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# Performance Evaluation of Semi-Solid Set Sprinkler Irrigation System at Field Scale

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## ABSTRACT

In recent years, enhancing irrigation system efficiency has become increasingly crucial for maximising agricultural output and resource utilization. The purpose of this study was to assess the efficacy of the semi-solid set sprinkler irrigation system at Mkulazi Sugarcane Estate in Tanzania's Kilosa District, Morogoro Region. Catch cans test experiments were carried out to evaluate the system efficiency in the sugarcane crop's specified zones and pressure measurements were taken at selected sprinkler lateral positions the distribution parameters Distribution Uniformity (DU) and Christiansen's Coefficient of Uniformity (CU) were computed. Furthermore, efficiency factors such as water application rate, Potential efficiency of the low quarter (PELQ), and delivery performance ratio (DPR) were calculated using the provided formula. According to the study's findings, the

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system's distribution uniformity, coefficient of uniformity, and Delivery Performance Ratio were 82%, 85%, and 0.93, respectively. These results showed that the overall performance of the sprinkler system was satisfactory. However, the tail parts of the sprinkler laterals experienced lower discharges due to clogging caused by deposited sediments. Proper filtration and regular flushing of the laterals was recommended to ensure a more uniform distribution and reduction of losses.

*Keywords: Semi-solid set sprinkler; performance; uniformity; efficiency.*

## 1. INTRODUCTION

Climate change continues to wreak havoc on agriculture and water supply, and the growing population, which is estimated to reach 9.7 billion by 2050 according to World Bank, necessitates increased production. Modernizing irrigation systems could significantly enhance services, especially in arid or semi-arid locations where water shortage impedes agricultural development. To accomplish modernization, various essential elements must be considered, including the specific characteristics of each region, crop type, and water supply. Modern irrigation technology has been used to replace less effective irrigation systems. These include sprinkler and drip systems, which have gained a lot of attention as a frequent solution to restricted water supply for lowering water use while increasing yields and profitability [1].

Sugar cane production in Tanzania is a crucial sector that heavily depends on irrigation to improve its productivity. According to Massawe and Kahamba [2], sugarcane production is a critical subsector of Tanzania's agricultural sector, accounting for around 35% of the total output of the food manufacturing industry. It is also a major employment, employing approximately 18,000 direct and 57,000 indirect workers. However, Tanzania still faces a significant deficit on sugar, as it currently produces 360,000 tonnes per year against the national demand of 440,000 tons per year. Among other initiatives, the Government has invested in development of sugar estates to bridge this gap. It is in this regard that among other implementations, Mkulazi Sugarcane Estate was initiated.

Mkulazi Sugar Estate (MSE) adopted sprinkler irrigation system as their mode of irrigation. Based on movement, sprinkler irrigation system can be classified as set-move, continuous move and solid-set irrigation system [3]. A solid-set sprinkler irrigation system has enough laterals and sprinklers covering the whole field, which are left permanent for the entire season[4]. However, the use of movable risers just enough to irrigate a portion of the field has been introduced to reduce the cost of installation of the solid-set irrigation system. This kind of modification is referred to as semi-solid set sprinkler irrigation system (SSSSIS) and is currently in use at MSE.

With the impending growing demand of water, irrigation designers have identified efficient use of water as a primary goal. Irrigation system's type and design affects its efficiency [5]. According to Imrak *et al*., [6], the effectiveness of an irrigation system, the uniformity of water delivery, and the reaction of the crop to irrigation are the three general definitions of irrigation efficiency. These irrigation efficiency measurements have a variety of spatial and temporal dimensions and are interconnected.

Irrigation systems are initially designed to achieve high uniformity and effective irrigation, resulting in water and energy savings that improve farm profitability. However, with time, the systems are prone to operational and management-based setbacks that in return affect their performance. By virtue of this, performance evaluation has been a vital aspect of irrigation since man first began harnessing water to boost agricultural output [7].

Research conducted by Reuben *et al*., [8] found that poor centre pivot performance was among the causes of poor yields at Kagera Sugar Estate in Tanzania. [9] in Iran found significantly low uniformity coefficient and distribution uniformity values which were considered unacceptable and in return had an adverse effect on the crop yield. Additionally, in Tunisia, [10] reported that wind speeds greater than 4m/s had a significant impact on uniformity, regardless of spacing of the sprinklers. In Ethiopia, despite reporting uniformity coefficient values above 80%, Dinka [11] also found values above unity for adequacy of water delivery, denoting excess delivery of water.

According to [12], sprinkler irrigation system's operation can be greatly improved by making simple changes such as changing operating pressures, nozzle sizes, riser heights, and water application durations; operating at different pressures at alternate irrigations; using alternate set sequencing; obtaining larger sized lateral pipes; and tipping risers along the edge of the field. All these require an in-depth analysis of measurements taken in the field while the system is operating under actual field conditions [13].

Despite adopting the semi-solid set sprinkler irrigation system, MSE has experienced varied setbacks in its system. During a preliminary field survey at MSE, it was pointed out that significant amount of water applied to the field was unaccounted for after an irrigation event through rain gauges set across the fields, with certain field blocks experience significantly lower operating pressure at the sprinklers. Additionally, it was noted that the water intakes had no filtration systems. The SSSSIS has gradually been preferred by sugarcane estates in Tanzania, even though no study has been conducted to ascertain its performance. It was therefore imperative to conduct a technical evaluation on the Sprinkler system at MSE to determine the pre-existing condition of the system in place and provide the necessary recommendations to the management.

