A COMPARATIVE EVALUATION OF IRRIGATION EFFICIENCIES FOR SMALLHOLDER IRRIGATION SCHEMES IN MURANG'A SOUTH DISTRICT, KENYA

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Abstract

Irrigation schemes are usually designed and implemented on the basis of assumed efficiencies in water application, water conveyance, and water distribution. However, over time, physical changes in the schemes such as poor maintenance of structures, soil property changes and deterioration of equipment may alter these efficiencies. It is therefore imperative that the efficiencies are periodically evaluated as a way of monitoring and evaluating the irrigation scheme. This study identified the irrigation technologies the farmers were using and evaluated the water flow rates and efficiencies of several smallholder schemes in Murang'a South District to ascertain whether these schemes were operating at their design recommendations and efficiencies. Water flow rates were measured using Parshall flumes, while soil water statuses were measured with tensiometers. Social economic data was collected using structured questionnaires. The results showed that the sampled schemes had high water conveyance efficiencies (95%). This was attributed to the use of pipes and lined canals in the main conveyance systems. Distribution efficiencies ranged between 76% and 95% while application efficiencies varied between 58% and 86%. The overall efficiency was between 44 and 77%. The water application uniformity was generally below acceptable limit, ranging between 41 and 71%. The low water application uniformity was attributed to the improper overlapping and spacing of sprinklers. It was therefore recommended that the farmers be retrained on the proper layout, spacing and overlapping of sprinklers in addition to water saving technologies in irrigation.

Key words: Irrigation efficiencies, uniformity, scheme evaluation, sprinkler overlapping

1 Introduction

In planning and designing an irrigation system, a major problem is to decide what water use efficiency to apply in the calculations. It is common practice that this efficiency is either conjectured or derived from existing irrigation systems which is unlikely to suit the conditions of a project area and its future state. To cover the uncertainty of water use efficiency in design of an irrigation system, canals, structures, and reservoirs are given a greater capacity than would be necessary if objective efficiency standards were available.

Irrigation performance is estimated using two measures: distribution uniformity and application efficiency. Distribution uniformity is a measure of how evenly water soaks into the ground across a field during irrigation. Overall application efficiency (E_p) is the product of conveyance efficiency (E_c), distribution efficiency (E_d) and application efficiency (E_a), expressed in equation 1.0.

$$E_p = E_c \times E_d \times E_a \quad \text{...} \quad (1)$$

$$\text{Conveyance efficiency } (E_c) = \frac{\text{Farm water supply}}{\text{Diverted supply}}$$

$$\text{Distribution efficiency} (E_d) = \frac{\text{Water received at the farm inlet}}{\text{Water received at the inlet to a field}}$$

$$\text{Application efficiency } (E_a) = \frac{\text{Volume of crop water requirement}}{\text{Volume of water delivered to the field}}$$

1.1 Smallholder Irrigation Development in Kenya

In Kenya smallholder irrigation development is one of the key strategies for land use intensification with expected positive effects on rural incomes and poverty alleviation, 20% of the irrigation potential or 106,000 ha is already under irrigation; 50% of this area is under smallholder irrigation; about 15,000 ha of the area under smallholder irrigation are operated by individual farmers while about 35,000 ha are under communal irrigation schemes (Hannover, 2007)

With over 80% of the smallholder irrigation schemes in Kenya being furrow-based, irrigation efficiency is very low, while facilities for post-harvest processing and handling are poorly developed (Mati, 2008)

1.2 Study Areas

All the schemes evaluated under the study are located in various divisions of Murang'a South and Kigumo districts of Murang'a County. In designing these schemes the efficiencies were assumed as follows:

Thangaini scheme: Conveyance efficiency=95%, Distribution efficiency =95%, Application efficiency=75%, therefore, overall efficiency =95*95*75**=**68%. The project is benefiting 50 farmers each irrigating 0.2Ha with a crop water requirement of 0.35l/s/ha (Gicheru, 2004).

