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Gashaw Sintayehu Angualie (✉ gashawsintayehu774@gmail.com)

woldia university

Alemshet Belayneh

Woldia University

Kibru Gedam Berhanu

Gonder University

Tirunesh Muluken Munye

Mekdela Amba University

Kefale Ejigu

woldia university

Chalachew Alemu

woldia University

Dawit Munye Tamirat

Debre Tabor University

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Evaluation of Hydraulic performance on Lower Areb small scale irrigation scheme
Amhara, Ethiopia

Gashaw Sintayehu^{1*}, Alemshet Belayneh², Kibrit Gedam³, Tirunesh Muluken⁴, Kefale Munyeh⁵ Chalachew Mulat⁶

¹Department of Water resources and Irrigation Engineering, Institute of Technology,
Woldia University, P.O.Box 400 Woldia, Ethiopia,
gashawsintayehu774@gmail.com;Tel.:+251-9-18-31-53-23

²Department of Water resources and Irrigation Engineering, Institute of Technology,
WoldiaUniversity, P.O.Box 400 Woldia, Ethiopia, E-Mail: alembe29@gmail.com
Tel.:+251-9-11-58-79-87

³Department of Hydraulic and Water Resources Engineering, Institute of Technology,
University of Gondar, P.O.Box 196 Gondar, Ethiopia, E-Mail:
meftihewgedam6477@gmail.com;Tel.:+251-9-36-58-48-45

⁴Department of Agricultural Economics, Collage of Agriculture, Mekdela Amba
University,Ginba,Ethiopia,E_Mail:muluken.tirunesh@gmail.com:Tel:+251_9_37_34_14
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⁵Department of Water resources and Irrigation Engineering, Institute of Technology,
Woldia University, P.O.Box 400 Woldia, Ethiopia, kefaemunye1921@gmail.com,Tel:
+251_18_60_09_47

⁶Department of Water resources and Irrigation Engineering, Institute of Technology,
Woldia University, P.O.Box 400 , Woldia, Ethiopia, mulatchalachew@gmail.com,Tel:
+251_18_37_26_32

ABSTRACT

This study was conducted in the Lower Areb small-scale irrigation scheme for one crop season from March to May 2018 to evaluate the hydraulic performance of the scheme by estimating the hydraulic performance indicators, physical performance indicators, and maintenance performance indicators. The primary data including water flow rate, soil physical properties, and water infiltration were collected. The secondary data collected were climatic, crop data, and data from different reports and design documents including the irrigation water users' interviews. The hydraulic performance of the irrigation scheme

was evaluated by estimating adequacy, efficiency, dependability, and equity indicators at nine selected offtakes; three each at the head, middle, and tail reaches of the scheme. The physical performance and maintenance indicators were determined using the irrigation ratio, the sustainability of the irrigated area, the effectiveness of infrastructure, and the water surface elevation ratio. The data were analyzed by using CROPWAT 8.0, ARC GIS 10.1 software, and Microsoft Excel 2013. The overall average values of adequacy, efficiency, dependability, and equity were found to be 0.89, 0.91, 0.096 and 0.07 respectively. Therefore, dependability, equity, and efficiency were under good condition and adequacy was under fair condition. The irrigation ratio and sustainability of irrigated areas were 54% and 123% respectively. The effectiveness of infrastructure and water surface elevation ratios were 73.33% and 94% respectively.

Keywords: Lower Areb irrigation scheme, Hydraulic performance, physical sustainability, and maintenance indicators.

ACRONYMS AND ABBREVIATIONS

AWSE	Actual Water Surface Elevation
CROPWAT	Crop Water Requirement Estimation Model Window 8
CV _R	Spatial Coefficient of Variation
CV _T	Temporal Coefficient of Variation
CWR	Crop Water Requirement
DWSE	Designed Water Surface Elevation
Dev.WSE	Deviation of Water Surface Elevation
EI	Effectiveness of Infrastructure
ET _C	Crop Evapotranspiration
ET _O	Reference Crop Evapotranspiration
IR	Irrigated Ratio
Masl	Meter Above Sea Level
PA	Adequacy
PD	Dependability
PE	Equity
PF	Efficiency
QD	Actual Delivered Discharge
QR	Actual Required Discharge

1. INTRODUCTION

Ethiopia has abundant rainfall and water resources, but the agricultural system does not use fully the technologies of water management and irrigation (Tariku, E & Ayana, M, 2017). The majority of the population in Ethiopia depends on rain-fed agricultural production for its livelihood. However, the total crop production is not sufficient to fulfill the food requirements of the country. One of the best alternatives to be considered for reliable and sustainable food security development is expanding irrigation development at various scales (Lambisso, 2008). Irrigation development is an important tool to stimulate economic growth and rural development, and it is considered a cornerstone of food security and poverty reduction in Ethiopia. Increased availability of irrigation and less dependency on rain-fed agriculture taken as a means to increase food production and self-sufficiency of the rapidly increasing population in the country (Rust and Snellen, 1993; Awulachew *et al.*, 2005).

In Ethiopia, there is a large irrigation potential (5.3 million ha), but the area developed under irrigation is less than its potential (Dejen *et al.*, 2015). Even, the developed irrigation schemes do not perform well as planned and expected because of several interrelated factors. The hydraulic performance of the irrigation scheme is one of the crucial issues, which hinders the irrigation development in Ethiopia attributed to low performances (Awulachew and Ayana, 2011). Among the factors which pose the low performance of irrigation schemes are poor design, inadequate irrigation scheduling, inadequate operation plan, waterlogging, inadequate water control facilities, lack of adequate maintenance, and other management gaps related to the distribution of irrigation water between beneficiaries (Awulachew, 2010; Dejen *et al.*, 2015; 2016; Dejen *et al.*, 2015; Firew, *et.al*, 2017; Woodroffe, 1993). To alleviate these problems and increase food production for sustainable food security of increased population growth, the irrigation scheme should be achieved by efficient and effective irrigation management (Tebabal and Ayana, 2015; Tariku & Ayana, 2017). Therefore, giving more consideration to the existing irrigation schemes and evaluating their performance is a crucial issue to minimize losses of water and improve the irrigation water use efficiency.

Performance assessment is used to identify the present status of the performance of the scheme using different indicators. These indicators evaluate the spatial and temporal distribution of the required and delivered water for the given irrigation scheme (Tebebal , 2015) The in-situ measurement can provide a quantitative assessment of overall system performance. Therefore, this study was intended to evaluate the hydraulic performance of the irrigation scheme with irrigation service at Lower Areb small-scale irrigation scheme, Ethiopia.