## 2. MATERIALS AND METHODS

**Description of Study Area:** Mkulazi Sugarcane Estate is located at Magole Ward in Kilosa District, in the lowland plains of the Wami River basin, at an elevation of 360-385 m above sea level. The landscape is almost flat, with very deep clay soils that show clear evidence of cracking and are classified as Fluvisol [14]. Kilosa district experiences bi-modal rainfall, with short rains from November to January and long rains from March to May. Rainfall in the southern flood plains ranges from 1000mm to 1400mm, while it ranges from 800 to 1100mm in the north. Kilosa's average annual temperature is 25°C, with temperatures ranging from 19°C in July to 30°C in March (Karimuribo *et al.*, 2015). Mkulazi Sugarcane Estate obtains its irrigation water from the Wami and Mkundi rivers. The Estate farm covers a total area of 4,856ha whereby 1531ha is under Semi Solid Set Sprinkler Irrigation System (SSSSIS) while 1255ha is under furrow irrigation and the rest is still under development.

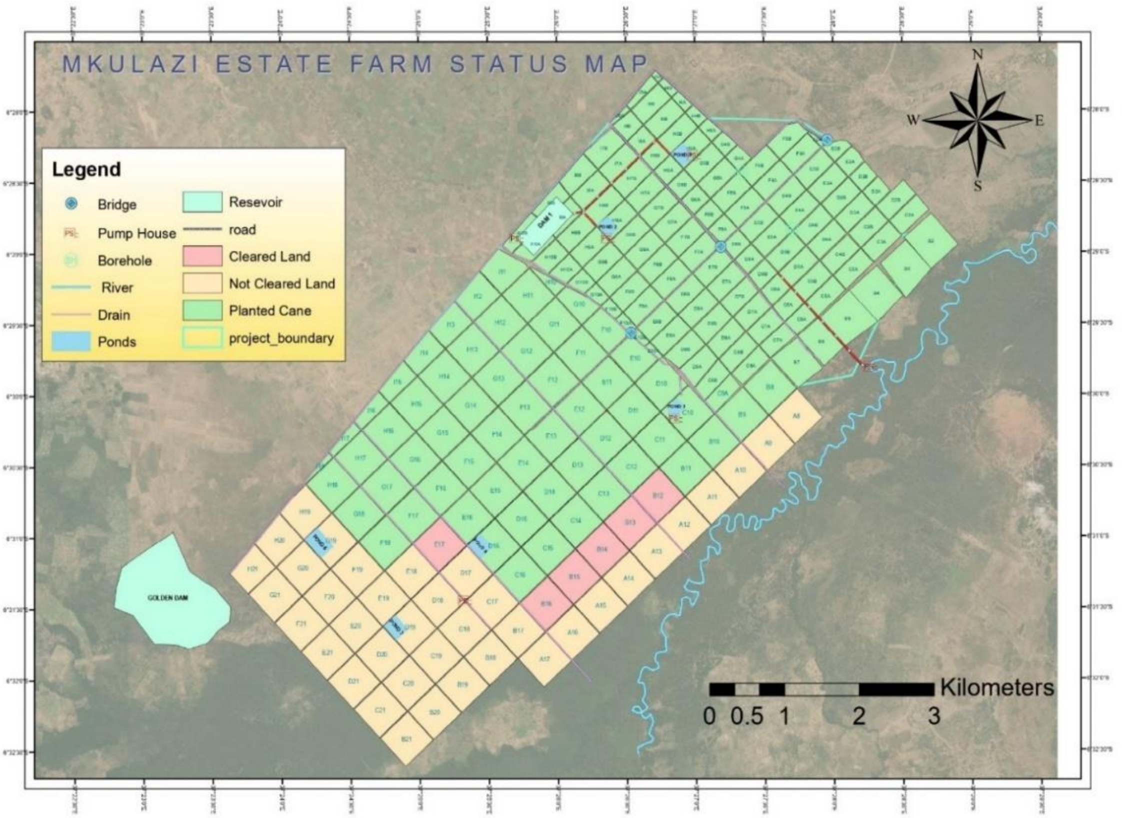



**Fig. 1. Study Area Map**

**Semi-Solid Set Sprinkler Irrigation System:** This system is one in which laterals a permanently fixed throughout the season, while each lateral has only one sprinkler and riser that is moved along the lateral for each irrigation event. During irrigation, all the other sprinkler positions on the lateral are shut except the one operating. Blocks are divided into two, with each side having a manifold that connects to the laterals, and a hydrant located at the middle of the block as shown in Fig. 2. and Table 1.

**Selection of Experimental Area:** The techniques by Merriam and Keller [12] and the American Society of Agricultural and Biological Engineers (ASABE) standard procedures were used to conduct the field evaluations. The field tests were carried out in 2023 on a 25ha sugarcane plantation plot during the dry season (July and August). The field measurements exercise was done throughout the day when normal irrigation was taking place. Six laterals (Laterals A1, B1 and C1 on one half and laterals A2, B2 and C2 on the other half) were purposively selected for the evaluation to represent the upper, middle and lower part of the selected block. On each lateral, 3 sprinkler positions were selected for the measurements. The sprinkler positions were also selected at the beginning, middle and end of the laterals.


