Performance Evaluation and Assessment of Quashni Small Scale Irrigation Scheme, in Amhara Region

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Abstract. Optimizing the use of irrigation water is of vital importance in conserving land and water resources as well as maximizing crop yield utilizing available water. Evaluating an irrigation system performance should measure and show the effectiveness of existing irrigation practice, provide remedial measures if necessary, as well as determining the impacts of the factors which affect the performance parameters. This study attempted to evaluate and assess the performance of Quashni irrigation scheme using internal and external performance indicators. Two irrigation seasons in the 2018 (February–May) and 2018/2019 (October–January) were carried out. Primary data, e.g. soil moisture before and after irrigation, discharge measurements, irrigation depth and soil physical properties, were collected. Secondary data, e.g. meteorological data and irrigated area per crops, were also collected. CROPWAT 8.0 computer model was used to calculate the CWR. The conveyance and application efficiency of the scheme was estimated as 71.8% and 51.2% respectively, which led to an overall scheme efficiency of 36.8%. RWS and RIS of the scheme were 1.24 and 1.12, respectively. Irrigation ratio of Quashni irrigation scheme was found to be 0.84, which implies that 16% of the command area could not be provided with irrigation coverage. In general, the evaluation and assessment indicated a low performance of the Quashni irrigation scheme.

Keywords: Small scale irrigation · Performance evaluation · Efficiency · Quashni irrigation scheme

1 Introduction

1.1 Background

Much of the increase in irrigated area had come as a result of expansion of traditional small-scale irrigation. Yet, the existing irrigation development in Ethiopia, as compared to the resource the country has, is very small. Furthermore, poorly designed, planned and

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managed irrigation undermines efforts to improve livelihoods. The country's irrigation efficiencies are low, of the order of 25 to 50% [1].

Small-scale irrigation has been recognized as a policy priority in Ethiopia for reduction of poverty and climate adaptation [2]. Despite this, the sector has largely been overlooked and not supported through improved water management methods. Due to land and water shortages and the need for food self-sufficiency in the region, it has become essential to improve the productivity of this sector [3].

Irrigation water management is highly expected to play a major role in the realization of Ethiopian food security and poverty alleviation strategy. Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, supports national economy by producing industrial crops that are used as raw materials for value adding industries and exportable crops. Irrigation projects are widely studied, planed and implemented throughout the country from this important view-point. However, little or no attention is given to the monitoring and evaluation of the performance of already established irrigation schemes [4].

Optimizing the use of irrigation water is vitally important in conserving land and water resources as well as maximizing yield with the available water [5]. [6] states that, Ethiopia has potentially reasonable quantities of irrigable land and water resources, but its agricultural system does not yet fully benefit from irrigated agriculture and proper technologies of agricultural water management; which results in very low agricultural productivity in Ethiopia as a whole. The main factors behind this is low uptake of inputs, such as, adequate irrigation application by farmers with due consideration of the daily crop water requirements and the different crop development stages; as well as the existing soil moisture content. Hence, it is believed that, these production constraints should be reduced using secured access to irrigation and efficient utilization of farming lands.

The performance of many irrigation systems are significantly below their potential due to a number of shortcomings, including poor design, construction, operation, maintenance, well effective water control and measurements misallocation [7] and also According to [8], head tail problems, leaky canals and malfunctioning structures because of delayed maintenance, leading to low water use efficiency and low yields are some of the commonly expressed problems. A large part of low performance may be due to inadequate water management at system and field level.

The performance of irrigation Operation has to be evaluated periodically, both at the system- and at farm-levels, using indicators that have been established. The results and recommendations of the evaluation exercises, when implemented, contribute towards maintaining the sustainability of the farms, for economic utilization of the limited water resource and generation of new data and information for the design and operation of new irrigation schemes. Huge expectation of the irrigation development to alleviate poverty versus inability to sustainably utilize them call for detailed explanation on the relative contribution of technical, support service and institutional problem contributing for the under performance of the irrigation schemes.