2. MATERIALS AND METHODS

2.1 Location of the Study Area

Lower Areb small-scale irrigation scheme is located in between North and South Achefer district of West Gojjam Zone, Ethiopia. The Lower Areb River is supplied water from the Upstream of Yismala passing through Gilgel Abbay River.

Geographically the project area is located at $11^{\circ} 30' 00''$ to $11^{\circ} 36' 00''$ latitude and $36^{\circ} 48' 00''$ to $37^{\circ} 00' 00''$ longitude. The elevation in the watershed varies from 1847 masl on the axis of the headwork to 2200 masl on the upper ridge. The headwork structure is located at an altitude of 1860 masl.

The location map of the Lower Areb small-scale irrigation scheme is shown in Figure 1.

Figure 1: Location map of Lower Areb small scale irrigation scheme

2.2 Background of Lower Areb small scale irrigation scheme

Lower Areb irrigation project was constructed in April 2006 with financial assistance from World Bank. The project has been given a four-year operational service period. The irrigation system encompasses one intake outlet at the left of the headwork and the canal network with 1 main canal and 12 tertiary canals. The intake outlet was controlled by the under sluice gate and the trash rack for guaranteeing the normal diversion and to remove sediment entering and flood to the main canal to keep the safe operation of the system. The main canal was a lined rectangular canal that starts from the intake outlet on the left side of the headwork conveys water for a length of 2.594 km. The tertiary canals were an earthen trapezoidal canal that offtakes water from the main canal and divides it among field canals. The water distribution was rotational for tertiary canals. The layout of the Lower Areb irrigation scheme is shown in Figure 2.

Figure 2: Layout of Lower Areb irrigation scheme

2.2.1. Soil

The soils of the project command area according to the design document were divided into two major soil types, Vertisols, and luvisols. Vertisols are deep and heavy clay soils that swell and shrink. Luvisols are deep reddish clay soil. Soils of the plains in the Lower Areb area were deep and possess good drainage characteristics. Soil texture in the study area was clay and clay loam with clay dominating.

2.2.2. Climate

The project area is characterized by “Woyenadega” agroecology based on the elevation of the area. The rainfall pattern of the project area is unimodal type in which one main rainy season occurs during July to August. The average monthly rainfall in July and August is 360.8mm and 378.3mm respectively. The mean annual rainfall of the area is 1630.2mm. The prevailing temperature considerably influences the selection of crops and their growing periods. The mean maximum and minimum annual temperature are 25⁰C in April and 9.3⁰C in January respectively. The mean monthly and sunshine hour duration of the project area varies between 4.2 hours per day to 8.9 hours per day with an annual average value equal to 7.1 hours per day. The mean monthly relative humidity in the project area varies from the lowest 44% in February to the highest 78.1% in August with a mean annual value equal to 61.8%. The mean monthly wind speed varies from 52 km per day in November to 93 km/day in May with the mean annual value equal to 75 km/day.

2.2.3. Crop

The major irrigated crops grown in the Lower Areb irrigation scheme are cereal and vegetable crops. The cereal crops are maize, teff, sorghum, barley, and wheat. The vegetables are potato, onion, tomato, and cabbage. Crops grown in the area vary from season to season. The crops grown during the present study period were potato, maize, onion, wheat, and barley. The dominant crop grown in the command area of this irrigation scheme was the potato.

2.3. Sampling Technique

Conducting in-situ measurements in all canal branches and for each offtake was a difficult task due to its time-consuming and cost-effectiveness. Therefore, the representative locations for data collection were selected through a stratified sampling technique. The measurements of delivered discharge in the command area were made at 9 selected offtakes out of 12 total offtakes. Three offtakes were selected at each of the upstream, middle, and downstream reaches of the main canal which grow a similar crop in all fields per offtake. In the present study, nine tertiary offtakes which grow similar crops per tertiary offtake were selected since CWR estimation is possible in these offtakes. The layout of the canal and the location of selected offtakes for discharge measurement are shown in figure 2.

2.4. Methodology and Data Collection

This study was carried out for one irrigation season, from March to May 2018. The choice of selecting this period for the study was because there was hardly any rain during the period and almost all field crops were irrigated. Both quantitative and qualitative data were collected from primary and secondary sources. The primary data were collected from direct field measurements, field visits, and laboratory analysis. The secondary data were obtained from the north Achefer district agricultural office, Amhara National Regional Bureau of Water and Irrigation energy, regional meteorological agency, related journals, published and unpublished thesis, and FAO documents.

2.5. Data Analysis Techniques

The hydraulic performance was evaluated in the present study by using hydraulic performance indicators, maintenance indicators, and physical sustainability performance indicators. These primary and secondary data were analyzed by using MS excel 2013, CROPWAT 8.0 model, and different relationships as proposed by Molden and Gates (1990).

2.6. Discharge measurement

The discharge measurements were one of the reliable data to evaluate scheme performance indicators. The water flow velocity and water flow depth of the offtakes were measured using the current meter and calibrated 3-inch Parshall flume.

2.6.1. Velocity measurement using current meter

The current meter is the most widely used device to measure the velocity of water flow. The velocity at the selected points of the reach was measured using SEBA-universal current meter F1 with synthetic propeller, 125mm diameter as shown in Figure 3. It measures the number of revolutions of the propeller per second.

The depth of flow water in the selected point was less than 0.6 meters which is a shallow depth of flow. Therefore, the flow velocity measurements with the current meter were made at 60% of the depth of water from the water surface (USBR, 2000 ; 2001). The velocity of flow using the current meter at the selected cross-section was determined by counting the number of revolutions within 30 seconds. The measurement was done three times at each location for the same period (30 seconds). The measurement was considered correct and

the average revolutions considered if the number of revolutions for all three measurements was almost the same.

The velocity of water flow was calculated from the measured values of the current meter propeller revolutions using Equations 2.1 to 2.4.

$$V = k \cdot n + \Delta \text{-----} (2.1)$$

$$V = 0.3117 \cdot n + 0.0193, \text{ if } 0.00 < n < 1.98 \text{-----} (2.2)$$

$$V = 0.3205 \cdot n + 0.0019, \text{ if } 1.98 < n < 10.27 \text{-----} (2.3)$$

$$V = 0.3344 \cdot n - 0.1409, \text{ if } 10.27 < n < 15. \text{-----} (2.4)$$

Where:

k is hydraulic pitch of the propeller (m).

Δ are characteristics of the current meter (ms^{-1})

n is the number of propeller rotations per second, and

V is the water flow velocity (ms^{-1}).