**Fig. 2. Semi-Solid Set Sprinkler Irrigation System at Mkulazi Sugarcane Estate**

**Table 1. Irrigation System Specifications at Mkulazi Sugarcane Estate**

| S/N | Features | Value |
|---|---|---|
| 1 | Sprinkler Type | Semi-Solid Set Sprinkler Irrigation System |
| 1 | Field Block size | 25ha (500 by 500m) |
| 2 | Main pipe | 315mm |
| 3 | Submain pipe | 110mm |
| 4 | Manifold and Lateral pipes | 75mm |
| 5 | Hydrants per block | 1 |
| 6 | Laterals | 28 in each half of the block |
| 7 | Sprinkler positions per lateral | 14 |
| 8 | Sprinkler Manufacturer | NaandanJain |
| 9 | Sprinkler Name and Model | Acurain 5035 SD |
| 10 | Sprinkler Inlet connection | ¾ inch male threaded |
| 11 | Sprinkler volumetric flow rate | 1490l/h or 1.490m$^3$/h |
| 12 | Sprinkler spacing | 18 by 18m |
| 13 | Wetted diameter | 28m |
| 14 | System operating pressure | 3 bars |
| 15 | Nozzle size | Dual nozzle 4.0*2.5mm Black |
| 16 | Riser height | 3.5m with tripod base and drag hose |

**Data Collection and Analysis:** Catch cans of 11cm diameter were set up in a diagonal formation around a single sprinkler [11] as shown in Fig. 3. The cans were raised by wooden pegs to avoid water splashing into the cans. Before any catch can test was done, pressure at the hydromatic valve that connects the lateral and the riser was measure as well as the sprinkler discharge to determine the actual precipitation. One-hour catch can test was conducted on every section in all selected sprinkler positions to determine Uniformity Coefficient(CU), Distribution Uniformity(DU) and Potential Efficiency of Lower Quarter( PELQ.

**Evaluation of Sprinkler Performance:** According to Eisenhauer *et al*., [15] water must be applied at the desired area, at the right rate and volume, and at the right time to meet management objectives. However, irrigation systems are not perfect and thus some places receive more water than others, while some is lost. These non-uniformities and inefficiencies are detrimental to the system's primary objectives. Owing to this, several measurements are taken to determine the performance of the system and several developed relationships are used to quantify the performance.

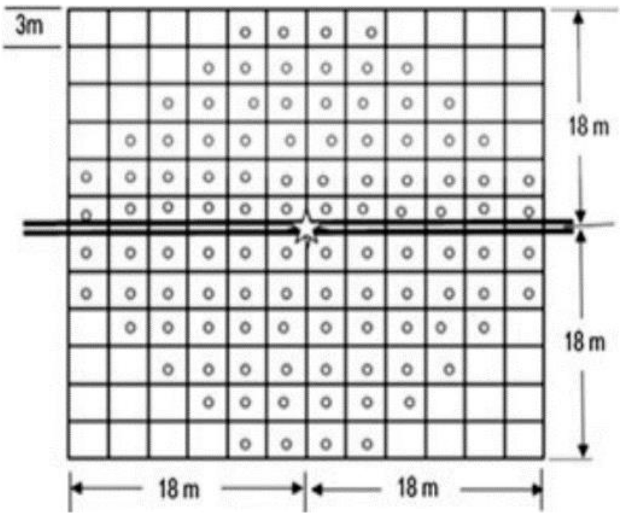



**Fig. 3. Arrangement of catch-cans around sprinklers**

**Table 2. Uniformity and Efficiency Measurements**

| Performance Indicator | Method | Standard/Design Value |
|---|---|---|
| Coefficient of Uniformity (CU) A measure of the average absolute deviation from the average irrigation amount using an array of catch cans. | $C_u = 100\left[1.0 - \frac{\sum x}{mn}\right]$ *x* = absolute deviation of the individual observations from the mean (mm) *m*=mean depth of observation (mm) *n* = number of observations. | CU>84% is recommended for high value and field crops [12] |
| Distribution Uniformity (DU) Indicates the uniformity of infiltration throughout the field [12] | $DU = \frac{D_{lq}}{D_{av}} \times 100$ $D_{lq}$=average weighted low quarter catch (mm) $D_{av}$=average weighted system catch-cans (mm). | 75% and above is recommended [16] |
| Potential Efficiency of Low Quarter (PELQ) a measure of system performance attainable under reasonably good management when the desired irrigation is being applied. | $PELQ = \frac{D_{lq}}{D_{av}} \times 100$ $D_{lq}$ = average low quarter depth caught (mm) $D_{av}$ = average depth of water applied (mm). | At least 90% is recommended [17] |

| Sprinkler Operating Pressure | Pressure gauge measurements | Design Value by Manufacturer |
|---|---|---|
| Sprinkler Discharge Rate | $Discharge = \frac{Volume(l)}{Time(s)}$ | Design Value by Manufacturer |
| Delivery Performance Ratio | $DPR = \frac{QA}{QR}$<br>QA: Actual discharge<br>QR : Required discharge | 1 |

**Discharge Measurements:** Discharge was measured across the selected laterals at three (first, middle and end) selected riser positions. A flexible hose was connected to the sprinkler nozzles, and the sprinklers were run for water to fill a known volume of a 10 litre for a measured period.

