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ADVANCEMENT OF WATER RESOURCES AND IRRIGATION PRACTICES: A CASE STUDY OF A FARMSTEAD IN CALABAR, SOUTHERN NIGERIA

Robert Ibingha Ekoms

Department of Civil Engineering

University of Cross River State, Calabar.

Phone Number: Email: robertekom@unicross.edu.ng

Abstract

This study investigates water resources advancement for irrigation in a selected farmstead, Royal International Farm, in Calabar, Southern Nigeria. The objectives were to determine the available moisture content of arable land, measure rainfall and infiltration data, parcel the land into measurable irrigated plots, and develop an irrigational requirement model using statistical analysis. Soil samples from 16 locations were analyzed for moisture content, and infiltration rates were measured using a double ring infiltrometer. Rainfall data were collected via non-recording rain gauges. Statistical analysis using SPSS yielded a model with an adjusted R^2 of 0.171, explaining 17.1% of the variance in irrigational processes. The derived model is $Y = -0.0179 + 0.0000006X_1 + 0.015X_2 - 0.000012X_3$, where Y represents infiltrated water, X_1 is irrigated land area, X_2 is soil moisture content, and X_3 is rainfall. The study highlights the need for comprehensive water resource management to address challenges such as surface water availability, pollution, and ecosystem health, recommending enhanced hydrological data collection and sustainable practices like rainwater harvesting and groundwater management.

Key words: Water resources, irrigation, infiltration, soil moisture, Calabar, statistical modeling.

1.0 Introduction

It is generally said that “Water is life”. This dictum has been widely embraced and accepted because, in every component of life, water appears to play a pivotal role to that existence. It is one commodity without which life cannot exist on this earth not only because it is essential for the actual living process, but also because it is necessary for supporting man’s material activities which lead to his material development (Hassanali,2005). With increasing human population and consequent increasing human activities coupled with decrease in natural resources, the need for water for survival has taken added dimensions in recent years. Progressive pollution of fresh water supplies by accelerated human activity has equally made an already critical problem even more acute (Olutu, *et al*, 2009). Water resources development and management remain at the heart of the struggle for sustainable development, growth and poverty reduction. (Getachew *et.al* 2019). Unless progress in water management is made, sustainable growth and poverty reduction cannot be achieved (Daniel, 2011). Water is used for irrigation as well as industrial and domestic purposes. The main source of water is rainfall occurring through hydrological cycle while other sources include ground water and surface water from the melting of snow. The unfortunate situation is that whenever water is available, user never think about its proper use and not only misuse it but waste a large quantity of it too. Therefore, conservation of water is a necessity for all the countries of the world. Water is a critical resource for life and agricultural productivity, often described as the backbone of sustainable development (Hassanal, 2005). In regions like Calabar, Southern Nigeria, increasing population pressure and environmental changes exacerbate the demand for efficient water resource management, particularly for irrigation. This study focuses on advancing water resources for irrigational purposes at the Royal International Farm, a 5.6-hectare arable land in Calabar Metropolis. The objectives were to assess soil moisture content, measure rainfall and infiltration rates, parcel the land into irrigated plots, and develop a statistical model for irrigational requirements. The study addresses the broader context of water resource challenges, including climate change impacts, pollution, and unsustainable groundwater extraction, aiming to contribute to sustainable agricultural practices in Nigeria.

2.0 Method

2.1. Study Area

The Royal Farm International is a privately owned farm in the Calabar Metropolis. The Metropolis itself lies between latitudes 04° 45' 30" North and 05° 08'30" North of the Equator and longitudes 8 ° 11' 21" and 8°27'00" East of the Meridian (Figure 1), while the farm is located approximately on latitude 05° 01' 41" North and longitude 8°22'25" East of the Meridian. The Metropolis, as a town, is flanked on its eastern and western borders by two large perennial streams viz: the Great Kwa River and the Calabar River respectively. These are aside from the numerous ephemeral channels which receive water after storm events to drain the area of study as shown in Figure 2 (Antigha, *et al*, 2014; Antigha, *et.al*, 2022). The Calabar River is about 7.58 metres deep at its two major bands. The city lies in a peninsular between the two rivers, 56km up the Calabar River away from the sea. Calabar has been described as an inter-fluvial settlement (Antigha, *et al*, 2014; 2021). The Metropolis occupies an area of about 223.325 sq.km, while the Royal International Farm sits on an aerial land space of 5.6 ha of arable land. As a coastal town in Nigeria, Calabar Metropolis has a high relative humidity, usually between 80% and 100%. Relative humidity drops with the rise in temperature to about 70% in the afternoon during the dry season (Antigha, *et al*, 2014).