Some of the problem observed in Quashni irrigation scheme for motivation of starting these study was, the first secondary canal use pressurized flow system through PVC pipes which crosses the river underneath to irrigate 40 ha command area at right side of the river is totally out of function, the main, secondary and field canals are covered with sediment loads and vegetation, The flow of water at the different segment of the secondary canal is stagnant, Guess work in water allocation; the water committee undertakes water allocation and defines water rights of members not based on study on water requirements of different crops, Lack of satisfactory support from local administrative and legal entities, Tail water users did not receive adequate water, Water users are not willing to register types of crops they grow (vegetables or perennials) and area of their irrigable plots with the committee for clear definition of water rights in spite of the law (bylaws). Even if the scheme has such problems, performance evaluation is not held so far. Therefore the actual performance of Quashni irrigation scheme is not known before this study.

The principal objectives of this study was evaluate and assess the performance of Quashni community managed small scale irrigation scheme. Specifically analyze the overall scheme performance using conveyance and Application efficiency, assess irrigation supply of the scheme satisfy crop water requirement of irrigated area and compare actual efficiency of the scheme with design efficiency. The performances evaluation of the system have the most appropriate tools for abundant save of resources and using them in proper ways; and most likely to increase livelihood of the country. Based on the above facts this study on evaluating the performance of Quashni community managed small scale irrigation scheme are crucial to determine the actual performance of the scheme using performance indicators for conveyances and field water application systems; for the purpose of identifying management practices and systems that can be effectively implemented to improve the irrigation efficiency and also provide relevant information in selecting better performing activity under existing condition.

2 Materials and Methods

2.1 Description of the Study Area

The study was conducted on Quashni small scale irrigation scheme which is found in Dangila woreda at Gayita kebele, geographically located at 36.83° N and 11.25° E having an elevation of 2180–2500 m above sea level. The watershed domain lies in two woredas, namely, Dangila and Fagita Lakma. The kebeles have a long history of traditional irrigation based on the Quashni River. Maize, finger millet, teff, and barely are the main crops grown through rain fed agriculture in the Mehere season in these kebele. In addition, farmers grow a variety of fruits and vegetables during the Bega season through traditional or modern irrigation. Out of 1501 ha of cultivated lands in the kebeles, about 1055 ha of land is irrigated, of which, 250 ha areas benefit from the IFAD built small-scale modern irrigation scheme (Quashni irrigation scheme). The rest is farmed through traditional irrigation (Fig. 1).

