

Evaluation of Hydraulic Performance of Irrigation Scheme at Kuraz Sugar Development Project, Jinka, Ethiopia

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Abstract: Performance assessment of irrigation system is important to conserve the scarce resource of water through improving performance of existing irrigation schemes. However, there was no study in the past on performance assessment of Kuraz Irrigation Scheme. Thus, this study was to evaluate the hydraulic performance of the irrigation scheme using hydraulic performance indicators. The study was carried out during the irrigation season from June to August, 2019. According to the results of the study, the value of adequacy, dependability, equity, equity ratio over head to tail, efficiency and deficiency were found to be 0.98, 0.03, 0.04, 0.91, 0.81 and 0.02 respectively. The values show that water delivery system of the scheme had a good performance. The conveyance system was satisfied 98% out of the total required amount of irrigation water during study period. The overall efficiency of the system was 81%, which implies that the efficiency of water supply was satisfactory. The overall average value of conveyance efficiency of the 3.33km Secondary canal was 81.20%. The conveyance loss was 18.80% of the water. Siltation and vegetation growth within the canal interferes with water flow reducing the conveyance efficiency. The values of effectiveness of infrastructure, water surface elevation ratio, delivery duration ratio and sustainability of irrigated areas were found to be 89.68%, 96%, 87.5% and 95.56% respectively. The results of maintenance indicators showed that the system requires minimum level of maintenance due to sedimentation of secondary canal, improper operation and management of the system. Hence, adequate maintenance and other proper management techniques are essential to improve the irrigation system performance.

Keywords: Hydraulic Performance, Water Utility Indicator, Conveyance Efficiency, Maintenance Indicators, 90 Degree V-Notch, Kuraz Irrigation Scheme

1. Introduction

Water scarcity is a growing worldwide problem challenging sustainable development and placing a constraint on producing enough food to meet increasing food requirements [1]. Water scarcity is a potential constraint to produce more foods to meet the demands of increasing world population. One possible approach to conserve this scarce resource might be through improving the performance of existing irrigation schemes [2]. Performance based management is a principal approach to improve the scheme performances.

Nowadays majority of operational irrigation schemes in the Ethiopia are characterized by a poor level of technical, hydraulic, operational and service delivery performance.

Shortcomings include inadequate irrigation scheduling, inadequate operation plan, water logging and salinization, lack of adequate institutional setups for management, inadequate physical water control facilities, canal sedimentation and lack of adequate maintenance, lack of appropriate asset management [3].

Irrigation development is a key for sustainable agricultural development which leads to overall development in Ethiopia [4]. Irrigation schemes are classified as small, medium and large-scale depending on the size of the command area [5]. Based on irrigation scheme classification small-scale irrigation scheme is defined as the area less than 200 ha; which are often community-based and traditional methods. Ethiopian irrigation scheme classification, medium scale irrigation scheme is covering 200 to 3,000ha which is

community based or publicly sponsored.. According to Ministry of Water Resources, large scale is covering more than 3,000 hectares, which is typically commercially or publicly [6].

Secondary canal was designed by Water Works Design Construction Supervision Enterprise in 2011. It was constructed by Ethiopian Water Works Construction Enterprise in 2014. The secondary canal, SC-4 is off taking at 17.135 kilometers of the main canal on left bank. The secondary has a length of 3.33 kilometers to irrigate a net irrigable area of 777.5ha and it has 10 off-taking tertiary canals. A total of 35 quaternary offtakes from tertiary canals supply irrigation water to the fields. The design discharge of the secondary canal-4 is 1.33 cubic meter and the bed width of the canal varies from 1.70m to 0.60m. There are 46 head regulating and 40 cross regulating structures in both secondary and tertiary canals to regulating the flow the system. The canals are constructed as an open channel excavated & shaped to the required cross section in natural earth or compacted fills [7]. Secondary canal four on left

bank of Omo Kuraz irrigation scheme, some of irrigation structures which were malfunctioned due to different reasons such as unreliable water deliveries, poor control and distribution system, lack of proper management, improper operation of water delivery system, delivery of excess water which causes canal bed scouring and sedimentation, improper operating of hydraulic gates, weed growth and flooding problems. The water delivery performance of the canals, the delivery of a fair share of water to the reaches, and the level of maintenance requirement of the system is not clearly understood. Hence, assessing the hydraulic performance of the schemes has now become a paramount importance to point out where the problem lies, and to identify alternatives for effective and feasible improvement of irrigation system performance. So far, specifically in the study area there is no any assessment done regarding hydraulic performance. Therefore, the aim of this study was to evaluate the hydraulic performance of Kuraz irrigation scheme.