The canal dimensions were measured using a tape meter. The canal discharge was calculated using Equation 2.6.

$$Q = A \cdot V \text{-----} (2.6)$$

Where:

Q = canal discharge (m^3s^{-1}),

A = flow cross-sectional area (m^2) and

V = flow velocity (ms^{-1})

2.6.2. Water flow depth measurement using Parshall flume

Parshall flume is the most commonly used open channel flow measuring device in an irrigation system. It was developed at Colorado State University by Ralph Parshall (Merkley, 2004). It is a critical depth measuring device that is installed in a canal, ditch, or furrow to measure the rate of water flow. The Parshall flume consists of a converging section with a level floor, a throat section with a downward sloping floor, and a diverging section with an upward sloping floor. A Three-inch Parshall flume was installed at the entrance of each field for each of the selected 9 offtakes. The water flow condition in the

Parshall flume was free flow as shown in Figure 4. The depth-flow relationship for free flow condition in Parshall flume as proposed by Merkley (2004) may be expressed by Equation 2.7.

$$Q = KH^n \text{-----} (2.7)$$

where:

Q = delivered discharge (m^3s^{-1})

H = upstream flow depth in the converging inlet section (m),

K = free flow coefficient and

n = free flow exponent.

The values of k and n are a function of the dimension of the constriction of the Parshall flume and measurement unit chosen. The value of the constant of k and n for three-inch Parshall flumes and metric units were 0.1771 and 1.55 respectively. The validity of the coefficients (free flow coefficient, K and free flow exponent, n) for the study area was examined by measuring the water flow velocity at three tertiary offtake measuring points using the Current meter. The tertiary offtake TO3, TO7, and TO9 were selected to cross-check the delivered discharge measured using the Parshall flume. The results obtained from the Parshall flume and current meter for the selected control points were almost similar. Therefore, the selected values of the coefficients $K=0.1771$ and $n=1.55$ for the 3-inch size Parshall flume were correct and further calibration of these coefficients was not mandatory.

The minimum and maximum discharge and head range of three-inch Parshall flume are 0.77 l/s and 32 l/s and 0.03 m and 0.33 m respectively (Merkley, 2004). The discharges may also be determined using Equation 2.7.

Figure 3: Discharge measurement using Current meter

Figure 4: Discharge measurement using Parshall flume

2.7. Estimation of Crop water requirement

The CROPWAT version 8.0 program was used to determine the amount of water required for different crops. The crop water requirements, irrigation requirements, and irrigation scheduling were estimated based on soil, climate, infiltration rate, total available moisture, and crop type. Crop characteristics were taken from FAO documents as given in CROPWAT 8.0 program; but, for Onion FAO (1998). The other crop data like planting date, harvesting date, and the length of crop growth period were obtained from the irrigation users. The overall irrigation efficiency for small-scale irrigation was assumed to equal 45% (Chancellor & Hide, 1997). The designers of the Lower Areb irrigation scheme also adopted this value of overall irrigation efficiency equal to 45%.

The CROPWAT Model was used to estimate the monthly reference crop evapotranspiration (ET_o) and effective rainfall (ER) using 30 years (1987-2017) average climatic data gathered from Regional Meteorological Agency. The climate data were mean monthly maximum and minimum temperature (°C), relative humidity (%), wind speed (km^d⁻¹), sunshine hours (hr.), and mean monthly rainfall (mm). The CROPWAT model uses FAO (1992) Penman-Monteith equation for computing reference crop evapotranspiration. The effective rainfall was computed by using the USDA soil conservation service method (Clarke, 1998). The crop water requirements (CWR) were computed from the crop factor (K_c) and the ET_o values for the crop planted. The reference crop evapotranspiration (ET_o) was determined by the CROPWAT 8.0 program using climate data of average monthly minimum and maximum temperature (°C), average monthly relative humidity (%), average monthly sunshine hours, and average monthly wind speed (km^d⁻¹). The additional data for determining the water need of crops were soil characteristics of the command area, agronomic data (crop planting date, harvesting date,), crop coefficient (k_c), critical

depletion, and yield response. The effective rainfall (ER) was determined by CROPWAT software using average monthly precipitation.

The allowable soil moisture depletion fractions for each crop at each growing stage were adopted from FAO Irrigation and Drainage paper 24 and 56, and different other research documents. After estimation of the ET_o and effective rainfall values for each crop, the crop water requirement and the duty of each crop were determined from the CROPWAT model. The crop water requirement was determined using Equation 2.8. The duty of the crops was determined using Equation 2.9.

$$ET_C = K_C * ET_o \text{-----} (2.8)$$

Where:

ET_C = Crop evapotranspiration (crop water requirement)

ET_o = Reference crop evapotranspiration

K_C = Crop coefficient

$$D = \frac{GIR}{8.64} \text{-----} (2.9)$$

where:

D = Flow duty (l/s/ha),

GIR = Gross irrigation requirement (mmd^{-1})

8.64 = Unit conversion factor

The gross irrigation water requirement (GIR) was estimated using Equation 2.10.

$$GIR = \frac{NIR}{E_i} \text{-----} (2.10)$$

where:

GIR = Gross irrigation requirement (mm)

NIR = Net irrigation requirement (mm)

E_i = Overall irrigation efficiency (fraction)

The values of NIR were estimated as under.

$$NIR = ET_C - ER \text{-----} (2.11)$$

Where:

ER = effective rainfall, estimated from actual rainfall using CROPWAT software

The required discharge (Q_R) for each crop was determined by multiplying the cultivated area of each crop by the duty of the crop as expressed by Equation 2.12.

$$Q_R = D * A \text{ ----- (2.12)}$$

where:

Q_R = the water required for the crop in each offtake structure ($l s^{-1}$)

D = Duty of each crop ($l s^{-1} ha^{-1}$)

A = Area covered by each crop irrigated by each offtake (ha).

2.8. Hydraulic performance indicators

The hydraulic performance of the Lower Areb small-scale irrigation scheme was evaluated using performance indicators adequacy (P_A), efficiency (P_F), dependability (P_D), and equity (P_E) as proposed by Molden and Gates, (1990).

Molden *et al* (1990) proposed standards for the hydraulic performance indicators as given in Table 1.

Table 1: Standards for hydraulic performance indicators (Molden *et al*, 1990)

Indicators	Poor	Fair	Good
Adequacy indicator (P_A)	<0.80	0.80–0.89	0.90–1.00
Efficiency indicator (P_F)	<0.70	0.70–0.84	0.85–1.00
Equity indicator (P_E)	>0.25	0.11–0.25	0.00–0.10
Dependability (P_D)	>0.20	0.11–0.20	0.00–0.10

These indicators were determined using the delivered discharge and required discharge at each of the nine- selected off-takes structures from March to May 2018 as described below.