Discharge measurements were determined using Equations 1 and 2 as used by [11]. The discharge from individual sprinkler was calculated using Equation 1. Then, the application rate (Ra) (Equation 2) was computed from the measured discharge and sprinkler spacing:

$$Discharge = \frac{volume\ of\ water\ colected\ (l)}{time\ period\ (s)} \quad (1)$$

$$R_a = \frac{3600q}{s_l \times s_m} \quad (2)$$

where Ra = application rate (mm/h), q = sprinkler discharge (l/s), $S_l$ = sprinkler spacing across the lateral (m) and $S_m$ = sprinkler spacing on the main line (m). In the case of the Mkulazi Sugarcane Estate $S_m$ = $S_l$ = 18 m.

**System Capacity Requirements:**

$$Q = N_{c\times} N_s \times Q_s \quad (3)$$

Equation 3 was used to determine the system requirements where: $Q$ = system capacity (m$^3$ /hr) $N_c$ = the number of laterals operating per shift $N_s$ = the number of sprinklers per lateral $Q_s$ = the sprinkler discharge (from the manufacturer's tables/charts).

**Soil and Water Characteristics:** Soil and irrigation water tests conducted at the beginning of the planting season were analysed to assess their effect on the irrigation system.

## 3. RESULTS AND DISCUSSION

**Irrigation Water Requirements:** Table 3 presents results of the determination of sugarcane water and irrigation requirements at Mkulazi Sugarcane Estate. Using the weather parameters obtained from Ilonga Meteorological Station (Table 4), The output from CropWat software gives a maximum ETo of approximately 5.11 mm/day at peak demand. Total crop water requirement (ETc) for a season was 1511mm. Irrigation water requirement was high from the months of May to October at MSE, and at the same time, the Wami river flow rates are on a decline as shown in Fig. 4. Due to this, total

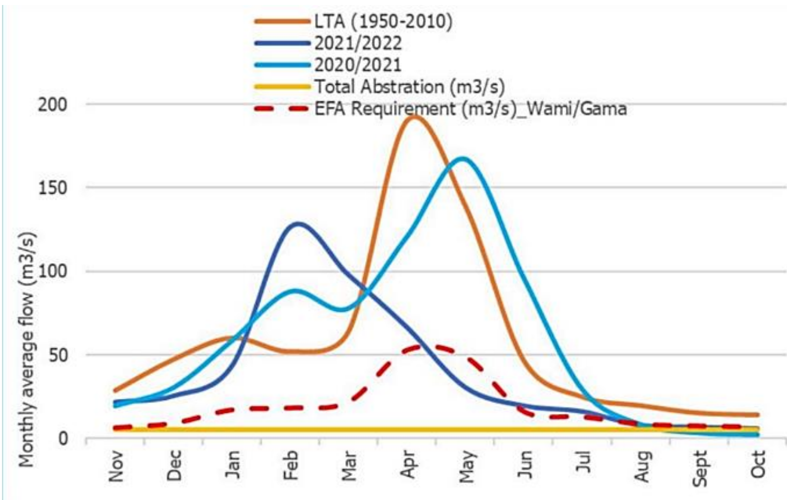



**Fig. 4. Flow comparison for 2021/2022 and Long-Term Averages(LTA) for Wami River**
***Source: URT,[19]***

dependence on this source of water during this period is not appropriate since shortage of water could directly affect the growth of sugarcane. The estate therefore is currently exploring other sources which includes building dams and ponds in the farm from which water can be stored and used. Pousa *et al*., [18] proposed avoiding irrigation during low flow periods as one of the solutions to avoid water stress. In the case of sugarcane, this can be achieved through proper timing of planting that aligns the highest crop water requirement period to high river flow rate season and lower crop water requirements period to low flow rate season. Even though, sugarcane irrigation at MSE is supplementary to the rainfall in the area and thus only about half of the total water requirements by the crop is provided through irrigation (767mm) as shown in Table 3.

