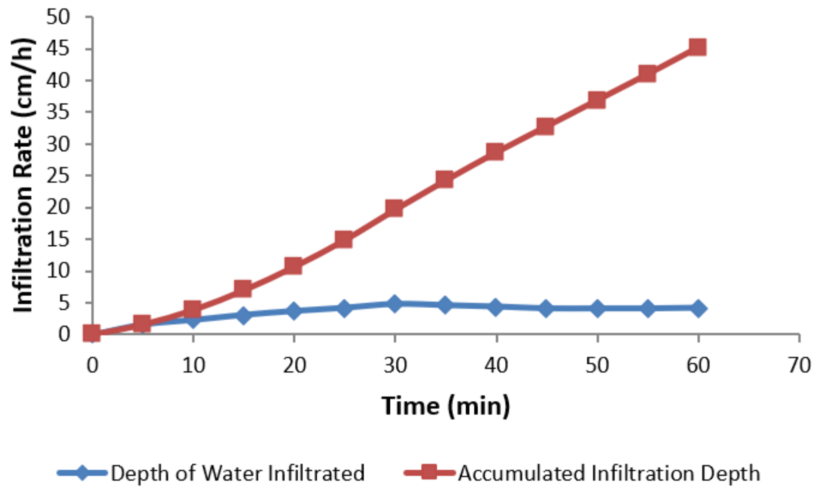

Figure 2: Plot of Infiltation Rate and Accumulated Infiltration Rate for Ikole Local Government Secretariat (Site 2)

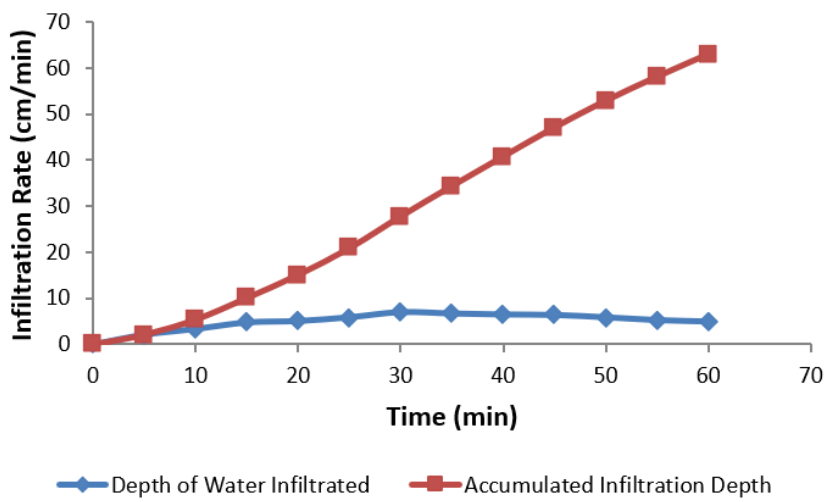

Figure 3: Plot of Infiltration Rate and Accumulated Infiltration Rate for FUOYE, Postgraduate (Site 3)

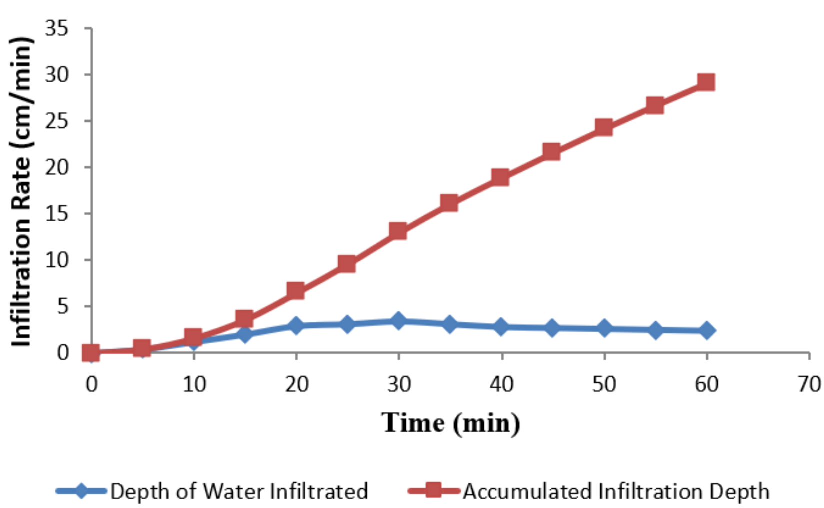

Figure 4: Plot of Infiltration Rate and Accumulated Infiltration Rate for FUOYE, OyeEkiti Campus (Site 4)

hydraulic gradient, which is the maximum rate of water transmission to through the soil.

A summary of the peak infiltration rate and intake rate are as shown in Table 5.

Table 5: Intake Rate and Peak Infiltration rate

Site Location	I	II	III	IV
Accumulated Infiltration Rate	34	45.2	29.1	63
Elapsed Time (min)	60	60	60	60
Intake Rate (cm/hr)	34	45.2	29.1	63
Peak Infiltration Rate	3.5	4.8	6.9	3.4

Table 5 presents data on infiltration rates across the four sites, indicating both accumulated infiltration and peak infiltration rates over a consistent elapsed time of 60 minutes. Accumulated Infiltration Rates range from 29.1 to 63 cm, with Site IV showing the highest rate. Peak Infiltration Rates vary from 3.4 to 6.9 cm/hr, with Site III achieving the maximum. High infiltration leads to moisture accumulation in structural layers, weakening support and accelerating distress, while low infiltration combined with poor drainage promotes surface water retention and related damage.

4. CONCLUSION

Infiltration rates of soils in Oye-Ekiti and Ikole-Ekiti, Ekiti State, were investigated and the following conclusions were drawn:

i. Infiltration rates initially increase as the soil dries and becomes more receptive to water, reaching a peak as the soil begins to saturate.
ii. Peak infiltration rates ranged from 3.4 to 6.9 cm/hr, with Site III having the maximum rate.
iii. Accumulated infiltration rates over 60 minutes varied from 29.1 to 63 cm, with Site IV showing the highest rate.
iv. Findings of this study could be incorporated into land use planning and agricultural extension services to promote sustainable water management practices.

This study confirms that infiltration rates significantly influence soil performance in Oye-Ekiti and Ikole-Ekiti of Ekiti State. Integrating infiltration measurements in soil will improve durability and service life, particularly under tropical rainfall conditions.

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