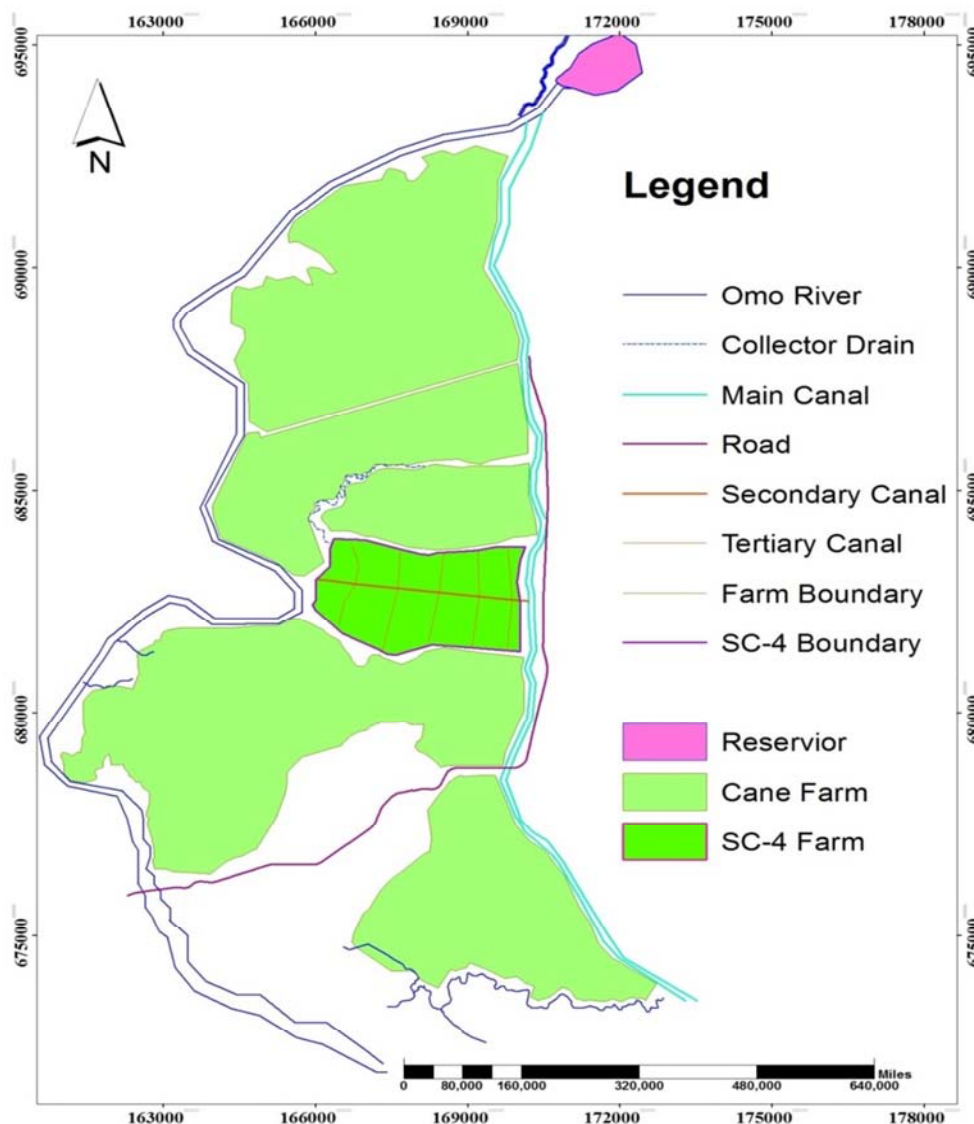


Figure 1. The irrigation Scheme layout.

2. Materials and Methods

2.1. Description of the Study Area

This study was conducted at Omo Kuraz Sugar project, it is found in South Omo Zone in the plain areas of the lower Omo basin of the Southern Nations Nationalities and Peoples Region, which is between $5^{\circ} 56' 00'' - 6^{\circ} 20' 00''$ latitude and $35^{\circ} 44' 00'' - 36^{\circ} 16' 00''$ longitude and its elevation ranges from 370 – 500 m.a.s.

