

INFILTRATION ANALYSIS IN FLOODPLAIN IRRIGATED SOILS of ABUJA FEDERAL CAPITAL TERRITORY, NIGERIA

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Abstract: The soils in the study area underwent an analysis of their infiltration rate utilizing a double ring infiltrometer with the falling head method, as outlined by Mbagwu (1997) and Oku (2012). Linear plots were constructed, depicting cumulative infiltration and equilibrium infiltration rates against time for three distinct soil units along the catena. The findings indicated consistently high instantaneous infiltration rates, ranging from 8.0 to 21.4 cm hr⁻¹. Notably, the upper slope unit exhibited a chaotic increase and decrease in the first 4 hours, while the middle and lower slopes displayed similar behavior just after 3 hours. The upper slope soils, initially drier in terms of moisture content, demonstrated a higher and rapid infiltration rate during the early hours of the process. Conversely, soils in the middle slope, already saturated, exhibited a slower rate of infiltration. The infiltration equilibrium varied across the three-slope segments. At the upper slope, equilibrium was achieved at a mean cumulative infiltration value of 110 cm. In the middle slope segment, equilibrium was reached much earlier, with a mean cumulative infiltration value of 44Qcm. Similarly, at the lower slope segment, infiltration rate reached equilibrium at a mean cumulative infiltration value of 64Qcm. Factors influencing infiltration included soil texture, bulk density, topography, and moisture content. These elements collectively contributed to the observed variations in infiltration behavior along the catena.

Keywords: Catena, floodplain, Irrigation, Infiltration.

INTRODUCTION

African soils exhibit a rolling topography, wherein the slope significantly influences soil properties from the crest to the valley bottom (Egbuchua, 2014). Beyond parent material and climate, topography plays a crucial role in soil mineral distribution. The relief dictates soil profile depth and drainage, with higher elevations having well-drained soils, while lower slopes consist of poorly drained and fine-textured soils (Atofarati et al., 2012). Topography further impacts drainage, soil erosion, textural composition, and other properties influencing crop development and productivity (Atofarati et al., 2012). Soils on hills or steep slopes tend to be shallow and gravelly due to minimal weathering and erosion, while those on gentle slopes allow substantial water infiltration, developing into a deep profile (Esu, 2010). Landscape topography can affect various soil characteristics, biomass production, solar radiation, precipitation, and overall agricultural output.

Floodplains and their riparian zones are susceptible to preferential flow, attributed to geomorphic depositions, abundant roots, and frequent drying and wetting cycles (Mulholland et al., 1990; Gold and Kellogg, 1997; Carlyle and Hill, 2001; Vellidis et al., 2001; Polyakov et al., 2005; Fuchs et al., 2009). Linear deposits of coarse-grained sediments, characterized by high infiltration rates,

give rise to preferential flow paths, such as gravel outcrops and macropores (Gotovac et al., 2009; Najm et al., 2010). These pathways establish a direct connection between distant floodplain areas and streams. While infiltration is commonly assumed to be uniform at the field level, this overlooks the substantial spatial variability (Biggar and Nielsen, 1976; Vieira et al., 1981) prevalent in anisotropic, heterogeneous floodplain soils (Heeren et al., 2010, 2011, 2014b).

Multiple studies (Thomas and Phillips, 1979; Fox et al., 2004; Djodjic et al., 2004; Akay and Fox, 2007; Gotovac et al., 2009) highlight the significant influence of macropores on both flow and solute transport within the soil. Gold and Kellogg (1997) specifically advocated for the development of distinctive sampling schemes and simulation models tailored to situations where substantial infiltration occurs through preferential flow pathways. However, there has been limited progress in monitoring, theoretical model development, and practical application up to the present. Despite the common assumption of uniform crop infiltration at the field scale, this oversimplification disregards the pronounced spatial variability inherent in anisotropic, heterogeneous floodplain soils (Heeren et al., 2010, 2011, 2014b).