Gatundu scheme: Conveyance efficiency=95%, Distribution efficiency =95%, Application efficiency=75%, overall efficiency =95*95*75**=**68%. The water source for the scheme is river Kirichiungu which drains to river Thika. The project is permitted to abstract 45 l/s with a crop water requirement of 0.313 l/s/ha (Gicheru, 2008).

Karathe- Thaara scheme: Conveyance efficiency for a lined canal = 95%**,** Distribution through pipes = 95%**,** Application efficiency =70 %**,** Overall efficiency = 95 x 95x70 =63 %. The water source for the project is river Thaara with a discharge 113l/s and the water demand for the project is 34 l/s and a crop water requirement of 0.51l/s/ha (Gicheru, 2005).

Kieni-Gathugu scheme: Conveyance efficiency=95%, Distribution efficiency =95%, Application efficiency=75%, overall efficiency =95*95*75=68% with a crop water requirement of 0.61 l/s/ha

1.3 Irrigation Technologies and Practice in the Schemes

Thangaini, Gatundu and Kieni-Gathugu schemes operated sprinkler irrigation method using low pressure sprinklers and hosepipes while Karathe operated surface irrigation. Water was abstracted from the rivers using weirs constructed at the intake points, conveyed through plastic pipes or concrete lined open channels and distributed using ½ inch piped and unlined canals to individual farmers as recorded in table 1.0.

Table 1: Irrigation technologies applied in the schemes

SCHEME	IRRIGATION METHODS	EQUIPMENT	SEQUENCE
GATUNDU	SPRINKLER	Impact sprinklers Hosepipes	Intake-6 inch conveyance plastic pipe-1/2 inch distribution pipe to each farmer- application by hose pipe or micro sprinkler
KIENI	SPRINKLER	Impact sprinklers Hosepipes	Intake-6 inch conveyance plastic pipe-1/2 inch distribution pipe to each farmer- application by hose pipe or micro sprinkler
THANGAINI	SPRINKLER	Impact sprinklers hosepipes buckets	Intake-4 inch conveyance plastic pipe-1/2 inch distribution pipe to each farmer- application by hose pipe or micro sprinkler
KARATHE	FURROW	Buckets	Intake- lined conveyance canal-open unlined distribution canals-application by bucket or furrows

Gatundu is the largest scheme of the four with an area of 35 ha and has the highest scheme discharge of 45l/s and Kieni-Gathugu has the largest number of farmers. All the schemes except Gatundu operates an irrigation interval of 12 hours, Gatundu operate a 10 hours irrigation interval. Table 2 shows scheme areas, discharge, and number of farmers per scheme as well as irrigation intervals.

Table 2: Irrigation practices in the schemes

SCHEME	Scheme area (ha)	Scheme discharge (l/s)	Number of farmers	Irrigation interval (hrs)	Area irrigated per farmer (ha)
KIENI	33	20	120	12	0.275
GATUNDU	35	45	52	10	0.4
THANGAINI	20	14	60	12	0.2
KARATHE	33	34	55	12	0.3

2 Methodology

Surveys and observations were carried out in the study areas to identify the geographical location of the schemes and familiarize with the areas and the farmers as well. Structured questionnaires and informal interviews to the farmers and designing engineers were used collect socio-economic data.

A mechanical flow meter method was used to measure flow through distributing pipes and sprinklers which involved Bucket-and-stopwatch flow measurements where volumetric flow of water was measured. Measurements were done in three farms per scheme. An open channel flow measurement was used in Karathe scheme where the level of the water flowing in the distribution and application channels was measured using the Parshall flume. This depth was converted to a flow rate according to formula of the form $Q=KH^X$ obtained by calibration of the flume.