**Table 3. Irrigation Water Requirements for sugarcane production at Mkulazi Sugarcane Estate**

| Month | Decade (10 days) | Stage | Kc Coeff | ETc mm/day | ETc mm/dec | Eff. rain mm/dec | Irr. Req. mm/dec |
|---|---|---|---|---|---|---|---|
| Nov | 1 | Init | 0.4 | 2.03 | 20.3 | 17.1 | 3.2 |
| Nov | 2 | Init | 0.4 | 2.02 | 20.2 | 21.4 | 0 |
| Nov | 3 | Init | 0.4 | 1.98 | 19.8 | 25.7 | 0 |
| Dec | 1 | Deve | 0.47 | 2.3 | 23 | 30.9 | 0 |
| Dec | 2 | Deve | 0.61 | 2.89 | 28.9 | 35.7 | 0 |
| Dec | 3 | Deve | 0.75 | 3.37 | 37.1 | 35.9 | 1.2 |
| Jan | 1 | Deve | 0.89 | 3.72 | 37.2 | 35.9 | 1.3 |
| Jan | 2 | Deve | 1.02 | 3.99 | 39.9 | 36.8 | 3.1 |
| Jan | 3 | Mid | 1.16 | 4.66 | 51.3 | 36.2 | 15.1 |
| Feb | 1 | Mid | 1.2 | 5.02 | 50.2 | 34.1 | 16.1 |
| Feb | 2 | Mid | 1.2 | 5.11 | 51.1 | 33 | 18.2 |
| Feb | 3 | Mid | 1.2 | 5.09 | 40.7 | 38.3 | 2.5 |
| Mar | 1 | Mid | 1.2 | 5.07 | 50.7 | 45.6 | 5 |
| Mar | 2 | Mid | 1.2 | 5.04 | 50.4 | 50.9 | 0 |
| Mar | 3 | Mid | 1.2 | 4.79 | 52.7 | 49.9 | 2.8 |
| Apr | 1 | Mid | 1.2 | 4.54 | 45.4 | 51 | 0 |
| Apr | 2 | Mid | 1.2 | 4.29 | 42.9 | 52.1 | 0 |
| Apr | 3 | Mid | 1.2 | 4.26 | 42.6 | 40.8 | 1.8 |
| May | 1 | Mid | 1.2 | 4.23 | 42.3 | 27 | 15.4 |
| May | 2 | Mid | 1.2 | 4.2 | 42 | 16.4 | 25.6 |
| May | 3 | Mid | 1.2 | 4.25 | 46.8 | 11.7 | 35.1 |
| Jun | 1 | Mid | 1.2 | 4.31 | 43.1 | 6.3 | 36.8 |
| Jun | 2 | Mid | 1.2 | 4.36 | 43.6 | 0.2 | 43.3 |
| Jun | 3 | Mid | 1.2 | 4.41 | 44.1 | 0.3 | 43.8 |
| Jul | 1 | Mid | 1.2 | 4.47 | 44.7 | 0.6 | 44.1 |
| Jul | 2 | Mid | 1.2 | 4.52 | 45.2 | 0 | 45.2 |
| Jul | 3 | Late | 1.2 | 4.63 | 50.9 | 0.8 | 50.1 |
| Aug | 1 | Late | 1.16 | 4.6 | 46 | 2.3 | 43.7 |
| Aug | 2 | Late | 1.11 | 4.53 | 45.3 | 3.2 | 42 |
| Aug | 3 | Late | 1.06 | 4.53 | 49.8 | 3.5 | 46.3 |
| Sep | 1 | Late | 1.01 | 4.51 | 45.1 | 3.4 | 41.7 |
| Sep | 2 | Late | 0.97 | 4.49 | 44.9 | 3.6 | 41.3 |
| Sep | 3 | Late | 0.92 | 4.41 | 44.1 | 5.2 | 38.9 |
| Oct | 1 | Late | 0.87 | 4.32 | 43.2 | 6.2 | 37.1 |
| Oct | 2 | Late | 0.82 | 4.22 | 42.2 | 7.2 | 35 |
| Oct | 3 | Late | 0.77 | 3.94 | 43.4 | 11.9 | 31.4 |
| **TOTAL** | | | | | **1511.2** | **781.3** | **767** |

**Table 4. Average weather parameters obtained from 2003-2022 for Ilonga Meteorological Station, Tanzania**

| | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Max ºC** | 29.4 | 29.7 | 29.1 | 28.9 | 28.2 | 26.5 | 25.6 | 24.9 | 24.4 | 25.3 | 26.8 | 28.3 |
| **Min ºC** | 18.7 | 19.5 | 19.5 | 19.3 | 19.4 | 18.9 | 16.8 | 14.6 | 13.8 | 14.4 | 15.4 | 17.1 |
| **Wind (m/s)** | 2.2 | 1.6 | 1.2 | 1.3 | 1.5 | 2.1 | 2.2 | 2.3 | 2.4 | 2.5 | 2.6 | 2.6 |
| **R.H (%)** | 66.4 | 68.4 | 72.2 | 73 | 78.3 | 82.4 | 76.4 | 67.7 | 63.8 | 63.6 | 61.7 | 62.9 |
| **Rain (mm)** | 72.6 | 129.5 | 140.7 | 133.9 | 234.6 | 225.1 | 60.9 | 6.8 | 1.3 | 9.2 | 12.5 | 26.3 |
| **Sunshine (hours)** | 8.2 | 8 | 5.6 | 6.5 | 7 | 5.9 | 6.4 | 7 | 7 | 6.7 | 7.1 | 8.1 |

**Table 5. Average Long-Term Flow rates (1950-2010) for Wami River Measured at Dakawa Station (Source:** [20])

| Month | Nov | Dec | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Annual Average Flow ($m^3/s$) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Flow Rate ($m^3/s$)** | 7.38 | 20.11 | 33.2 | 25.4 | 28.46 | 66.14 | 55.72 | 21.98 | 11.49 | 9.23 | 7.02 | 5.82 | **24.33** |