Limited research has been conducted on the impact of variation and catena (slope position) on infiltration in floodplain irrigated

soils in lowland Nigeria. This scarcity of research is due to the perception that, unlike in hilly terrain, elevation variation is not considered significant in lowland areas. Boling et al. (2008) addressed this gap by investigating the influence of topo-sequence position/catena variation on soil properties, hydrology, and rice yield in Southeast Asia. In Southeast Asia, a substantial portion of rainfed lowland rice is cultivated in gently sloping areas with minimal elevation differences. According to Boling et al. (2008), even slight differences in elevation can result in variations in soil properties and hydrological conditions, thereby impacting crop performance and yield. The study suggests that in rainfed areas, it might be appropriate to replace general crop management recommendations with topo sequence-specific management strategies (Boling et al., 2008).

Hence, this research was conducted to evaluate the influence of catena variation on infiltration in floodplain irrigated soils in the lowlands of Kwali Area Council, Abuja Federal Capital Territory, Nigeria.

MATERIALS AND METHODS

Study area

Kwali Area Council, situated in the Federal Capital Territory, was established on October 1, 1996. Geographically, it lies between $8^{\circ} 28' - 8^{\circ} 54'$ North of the Equator and Longitude $6^{\circ} 50' - 7^{\circ} 13'$ East of the Green Witch Meridian, covering a total land area of

approximately 1700 square kilometers. The settlement pattern is dispersed, featuring indigenous clustered types in Kwali, Leda, Dangara, Gada-biyu, Sheda, Kilankawa, Dabi, and Pai. The major ethnic groups include the Gbari, Ganagana, Bassa, Fulani, and others (CIFIIP, 2013).

The climate in Kwali is characterized as hot and humid tropical. It exhibits transitional elements between the southern and northern parts of the country, experiencing distinct wet (March - October) and dry (November - February) seasons. The average annual rainfall is 1358.7mm, with a mean temperature range between 20.7°C and 30.8°C (Balogun, 2001). Rainfall plays a crucial role in agricultural activities within the region, with most farming activities heavily reliant on precipitation (Balogun, 2001).

The study area features notable alluvial soils in Iku plains, gleysols, and fluvisols. These soils exhibit complexity in taxonomic variations, and their drainage conditions are influenced by the depth of the water table. The color of the soils is affected by mottling due to poor drainage. The soil texture comprises clayish and sandy loam, with occasional swampy areas utilized for fadama (irrigated) farming. Additionally, there are upland soils of the ferruginous red tropical type, often derived from crystalline acid or sandy rocks, containing a high proportion of silt. These soils are well-suited for the production of cereal and tuber crops (Balogun, 2001).