Calibration of Parshall flume was done by placing it in an open channel and discharge was measured with a 90^o V notch. The head, h (m), on the Parshall flume was measured at varying discharge rates . Equation 2.0 was used to calculate the coefficient of discharge K.

$$K = 81.2 + \frac{0.24}{H} + (8.4 + \frac{12}{\sqrt{D}})(\frac{H}{B} - 0.09)^2 \quad \text{..........} (2)$$

Where:
B – Width of the open channel, (m)
D – Depth of the ''V'' notch from the bottom of the waterway, (m)
H – Water head on the V- notch, (m)
K – Coefficient of discharge
Q - Flow rate (m^3/min)
h - Upstream depth in the Parshall flume, (m)

Flow rates measured using the Parshall flume were calculated using equation 3.0.

$$Q = 4.9952\, h^{1.5919} \quad \text{..........} (3)$$

Uniformity of distribution was measured using a grid of catch cans set out in a pattern of 2m x 2m on a level field in 3 farms in each scheme and the volume of water in each can is obtained noting its location with reference to the sprinkler location. The % Christiansen's Uniformity Coefficient (CUC) for each farm under the prevailing conditions was determined using equation 4.0.

$$\% CUC = 100 \times \left(1 - \frac{\text{average deviation}}{\text{Average depth}}\right) \quad \text{..........} (4)$$

3 Results and Discussion

Irrigation efficiencies varied from farm to farm in the schemes depending on management practices carried out by a particular farmer as illustrated in Figure 1.

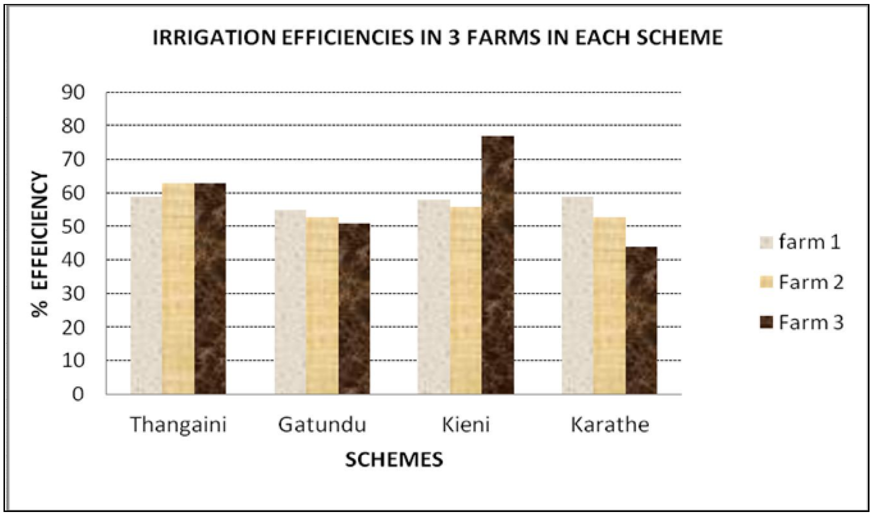

Figure 1: Irrigation efficiencies for 3 farms in each scheme

Karathe scheme had the lowest range of 44-53% since they operated furrow irrigation method and water losses occurred by seepage and evaporation, followed by Gatundu with a range of 51-55%; Thangaini with a range of 59-63% and Kieni-Gathugu with a range of 56% -77%.

On average, the surface irrigating scheme Karathe operated at the lowest efficiency of 52% while of the 3 sprinkler irrigation schemes, Gatundu ranked third operating at 53% followed by Thangaini and Kieni at 62% and 64% respectively. All the farms evaluated were operating at efficiencies lower than the design assumed efficiencies as shown on Figure 2.