**Sprinkler Uniformity:** Results of uniformity indicators evaluated in the study area for sprinkler irrigation system are presented in Table 6. Christiansen's Coefficient (CU) values ranged from 72% to 92%. The distribution uniformity (DU) values ranged from 68% to 90%. The average CU was 85% and DU was 82%. The values showed no significant differences from the recommended values of 84% and 75% respectively (p>0.05). The good uniformity of the sprinklers was related to the nature of operation of the semi-solid sprinkler system, in which despite having permanent laterals and sprinkler positions, only one sprinkler per lateral operates at each irrigation time. The results obtained in this study for CU, DU and are similar to the findings from [21, 22]. Referring to the recommendations set by [23] and Merriam & Keller [12] the mean values of CU (85%) and DU (82%) resulted from the study fall in the desirable category; and that indicates a good performance of the irrigation system. A higher uniformity could be achieved with proper filtration to avoid accumulation of silt in the sprinkler laterals which in turn lowers the uniformity. The DU values indicated the degree of uniformity of water distribution over the irrigated region in the lower quarter (25%) and thus represent the amount of technical and administrative challenges associated with water distribution to irrigated areas[24]. The lower the value of DU, the greater the water loss and the difficulty in maintaining the irrigation system.

It was however noticeable that CU and DU values in the third sections of measurements in all selected laterals were relatively low as compared to the other sections. This was associated with observed accumulation of silt at the ends of the laterals after irrigation. Since there is only one outlet sprinkler at a time, particles present in the system are carried and deposited at the ends of the laterals. Due to this, sprinklers operating around this area experience low pressures due to blockages, and hence low uniformity. As explained by Gurmu *et al*., [25] river sediment brought in with the irrigation water via intake structures is one of the sources of sedimentation in irrigation systems, which could be the case at Mkulazi Sugarcane Estate. These sediments cause adverse effects specifically on pumps and sprinkler nozzles, creates turbidity and impairs water distribution [26]. Although it is not feasible to prevent the sediments entering the irrigation system entirely, proper filtration at the intake can help alleviate this challenge. The study also found out that towards the ends of the selected laterals, the discharge rates were lower. This was related to the fact that pressure is lowest at the distal end and progressively increase towards the source in a level lateral [23], which in return leads to a gradual decrease in sprinkler discharges towards the end of the lateral.

The study also revealed that, at the tail ends of the selected laterals, there was a notable decrease in discharge rates when compared to the upper sections, as depicted in Fig. 5. This decrease in discharge rates can be attributed to not only the expected head losses along the lateral, leading to pressure reduction towards the tail end but also the accumulation of sediments at the ends, which led to clogging and consequently resulted in substantially reduced discharge. In certain positions of the sprinkler system, this accumulation of sediments even led to complete blockages. This situation results in adequate irrigation depth at the upper section of the lateral, but insufficient watering at the tail end. The operation of the SSSSIS offers a chance to rectify this issue by extending the irrigation duration when the sprinklers are functioning at the tail end. As the system progresses towards the upper section, the irrigation time can be gradually reduced to ensure optimal water application without any runoff, particularly at the upper end.

**Table 6. CU and DU values at selected lateral points**

| Test Lateral | Area | Pressure (bar) | CU (%) | DU (%) |
|---|---|---|---|---|
| Lateral A1 | Upper | 3.1 | 89.52 | 92.20 |
| | Middle | 3.0 | 92.33 | 87.99 |
| | Tail | 2.9 | 84.62 | 76.60 |
| **Average** | | **3.0** | **88.82** | **85.60** |
| Lateral B1 | Upper | 3.1 | 87.20 | 86.77 |
| | Middle | 2.8 | 82.65 | 83.97 |
| | Tail | 2.7 | 76.04 | 78.73 |
| **Average** | | **2.9** | **81.96** | **83.16** |
| Lateral C1 | Upper | 2.9 | 89.77 | 88.00 |

| | | | | |
|---|---|---|---|---|
| | Middle | 2.8 | 92.30 | 87.90 |
| | Tail | 2.7 | 72.34 | 70.43 |
| **Average** | | **2.8** | **84.80** | **82.11** |
| Lateral A2 | Upper | 3.0 | 92.14 | 86.82 |
| | Middle | 2.9 | 91.33 | 89.00 |
| | Tail | 2.8 | 78.23 | 73.58 |
| **Average** | | **2.9** | **87.23** | **83.13** |
| Lateral B2 | Upper | 3.1 | 89.09 | 84.67 |
| | Middle | 2.8 | 83.98 | 87.55 |
| | Tail | 2.7 | 78.02 | 72.13 |
| **Average** | | **2.9** | **83.70** | **81.45** |
| Lateral C2 | Upper | 2.9 | 84.40 | 80.20 |
| | Middle | 2.8 | 83.36 | 82.65 |
| | Tail | 2.7 | 78.62 | 68.57 |
| **Average** | | **2.8** | **82.13** | **77.14** |

