FACTORS INFLUENCING FARMERS' DECISIONS ON TIMING AND APPLICATION RATES OF IRRIGATION WATER IN MWALA, MACHAKOS COUNTY

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D.M. Onyancha, C.K.K. Gachene, and G. Kironchi
University of Nairobi, Nairobi, Kenya
e-mail: deborahmongína@gmail.com; +254 713 377 983

ABSTRACT

This study examines the factors influencing farmers' water application decisions in arid and semi-arid regions, where water scarcity is a significant challenge due to unreliable rainfall. The research involved interviews with 41 farmers from the Equity Group Foundation extension scheme, focusing on their irrigation practices, including scheduling, timing, application rates, and considerations of plant and soil conditions. Additionally, soil samples from farms using furrow, drip, sprinkler, and hosepipe irrigation systems were analyzed, with field measurements taken to estimate water application rates. The findings reveal that farmers prioritize plant conditions (97% degree of importance) when deciding when to irrigate, followed by soil conditions and days since the last irrigation (both 95%), with recent rainfall also playing a key role (87%). For determining the amount of water to apply, soil conditions were deemed most important (80% importance), followed by plant conditions (75%) and recent temperature (70%). The study also found that water application amounts often exceeded the crops' requirements across all irrigation methods, with furrow irrigation having the highest flow rate (0.479 litres per second). The soils were found to have high coarse-textured contents, resulting in low moisture retention capacities and high hydraulic conductivity. The study concludes that proper irrigation scheduling is essential for effective water use and recommends enhancing extension services to provide farmers with training on soil water holding capacity, crop water needs, and plant characteristics to guide irrigation decisions.

Key words: Irrigation scheduling, Plant conditions, Soil conditions, Irrigation requirement

INTRODUCTION

Water scarcity and the growing competition for resources, especially in arid and semi-arid regions, have made efficient water use in agriculture increasingly critical (Priyan, 2021). To address this challenge, proper irrigation scheduling has become essential for minimizing water wastage. For farmers to make informed decisions on how often and how much water to apply, they must have accurate information about crop water use and soil moisture content (Ara et al., 2021; Lakhiar et al., 2024). Several key factors influence irrigation decisions, including the properties of the soil, characteristics of the crops, availability of water, and climatic conditions such as rainfall and temperature (Gu et al., 2020; Zinkernagel et al., 2020). Understanding soil type and its water-holding capacity is vital for determining the frequency of irrigation, as different crops require varying amounts of water throughout their growth cycles, depending on environmental conditions (Pereira et al, 2021, Plett et al., 2020).

Effective irrigation scheduling not only optimizes the use of water but also ensures the efficient use of energy and other agricultural inputs, leading to improved crop yields, enhanced crop quality, and lower production costs (Ray and Majumder, 2024, Lakhiar et al., 2024). Despite these benefits, research has shown that many farmers fail to practice proper irrigation scheduling, often due to a lack of understanding of crop water needs or because water is perceived as being inexpensive (Sun et al., 2022; Fernández García et al., 2020). This study explores the factors that influence farmers' decisions regarding the timing and application rates of irrigation water in Mwala, Machakos County, Kenya.

MATERIALS AND METHODS

Study design and data collection

The study was realized from survey statistics and field measurements done at the study area, Mwala, Machakos County. The specific irrigation scheduling technique adopted by farmers in irrigating crop(s), the factors influencing their timing and application rates, and any additional information including the plant and soil conditions, planting dates and the farmers' source of technical advice was obtained in form of an interview questionnaire. This was administered to the forty-one purposefully selected farmers who are registered by the Equity Group Foundation extension scheme.

Laboratory soil analyses and field assessments of irrigation timing and application rates

Baseline soil characterization was done through laboratory analyses of disturbed and undisturbed samples collected from farms using furrow, drip, sprinkler, and hosepipe irrigation systems, focusing on soil texture, organic carbon, hydraulic conductivity, moisture retention, and bulk density. The data collected to estimate the irrigation timing and application rates for the various irrigation methods in the field measurements included: flow rate, the volumes of water applied and dimensions of the irrigation units. The flow rate (Q) was assessed by measuring the time (T) required to fill containers of a known volume (V) for drip, sprinkler and hosepipe irrigation systems using Equation 1 as described by Trimmer (1994):

$$Q = \frac{\Delta V}{\Delta t} \qquad \text{Equation 1}$$

where: Q= flow rate in liter per second (l/s), V= volume in liters (l), t= time in seconds (s)