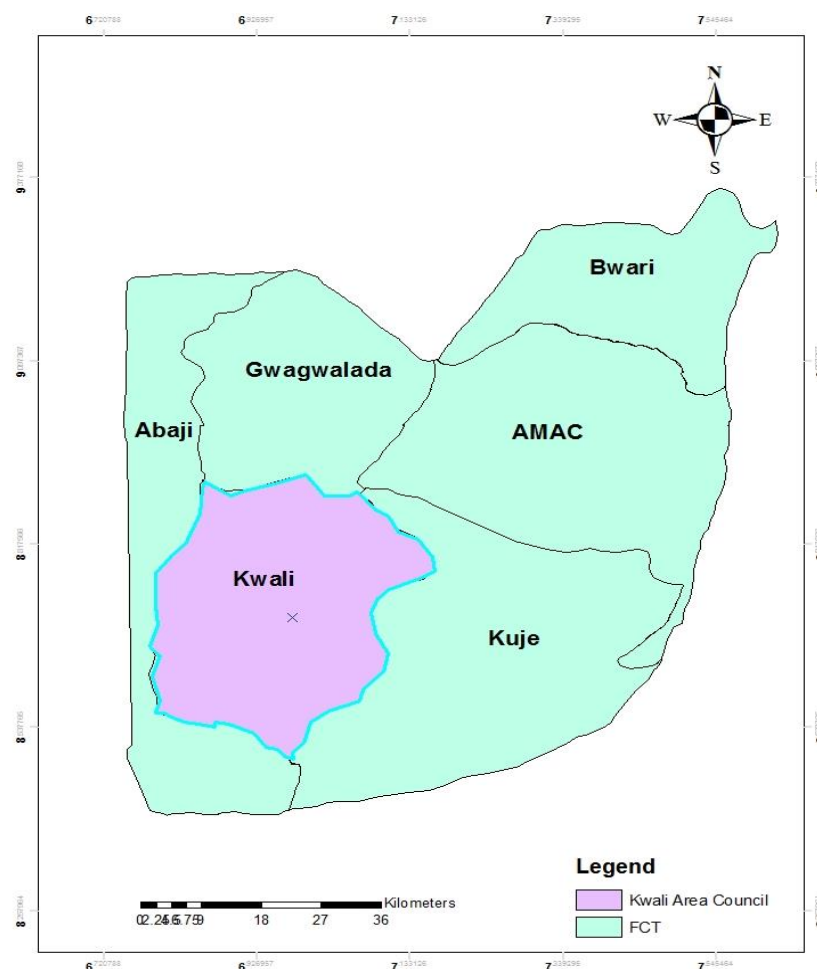


Fig i: FCT Showing Kwali Area Council

Source: Ahmad et al, 2020

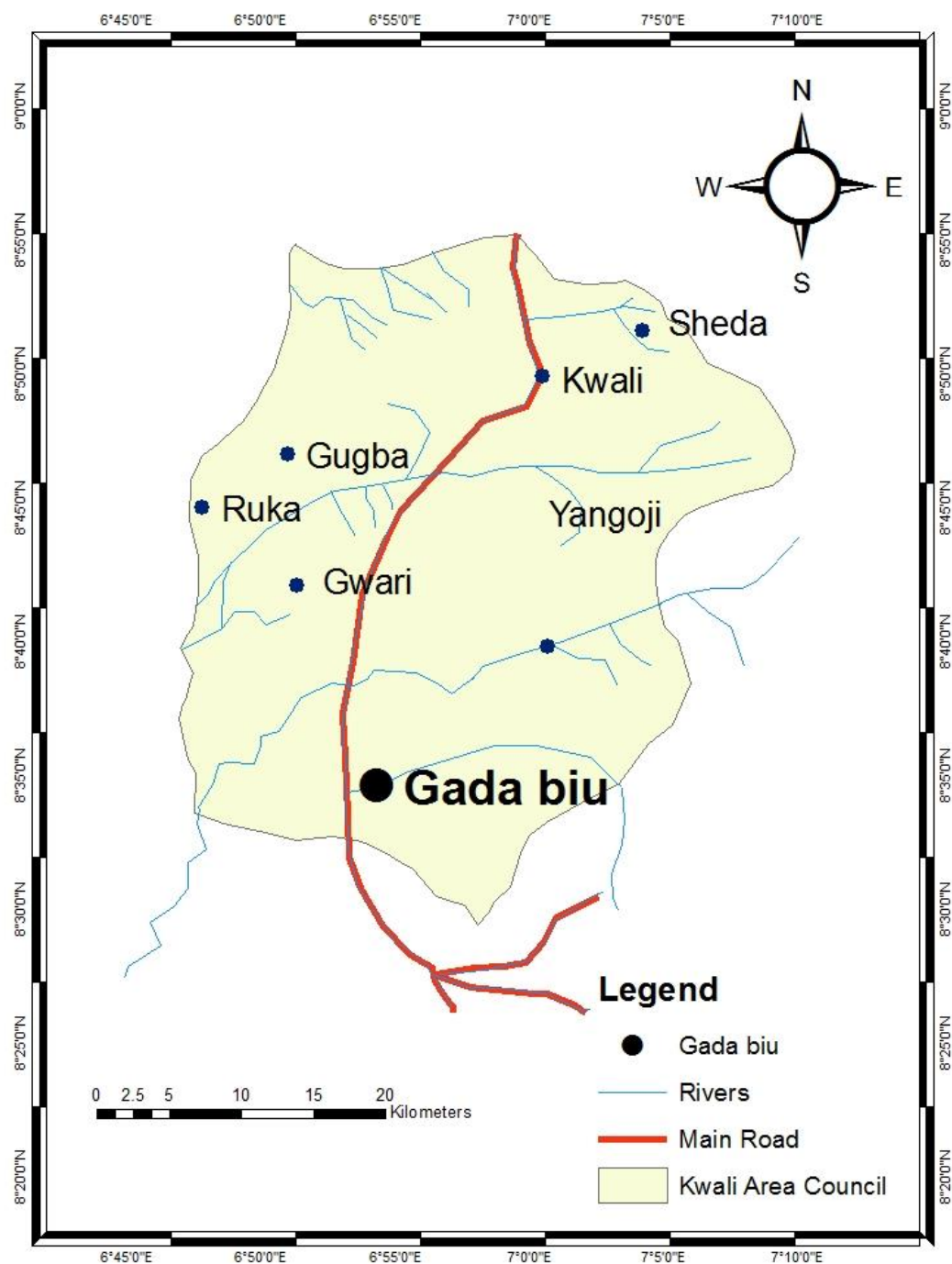


Fig ii: Map of Kwali Area Council showing the Study Area

Source: Ahmad et al, 2020

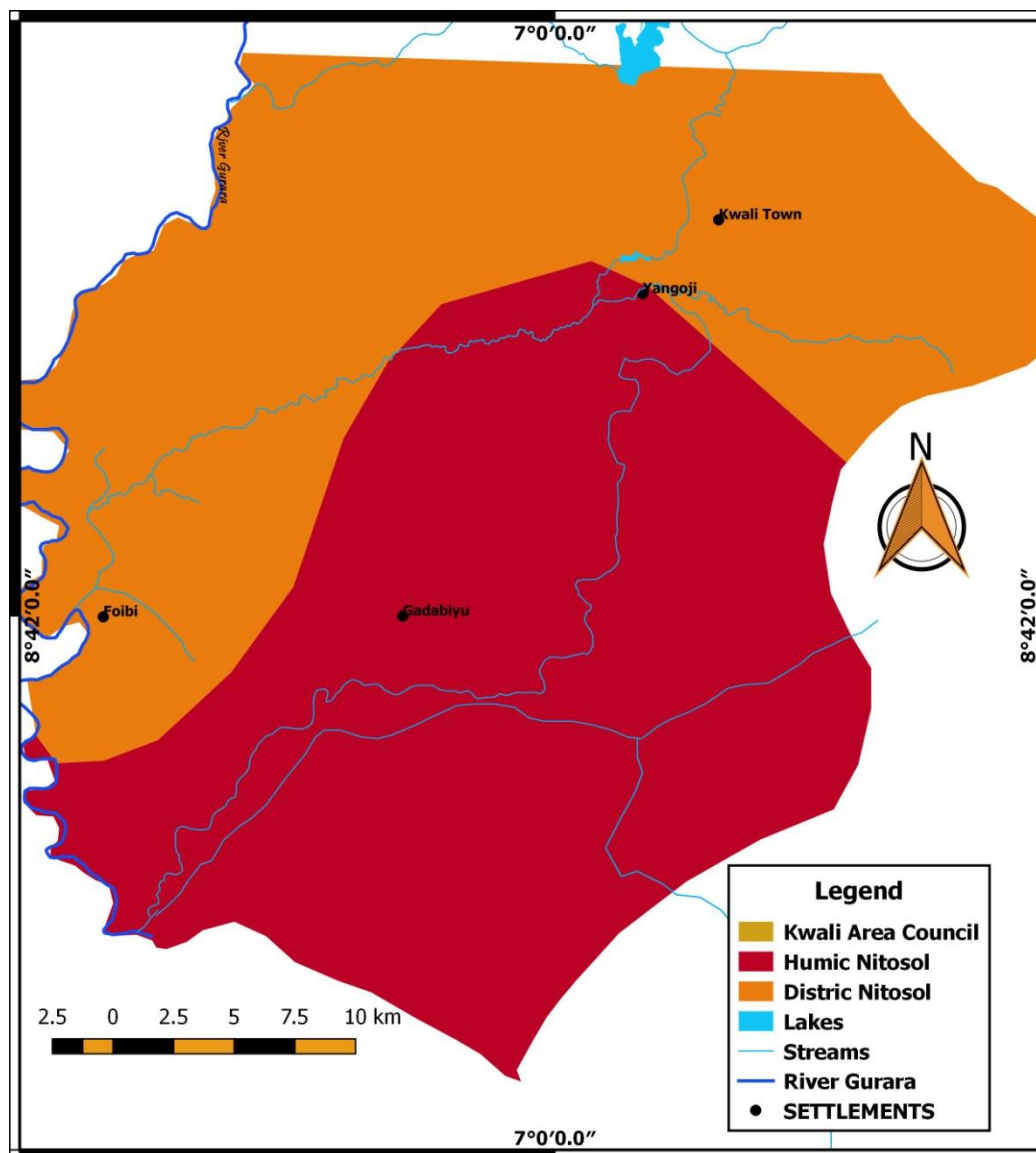


Fig iii: Soil Map of the Study area,
Source: Ahmad et al, 2020

Kwali Area Council boasts an extensive land area conducive to various agricultural activities. The fertile land is ideal for cultivating a diverse range of crops, with a substantial expanse of fadama land particularly suitable for rice farming. According to CIFIIP (2013), the estimated Fadama land in Kwali Area Council spans over 40,000 hectares.