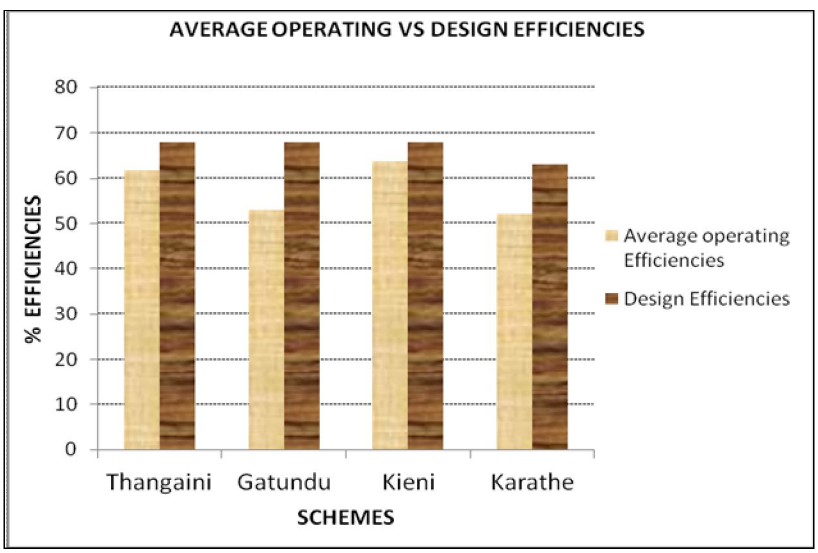

Figure 2: Average operating and design efficiencies of the schemes

These results could be probably due to leakage in the distribution pipes observed in most farms especially in Gatundu and Thangaini schemes; lack of knowledge of sprinkler precipitation rates, flow rates, crop water requirements and the required irrigation scheduling; lack of knowledge on the amount of water farmers apply on their farms due to lack of measuring equipment and knowledge; most farmers operate impact sprinklers which are designed to spray in a fixed full circle thus irrigating roads and fences when irrigating the edges of the fields; weeds growing in the conveyance ditches leading to water losses though transpiration in Karathe scheme and water loss by seepage through the unlined canals in Karathe.

The Christiansen's coefficient of uniformity is an indicator of how equal (or unequal) the application rates are throughout a field. The lowest range of CUC values in 3 farms of each sprinkler irrigated schemes were observed in Kieni at 41-49%, followed by 41-54% in Thangaini and 65-71% in Gatundu as illustrated by Figure 3.

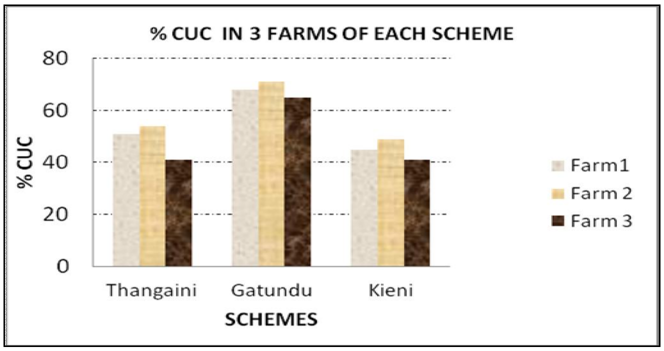

Figure 3: Christiansen's uniformity coefficients for 3 farms in the schemes

Acceptable values of uniformity coefficients vary with the type of crop being grown. For shallow rooted crops, the uniformities should be high CUC values greater than 87%. For typical field crops, CUC values greater than 81% are reasonable. For deep rooted orchard and forage crops, uniformities may be fairly low if chemicals are not injected CUC values above 72% are allowed (Smajstrla *et al*, 2009).

On average, The CUC values achieved in the schemes were not acceptable even for typical field crops, Kieni recorded the lowest values at 45%, 49% in Thangaini and 68% in Gatundu illustrated in Figure 4.