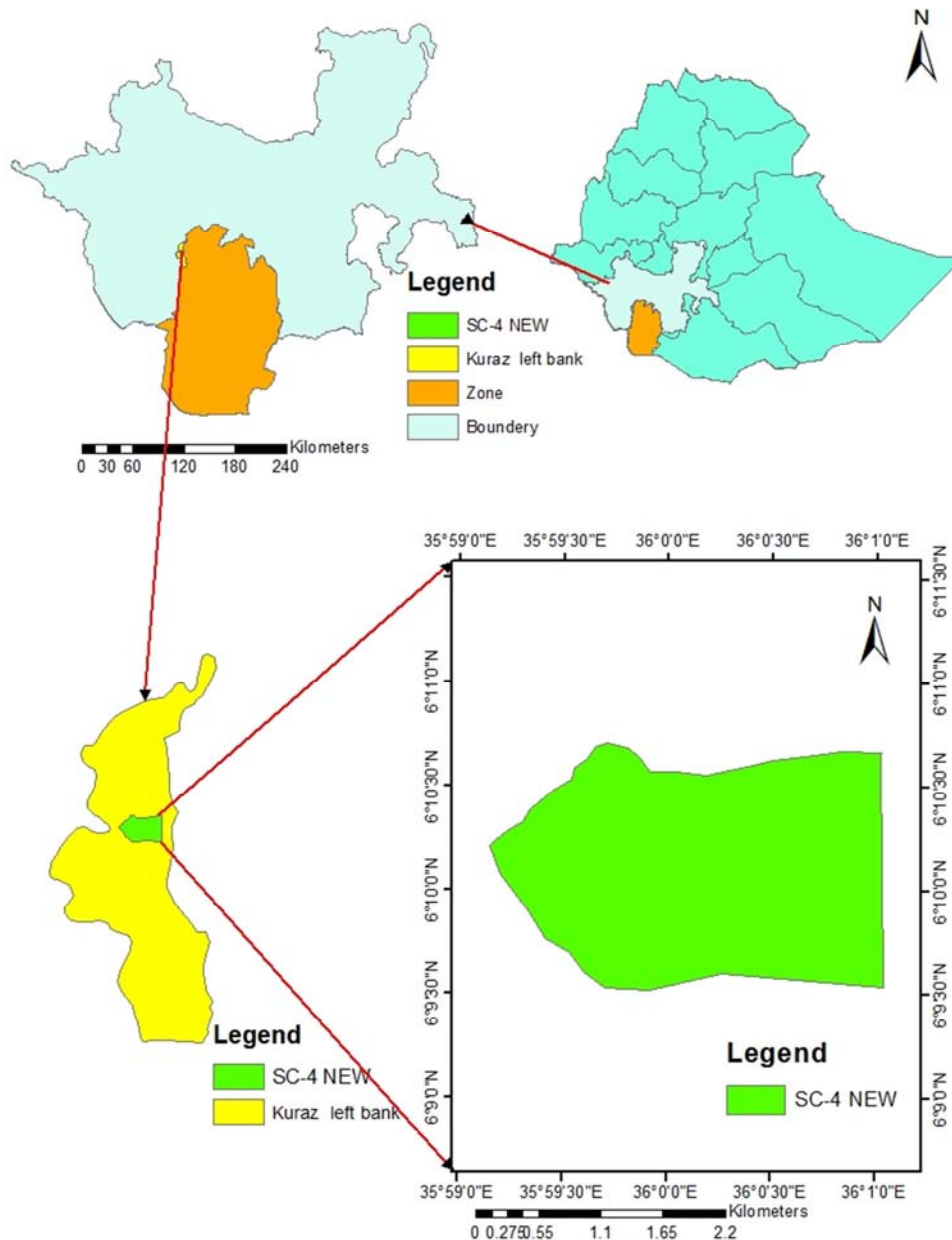


Figure 2. Location map of the study area.

2.2. Methods

2.2.1. Methods of Data Collection

Data were collected from the two sources, which are primary and secondary sources. The primary data were collected in direct measurement of discharge, water surface elevation at the head, middle and tail reach of secondary and tertiary canal and field observation of functionality and non-functionality of structures of the irrigation system. The

secondary data were collected was design documents filed from the office of sugar project, Climate data, actual command areas, standard values of performance indicators and designed features of the scheme in the design document are major data which were utilized in the study.

2.2.2. Discharge Measurements

In this study, two methods were used for measuring canal irrigation water supply. These are: - 90° V-notch weir and current meter (SEBA Universal current meter F1). By using

current meter, velocity measured with current meter and flow area was computed from the flow geometry. The cross section of a canal was divided into a number of verticals, at which water depths and depth-averaged velocities are measured. The flow between any two adjacent verticals is a product of the width between verticals, the mean of water depths of two adjacent verticals and the mean of the average velocities over those two verticals. The total discharge at the section was determined as a sum of the discharges in each sub section. A 90° V-Notch was used to measure flow the discharge through each off-take along the tertiary canals. According to the established water delivery plan, this flow depth is measured three times per month with the interval of ten days.

2.2.3. Water Surface Elevation Measurements (WSE)

During irrigation, water surface elevation of the secondary canal was measured in the reaches at head, middle and tail. Actual WSE data were taken from selected reaches in a given interval. The actual WSE data were taken from 8 measuring stations sub divided into 3 segments with 1.11k.m interval length of the canal. From each reach, the data were taken from 8 monitoring stations at the interval 150m. The first measurement was taken 25 meter far from the secondary head regulator (HR). Generally, actual WSE data were taken on 24 inspection stations along the secondary canal in head, middle and tail reaches.

2.2.4. Field Observation

The conditions of existing irrigation scheme structures were inspected during irrigation water application time. Overall operational activities were identified and a number of functional and non-functional structures in the scheme were documented and recorded.

2.3. Data Analysis and Interpretation

For evaluating the hydraulic performance of the irrigation system, several performance indicators are evaluated according to the following three groups [8-10]: (I) Utility of water supply (i.e. Adequacy, Dependability, Equity, Equity ratio at head and tail, efficiency and deficiency), (II) Conveyance of water supply (i.e., conveyance efficiency and conveyance loss) and (III) maintenance performance indicator of the system (i.e. Water surface elevation ratio, Efficiency of infrastructure, Sustainability of irrigable area, Delivery Duration ratio and Overall reliability).

2.3.1. Utility of Water Supply

1) Adequacy (PA)

Adequacy is an indicator for a utility of water supply system whether it achieved a target or required water delivery over a certain period of time. In this study the time frame to be considered with in a period of three months. It relates to the actual to delivery desired amounts of water needed for crop irrigation to delivery points in the system [11]

$$PA = \frac{1}{T} \sum_T \left(\frac{1}{R} \sum_R \left(\frac{QD}{QR} \right) \right) \quad (1)$$

Where, If $QD \leq QR$, otherwise $PA=1$, PA is the adequacy performance indicators, T is time and R is site where canals are located. QD is actual amount of water delivered by the system and QR is the amount of water required for crop

2) Dependability (PD)

It is defined as the temporal uniformity of the ratio of the delivered amount of water to the required amount [12]. This performance measurement indicates the uniformity of QD/QR over time. The dependability parameter is defined:

$$PD = \frac{1}{R} \sum_{i=R} C_v T \frac{QD}{QR} \quad (2)$$

Where, QD is actual amount of water delivered by the system and QR is the amount of water required for crop consumptive use, $C_v T$ is temporal coefficient of variation (ratio of standard deviation to mean) of the ratio QD/QR over discrete location in a region R and a time span T.