The climate in this region is favorable for the production of a wide variety of crops, encompassing legumes (groundnuts, soya bean, lima bean, Bambara nut, and pigeon pea), cereals (maize, millet, sorghum, and rice), solanaceous crops (peppers, tomato, garden eggs, and ginger), tree crops (guava, cashew, mango, orange, and paw-paw), and root and tuber crops (yam, sweet potatoes, cocoyam, and cassava). Livestock production in the area primarily involves swine, goats, sheep, and poultry. Additionally, hunting and beekeeping are practiced as supplementary activities (CIFIIP, 2013).

The majority of the area is occupied by smallholder rainfed and irrigation farmers engaged in the cultivation of various crops, including yam, rice, melon seed, cocoyam, cassava, pepper, tomato, okra, onion, garden eggs, spinach, benniseed, and millet,

among others (CIFIIP, 2013). Refer to figures I, II, and III for further details.

Field procedures

The survey of the topo-sequence/catena/slope segment was conducted utilizing a Germin GPS, which facilitated the identification of different segments based on geodetic heights and the corresponding coordinates of these segments, referred to as Mapping Units. Three distinct slope segments were identified, and the slopes have been categorized as outlined in Table I.

FIELD INFILTRATION ANALYSIS

Prior to the infiltration analysis, the irrigation field was divided into three slope positions (catena) based on elevations determined using a GPS device. These slope units were denoted as MU1 (Mapping Unit 1), MU2 (Mapping Unit 2), and MU3 (Mapping Unit 3), corresponding to the upper slope, middle slope, and lower slope, respectively.