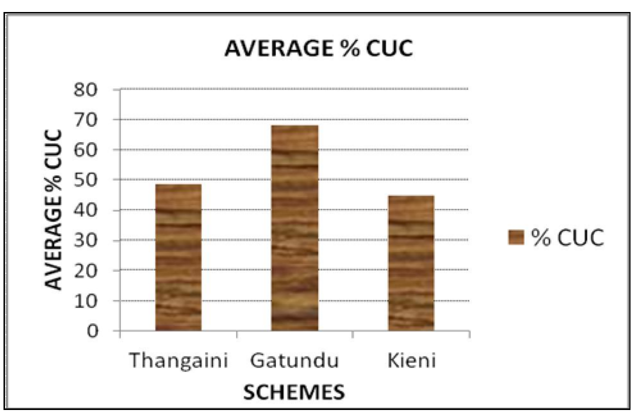

Figure 4.0: Average Christiansen's uniformity coefficients in the schemes

These low coefficients of uniformity could be due to inadequate sprinkler overlap in sprinkler irrigation due to too large spacing between sprinklers, wind effect on sprinklers sprays which was enhanced by mounting the sprinkler too high so as to supply a wider diameter practiced by some farmers and sprinkler nozzles clogging by solid particles in the irrigation water that leads to uneven application since the sprinkler has to keep on being unblocked manually.

Following the predetermined sprinkling diameter of 10m in farm 3 of Kieni- Gathugu scheme, sprinkler spacing for a square pattern was implemented and evaluated for uniformity of distribution. Measurements were made and the farm pegged to mark the position of sprinkler when transferring. The sprinklers were placed at a distance of 0.9R where R is the sprinkling radius. As illustrated by Figure 5.

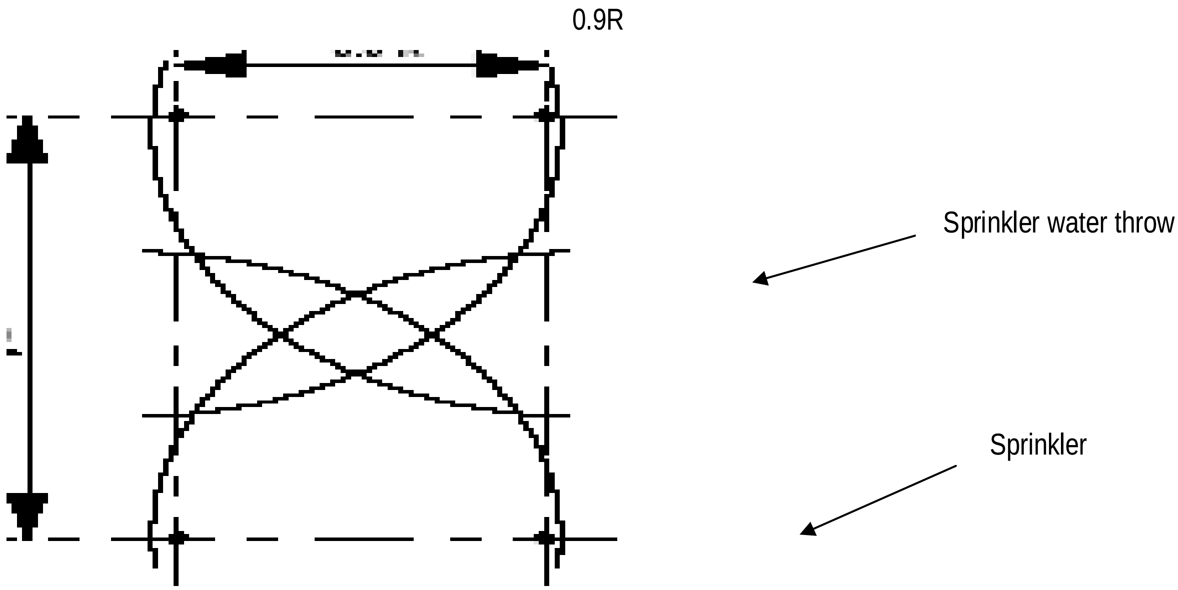

Figure 5.0: Illustration of implemented and evaluated sprinkler spacing

The uniformity of distribution was determined using a grid of catch cans and a CUC of 80% was achieved. This is higher compared to the CUC achieved by the farmers and this sprinker spacing and arrangement was recommended to the farmers.