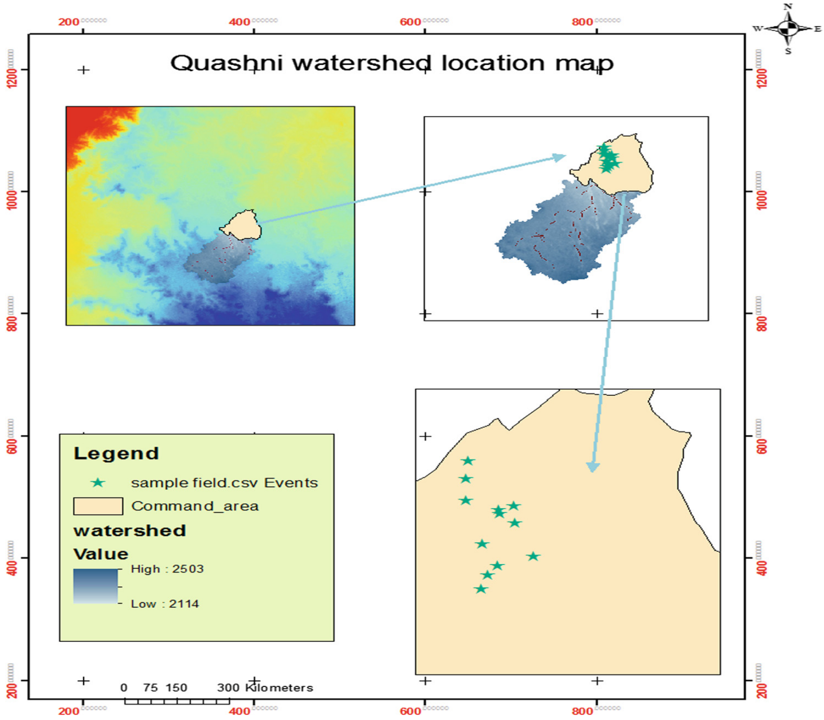

Fig. 1. Location map of Quashni irrigation scheme

2.2 Irrigation Scheme

The weir structure was constructed by financial and technical support of IFAD and become functional in 2013. The designed and actual command areas in irrigation were 250 and 210 ha respectively. It was intended to serve around 343 households found in Gayita kebele. The conveyance system of the irrigation scheme consists of a Main canal (MC1) taking water from the corresponding intake of the weir. The Main canal starts from Water abstraction site on the left side of the weir and conveys water for a length of 1014 m of main canal, for the first 202 m it is masonry lined canal and for the rest it is unlined and delivers water to secondary canals. There are 16 secondary canals in the scheme. Based on functionality of canals divide in three categories, 7 secondary canals functional, 4 secondary canals nonfunctional, 5 secondary canals nearly functional. So for evaluating conveyance efficiency of secondary canals flow measurement was taken on 7 functional secondary canals. The command area available to the left is 205 ha and to the right of it 46.72 ha. However to irrigate the command area at the right side of the river a secondary canal of pressurized pipe crossing the river is installed but until now this secondary canal not functional.

2.3 Sample Size and Techniques

A performance of the schemes was evaluated using both internal and external performance indicators. The internal performance indicators computed were conveyance efficiency, application efficiency and overall scheme efficiency. For computation of absolute performance of application efficiency irrigation fields with potato crop in the first season and pepper crops in the second season were purposely selected. For this purpose, a total of three farmer fields in the first irrigation season in 2018 irrigation period and 9 farmers field in the second season were selected from irrigation scheme as shown in Fig. 2. Farmer's irrigation field selection a technique in this study was based on upper, middle and downstream user's field consideration. Therefore, the first irrigation season select 1farmer's field in upper user, 1in middle user and 1 in downstream user. To increase accuracy of the result repeated data taken prefers so in second irrigation season increase samples for 9 farmers field which means 3 in upper users, 3 in middle users and 3 in downstream users.