Infiltration measurements were conducted in all identified mapping units during the dry season. A double-ring infiltrometer was employed to measure soil permeability using the falling head

method, following the procedures outlined by Mbagwu (1997) and Oku (2012). The dimensions of the rings used were 50 cm in height and 30 cm in inner diameter, while the outer ring had a height of 50 cm and a diameter of 60 cm. These cylinders were inserted into the soil surface, and ponded water was maintained in both rings. Water intake measurements were specifically recorded in the inner cylinder. Consistent with Mbagwu (1997)'s description, one side of the inner cylinder was marked at two points (5 cm and 15 cm) from the ring, using a meter rule permanently affixed inside the inner ring as a reference. These reference points aided in the measurement process.

The infiltration process involved pouring water into both the inner and outer rings. As the water level dropped to the 5 cm reference point, additional water was swiftly added to restore the water level to its initial point. The stopwatch recorded the time and level before and after each filling. This process continued until a steady-state rate was achieved. To prevent water intake during refilling, the rings were filled at short intervals, assuming instantaneous refilling in the subsequent data analysis.

DISCUSSION OF RESULT

The analysis of data from double-ring infiltration tests conducted in the Kwali Irrigation study revealed distinct patterns in the infiltration rates of the three soil units along the topo sequence. These rates were plotted against time to illustrate cumulative and equilibrium values, with the results presented in Table II.

The instantaneous infiltration rates were consistently high, ranging from 8.0 to 21.4 cm hr⁻¹. Notably, the upper slope unit exhibited chaotic increases and decreases in the first 4 hours, while the middle and lower slopes showed similar patterns just after 3 hours. This behavior was attributed to the presence of an intricate network of ant channels in the upper slope unit.

The overall medium soil texture in the area facilitated rapid water infiltration, especially in the upper and lower slope units. Consequently, irrigation frequency should be adjusted based on crop types and their moisture requirements. While rapid water movement into the soil may lead to high leaching, there is minimal surface run-off due to the well-drained nature of the soils. Excess water from irrigation or heavy rainfall is efficiently absorbed, minimizing surface run-off. However, this implies that more water is needed for irrigation at any given time, depending on crop water requirements.

The control of water infiltration is influenced by the permeability of both surface and subsoil. Measuring infiltration rates is crucial in surveys related to irrigation development or soil conservation, aiming to optimize soil use sustainably. It is considered a pivotal process in landscape hydrology, impacting plant moisture regimes and influencing soil degradation, chemical run-off, and down-valley flooding (Brady and Weil, 2002).

The upper-slope soils, initially drier in terms of moisture content, exhibited a higher, rapid, and chaotic infiltration rate in the early hours. Conversely, already saturated middle slope soils displayed a slower infiltration rate. Soil texture, bulk density, topography, and moisture content were identified as factors influencing infiltration. Additionally, the infiltration equilibrium varied along the three-slope segments. At the upper slope, equilibrium was reached at a mean cumulative infiltration value of 110 cm. In the middle slope segment, equilibrium occurred earlier, at a mean cumulative infiltration value of 44 Qcm, while at the lower slope segment, equilibrium was reached at a mean cumulative infiltration value of 64 Qcm. Figures IV, V, and VI visually depict these findings, confirming the trends outlined in Table II.