3) Equity (PE)

Equity describes the degree of variability in relative water delivery from point to point over the region. The coefficient of variation (CV) of the ratio of delivered (QD) to required (QR) over an area R and time T. The value of PE is close to zero, the greater the degree of equity (special uniformity) of water delivery. The measure is given by:

$$PE = \frac{1}{T} \sum_T C_v R \left(\frac{QD}{QR} \right) \quad (3)$$

Where CVR= special coefficient of variation of the ratio of delivered water to required water (QD/QR) over the region R.

4) Equity Ratio for Head to Tail (ERHT)

It focused on the equity of water distribution for head and tail at different levels of a system. An equity ratio for head to tail (ERHT) components of a distribution sub-system is given as:

$$ERHT(MDR) = \frac{\frac{1}{n} \sum_{t=1}^{t=n} MDR(head)}{\frac{1}{n} \sum_{t=1}^{t=n} MDR(tail)} \quad (4)$$

Where t is the time period, n is the number of periods monitored while, MDR is discussed as: Management Delivery Ratio (MDR): Conveys similar information to Delivery Performance Ratio, according to [13, 14], the ratio is described as:

$$MDR = \frac{QD}{QR} \quad (5)$$

Where, QD is the actual volume of water delivered and QR is the required volume of water to be delivered.

5) Deficiency

It is given as the ratio of water deficiency to the required amount. A measure of deficiency is considered as the temporal and spatial average of the ratio of (QR-QD) and QR [15].

$$PDF = \frac{1}{T} \sum_T \left(\frac{1}{R} \sum_R \frac{QR - QD}{QR} \right) \quad (6)$$

If $QR > QD$, Otherwise = 0

The expression gives water deficiency over the system in each period and overall deficiency over the period.

6) Efficiency

It is commonly interpreted as the volume of water stored in the soil for evapotranspiration compared to the volume of water delivered to this purpose [15-17]. The ratio is given as:

$$PF = \frac{1}{T} \sum_{T=0}^T \left(\frac{1}{R} \sum_{R=1}^R \frac{QR}{QD} \right) \quad (7)$$

If $QR < QD$, Otherwise, $PF = 1$

Where, PF is the spatial and temporal average of the ratio QR/QD . The more the value of PF closer to unit, the more the system becomes efficient. A delivery system for which PF values ranges between 0.7 and 0.84 is measured as fairly efficient [11].

2.3.2. Conveyance Indicators

1) Conveyance Efficiency

Conveyance efficiency is the total amount of water flowing in to a canal system at a given point divided by the amount of water reaching a certain distance downstream of a previous point. As a performance indicator, E_c is assessed by measuring inflow and outflow of selected canal reaches and calculated using Equation 8 developed by [10].

$$E_c = \frac{Q_{out}}{Q_{in}} * 100 \quad (8)$$

Where; E_c is the conveyance efficiency expressed as a percentage [%], Q_{in} is the total water flowing into a specific section of the canal ($m^3.s^{-1}$), and Q_{out} is the total water flowing out of a specific section of the canal ($m^3.s^{-1}$).

2) Conveyance loss

It measures the efficiency of the canal system to convey water and shows the of water loss over a given travel distance. A water conveyance loss ratio can be calculated for each section of the secondary canal using Equation 9 [18].

$$WLC = \frac{Q_{in} - Q_{out}}{Q_{in}} * 100 \quad (9)$$

Where WLC is the water conveyance loss ratio expressed as a percentage [%], and Q_{in} and Q_{out} are as previously defined in equation 8.

2.3.3. Maintenance Indicators

Proper maintenance enables the keeping of water control and distribution infrastructure in good working condition so that the design water level is maintained. The hydraulic performance of the scheme could also be evaluated through maintenance performance indicators; the performance was estimated through the indicators recommended [8-10].

1) Effectiveness of Infrastructure

It measures the ratio of the number of functioning structures to the total number of structures initially installed. The efficiency of infrastructure was calculated as:

$$EI = \frac{\text{Number of Function Structures}}{\text{Total Number of Structures}} \quad (10)$$

2) Water Surface Elevation Ratio (WSER)

The parameter is defined by measuring the actual water surface elevation at intended water level recorded below the FSL [20]. If $WSER > 1$, indicate an erosion problem. and if $WSER < 1$, then there is a probability of rising canal bed level due to siltation and weed incidence in a canal. $WSER$ can be calculated as:

$$WSER = \frac{\text{Actual Water Surface Elevation at FSL}}{\text{Target Water Surface Elevation at FSL}} \quad (11)$$

3) Delivery Duration Ratio or Dependability Duration (DDR)

This parameter is estimated as the ratio of the duration of actual irrigation water delivered to the intended duration of water delivery.

$$DDR = \frac{D_{ac}}{D_{in}} \quad (12)$$

Where, D_{ac} is actual duration of water delivered (day) and D_{in} is intended duration of supply (day)

4) Sustainability of Irrigated Area (SIA)

It is the ratio of currently irrigated area to initially irrigated area when designed [10].

$$SI = \frac{\text{Actual.Irrigated.Area}}{\text{Designed.Irrigated.Area}} \quad (13)$$

Table 1. Range of Performance Indicators.