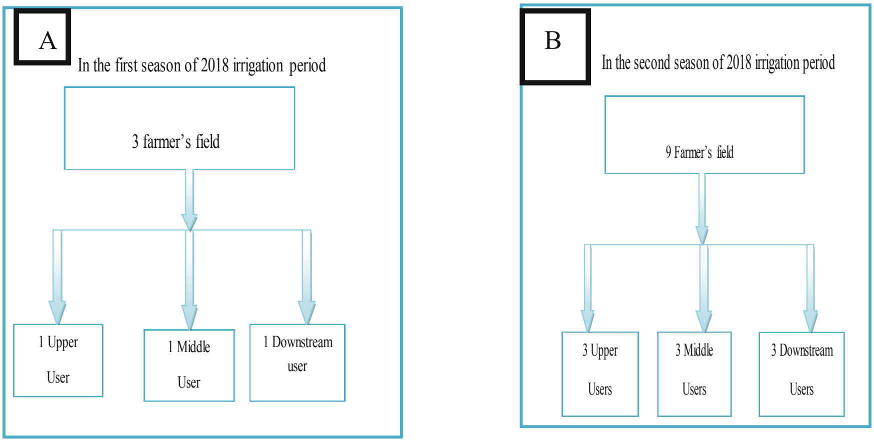

Fig. 2. Sample size flow charts for 1st (A) and 2nd (B) irrigation season

2.4 Data Collection

Measurements of water discharge at diversion points of irrigation scheme was taken and also at the initial and final points of secondary and field canals. Soil moisture before and after irrigation was measured by gravimetric method in the first season and TDR used in the second season. To determine soil texture of farmer's field, six soil samples from three locations of scheme at two different depths were collected. And also using core sampler undisturbed soil samples were collected from different depths and the bulk densities were determined. Secondary data were collected from the Dangila Agricultural and Rural Development Office, Water Resource and irrigation offices at regional and zonal levels. Secondary data includes Irrigated area per crops; meteorological data taken from Dangila and Bahir dar Meteorological Station include rainfall, minimum and maximum air temperature, sunshine hours, wind speeds, relative humidity and solar radiation, books and journals.

Among different canals discharge measurement techniques in this study, floating method (measuring surface velocity) was used in this study. Mean velocity was obtained using a correction factor. In the first irrigation season soil samples at four irrigation events on potato crop were collected to determine the soil moisture content one day before and after irrigation by collecting about 72 soil samples from three farmers field in the schemes with an interval of 0–20, 20–40 and 40–60 cm depths. In the second irrigation season moisture content at two irrigation event of farmers field was measured by using Time Domain Reflectometry (TDR) measuring instrument but this measuring instrument was calibrated by gravimetric method. Measuring depth intervals were the same as oven dry method as listed in the above. Totally 108 times at nine farmers' field was measured. Summary of data collection were listed in Table 1 and Fig. 3.

Table 1. Summary of data collections

No	Data type	Source	Purpose
1	Soil moisture before and after irrigation	Field measurement	For application efficiency evaluation
2	Irrigation depth	>>	To know applied water to the field
3	Flow measurement	>>	Know discharge
4	Soil sample analysis	>>	Physical property of soil
5	Meteorological data	Metrological station	Input for CROPWAT

2.5 Determination Internal Performance Indicator

Conveyance Efficiency

Water conveyance efficiency (Ec) is the ratio in percent of the amount of water delivered by a channel or pipeline to the amount of water delivered to the conveyance system. Ec was computed using the following formula [9].

$$EC = \frac{Qo}{Qi} * 100 \quad (1)$$

Where, E_c is conveyance efficiency (%); Q_o = quantity of water delivered by a conveyance system (outlet); and Q_i = quantity of water delivered to a conveyance system (inflow).

Application Efficiency

The application efficiency (Ea) was computed as the ratio of water stored in the root zone to the water delivered to the farm. The depth of water delivered to the field was measured as an averaged estimate using a Parshall flume designed to measure up to 220 mm. To determine the amount of moisture content stored in the root zone by gravimetric method soil sample four replications of potato crop at three different depths (0–20 cm, 20–40 cm

a) Soil sample taking using core sampler

b) Soil sample dry in oven

c) Soil moisture measurement using TDR

d) Flow measurement (floating method)

Fig. 3. Different data collection techniques.

and 40–60 cm) on three farmers' field in first season was taken and 9 farmers field in the second season was determined by TDR reading. The following equation from Ramulu (1998) was used to estimate Ea.

$$\mathrm{Ea} = \frac{\mathbf{Zr}}{\mathbf{D}} \tag{2}$$

Where, Ea is application efficiency (%), Z_r is depth of water store in the root zone (mm), and D is depth of water applied to the field (mm).

Overall Scheme Efficiency

The overall scheme efficiency (Ep) was calculated as the product of conveyance (Ec) and application efficiency (Ea). It was computed using following formula Ramulu (1998):

$$\mathrm{Ep} = \mathrm{Ec} * \mathrm{Ea} \tag{3}$$

2.6 Determination of External Performance Indicator

Water Use Performance Indicators

Two types of indicators namely relative water supply (RWS) and relative irrigation supply (RIS) were used for evaluating irrigation performance. Both indicators (in %) were calculated by using the following formulas of [10].

$$\text{RWS} = \frac{\text{TWS}}{\text{Crop water demand}} * 100 \quad (4)$$

$$\text{RIS} = \frac{\text{Irrigation supply}}{\text{Irrigation demand}} * 100 \quad (5)$$

Where, TWS (m^3) is total water supply or diverted water for irrigation plus rainfall, crop water demand (m^3) is the potential crop evapotranspiration (ETp), or The real evapotranspiration (ETc) when full crop water requirement is satisfied, and irrigation supply (m^3) is surface diversions and net groundwater drafts for irrigation, and irrigation demand (m^3) is the crop ET minus the effective rainfall.