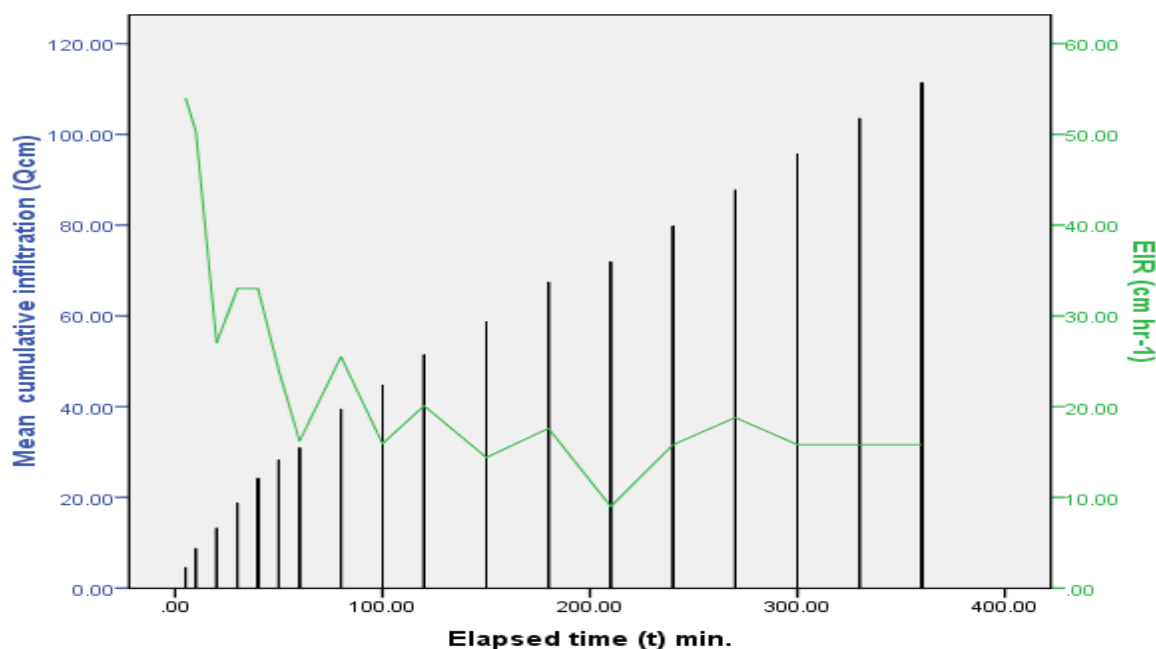


Fig iv: Upper Slope Infiltration Trend

Source: Fieldwork

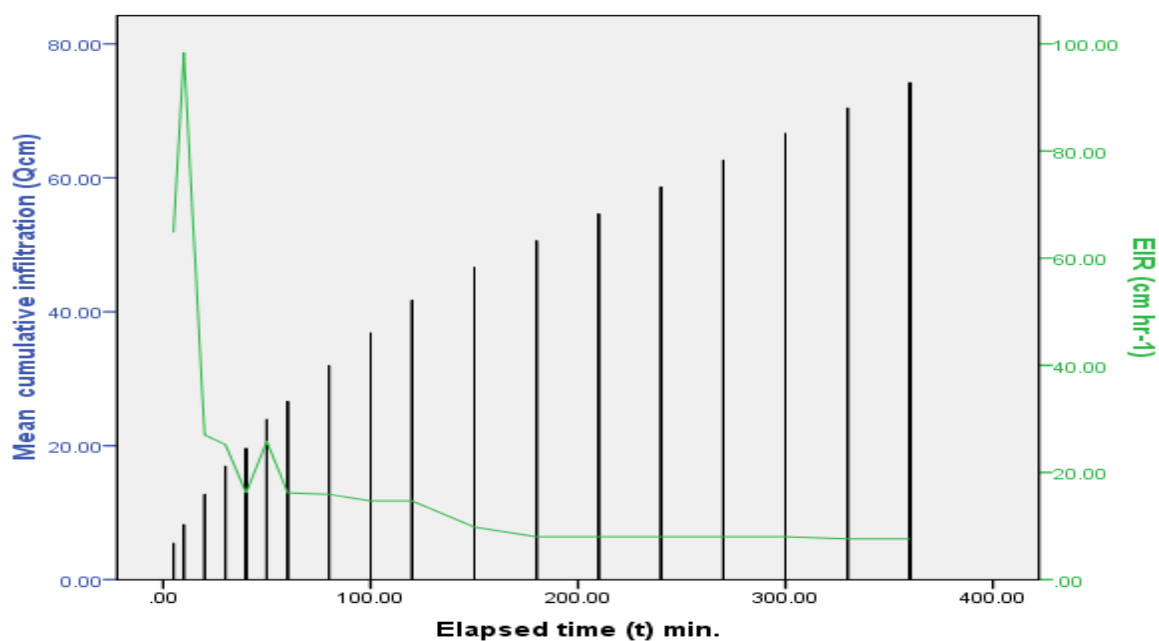


Fig v: Middle Slope Infiltration Trend

Source: Fieldwork

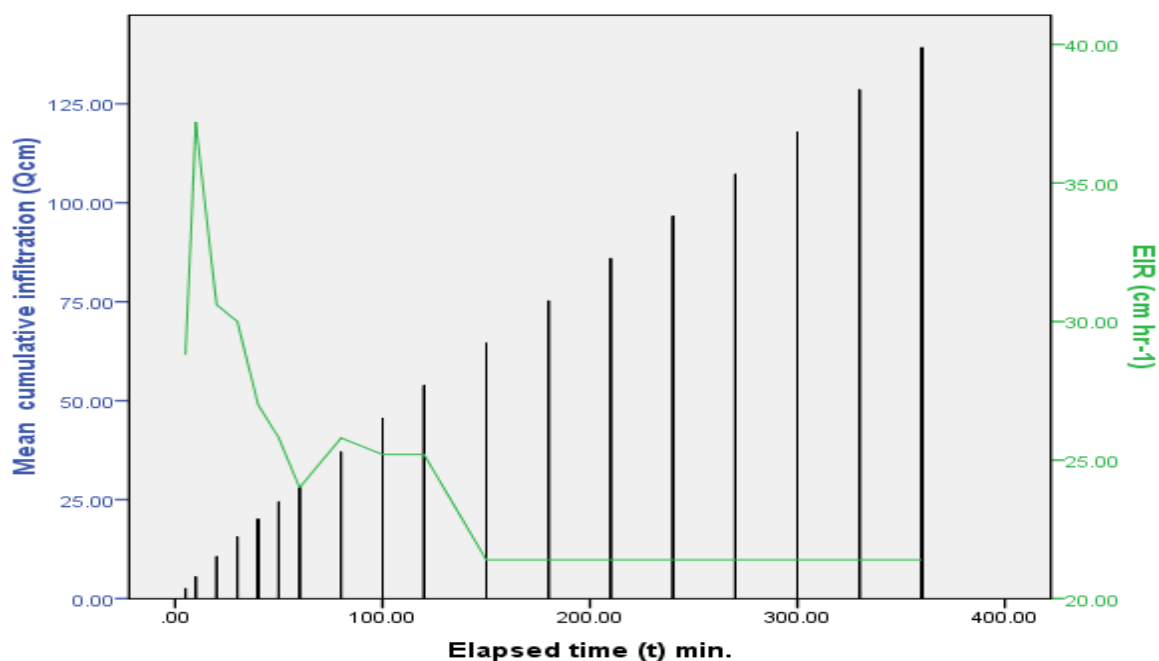


Fig vi: Lower Slope Infiltration Trend

Source Fieldwork

CONCLUSION AND RECOMMENDATION

Irrigated field surveys are essential for monitoring soil quality and productivity changes. This study aimed to assess the impact of irrigation practices on soil infiltration rates in the Kwali irrigation area. Methodology followed standard procedures, and a literature review informed the study.

Equilibrium infiltration rates were categorized as moderate, slow, or rapid based on soil texture and waterlogging influence. The results suggest that excessive irrigation may be causing issues,

particularly on the middle and lower slopes. In the Kwali irrigated area of the Federal Capital Territory, Abuja, the study indicates a moderate effect of irrigation on soil infiltration rates across the three catenae studied. Furthermore, this effect varies within and along different slope segments or positions.

The study recommends implementing slope segment-specific water management practices during irrigation, considering the distinct responses of each segment to water application. This approach aims to optimize irrigation practices and mitigate potential negative impacts on soil infiltration rates.

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