Figure 1: Google Earth Imagery of the Study Location (Source: Google Earth, 2022 App)

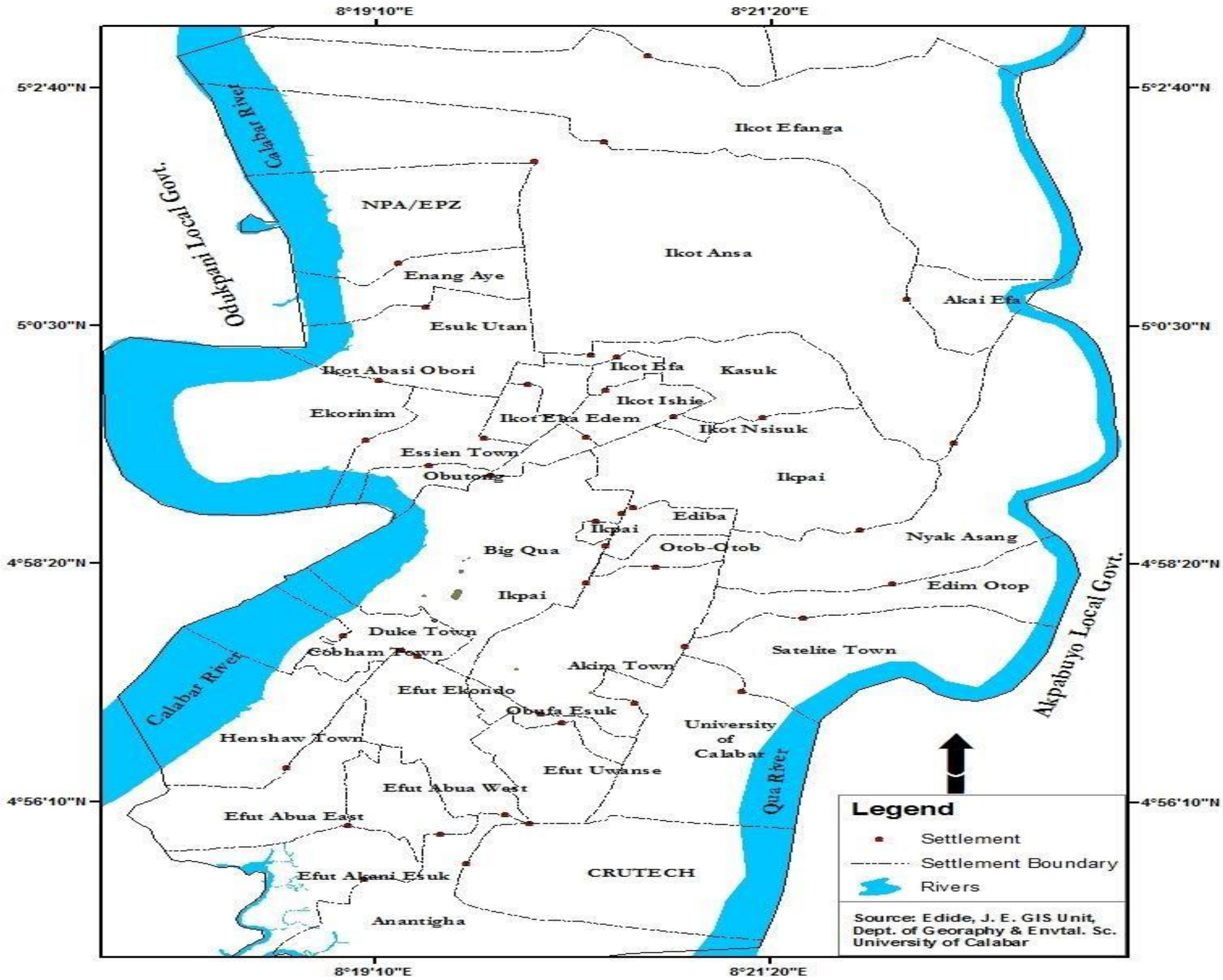

Figure 2: Layout of Calabar Metropolis (Source: Antigha, *et al.,* 2014)