Physical Performance Indicator

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. The selected indicator used for evaluation of physical performance was irrigation ratio which can be expressed as the follows [11]

$$\text{Irrigation ratio} = \frac{\text{Irrigated cropped area}}{\text{command area}} \quad (6)$$

Where, Irrigated crop area (ha) is the portion of the actually irrigated land (ha) in any given Irrigation season, and command area (ha) is the potential scheme command area.

2.7 Determination of CWR and IWR

CROPWAT 8.0 computer program was used to estimate the total water requirements of major crops grown in the irrigation schemes on studying season. The model needs climatic, crop and soil data for the determination of crop water and irrigation requirements. 20 years mean monthly minimum and maximum temperature (^{o}C), relative humidity (%), wind speed (km/day) and sunshine hours (hr) data of Dangila meteorological station were used, while crop data were used based on Food and Agriculture Organization (FAO) recommendations and also soil data derived from laboratory analysis.

3 Results and Discussion

3.1 Determination of Crop and Irrigation Water Requirements

Rainfall Data Analysis

The minimum and maximum rainfall amount occurs in January (2.8 mm) and August (387.6 mm), respectively. The study area has an average total annual rainfall of 1672.8 mm. Scheduling irrigation based on crop demand requires an estimate of effective precipitation or rainfall. Effective rainfall estimates are also important for planning cropping sequences in irrigation crop production. Effective rainfall is the amount of rainfall stored in the crop root zone. Rainfall that runs off the soil surface or passes through the root zone does not contribute to crop growth and yield. As can be seen from Table 2 the highest effective rainfall occurs during August and is about 163.8 mm. The total annual effective rainfall of the area is 945.9 mm.

Table 2. Monthly effective rain fall of the area (USDA S.C Method)

Month	Rain fall depth in (mm)	Effective rainfall (mm)
January	2.8	2.8
February	4	4
March	15.1	14.7
April	47.4	43.8
May	165.9	121.9
June	267.4	151.7
July	366.7	161.7
August	387.6	163.8
September	261.8	151.2
October	117.2	95.2
November	32.7	31
December	4.2	4.2
Total	1672.8	945.9

3.2 Determination of Reference Evapotranspiration (ETo)

As discussed in the methodology, ETo was determined by CROPWAT 8.0 software using Penman-Monteith equation. Table 3 shows a summary of the monthly ETo in the study area. The minimum and maximum monthly ETo values of the irrigation scheme were 2.86 mm/day in July and 3.77 mm/day in April. The annual average value of ETo was 3.23 mm/day (Figs. 4 and 5).

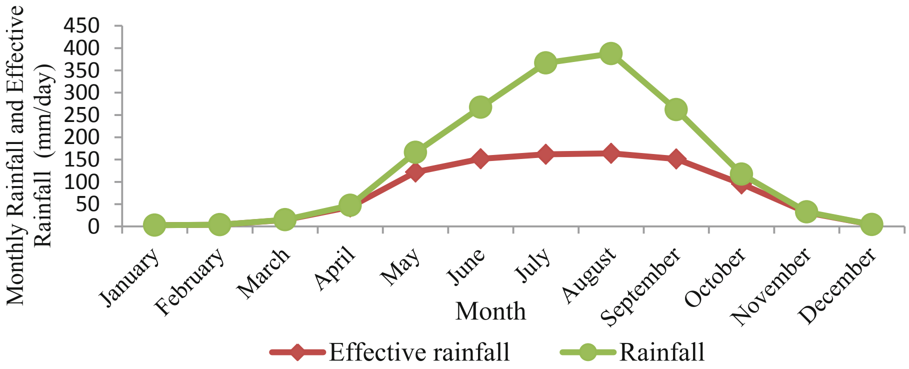

Fig. 4. Relationship between rainfall and effective rainfall

Table 3. Monthly reference evapotranspiration ETo (CROPWAT output)