Indicators	Ranges			
	Poor	Fair	Good	Excellent
PD	> 0.20	0.11- 0.20	0.00-0.10	
PA	< 0.80	0.80-0.89	0.90-1.00	
PE	> 0.25	0.11-0.25	0.00-0.10	
PF	< 0.70	0.70-84	0.85-1.00	
ERHT (MDR)	< 0.7 or > 1.3	0.7-0.79 & 1.21-1.3	0.8-0.9 & 1.1-1.2	
DDR	0 or > 1.0	1		0.9-1.10

Source: Mohsen et al. (2012) and Molden and Gates (1990)

2.4. Estimation of Irrigation Water Requirement

The crop water requirement was computed from secondary data using CROPWAT 8.0. The reference evapotranspiration (ET_o) for the succeeding months was estimated using the FAO Penman-Monteith method [21]. The crop water requirement (ET_c) was computed by using (in equation 14) from the ET_o and the crop factor (K_c) values for each growing stages of sugarcane crop during irrigation season.

$$ET_c = ET_o * K_c \quad (14)$$

Where, ET_c is crop water requirement, ET_o is evapotranspiration and K_c is crop coefficient

According to equation 15, the irrigation requirement (IR) indicates the difference between the Evapotranspiration of the crop under ideal conditions (ET_c) and the effective rainfall (E_{eff}) contributions during the same time period [22] and it is expressed in mm or m³.

$$IR = ET_c - R_{eff} \quad (15)$$

$$GIR = \frac{IR}{E_i} \quad (16)$$

Where, GIR is gross irrigation requirement and E_i efficiency of irrigation (0.8)

Then, irrigation requirement (l/s/h) to feed each tertiary outlet was converted into flow rate by multiplying the area which was fed the tertiary off takes. The flow was the product of GIR in l/s/ha per month and the command area (ha) served for irrigation (in equation 17). As a final point, to evaluate water delivery performance indicator, the flow rate was converted in to volume (QR, in m³).

$$QR = GIR * A \quad (17)$$

Where, QR is the required discharge, IR is irrigation water requirement and A is areas covered by crop (sugarcane)

3. Result and Discussion

3.1. Evaluation of Irrigation Scheme Performance

The results of this study was based on the delivered discharge, required discharge of the secondary canal and tertiary canals, the irrigated area and total command area, duration of water supply; and functional and total structures of the irrigation system. The required amount of water (QR) for the growing season was calculated using CROPWAT 8 program (Clarke, 1998). Crop water requirement was computed for sugarcane plant with different growing stages in the command areas and then total sum of irrigation water requirements of each off take of tertiary canal was calculated. The volume of water required (QR) by the tertiary canals at each measuring points was the product of IR and the command area served for irrigation. Secondary canal system performance was estimated based on the monthly required discharge. These outcomes are the averages of three consecutive months i.e., June, July and August 2019. Then, the performance indicators under conveyance, utility and maintenance category could be discussed in the following section using a statically approach.

3.2. Rainfall Data Analysis

In Kuraz scheme the mean minimum and maximum rainfall amount occurred in months of January (9.6 mm) and April (229.07 mm), respectively. Kuraz irrigation scheme has an average total annual rainfall of 974.13 mm. The mean total annual effective rainfall amount of the study area was 788.2 mm. Hence this effective rainfall contributed to support the crop water demand in the irrigation seasons.

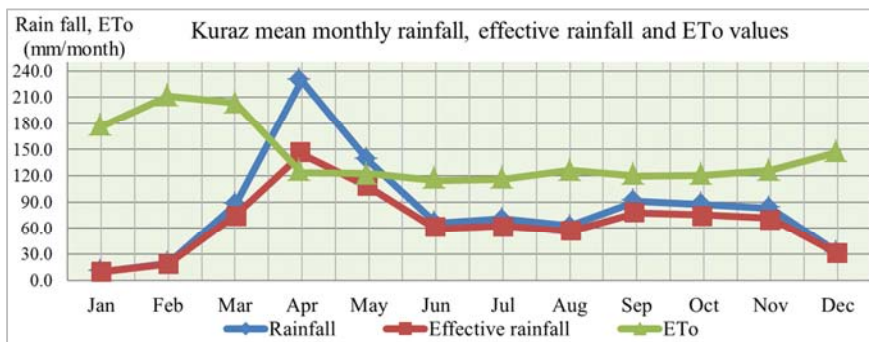


Figure 3. Kuraz scheme mean monthly rainfall, effective rainfall and ETo values.

Table 2. Average delivered and required discharge in each tertiary canal off-take (m³/s).