2.8.1. Adequacy

Adequacy is a measure of the delivery of the required amount of water for optimal plant growth. It relates the actual delivery to the desired amounts of water needed for crop irrigation at delivery points in the system. Adequacy is the ratio of water delivered (QD) to water required (QR) for a single offtake. The adequacy was determined for service area (R) represents the sub-region of the system whose performance is determined and averaged over three months of the study period (T) from March to May 2018 represents the period in which system performance was determined of the entire irrigation system. The adequacy was evaluated as the spatial variation of adequacy levels at the head, middle, and tail offtakes and the temporal variation of adequacy levels throughout the three months using Equation 2.13.

$$P_A = \frac{1}{T} \sum_T \left(\frac{1}{R} \sum_R \frac{Q_D}{Q_R} \right) \text{-----} (2.13)$$

where:

P_A = adequacy indicator over an area R and Period T,

Q_D = Actual Amount of Water Delivered at each offtake for a specific period,

Q_R = irrigation water required for crop consumptive use at each offtake for a specific period.

2.8.2. Efficiency

Efficiency is the measure of the excess of water delivered in comparison with the requirements. It expresses the ability to conserve water by matching the water deliveries with water requirements and if the system is supplying more than the water requirement, it indicates the non-conservation of the resources. Efficiency is determined as the ratio of required to delivered flows (Q_R/Q_D). Efficiency was determined for the head; middle and tail reach off takes using Equation 2.14.

$$P_F = \frac{1}{T} \sum_T \left(\frac{1}{R} \sum_R \left(\frac{Q_R}{Q_D} \right) \right) \text{-----} (2.14)$$

Where:

P_F = efficiency indicator over an area R and period T.

2.8.3. Dependability

It is an indicator of the degree of reliability of water delivery. It is the degree of temporal variability in the ratio of the amount delivered to the amount required ($\frac{QD}{QR}$) over a region. This performance measurement indicates the uniformity of QD/QR over time. An irrigation system that achieves almost steady water distribution is considered to be dependable when the value of PD approaches zero and PD values close to 1.0 indicate serious unreliability of water distribution. This indicator may be estimated using Equation 2.15.

$$P_D = \frac{1}{R} \sum_R CV_T \left(\frac{QD}{QR} \right) \text{-----} (2.15)$$

where:

P_D = dependability indicator over some time T for a region R, and

CV_T = temporal coefficient of variation of the ratio QD/QR over time T.

The above equation is the general equation of estimating the overall average value of the temporal coefficient of variation of dependability through the time of three months from March to May of the selected 9 offtakes. The value of the temporal coefficient of variation was determined by the ratio of temporal mean and standard deviation. The temporal mean can be determined by the average QD/QR value of a single offtake for three months.

2.8.4. Equity

Equity as related to the water delivery system can be defined as the delivery of fair shares of water to the users throughout the system. It is a measure of the spatial uniformity of the water deliveries of the ratio of the amount of water delivered to the amount of water required over the interesting period and shows the fairness of water delivery across the delivery points. The value of Equity close to zero, the greater the degree of equity (special uniformity) of water delivery. The equity was calculated using Equation 2.16.

$$P_E = \frac{1}{T} \sum_T CV_R \left(\frac{QD}{QR} \right) \text{-----} (2.16)$$

Where:

P_E = equity indicator over an area R for a period of T, and

CV_R = spatial coefficient of variation of the ratio QD/QR over a region R.

The value of the spatial coefficient of variation was determined by the ratio of the spatial mean over standard deviation. The spatial mean can also be computed by the average ratio of QD and QR values for nine selected offtakes.

2.9. Physical Sustainability Performance Indicators

The hydraulic performance of the scheme could also be evaluated through physical sustainability performance indicators. The physical sustainability indicators are related to the changing or losing of irrigated land in the command area due to different reasons. The two relevant physical sustainability performance indicators used in this study were the sustainability of irrigated areas and irrigation ratio as proposed by (Tariku & Ayana, 2017).

2.9.1. Sustainability of irrigated area

SIA is a useful indicator for evaluating the sustainability of irrigated agriculture. The values of SIA were computed by using Equation 2.17.

$$SIA = \frac{\text{Currently irrigated Area}}{\text{initially irrigated area}} \text{-----} (2.17)$$

The actual irrigated area and initially irrigated area were obtained from district experts, the Water user association, and Development agents. The actual irrigated areas for the irrigation scheme were determined in two ways, the first was by collecting the list of irrigation water users along with their irrigated land holdings compiled by the scheme water user associations and the second was, by using GPS conducted to determine non-irrigated lands, residential areas, and grazing land. The net irrigated land area was then determined as the difference between total command areas and the sum of all non-irrigated land areas within the command.

2.9.2. Irrigation ratio (IR)

The irrigation ratio shows the degree of utilization of the available irrigable command area for irrigated agriculture for a particular production period. The value of IR was estimated using Equation 2.18.

$$IR = \frac{\text{Currently Irrigated area}}{\text{Currently irrigable area}} \text{-----} (2.18)$$

The irrigable area of the irrigation system was determined by locating GPS to the boundary of the irrigable area.

2.10. Maintenance indicators

Appropriate maintenance enables the keeping of water control and distribution infrastructure in good working condition to maintain the design water level. The hydraulic performance of the scheme could also be evaluated through maintenance performance indicators as recommended by Tebebal and Ayana (2015). The maintenance-based performance indicators for the present study were: effectiveness of infrastructure (EI) and water surface elevation ratio (WSER).

2.10.1. Effectiveness of infrastructure

The assessment was focused on the physical structures in the irrigation system components including weir and under sluice except for the drainage system. The existing condition of the main canals was inspected in its operating length alone. The values of EI were estimated using Equation 2.19.

$$\text{Effectiveness of infrastructure} = \frac{\text{number of functioning structure}}{\text{Total number of structures}} \quad (2.19)$$

2.10.2. Water surface elevation Ratio (WSER)

This indicator provides to foresee the scouring and siltation problems in the physical irrigation system. The actual water surface elevation can be computed by using this Equation 2.20. The actual water surface elevation at FSL was measured from the field but the design Water surface elevation was taken from the design report of the Lower Areb irrigation scheme.

$$\text{WSER} = \frac{(\text{AWSE})}{(\text{DWSE})} \quad (2.20)$$

where:

WSER = water surface elevation ratio in %,

AWSE = actual water surface elevation in m

DWSE = design water surface elevation in m

3. RESULTS AND DISCUSSIONS

3.1. Determination of Required Amount of Water

The required amount of water for the farmer's field at each of the nine selected offtakes for each of the month's March, April, and May 2018 were estimated using Equation 2.12. The

estimated values are given in Table 2. The variation of spatial and temporal average values of the required discharge during different months and at different reaches are shown in Figures 5 and 6. The variation of the required discharge was due to the variation of area coverage and growth stage of the crop. The area coverage of the nine selected offtakes of TO1, TO2, TO3, TO4, TO5, TO6, TO7, TO8, and TO9 were 3, 4, 5, 3, 4, 3.5, 4, 3.5, and 5 ha respectively. The overall mean required discharge of the nine tertiary off-takes during the study period was 3.01l/s. It may be observed from Figure 5 that the spatially averaged values of the required amount of water during March, April, and May were 3.24l/s, 3.53l/s, and 2.27l/s, respectively. The required discharge for each offtake was low during March compared to April, because during March the crops were at the initial crop growth stage and the crops need lighter and frequent irrigation. The crops during April were at the mid-season and developmental stage the crop water required during April was the higher depth of irrigation water were larger and irrigation was done less frequently. During May crops reached the end of the developmental stage and were late-season stage and thus crop water requirement decreased. Additionally, there were some rains during May and thus the crop irrigation requirements further decreased. It may be observed from table 2 that the reach-wise temporal average values of required discharge were 3.01ls⁻¹, 2.65 ls⁻¹, and 3.38 ls⁻¹ for the head, middle, and tail reach respectively. The required discharge of the middle reach offtakes was low as compared to head and tail reaches. This discharge variation may be due to the difference in area coverage under each offtake and the variation in crop water requirement at different offtakes. The area coverage at the head, middle and tail reach were 12, 10.5, and 12.5 ha respectively.

3.2. Determination of Delivered Amount of Water

The estimated results of the delivered amount of water in the selected nine tertiary offtakes are given in Table 2. The variation of temporal average values for each offtake is shown in Figure 5. The delivered flow varied from 2.10 ls⁻¹ to 4.52 ls⁻¹. The variation of the delivered discharge was based on the area coverage and the availability of water to each offtake or the source of the supply canal to each offtake.

The spatial average values of the delivered amount of flow were 3.56 ls⁻¹, 2.82 ls⁻¹, and 2.59ls⁻¹ during March, April, and May respectively. It may be observed from the results during March the delivered discharge was greater than the required discharge because at an initial stage the crop needs less depth of water, but during April the required water was greater than the delivered because in the middle and developmental stage the crop needs

more depth of water than another stage. During May the delivered discharge was greater than the required discharge because at this month the crop reaches the end of developmental and the start of late-stage at this stage the crop needs less depth of water as compared to the middle and developmental stage. This variation occurred due to the area coverage, crop growth stage, and the availability of water in each offtake, and the diverted water from the canal. The delivered amount of water varied temporally from one location to another location. The temporal average value of delivered flow for the head, middle and tail reaches were 3.64, 2.58, and 2.74 l/s respectively.

The temporal average delivered discharge at the head flow was high. This was because due to more area coverage and there was adequate water as compared to middle and tail reach. In the middle and tail delivered discharge was low as compared to the required discharge and the delivered discharge in the head reach. This may be due to the problem of non-effective water usage, the inequitable share of water, and area coverage. The overall mean delivered flow for all of the nine tertiary off-takes during the study period was 2.99 l/s. The overall mean delivered flow was slightly lower than the overall mean of required flow. There may be due to the shortage of water, failure of the intake structure, canal sedimentation problem, and maintenance problem.

Figure 5: Temporal Average values of required and delivered flow.

Table 2: Estimated Values of Required and Delivered Flow in ls^{-1}

Reach location	Offtakes code	Months				Temporal			
		March		April		May		Mean	
		QR	QD	QR	QD	QR	QD	QR	QD

Head	TO 1	2.73	4.55	3.00	2.49	1.80	2.57	2.51	3.20
	TO2	2.88	4.64	3.20	2.68	2.36	2.26	2.81	3.19
	TO3	4.05	5.80	4.30	3.88	2.80	3.89	3.72	4.52
	mean	3.22	5.00	3.50	3.01	2.32	2.90	3.01	3.64
Middle	TO 4	2.73	2.52	3.00	2.43	1.80	2.87	2.51	2.60
	TO5	3.24	3.09	3.44	2.89	2.24	2.14	2.97	2.70
	TO 6	2.52	2.18	2.80	2.28	2.07	2.87	2.46	2.44
	mean	2.83	2.59	3.08	2.53	2.04	2.63	2.65	2.58
Tail	TO 7	3.64	3.21	4.00	2.89	2.40	2.41	3.35	2.84
	TO8	2.84	2.33	3.01	2.28	1.96	1.705	2.60	2.10
	TO9	4.55	3.76	5.00	3.54	3.00	2.57	4.18	3.29
	mean	3.68	3.10	4.00	2.90	2.45	2.23	3.38	2.74
	Spatial Mean	3.24	3.56	3.53	2.82	2.27	2.59	3.01	2.99

3.3. Evaluation of Hydraulic Performance Indicators

3.3.1 Adequacy

The adequacy values were calculated by using Equation 2.13. The graphical variation of the temporal average adequacy values for each offtake is shown in Figure 6. The average values of spatial and temporal adequacy for nine selected tertiary offtakes at the head, middle, and tail reach during the period of one irrigation season from March, April and May are given in Table 3. The temporal average values of adequacy for each of the nine selected offtakes of the study area were varied from 0.80 for tertiary offtake (TO9) to 0.97 for Tertiary offtake (TO3).

Figure 6: Average temporal adequacy for selected offtakes

It may be observed from Figure 6 that the temporal adequacy values at the tail and head were lower and higher respectively. The adequacy values of tertiary offtakes were 0.89, 0.87, 0.82, and 0.80 for TO6, TO7, TO8, and TO9 respectively. These offtakes were grouped under fair performance conditions. The values for the other five tertiary offtakes were 0.94, 0.93, 0.97, 0.91, and 0.92 for TO1, TO2, TO3, TO4, and TO5 respectively. These offtakes were under good performance conditions.

The spatial average values of adequacy were 0.92, 0.80, and 0.96 during March, April, and May respectively. In contrast, the highest spatial adequacy value was found in May and the lowest value was found in April. The amount of water delivered was high during May as compared to March and April. It rained during May reducing irrigation requirements and resulting in higher river flow due to high runoff from upstream catchments areas. The crop was also at the late crop development stage having a lower crop water requirement during May. The water delivered to each offtake during April was lower as the availability of river flow was low during April due to the increase of atmospheric evaporative demand, increased consumption upstream, and absence of rainfall. The crop water requirement during April was also high due to the development crop growth stage. Accordingly, the adequacy during April was lowest. The Adequacy was fair in April and good in March and May as per ranges of water delivery performance standards given by Molden and Gates (1990) in Table 1.