Furrow irrigation timing and application rates were estimated by measuring furrow lengths, recording water flow times at various stations, and periodically measuring inflow and outflow rates. The final inflow-outflow measurements and the maximum depth of flow were then recorded according to the methods as outlined by Vázquez et al. (2005) (Equation 2)

$$Q \times t = d \times A \qquad \text{Equation 2}$$

where: Q= flow rate, in liters per second (l/s); t= set time or total time of irrigation (s); d= depth of water applied (mm) and A= area irrigated (m^2).

Soil samples were collected at different depths along furrows to estimate the wetting front by measuring moisture content differences, with this process replicated three times on three farmers' fields. Measurement of the amount of irrigation water applied (d) in mm is deduced by (Equation 3):

$$d(mm) = \frac{Q(l/s)}{A(m^2)} \qquad \text{Equation 3}$$

where: Q= flow rate, in liters per second (l/s); d= depth of water applied (mm) and A= area irrigated (m^2).

The collected data was analyzed using ANOVA in Genstat 15th version, with significance determined at $P \leq 0.05$, and further analysis was conducted using SPSS (Ver 21)

RESULTS AND DISCUSSION

Timing of irrigation application rates

The results of the analysis of farmers' responses showed that majority ranked plant conditions (97%), soil conditions (95%), days since last irrigation (95%), and recent rainfall (88%) as the most critical factors in determining when to irrigate using a Likert scale. Key soil conditions included moisture, soil type, and topography, while plant factors included crop type, drought sensitivity, development stage, and fruiting. Farmers varied their irrigation schedules based on weather conditions and relied on personal experience, extension personnel, and consultants for guidance. These findings are consistent with recent studies by Dong (2022) and Owino and Söffker (2022) which highlighted the importance of soil and plant conditions, weather, and evapotranspiration in efficient irrigation scheduling.

Factors Influencing Irrigation Application Amounts

Regarding the amount of water applied, farmers identified soil moisture, water-holding capacity, soil texture, topography, and plant conditions (such as stress, growth stage, rooting depth, and crop yield) as the most important factors. However, while all farmers timed their irrigation, 60% did not monitor the exact amount of water applied, often relying on rough estimates. Only 40% carefully checked water application by visually assessing soil wetness or timing the emptying of tanks. This lack of precise monitoring is concerning in water-scarce regions like Mwala, Machakos County, as it could lead to either under- or over-irrigation, thereby failing to meet crop needs or wasting water. These findings align with studies by Singh et al. (2024) and Nesamvuni et al. (2022), which reported that farmers often apply excess water due to perceived yield benefits or the inconvenience of irrigation scheduling. However, careful water management is crucial for maximizing irrigation efficiency, conserving water, and reducing energy use (Ray and Majumder, 2024, and Kilemo, 2022).

Measurement of Irrigation Water

The results as illustrated in Figure 1 show that furrow irrigation exhibited the highest quantities of irrigation water application per irrigation event as compared to the other systems. Drip had the least but required more applications especially for mangoes and oranges. This data collection on irrigation monitoring was done in the mid growth stage of the crops during the dry season. The application amounts were then compared to the CROPWAT computed data on irrigation water requirements to assess whether the farmers were practicing efficient irrigation application. The lowest average differences between applied water and the irrigation requirements were observed in vegetables, which was 8 mm and bananas 3 mm, and the largest in mangoes, 75 mm and oranges, 64 mm; followed by French beans, 36 mm, maize, 25 mm, and tomatoes, 18 mm. From these comparisons, it is revealed that farmers were irrigating more than was required on the crops especially on oranges and mangoes.

Field measurements revealed significant differences in flow rates among irrigation systems, with furrow irrigation exhibiting the highest flow rate (0.479 l/s), use of hosepipe, 0.232 l/s, sprinkler, 0.074 l/s and drip irrigation the lowest (0.003 l/s). The lower flow rates in drip and sprinkler systems are attributed to their more controlled water application methods, making them more efficient compared to furrow and hosepipe systems. These findings are supported by studies such as Asif et al. (2024) and Olamide et al. (2022), which demonstrated that drip irrigation systems use less water and are more efficient than furrow systems.