Month	Head				Middle						Tail									
	TC1		TC2		TC3		TC4		TC5		TC6		TC7		TC8		TC9		TC10	
	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R	Q _D	Q _R
June	0.04	0.027	0.028	0.032	0.039	0.026	0.041	0.023	0.045	0.03	0.035	0.023	0.025	0.029	0.04	0.027	0.026	0.017	0.016	0.019
July	0.046	0.025	0.046	0.03	0.021	0.024	0.034	0.021	0.048	0.028	0.042	0.022	0.036	0.027	0.049	0.025	0.041	0.016	0.038	0.017
August	0.054	0.03	0.058	0.037	0.049	0.029	0.053	0.026	0.043	0.034	0.046	0.026	0.042	0.033	0.041	0.03	0.043	0.019	0.042	0.021

Where, Q_D and Q_R is the delivered and required discharge from the off taking point of tertiary canal TC_i is tertiary canal and i is 1, 2, 3...10

[illegible]

From Table 5 the estimated value of ERHT for June, July and August are 0.97, 0.73 and 1.03 respectively. The average value of ERHT is 0.91. The overall average value is 0.91 which lies in between 0.8-0.9 & 1.1-1.2, so the system has a good performance. However, during July month result of ERHT obtained in Table 5 is 0.73 which is satisfactory.

5) Deficiency

The parameter helps the system managers and users to take corrective measurements for improving the system in the deficit area. As the value of PDF equal to or close to 0.00, supply is uniform at each off-take. However, PDF value is greater than zero ($PDF > 0$) a deficiency in supply was happened. In this case, crops may suffer from water stress [15].

Table 6. Average spatial and temporal Deficiency (PDF) of system.

Month	Head				Middle		Tail				Spatial Ave
	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	
Jun	0.00	0.14	0.00	0.00	0.00	0.00	0.16	0.00	0.00	0.14	0.04
Jul	0.00	0.00	0.12	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.02
Aug	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Temporal Ave. at TC	0.00	0.05	0.04	0.00	0.04	0.00	0.05	0.00	0.00	0.05	0.02
At reaches	0.02				0.02		0.02				

As per Table 6, the temporal averaged values of deficiency at the tertiary outlet points were ranges from 0.00 (0%) to 0.05 (5%). The higher deficit was observed at tertiary outlet points TC2, TC3, TC5, TC7 and TC10 and all the remaining outlet points had the lowest values (0%).

In general average overall deficiency of the delivery system was found to be 0.02. During the three successive months the system has been supplied ninety eight percent (98%) of the total required amount of irrigation water. Only

two percent (2%) of the irrigated commands has not been satisfied by the system. Therefore, system has negligible amount of deficiency and performance of the system is satisfactory.

6) Efficiency

The parameter shows how the water resource would be conserved [14] and knowing how the system was conveyed a required amount.

Table 7. Average spatial and temporal efficiency of the system.

Month	Head				Middle		Tail				Spatial Ave (PF)
	TC1	TC2	TC3	TC4	TC5	TC6	TC7	TC8	TC9	TC10	
Jun	0.67	1.00	1.00	1.00	0.66	1.00	0.57	1.00	0.67	1.00	0.86
Jul	0.53	1.00	0.65	0.71	1.00	1.00	0.63	1.00	0.58	1.00	0.81
Aug	0.56	0.63	0.63	1.00	0.60	1.00	0.50	1.00	0.79	1.00	0.77
Temporal Average	0.59	0.88	0.76	0.90	0.75	1.00	0.56	1.00	0.68	1.00	
Average (PF)	0.78				0.88		0.81				0.81

The monthly spatial average efficiency values were gradually declined from June to August. The values show that the efficiency spatially perceived in June was rated as 'good' (higher than 0.84). The efficiency of water supplied in the head and tail reaches were rated as fair. This problem was leakage due to uncontrolled delivery of water in the tertiary canal outlet of TC1, TC3, TC7 and TC9 (Table 7). The overall efficiency (PF) of a system was estimated to be 81 percent. Based on Molden and Gates (1990) suggested the range of performance evaluation criteria, the efficiency performance value found was considered as fair.

3.2.2. Conveyance Indicators

The main purpose of the conveyance system is to transport the delivered amount of the location of crop field. In unlined earthen canal, part of water conveyed is lost and reduced amount of water reaches to the field.

Conveyance efficiency and conveyance losses were calculated as shown in (8) and (9) respectively. The estimated average values of inflow, outflow, water conveyance efficiency and water conveyance losses for different section

of the secondary canal are presented in Table 8. In Left bank of Omo Kuraz irrigation scheme, the conveyance efficiency of the secondary canal four (SC-4) was decreased as far from head to tail reaches of the canal. The mean observed conveyance efficiency ranges from 75-85.31%, the minimum value occurred during June month at the tail reach (From 2+350 to 3+33m) of secondary canal. This is because of the reach of the canal was cracked which resulted seepage and leakage losses. The overall average value of conveyance efficiency of the 3.33km Secondary canal was 81.20%. The canal losses were 18.80% of the water through seepage due to the fact that it is an earthen canal. Siltation and vegetation growth within the canal interferes with water flow reducing the conveyance efficiency. According to the FAO guidelines, the indicator parameter values of the conveyance efficiency for adequately maintained earthen canals having more than 2000m canal length with clay soils should be 80%. This indicates that the maintenance at secondary canal was adequate and therefore there was no need of routine maintenance.