Month	Min Tem (°C)	Max Temp (°C)	Humidity (%)	Wind (km/day)	Sunshine (hr)	Radiation (MJ/M2/DAY)	ETo (mm/day)
Jan	5	26	50	1	9	20.3	2.96
Feb	7	28	46	1	9	21.7	3.35
Mar	9	29	45	1	8	21.4	3.58
Apr	11	28	46	1	8	21.9	3.77
May	12	26	63	1	7	20	3.63
Jun	12	24	77	1	6	18.2	3.36
Jul	12	22	83	1	4	15.3	2.86
Aug	12	22	83	1	4	15.5	2.87
Sep	12	23	79	1	6	18.4	3.29
Oct	11	24	74	1	6	17.5	3.09
Nov	8	25	66	1	8	19.1	3.09
Dec	5	26	58	1	9	19.7	2.96
Avg.	9.7	25.3	64	1	7	19.1	3.23

Cropping Pattern

There are two irrigation seasons in study area, one from October–January and the other from February–May. The Gayita Kebele agricultural development office reported that about 120 ha of land was cultivated in the 2018 (February–May) irrigation season and 210 ha of land was cultivated in the 2018/2019 (October–January) irrigation season in the study period (Table 4).

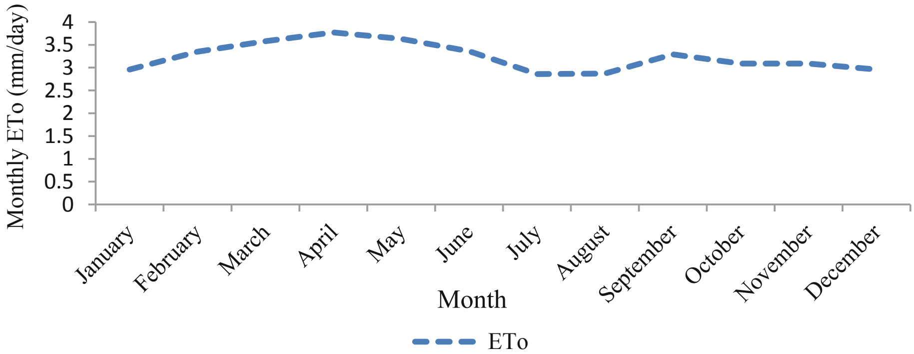

Fig. 5. ETo variation on each month

Table 4. Crop area coverage and LGP of crops in studying season

S.No.	Crop type	Coverage (ha)	% of Coverage	LGP
1	Potato	52	43.34	130
2	Maize	68	56.66	180
Total		120		

3.3 Crop Water Requirements and Irrigation Requirements

The seasonal crop and irrigation water requirements of the major crops (Potato and Maize) grown in the study area during the study period as estimated by the CROPWAT 8 model, are indicated in Tables 5 and 6. The results indicated that the seasonal crop and irrigation water requirement of Potato, which was planted at the beginning of January and harvested during the first decade of May, was estimated as 413.9 mm and 302.5 mm respectively. (Table 5) Similarly, Seasonal crop and irrigation water requirement of Maize, planted at the beginning of January and harvested during May was estimated to be 464.3 mm and 336.4 mm respectively.

Furthermore, irrigated crops in studying season had the highest crop and irrigation water requirement during their mid-season stage. This being so, the water requirement of potato during the initial, developmental, mid-season and late-season stages accounted for 5.5, 31.6, 38.9, and 30.2%, respectively, of the seasonal water requirement of the crop. Similarly, the figures for the same growth stages of tomato were 6.7, 31.6, 38.9, and 22.8%, respectively, of the seasonal water requirement (Table 6).