3.1 Farmer training and capacity building

Inadequate training was recorded in the schemes especially Thangaini and Gatundu. 100% of respondents in Kieni had been trained on sustainable irrigation development. Percentage farmers ever trained on irrigation, those aware of water conserving irrigation technologies and those that need more training per scheme as obtained from the questionnaires analysis are as shown on Figure 6.

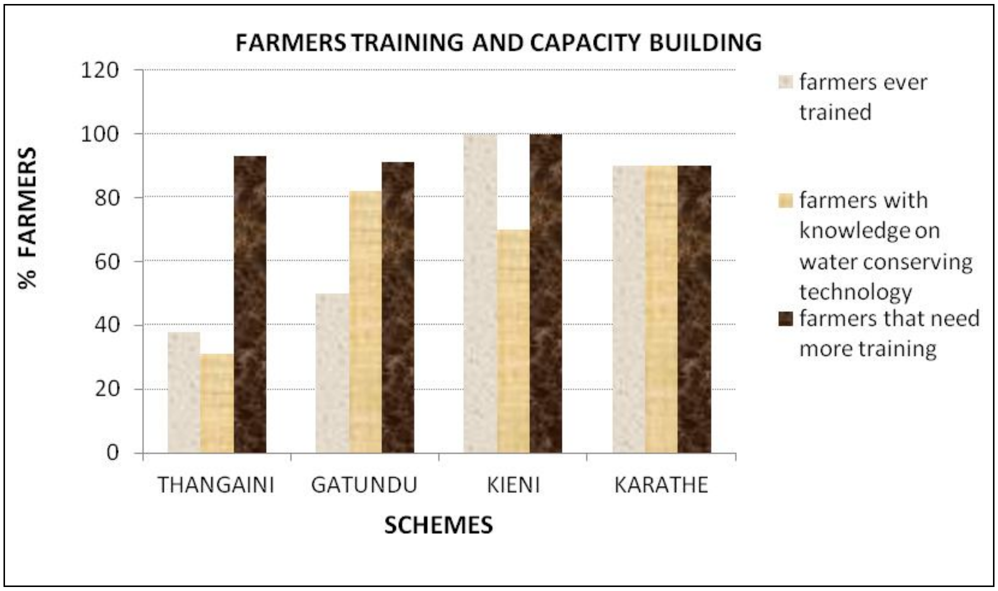

Figure 6:Percentage farmers ever trained and those that need more training

Most farmers requested for more training and they suggested topics of training such as: improved agriculture production, crop selection, improved irrigation skills such as sprinkler spacing, record keeping, pest and disease control, Irrigation water conservation methods, marketing and soil and water management.

4 Conclusion and recommendation

4.1 Conclusion

All the schemes were not operating at the design efficiencies assumed as 68 % for Thangaini, 68% for Gatundu, 68% for Kieni- Gathugu and 63% for Karathe- Thaara. Kieni Gathugu scheme has the highest record of the irrigation efficiency of 77% in farm 2. This could be due to training undertaken by 100% farmers of the scheme on sustainable irrigation development and practicing soil and water conservation, compared to the other schemes where only some of the farmers have been trained and practice soil and water conservation. The lowest record of irrigation efficiency was in Karathe farm 3 at 44% where water is distributed on unlined canals which are overgrown with weeds.

Highest recorded CUC% was 71% is lower than 81% recommended for typical field crops caused by inadequate sprinkler overlap in sprinkler irrigated farms due to improper sprinkler spacing. The implemented sprinkler spacing of 0.9R, achieved a CUC of 80% which is close enough to the recommended for field crops and it was recommended to farmers.

4.2 Recommendations

Farmers should be trained on proper irrigation practices especially sprinkler spacing, water conserving practices and other main topics as requested. All leaking pipes in the sprinkler operating schemes should be repaired or replaced to reduce loss and wastage of water; The unlined canals should be lined to reduce seepage losses in Karathe scheme and the farmers operating sprinkler method should practice proper sprinkler spacing to ensure overlapping of the sprinkler sprays improving the uniformity of distribution.

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