Table 8. Conveyance Efficiency of Secondary canal.

Month	Chain- age (m)	Location	Inflow (m ³ /s)	Outflow (m ³ /s)	Ec (%)	Lc (%)
June	From 0+20 to 0+150	Between HR and BD-1	0.46	0.385	83.7	16.3
	From 0+150 to 0+850	Between BD-1 and BD-2	0.34	0.28	82.35	17.65
	From 0+850 to 1+650	Between DB-2 and BD-3	0.22	0.177	80.45	19.55
	From 1+650 to 2+350	Between DB-3 and BD-4	0.11	0.087	79.09	20.91
	From 2+350 to 3+330	Between DB-4 and BD-5	0.06	0.045	75	25
July	From 0+20 to 0+150	Between HR and BD-1	0.51	0.43	84.31	15.69
	From 0+150 to 0+850	Between BD-1 and BD-2	0.37	0.31	82.43	17.57
	From 0+850 to 1+650	Between DB-2 and BD-3	0.26	0.21	79.83	20.17
	From 1+650 to 2+350	Between DB-3 and BD-4	0.09	0.07	81.11	18.89
	From 2+350 to 3+330	Between DB-4 and BD-5	0.07	0.06	81.43	18.57
August	From 0+20 to 0+150	Between HR and BD-1	0.57	0.48	84.21	15.79
	From 0+150 to 0+850	Between BD-1 and BD-2	0.41	0.34	82.93	17.07
	From 0+850 to 1+650	Between DB-2 and BD-3	0.32	0.26	81.14	18.86
	From 1+650 to 2+350	Between DB-3 and BD-4	0.18	0.14	81.37	18.63
	From 2+350 to 3+330	Between DB-4 and BD-5	0.07	0.06	78.57	21.43
Overall average					81.2	18.8

3.2.3. Maintenance Indicators

Maintenance performance inspection of irrigation scheme is important to insight the feature of maintenance situations. Inspection of the maintenance statuses of the system was required to identify the problems. The maintenance innovation of a system have a duty undertaking for the purposes of safety improvement, keeping water control, distribution and other infrastructures in good working condition designed in sustainable base [19]. In order to improvement system performance in this study, maintenance requirement was observed according to the maintenance indicators of effectiveness of infrastructure, water surface

elevation ratio, delivery duration ratio and sustainability of irrigated area.

1) Effectiveness of Infrastructure

Effectiveness of infrastructure is measured by the ratio of the number of functioning structures to the total number of structures initially constructed. The total number of structures that were initially constructed on Irrigation scheme was 142. Out of 142, only 118 structures are functional (shown in Table 9). The average values of effectiveness of infrastructures estimated to be 89.68% which indicates that the maintenance activity of the system was fair.

Table 9. Functional and mal-functional irrigation infra structures.

SN	Infra structures	Total number of installed structures	Functional	Mal-functional	effectiveness of infra structures
1	Secondary head regulator	1	1	0	100
2	Secondary cross regulator	5	4	1	80
3	Division box	5	5	0	100
4	Tertiary head regulator	10	9	1	90
5	Quaternary regulator	35	26	9	74.3
6	Tertiary cross regulator	35	26	9	74.3
7	Drop structures	6	6	0	100
8	Tertiary off takes	10	10	0	100
9	Quaternary off takes	35	31	4	88.6
	Total	142	118	24	89.68
	Position (%)		83.1	16.9	

In addition to the above calculation, the existing condition of irrigation infrastructures of the scheme was also evaluated by setting condition grade for the infrastructures. A condition assessment was conducted using a top down approach based upon staff knowledge, maintenance records, customer complaints (water users) and performance records. A physical check was conducted whenever routine maintenance was done. Information collected on the condition was recorded in the infrastructure register and updated in the strategic plans where necessary (Internet: www.treasury.gov.za). Each infrastructure was inspected on a risk based cycle, with an accurate description of condition,

and identification of specific defects. These defects were due to physical deterioration in irrigation system and inefficient management of scheme. Each and every structure including secondary and tertiary canals was evaluated by using condition determination parameter according to its physical state of structures inspected according to their original design standards. According to condition determination parameter the average condition of secondary canal, tertiary canals, division boxes, drops, tertiary and quaternary off takes, head and cross regulators on secondary canal and head and cross regulators were 81, 66.8, 86.6, 84.8, 87.4, 86.8 and 52 percent respectively.

2) Water Surface Elevation Ratio (WSER)

WSER is important parameter to predict the impact of sedimentation, canal bed scouring problem and erosion problem on the irrigation scheme. It was calculated by

measuring the actual water depth from the canal bottom on different measurement points in each individual monitoring station and comparing it with the design water depth at (FSL) at the same position in the secondary canal (equation 11).

Table 10. Average Water Surface Elevation (WSE) of the secondary canal.