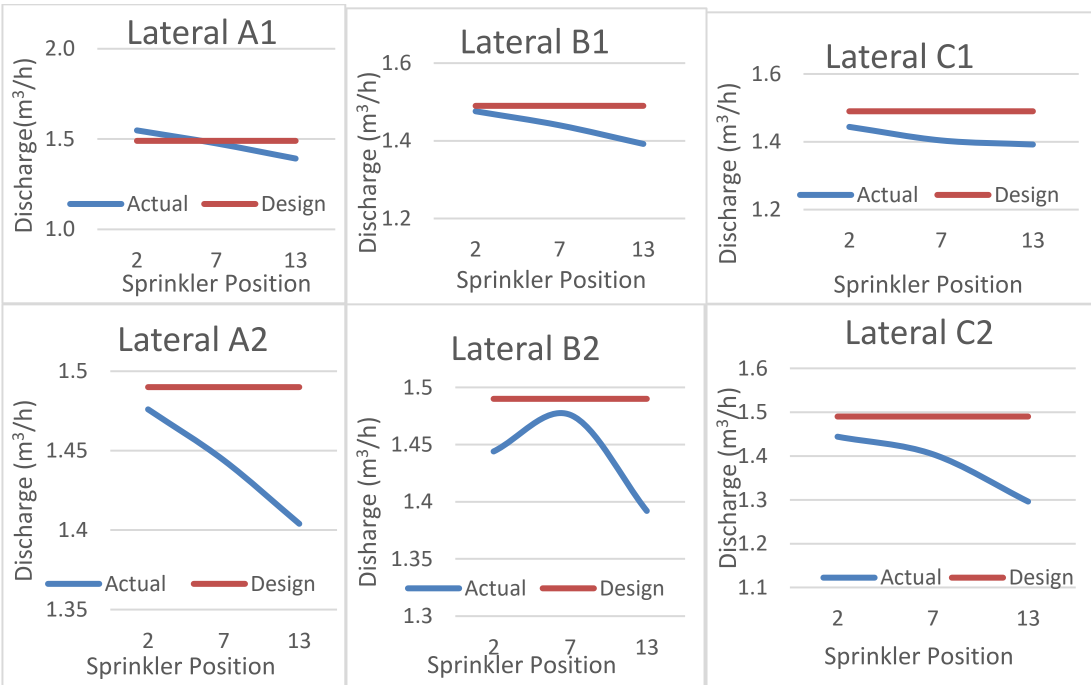



**Fig. 5. Sprinkler discharge rates along the selected laterals**

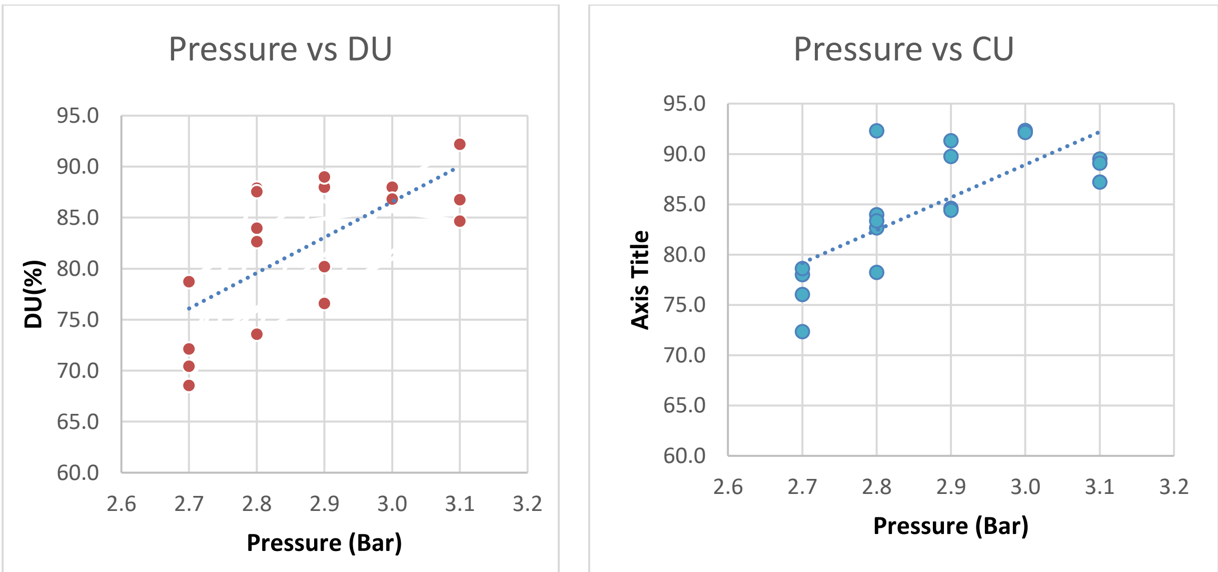
Table 7. displays the range of values for the Potential Efficiency of Low Quarter (PELQ), which spans from 64.8% to 72.2%. PELQ serves as a measure of how effectively irrigation is being implemented and how water is being distributed. Essentially, it reflects the quality of irrigation management. Lower PELQ values signalled issues with either the irrigation system's design or administrative processes in the field irrigation operation. These problems manifest as extended irrigation durations and application depths exceeding the required levels. Consequently, they resulted in increased water losses due to evaporation, surface runoff, and percolation[27]. The estimated PELQ values also pointed to deviations from the design specifications related to the arrangement and distribution of sprinklers, which are administrative challenges. These deviations lead to suboptimal irrigation scheduling, prompting operators to take measures to circumvent these issues. The average Delivery Performance Ratio( DPR) was 0.93, indicating a 93% efficiency of water delivery, while the 7% was associated to losses by wind drift and evaporation[28].