Table 5. Crop water requirement of Potato crop

Month	Decade	Stage	Kc	ETc (mm/day)	ETc (mm/dec)	Eff. Rain (mm/dec)	Irr. Req (mm/dec)
Jan	1	Init	0.5	1.48	7.4	0.5	6.9
Jan	2	Init	0.5	1.48	14.8	0.8	13.9
Jan	3	Deve	0.5	1.55	17	1	16
Feb	1	Deve	0.64	2.06	20.6	0.9	19.7
Feb	2	Deve	0.86	2.87	28.7	0.9	27.7
Feb	3	Deve	1.05	3.6	28.8	2.3	26.6
Mar	1	Mid	1.15	4.03	40.3	3.1	37.1
Mar	2	Mid	1.15	4.12	41.2	4.1	37.1
Mar	3	Mid	1.15	4.19	46.6	7.6	38.5
Apr	1	Mid	1.15	4.26	42.6	9.8	32.8
Apr	2	Late	1.13	4.26	42.6	12.3	30.3
Apr	3	Late	1.01	3.76	37.6	21.7	15.8
May	1	Late	0.88	3.22	32.2	33.4	0
May	2	Late	0.78	2.82	14.1	21.4	0
					413.9	120	302.5

Table 6. Crop water requirement of Maize crop

Month	Decade	Stage	Kc Coefficient	ETc (mm/day)	ETc (mm/dec)	Eff. Rain (mm/dec)	Irr. Req (mm/dec)
Jan	1	Init	0.7	2.07	10.3	0.5	9.8
Jan	2	Init	0.7	2.07	20.7	0.8	19.8
Jan	3	Deve	0.7	2.16	23.8	1	22.8
Feb	1	Deve	0.78	2.51	25.1	0.9	24.2
Feb	2	Deve	0.91	3.03	30.3	0.9	29.4
Feb	3	Deve	1.02	3.49	27.9	2.3	25.6
Mar	1	Deve	1.13	3.96	39.6	3.1	36.5
Mar	2	Mid	1.2	4.3	43	4.1	38.9
Mar	3	Mid	1.2	4.37	48.1	7.6	40.5
Apr	1	Mid	1.2	4.45	44.5	9.8	34.6
Apr	2	Mid	1.2	4.52	45.2	12.3	32.9
Apr	3	Late	1.16	4.31	43.1	21.7	21.3
May	1	Late	0.9	3.31	33.1	33.4	0
May	2	Late	0.62	2.24	22.4	42.9	0
May	3	Late	0.41	1.44	7.2	20.7	0
					464.3	162.1	336.4

Table 7. NCWR, NIR of the scheme in studying season

Crop name	CWR (mm/season)	IWR (mm/season)	Area (ha)	NCWR (m^3/season)	NIWR (m^3/season)
Potato	413.9	302.5	52	215,228	157,300
Maize	464.3	336.4	68	315,724	228,752
Total			120	530,952	386,052

3.4 Internal Performance Indicators

Conveyance Efficiency

In Quashni irrigation scheme about 202 m length of the main canal (MC11) was lined the rest is unlined. The results of the conveyance efficiency evaluation revealed that this indicator varied within a canal at different points, between main canal & secondary canal in the scheme. The overall conveyance efficiency values which indicate the amount of water lost during transportation of water from the diversion point or source to the cultivated area of Quashni irrigation schemes were found to be 71.8%. However, the values of conveyance efficiency of the schemes are between the recommended value i.e. 70% unlined poorly managed main canals MoAFS (2002) but as compared to the design conveyance efficiency of the scheme it reduced by 18.2% (Table 8).