Station	Head			Middle			Tail			Over all	
	Chain (m)	DEV. WSEa	WSER	Chain (m)	DEV. WSEa	WSER	Chain (m)	DEV. WSEa	WSER	WSER	DEV. WSE
H1	20	0.01	1.00	1200	0.03	0.96	2300	0.003	1		
H2	110	0.02	0.98	1350	0.02	0.98	2450	0.13	0.76		
H3	250	0.02	0.98	1500	0.02	0.98	2600	0.01	0.98		
H4	400	0.02	0.98	1650	0.02	0.97	2750	0.03	0.93		
H5	600	0.01	0.98	1800	0.04	0.93	2900	0.04	0.9		
H6	800	0.01	0.99	1950	-0.06	1.11	3050	0.01	0.98		
H7	1000	0.04	0.95	2100	-0.02	1.03	3200	0.04	0.9		
H8	1110	0.03	0.96	2220	-0.03	1.05	3330	0.02	0.95		
Ave.		0.02	0.98		0.01	1.00		0.04	0.92	0.965	0.011
Max.		0.04	1.00		0.04	1.11		0.13	1.00		

Average Parameter of WSER at head and tail reaches of the secondary canal during the monitoring period was less than one, thus it shows that the secondary canal has an effect of sedimentation problem [20]. Overall average value of WSER was found to be 0.96 which means water surface elevation was 3.5 percent was reduced in the intended water depth of the secondary canal. This indicates the canal had an effect of sediment accumulation and choked with grass did not have maintenance schedule for sediment clearing and weed removal.

3) Dependability Duration (DDR)

Dependability Duration is the ratio of actual duration of irrigation water delivery (hours) to the intended irrigation water duration (hours).

According to the design document the intended duration of water delivery was 24 hours per day. Because entry of silt, debris and foreign material to the main canal, excess flow of river water which caused unstable full supply level in canal and deterioration of side slope material due to sudden draw down condition, the average delivery duration is reduced to 21 hours. The value of delivery duration ratio (DDR) was calculated using equation (12) Thus, DDR is 0.875; according to the standard presented in Table 1 the value is ranked 'poor'.

4) Sustainability of Irrigated Area (SIA)

SIA is an indicator used to point out the command areas planned to irrigate is either fully exhausted or not. This indicator enabled to investigate the variation in the area actually irrigated against the designed area in terms of ratio and provide valid reasons for such variation [23]. On the design document of the planned irrigable area of secondary four at Left bank Omo Kuraz irrigation scheme was 777.85ha. The actual irrigated area in the irrigation season was 743.334ha. Hence, SIA was 95.56 percent using equation (14). The command areas were reduced because of delaying of land preparation operation 34.516ha was not planted. Hence, the maintenance of irrigation system is not the limiting factors in the reduction of irrigated area.

4. Conclusions and Recommendations

4.1. Conclusions

Assessing the performance of an irrigation scheme is important management functions which indicates the state of the scheme and suggest possible remedial measures to improve the effectiveness of the scheme. This study was to assess the performance of Omo Kuraz irrigation scheme with respect to utility of water supply indicators, conveyance indicators and maintenance indicators. Overall Performance of the scheme in terms of utility of water supply indicators of the secondary canal were found to be good in terms of adequacy, dependability, equity, equity ratio for head to tail and deficiency respectively, however, overall efficiency for the system was satisfactory performance. This was due to malfunctioning of head and cross regulators, some parts of the canal observed was braced with grass, cleaning the canals without specific standards has made some of its sections to enlarge, the absence of flow measuring devices in order to deliver only required water, bed scouring and sedimentation of parts of the reaches secondary canal and improper operation of water delivery system.

The average conveyance efficiency in the secondary canal was found to be 81.2%, slightly above 80% according to FAO guidelines, it was recommended for unlined earthen canals with more than 2000m canal length. It was concluded that conveyance efficiency was higher at the head reach because the canal section at the head reach was intact and having stable banks with no visible seepage. However, it was lower in the tail-reaches due to Siltation and vegetation growth within the canal interferes with water flow reducing the conveyance efficiency. The secondary canal needs maintenance to minimize water losses in the tail reach of the canal.

Performance of the scheme related with maintenance has been unsatisfactory. On average, the mean level of surface water for secondary canal has been reduced by three percent from the full supply level. From gross planned command

areas of the irrigation scheme 34.52ha was not covered by sugar cane which means total intended area was reduced by five percent. Therefore, proper maintenance of hydraulic gates and hoists is very essential for satisfactory operation of gates to control water heads and distribute adequate and equitable amount of water throughout the system, for their long term sustainability and continuous monitoring and maintenance is required to improve the performance.

4.2. Recommendations

- 1) Flow at every delivery tertiary outlet point (at head, middle and tail reaches of the system) should be monitored for a sustainable irrigation water management. It could be important for supplying the only amount of irrigation water which crop needs, increasing efficiency the irrigation system and also important for evaluating service delivery of the irrigation system.
- 2) Even if the service years of the irrigation scheme are only six years, the system has been facing a number of challenges especially those related with operating gates. Most operating sluice gates are totally nonfunctional should be maintained and completely damaged parts of the gates would be replaced by the new components would result in lower future maintenance costs, less frequent breakage, easily operated.
- 3) Applying proper water distribution plan in the system according to the crop required amount which might be vital for improving proportional irrigation water supply and demand among tertiary outlet. The crop water requirement varies according to its growth stages; hence the rotation shall be based on crop water demands in the area.
- 4) In order to reduce water losses, the secondary canal at the tail reach should be regularly maintained. At high fill reaches of the canal should be lined in order to be more effective and permanently reduce water conveyance losses.
- 5) The physical restoration and implementation of new management technique must be included in the operational changes.

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