The average temporal values of adequacy at the head, middle and tail reach of the system were 0.95, 0.91, and 0.83 respectively.

It may be observed from table 3 that the average temporal adequacy value was good at the head and middle reach and fair at the tail reach. The overall adequacy of the system was

under the fair category with a value of 0.89. The result indicated that the scheme was found under satisfactory conditions.

Table 3: Estimated values of adequacy

Reach	Field code	March QD/QR	April QD/QR	May QD/QR	Temporal mean
Head	TO 1	1.00	0.83	1.00	0.94
	TO2	1.00	0.84	0.96	0.93
	TO3	1.00	0.90	1.00	0.97
	Average	1.00	0.85	0.99	0.95
middle	TO 4	0.92	0.81	1.00	0.91
	TO 5	0.95	0.84	0.95	0.92
	TO 6	0.86	0.81	1.00	0.89
	Average	0.91	0.82	0.98	0.91
Tail	TO 7	0.88	0.72	1.00	0.87
	TO 8	0.82	0.76	0.87	0.82
	TO9	0.83	0.71	0.86	0.80
	Average	0.84	0.73	0.91	0.83
Spatial mean		0.92	0.80	0.96	0.89

3.3.2. Efficiency

Efficiency was calculated by using Equation 2.14 for the selected nine tertiary offtake structures. The variation of temporal efficiency at nine selected tertiary offtakes is shown in Figure 7. The temporal efficiency of the selected offtakes varied from 0.77 to 1.00. The irrigation system of the study area was surface irrigation. These values of all reaches were within the acceptable range according to (Molden and Gate, 1990). The maximum value of temporal efficiency at this offtake TO5 was high approaches to one, not exactly one because at this offtake the water users use water effectively and the water requirement of the crop was high. It may be seen from Figure 7 that the values of temporal efficiency were lower at the head offtakes especially at TO1 and TO3 with the respective value of 0.77 and 0.81, while it was high at TO2 in head reach and for all middle and tail reaches. The offtakes TO1 and TO3 were grouped under fair efficiency level and the other remaining seven offtakes were under good efficiency level. This implies that the irrigation users located at

TO1 and TO3 abstracted more water due to uncontrolled delivery of water and used the received water less efficiently.

Figure 7: Temporal Average PF

The average spatial efficiency values were 0.88, 1.0, and 0.86 during March, April, and May respectively. The spatial average efficiency value was relatively less during March and May as a result of the delivered amount of water not being used effectively. The delivered amount of water was more than the required water for the crop and the crop water requirement need was less during the period. Generally, during this period there was problem-related to operation and management. Whereas, the spatial efficiency during April was very high, during this month the crop stage was the developmental and mid-stage, at this stage all crops need more water than the delivered amount of water. Therefore, there was high water consumption, and the irrigation users used water efficiently. According to the ranges of water delivery performance standards given by Molden and Gates (1990) in Table 1. The performance level of the spatial mean value of efficiency was categorized under good performance level during March, April, and May months. The average temporal efficiency at the head, middle, and tail were 0.82, 0.93, and 1.00 respectively the efficient water usage at the tail was greater than the head and middle reach. It may be seen from the values of the water at the tail was efficient due to less opportunity to get excess water the water delivered towards the tail end decreased due to unfair water distribution and loss of water in conveyance as compared to head and middle reach. The irrigation users at head reach were in fair performance condition and the users located at middle and tail reaches were grouped under good performance conditions. The overall efficiency of the scheme

was 0.91. Thus the overall performance condition was categorized under good performance condition.

Table 4: Estimated values of efficiency

Field code	March QR/QD	April QR/QD	May QR/QD	Temporal PF
TO 1	0.60	1.00	0.70	0.77
TO2	0.62	1.00	1.00	0.87
TO3	0.70	1.00	0.72	0.81
Average	0.64	1.00	0.81	0.82
TO 4	1.00	1.00	0.63	0.88
TO5	1.00	1.00	1.00	1.00
TO 6	1.00	1.00	0.72	0.91
Average	1.00	1.00	0.78	0.93
TO 7	1.00	1.00	0.99	1.00
TO8	1.00	1.00	1.00	1.00
TO9	1.00	1.00	1.00	1.00
Average	1.00	1.00	1.00	1.00
Spatial PF	0.88	1.00	0.86	0.91

3.3.3. Dependability

This dependability was computed as the coefficient of variation of the adequacy values for individual offtakes of the system over three months using Equation 2.15. The adequacy answers the question; does the timing of the water deliveries match the growth needs of the crops and the expectations of the users? (Molden and Gates, 1990) in Table 1. The computed values of dependability are given in Table 5. The temporal coefficient of variation for different offtakes is shown in Figure 8.

Figure 8: Temporal coefficient of variation (CVT)

It may be observed from Figure 8 that the temporal average coefficient of variation of adequacy varied from 0.06 to 0.16. The minimum and maximum values were observed for offtake TO3 and TO7 respectively. The delivered amount of water highly varied from one month to another month at offtake TO7, while at offtake TO3 temporal variation of delivered water was low during March, April, and May. The performance level of the Temporal mean value of the coefficient of variation at offtake TO1, TO6, and TO7 was categorized under fair performance level as compared to the ranges of water delivery performance standards given by Molden and Gates (1990) in Table 1. The remaining offtakes were grouped under a good performance level in the reliability of water delivery. Thus the water user associations in tertiary offtakes TO1, TO6, and TO7 did not follow timely and effective water distribution. While the water user association committee followed timely and effective water distribution in tertiary offtake TO2, TO3, TO4, TO5, TO8, and TO9.

The temporal average values of coefficient of variation at the head, middle and tail reach were 0.085, 0.093, and 0.11 respectively. It may be observed from these value the coefficient of variation at tail reaches is as high as compared to head and middle reaches. Thus the farmers at tail reach were not receiving the delivered water timely and in the required amount due to unfair water distribution. While the irrigation users located at head and middle reaches abstracted more water compared to the irrigation users at tail reach. This was due to the weak management of the water committee in distributing irrigation water as per the arranged schedule. The performance levels in the reliability of the irrigation water delivery were good performance at the head and middle reach, while fair performance

condition at the tail reaches according to the standards proposed by Molden and Gates, (1990) Table 1. The overall temporal coefficient of variation for the selected nine tertiary off-takes was equal to 0.096. This indicates the irrigation scheme was under good performance conditions concerning the reliability of water delivery.