The semi-solid set sprinkler irrigation system boasts a distinctive characteristic that sets it apart from traditional solid set systems: a continuous flow of water throughout the entire irrigation cycle, irrespective of the position of the operating sprinkler. This unique feature, while contributing to the efficient utilization of the system, also presents certain challenges related to sediment accumulation. In a conventional solid set irrigation system, water flows only during the designated irrigation time, and once the cycle is complete, the system remains idle until the next scheduled irrigation cycle. This intermittent operation ensures that the system remains relatively free from sediments since the water flow is limited to specific periods. However, the semi-solid set sprinkler irrigation system diverges from this norm. It maintains a continuous flow of water throughout the entire irrigation process, even though there is only one sprinkler operating per lateral. This continuous flow though beneficial as it ensures that the system is put into prudent use, it presents a downside in the form of sediment accumulation. As water moves through the system non-stop, it carries suspended particles and sediments along with it. These particles majorly originate from the water source. Over time, the accumulation of sediments poses adverse effects on the system's efficiency and performance.

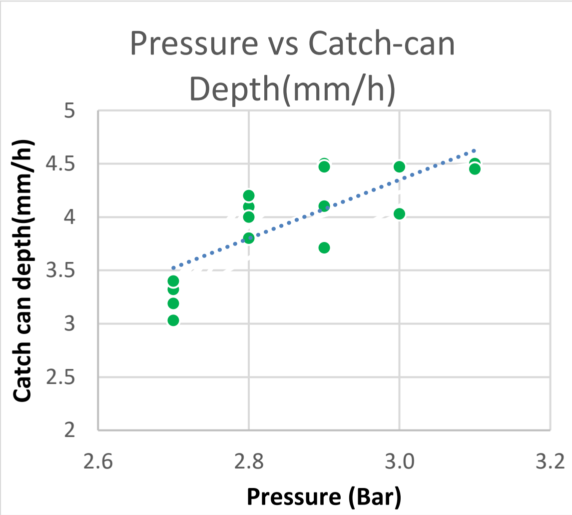
**Sprinkler Efficiency:** Fig. 6 shows the relationship between the uniformity parameters measured as well as the catch can depth and actual sprinkler discharges. The results indicated a direct relationship between pressure and CU, DU, catch can depth and actual sprinkler discharges. Since sprinkler operating pressure affects sprinkler discharge rate and amount applied, it is generally accepted that the limit of discharge varied in different parts of laterals should not exceed 10% of average discharge. Pressure variation constraints shouldn't be more than 20% of the normal operating pressure to improve performance. Above this limit, more pressure variation would affect water distribution uniformity (DU), resulting in certain areas of the surface receiving more water than others.

**Table 7. Average PELQ and Discharge rates for selected test laterals**

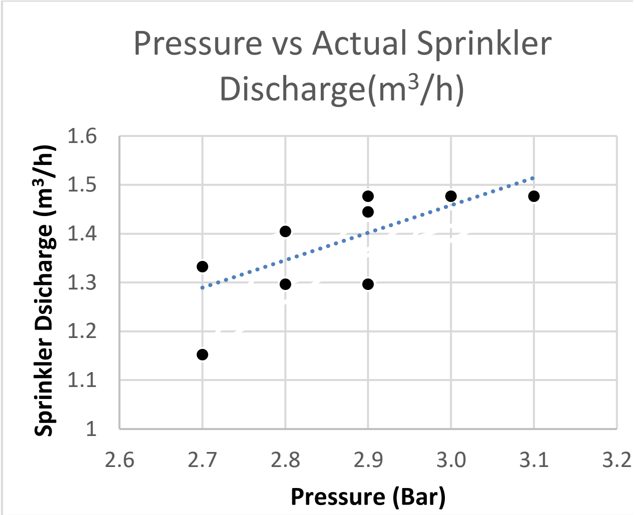
| Test Lateral | Actual Discharge $m^3/h$ | Design Discharge $m^3/h$ | PELQ % | DPR % |
|---|---|---|---|---|
| A1 | 1.416 | 1.49 | 83.4 | 95.03 |
| B1 | 1.404 | 1.49 | 81.8 | 94.23 |
| C1 | 1.344 | 1.49 | 82.2 | 90.20 |
| A2 | 1.405 | 1.49 | 75.2 | 94.30 |
| B2 | 1.404 | 1.49 | 85.8 | 94.23 |
| C2 | 1.344 | 1.49 | 79.1 | 90.20 |




***a)*** ***b)***




*c)*




*d)*

**Fig. 6. Relationship between pressure and other uniformity and efficiency parameters**

**Fig. 7. Location of water intake at Wami River**

The absence of a filtration system at the intake enables sediments from the river to move into the system and are deposited at the ends of the sprinkler laterals. This is reflected by the low discharge rates at the ends of the laterals. Further observation showed that the location of the intake could one of the reasons for excessive accumulation of sediments in the system. The intake as shown in Fig. 7 is located directly opposite the slow-moving side of River Wami, where deposition of sediments carried from upriver occurs.

## 4. CONCLUSION

Solid set sprinkler irrigation system remains the most favourable system for sugarcane irrigation at MSE. The system has high uniformity levels of water application which means that the required depth of irrigation is achieved in most areas of the field. Besides the cost saving feature associated with acquiring less sprinklers, this system is easy to manage. Proper maintenance however should be adhered to ensure that the system operates according to its principal design.

Proper filtration at the intake should be enhanced to minimize the amount of sediments that get into the system and are then deposited at the ends of the laterals. To control regular lateral lockage, the operators should ensure regular flushing of the laterals.

## DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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