2.2 Data Collection

Soil samples were collected from 16 sampling points at a depth of 0.5 meters across a 125.3 m² area. A double ring infiltrometer was used to measure infiltration rates at intervals of 5, 10, 15, and 30 minutes until steady-state equilibrium was reached. Rainfall data were obtained using non-recording rain gauges, and soil moisture content was determined through laboratory analysis following ASTM D698-70 and D1557-70 standards. The samples were dried, sieved, and weighed to calculate moisture content. The arable land was parceled into plots to facilitate measurement of irrigated portions.

2.3 Data Analysis

Data were subjected to statistical analysis using SPSS (2021). Parameters included infiltration rate (cm/s), irrigated area (m²), soil moisture content (%), and rainfall (mm). A correlation matrix was generated to assess relationships between variables, and a multiple regression model was developed to predict infiltrated water for irrigation. Exploratory and rotated factor analyses were conducted to evaluate variable influence.

3.0 Results and Discussion

The modification of water resources development in relation to irrigation involved obtaining infiltration for the catchment from (16) sampling points for cumulative time intake for 5,10,15,20,30,35,40 minutes respectively.

3.1 Soil Moisture Content

Soil samples were collected from each sampling point and the Moisture content tests (Tables 1) showed average values ranging from 8.8% (Plot 3) to 17.5% (Plot 8). The highest rainfall was recorded at Plot 1 (714.4 mm, 691.72 m²), and the lowest at Plot 11 (350 mm, 553.14 m²). Infiltration rates varied from 0.054 cm/s (Plot 1) to 0.2 cm/s (Plot 7). Likewise, irrigated areas ranged from 427.4 m² (Plot 3) to 691.72 m² (Plot 1).

Table 1: Values of All Parameters for All Locations

LOCATION	INFILTRATION RATE (cm/s)	IRRIGATED AREA (M^2)	SOIL MOISTURE CONTENT	RAINFALL
PLOT 1	0.054	691.72	10.4	714.4
PLOT 2	0.186	609.06	12	386.6
PLOT 3	0.062	427.4	8.8	454.6
PLOT 4	0.179	553.55	12.7	437.2
PLOT 5	0.149	550.22	11.15	568.5
PLOT 6	0.127	661.85	13.2	576.8
PLOT 7	0.2	513.43	13.5	363
PLOT 8	0.14	436.26	17.5	501.5
PLOT 9	0.107	480.69	12.8	477.3
PLOT 10	0.193	563.55	14.5	363.3
PLOT 11	0.119	553.14	12.1	356
PLOT 12	0.124	541.85	13.6	462.7
PLOT 13	0.206	512.41	13.6	462.8
PLOT 14	0.254	492.47	15.5	597.4
PLOT 15	0.2	550.93	13.1	367.5
PLOT 16	0.1	547.26	13.7	378.6