3.3.4. Equity

Equity of water distribution was calculated as the coefficient of variation of the adequacy values between different locations throughout three months using Equation 2.16. The estimated results of spatial coefficient of variation (PE) of water distribution over the study period are shown in Table 5. The value of the spatial coefficient of variation varied from 0.059 to 0.079. The spatial coefficient of variation of equity during March, April, and May was 0.079, 0.077, and 0.059 respectively.

The degree of spatial variation of hydraulic performance for nine selected tertiary offtakes over three months is presented in Figure 9.

Figure 9: Equity during three months

It may be observed from Figure 9 that the spatial coefficient of variation was higher during March and April due to the unfair share of irrigation water in each offtake structure. While during May spatial coefficient of variation was less in each offtake structure distributed irrigation water. According to standards as proposed by Molden and Gates (1990) Table 1, the equitable share of water in the selected nine tertiary offtakes was good performance conditions during March, April, and May. The overall Average spatial coefficient of variation of the study area was 0.07. Thus, the irrigation scheme was found under good performance conditions in distributing irrigation water in the selected tertiary offtakes during the study period.

Table 5: Estimated values of equity and dependability

		March	April	May	Temporal	St.dev	CVT, PD
	Field code	QD/QR	QD/QR	QD/QR	Mean		
	TO 1	1.00	0.83	1.00	0.94	0.10	0.11
Head	TO2	1.00	0.84	0.96	0.93	0.08	0.09
	TO3	1.00	0.90	1.00	0.97	0.06	0.06
	TO 4	0.92	0.81	1.00	0.91	0.10	0.10
Middle	TO 5	0.95	0.84	0.95	0.92	0.07	0.07
	TO 6	0.86	0.81	1.00	0.89	0.10	0.11
	TO 7	0.88	0.72	1.00	0.87	0.14	0.16
Tail	TO 8	0.82	0.76	0.87	0.82	0.06	0.07
	TO9	0.83	0.71	0.86	0.80	0.08	0.10
	mean	0.92	0.80	0.96			0.10
	St.dev	0.07	0.06	0.06			
	CVR,PE	0.079	0.077	0.059	0.072		

3.4. Physical Performance indicators

3.4.1. Sustainability of irrigated area

The sustainability of irrigated area (SIA) of the present study was estimated by using equation 2.17. The estimated value of SIA for two irrigation seasons is given in Table 6 and the graphical variation is shown in Figure 10.

The irrigated area in the 2018 and 2017 irrigation seasons was 43 ha and 50.25 ha, respectively. The estimated value of SIA was 123% and 144% in the 2018 and 2017 irrigation seasons respectively. The computed value of sustainable irrigated areas during both of the irrigation seasons 2017 and 2018 was more than 100%. This indicated that the current irrigated area expanded compared to the initially irrigated area in both of the irrigation seasons. The level of sustainability in 2017 was higher by 21% as compared to the 2018 irrigation season. This was due to poor maintenance activity of the conveyance structure and failure of some of the flow control structures at the tail reach of the irrigation scheme during 2018.

The sustainability of irrigated areas in the Lower Areb irrigation scheme was higher by 23 % and 44 % in the 2018 and 2017 irrigation seasons respectively. The sustainability of irrigated areas is a long-term process of irrigation system functions working or fails. The sustainability of the scheme over a long period may decrease or increase. Therefore, concrete conclusions may not be drawn based on two-year results of sustainability. Dejen et al. (2012) conducted irrigated area sustainability studies for the Golgota irrigation scheme obtained SIA to be 1.22. Thus the irrigated area at Golgota scheme expanded by about 22% since commissioning. The results of the present study were similar to the results obtained by Dejen et al (2012) for the Golgota scheme. The contributing factors for the expansion of the irrigated area were dependability of irrigation water supply, farmer's positive attitude to irrigation development, absence of irrigation water fee, and better land productivity.

Table 6: Data related to the area of land at the scheme

Irrigation season	Current irrigated Area(ha)	Designed command area(ha)	Initially irrigated (ha)	Irrigable area (ha)	sustainable irrigated Land (%)	Irrigation Ratio (%)
2018	43	65	35	79	123	54
2017	50.25	65	35	79	144	64

Figure 10: Irrigation ratio and Sustainability of irrigated area

3.4.2 Irrigation ratio

The irrigation Ratio for the present study was estimated using Equation 2.18. The estimated value of IR is given in Table 6 and the graphical variation of irrigation ratio during two irrigation seasons is shown in Figure 10. It may be observed from Table 6, that the irrigated area during 2017 and 2018 was 50.25 ha and 43 ha respectively. Thus the irrigated area decreased by 7.25 ha from 2017 to 2018. The estimated value of IR was 54 % and 64 % in the 2018 and 2017 irrigation seasons respectively. This means that about 46 % and 36 % of the command irrigable area of the scheme was under irrigation during the 2018 and 2017 irrigation seasons respectively. However, the value of IR in 2017 was higher by 10 % as compared to the 2018 irrigation season. The reasons were similar as for SIA, poor maintenance activity of the conveyance structure and failure of some of the flow control structures at the tail reach of the irrigation scheme. It may be seen from the above Table 6 that the difference in the designed command area and the irrigable area was 14 ha. The potential of the irrigable area was greater than the potential of the scheme. The scheme was designed to irrigate only 65 ha of land.

3.5. Maintenance indicators

The maintenance indicators of the scheme were assessed in terms of the effectiveness of infrastructure, the physical condition of the canal, and water surface elevation.

3.5.1 Effectiveness of infrastructure

The effectiveness of the infrastructure of the irrigation system was computed using Equation 2.19. According to the design document and the field survey, the total number of structures such that weir, sluice gate, intake gate that were installed in the irrigation scheme, and the structures installed on the main and tertiary canals were 60 structures. However, only 44 structures were currently functional. The detail is given in Table 7. Therefore, the value of effectiveness of infrastructures was estimated to be 73.33 %. The rest 18.33 % structures were nearly operative and 8.33 % were nearly inoperative. Thus all of the structures in the scheme were not fully functional and were not working efficiently. The result indicated that the maintenance activities of the infrastructure of the scheme were not enough. The reasons were improper design and poor maintenance of the scheme. The infrastructure of the scheme needs maintenance requirements and monitoring physical assets of the irrigation system. Some of the structures located in the irrigation system were

unable to distribute irrigation water fairly and adequately due to design problems and the absence of a controlling gate. Some of the existing physical problems in irrigation structures are shown in Figures 11 & 12.