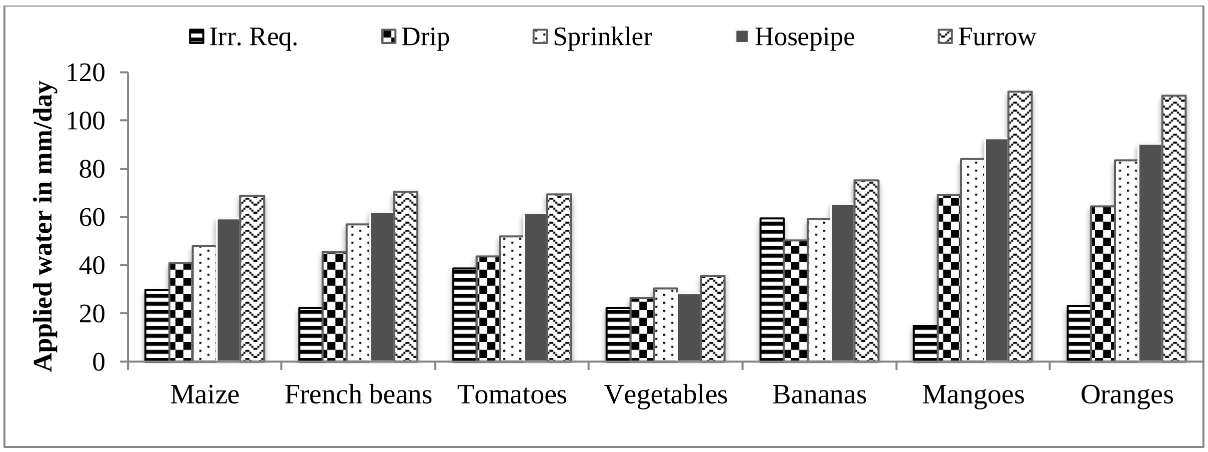

Figure 13. Comparison of applied water and irrigation requirements of various crops.

Soil-Water Relationships

Soil properties under different irrigation systems were also examined, revealing significant differences in sand content, bulk density, hydraulic conductivity, and soil moisture retention (Table 1). Soils under hosepipe irrigation exhibited the highest sand content and hydraulic conductivity, leading to faster water infiltration and lower water retention capacity. This contrasts with drip irrigation, which showed lower sand content and higher water retention. These findings align with studies by Rivier et al. (2022) and Wang et al. (2021), which highlighted the impact of soil texture on hydraulic properties and irrigation efficiency. Additionally, the low organic carbon content in soils (ranging from 0.68% to 0.91%) was attributed to the arid and semi-arid conditions of the study area, as noted by Lei et al. (2022) and Hag Husein et al. (2021). The lack of organic matter application by farmers further exacerbated this issue, emphasizing the need for improved soil management practices to enhance irrigation efficiency.

Table 1. Soil properties under different irrigation methods.

Soil properties	Irrigation methods				L.S. D	p Value
	Drip	Furrow	Hosepipe	Sprinkler		
Hydraulic conductivity (cm/hr)	0.48a	0.69b	3.09d	2.36c	**0.09**	<.001
Soil moisture retention (vol%)	95.80c	92.67c	81.00a	87.89b	**3.54**	<.001
Bulk density (g/cm^3)	1.31a	1.47b	1.65c	1.54b	**0.08**	<.001
Organic carbon (%)	0.76ab	0.91b	0.68a	0.84b	**0.15**	0.037
Sand (%)	64a	72bc	77c	71b	**6.10**	0.01
Clay (%)	29b	22ab	20a	23a	**4.77**	0.011
Silt (%)	7a	6a	3a	6a	**3.65**	0.105

CONCLUSIONS AND RECOMMENDATIONS

The study assessed factors influencing farmers' decisions on irrigation timing and water application, revealing that plant and soil conditions, recent rainfall, and days since last irrigation were key determinants. Results showed significant differences in water application rates and net irrigation requirements across irrigation methods, with furrow and hosepipe methods applying the most water due to higher flow rates. Farmers' limited knowledge on proper irrigation scheduling often led to excessive water use, which could be mitigated by improving extension services, training on soil and crop characteristics, and encouraging better water management practices, such as reducing irrigation time and applying manure to enhance soil water retention.

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