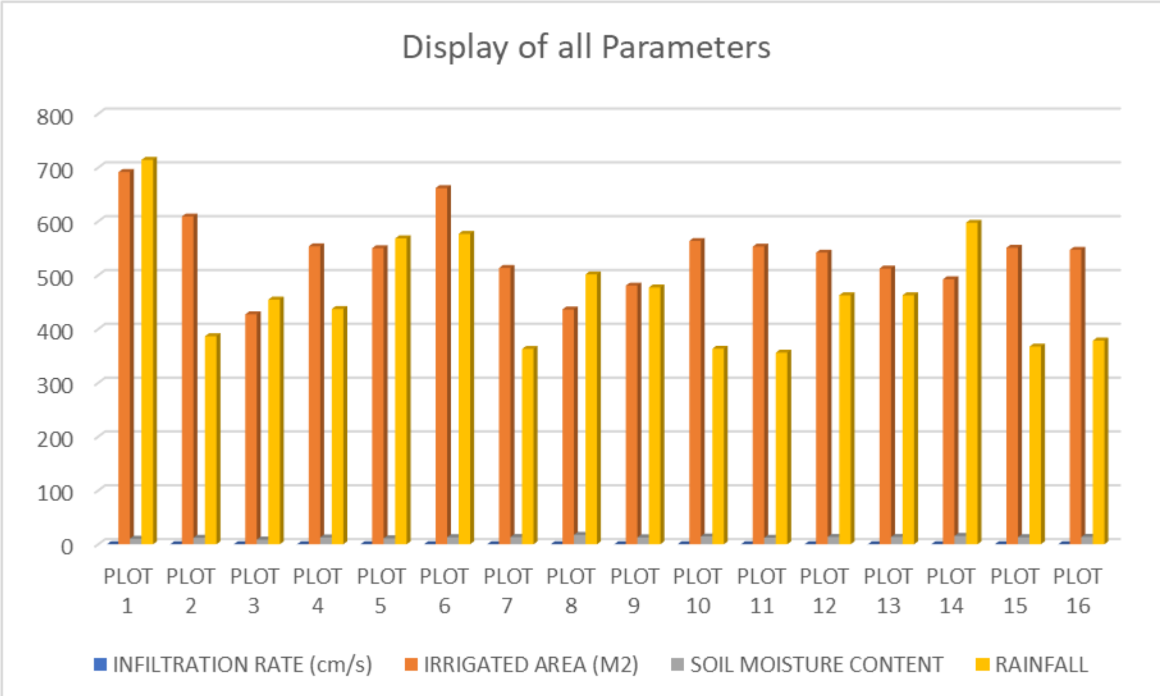

Figure 3: Display of All Parameters for Locations 1 – 16

3.2 Statistical Analysis

The correlation matrix indicated a positive correlation between infiltration rate and soil moisture content (0.54) and between rainfall and irrigated area (0.31). The regression model yielded an adjusted R^2 of 0.171, a multiple R of 0.58, and a standard error of 0.0506, explaining 34% of the variance in irrigational activities. The model equation is:

$$Y = -0.0179 + 0.000006X1 + 0.015X2 - 0.00012X3 \quad (1)$$

Where Y is the infiltrated water into the soil for irrigational purpose

X1 is the irrigated land area

X2 is the soil moisture content and,

X3 is the rainfall.

4.0 Discussion

The study revealed moderate correlations between infiltration rate and soil moisture content, consistent with (Giuseppe *et al.* 2012), who noted that infiltration depends on soil moisture, vegetation, and soil type. The low adjusted R^2 (0.171) suggests that the model accounts for only 34% of the variance in irrigational processes, indicating other unmeasured factors (e.g., soil compaction, vegetation cover) may influence outcomes. The highest rainfall and irrigated area at Plot 1 align with Calabar's high humidity and rainfall patterns (Antigha *et al.*, 2014). The model's standard error (0.0506) is lower than that of a rotated factor analysis (72.277), confirming its suitability for predicting irrigation requirements. These findings underscore the need for integrated water resource management to address spatial and temporal variability in water availability, as highlighted by Kumar (2013).

5.0 Conclusion

In recent times, climate change, both spatial and temporal, is having a momentous influence on weather patterns, precipitation and the hydrological cycle, affecting surface water accessibility as well as soil moisture accretion and groundwater recharge, especially through the baseflow (dry-weather flow) component. It should be noted that the available water resources are irregularly distributed in intergalactic period. This therefore makes them to be constantly under pressure due to major population revolution and amplified request. Access to reliable data on the availability, quality and quantity of water, and its variability, form the necessary foundation for sound management of water resources. The diverse possibilities for augmentation inflate the boundaries of the water resource in a conventional sense, thus helping to match demand with supply. Our water resources, irregularly distributed in space and time, are under pressure due to major population change and increased demand. Access to reliable data on the availability, quality and quantity of water, and its variability, form the necessary foundation for sound management of water resources. The different options for augmentation expand the boundaries of the water resource in a conventional sense, helping to match demand and supply. All components of the hydrological cycle, and the influence of human activities on it, need to be understood and quantified to efficiently and sustainably develop and protect our water resources.

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