Table 7: Effectiveness of irrigation structures in Lower Areb irrigation system

No	Structure Name	Initially Installed	Operative	Nearly operative	Nearly Inoperative
1	Diversion weir	1	1		
2	Under sluice gate	1		1	
3	intake gate	1		1	
4	offtake gate	22	18	2	2
5	Division box	18	12	3	3
6	Footbridge	4	4		
7	Drop structure	6	5	1	
8	Culvert	3	2	1	
9	washing basin	4	2	2	
total structure		60	44	11	5
Effectiveness of Infrastructure (%)			73.33	18.33	8.33

Figure 11: Some of the existing problems in the irrigation structure

Figure 12: Some of the existing problems in the irrigation structure

Vudhivanich (2008) recommended that the acceptable level of well-functioning infrastructure should not be less than 70 % effective of infrastructure level. The result of the effectiveness of infrastructures for the present study was above the recommended value by Vudhivanich (2008). Thus the overall performance of the infrastructures in the Lower Areb irrigation scheme was in good condition.

3.5.1.1 Physical inspection of canal condition

The physical state of the main canal regarding the canal operating condition was estimated using Equation 2.19. The observed condition of the effectiveness of different structures in different reaches of the main canal is given in Table 8. The conditions of the main canal under different categories in different reach are shown in Figure 13. The estimated values of operative, nearly operative, and nearly inoperative sections of the main canal were 81.53 %, 9.83%, and 0.93 % respectively. The reach-wise values of the effectiveness of the main canal were 35.66 %, 25.83 %, and 20.05 % at the head, middle, and tail reach respectively. The overall operational efficiency of the main canal length was 81.53 %. Vudhivanich (2008) recommended that the acceptable level of effectiveness for well-functioning infrastructure should not be less than 70%. The estimated value of the effectiveness of the main canal for the present study was more than the recommended value. Therefore, the overall performance of the main canal effectiveness for the Lower Areb irrigation scheme was good. Table 8 physically inspected the effectiveness of infrastructure in different reaches of the main canal in the Lower Areb Irrigation Scheme.

Structure Name	Reaches	Operative in (m)	Nearly operative(m)	Nearly Inoperative (m)	Effectiveness (%)
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	head	925	75		35.66
Main canal	middle	670	130		25.83
	tail	520	50	24	20.05
Total length	2594	2115	255	24	
Effectiveness (%)		81.53	9.83	0.93	

Table 8: Effectiveness of infrastructure of the main canal

Figure 13 a: Physical conditions of the main canal under different categories

Figure 13 b: Physical conditions of the main canal under different categories

Figure 13 c: Physical conditions of the main canal under different categories

3.5.2. Water Surface Elevation Ratios (WSER)

The water surface elevation ratio was estimated by using Equation 2.20. The estimated values of average WSER at the selected monitoring locations in the head, middle, and tail reaches of the main canal are given in Table 9.

Table 9: Average water surface elevation ratio in different reaches of the main canal.

Head			Middle		Tail		Overall	
Dev.WSE (m)		WSER	Dev.WSE (m)	WSER	Dev.WSE (m)	WSER	Dev.WSE (m)	WSER
Average	0.017	0.93	0.015	0.94	0.005	0.96	0.01	0.94

The design water depths according to the design document of the main canal were 0.25 m and 0.12 m from chainage 0- 2 km and 2- 2.594 km respectively. The current average actual water flows depth at full supply level at the head, middle, and tail reaches were 0.234 m, 0.235 m, and 0.115 m respectively. It may be observed from Table 9 that at the head, middle and tail reaches of the main canal, the average deviation of water surface elevation at full supply level was 0.017 m, 0.015 m, and 0.005 m and WSER were 0.93, 0.94, and 0.96 respectively. The overall average WSER and deviation of WSE were 0.94 and 0.01 m respectively. Thus the depth of water flow in the main canal reduced on average by 1 % from the designed water flow depth. This reduction in water flow depth was due to different factors such as weed growth, seepage, erosion of canal beds, and evaporation on the main canal.

In the present study at the 20 measuring points, the positive deviation of WSE was observed at 15 measuring points and negative deviation was observed at 5 measuring points. The positive deviation of the water surface elevation may be due to the factors such as weed growth, seepage, erosion of canal bed, and evaporation on the main canal. The weed growth on the main canal decreased the water surface elevation due to increased water demand by vegetation. Similarly, the evaporation or atmospheric demand, seepage or leakage, and erosion of the canal bed decreased the water surface elevation positively. The negative deviation of water surface elevation may be due to siltation resulting in water overflow if the canal conveyed design discharge. This fluctuation of water surface elevation from the intended value harmed water delivery performance. Therefore, immediate management and engineering measures are needed to take for the main canal for weed removal, sediment clearance, and other preservation works.

Conclusions

Performance evaluation of irrigation schemes has especially been an important and active field of research during the last few decades. It is used to identify problems and understanding how the system can be effectively implemented to improve the system performance.

The overall average irrigation water required for the selected nine tertiary offtakes for the selected crops such as maize, onion, and potato grown in the command area as compared to irrigation water delivered was more during April but less during March and May. The water delivered by the canal was more than the crop water requirement at head and middle reach but less at tail reach. The temporal and spatial variations of canal water supply in each tertiary offtake were due to weak management of WUAs in irrigation scheduling, cleaning canals sedimentation and weeds, water losses in canals, and damaged water control structures.

The Hydraulic performance of the irrigation scheme was evaluated using adequacy, dependability, efficiency, and equity hydraulic performance indicators. The hydraulic performance of the irrigation scheme as compared to standards proposed by Molden and Gates (1990) was found to be good for dependability, efficiency, and equity, but fair inadequacy. Although the overall hydraulic performance of the irrigation scheme was found to be good, there was some shortage of water during April and an inequitable share of water distribution in the tail reaches.

The considered maintenance and physical sustainability performance indicators were water surface elevation ratio, the effectiveness of infrastructure, canal operating condition, the sustainability of an irrigated area, and irrigation ratio. Generally, the maintenance performance of the irrigation scheme as per standards proposed by Vudhivanich (2008) was fair. The physical sustainability performance of the irrigation scheme was fair. The irrigation scheme has sustainable irrigated land which can be explained by the expansion of irrigated areas from initially designed.

Generally, the hydraulic performance of the lower Areb irrigation scheme was below the intended objective; this was due to lack of regular maintenance, weak management of WUAs, and stolen flow control gates. Finally, agreements were reached through discussion and persuasion with the irrigation water users and WUAs so that problems could be solved with their contribution and active participation for regular canal maintenance and efficient water distribution and use.

DECLARATIONS

I, the undersigned declare that this thesis comprises my original work and is not published by any other publishing company. In compliance with internationally accepted practices, I have duly acknowledged and refereed all materials used in this work.

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Competing interest

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Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Author contribution

All authors took part in the research design, data collection process, and manuscript preparation for this publication.

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