Table 8. Main canal conveyance efficiency result

Day	MC11 (202 m)			MC12 (406 m)			MC13 (406 m)		
	Inflow (l/s)	Outflow (l/s)	Ec (%)	Outflow (l/s)	Outflow (l/s)	Ec (%)	Outflow (l/s)	Outflow (l/s)	Ec (%)
17-03-18	83	73	88	73	51	69.9	51	37	72.5
24-03-18	108	97	89.8	50	39	78	–	–	–
31-03-18	117	103	88	88	66	75	39	30	76.9
07-04-18	117	103	88	93	71	76.3	–	–	–
14-04-18	105	93	88.6	86	66	76.7	64	47	73.4
21-04-18	104	93	89.4	89	70	78.7	–	–	–
28-04-18	113	91	80.5	82	63	76.8	66	44	66.7
05-05-18	92	82	89.1	75	59	78.7	70	44	62.9
12-05-18	71	61	85.9	59	44	74.6	–	–	–
12-05-18	94	77	81.9	71	50	70.4	56	42	75
29-12-18	161	135	83.9	377	222	58.9	118	75	63.6
05-01-19	174	137	78.7	357	239	66.9	111	74	66.7
12-01-19	172	132	76.7	272	196	72.1	92	62	67.4
19-01-19	169	147	87	236	173	73.3	108	69	63.9
Average Ec (%) = 76.1									

In Quashni irrigation scheme totally 1014 m length of main canal. The first 202 m was lined the rest unlined main canal. The distance in the main canal from source to upper, from upper to middle and from middle to lower- end was 202 m, 406 m and 406 m respectively. As we can see in the above Table 4.8, the conveyance efficiency in upper part of lined main canal (MC11) was 85.8%. Middle of main canal (MC12) and Downstream of main canal (MC13) conveyance efficiency was 73.4 and 69% respectively. The mean overall conveyance of the main canal was 76.1%. According to MoAFS (2002) report the minimum recommended main canal water conveyance efficiency was 70%. Main canal water conveyance efficiency in Quashni small scale irrigation scheme is very good in upper part of lined main canal, middle and downstream of main canal as compare to the minimum recommended efficiency value (Fig. 6).

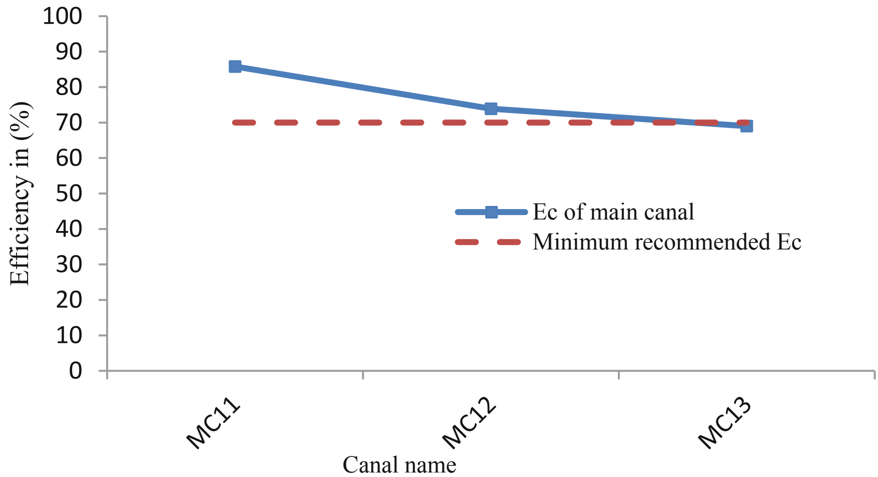

Fig. 6. Conveyance efficiency of main canal with recommended value

As compared to lined and unlined main canal, the conveyance efficiency of lined main canal was higher than unlined main canal. The water loss of main canal was 14.2% at the upper part of main canal, 26.6% at the middle part of main c anal and 31% at the Downstream of main canal as shown in Fig. 4.3. This shows that 23.9% loss of water occurred in the main canal. [4] reported that about 10 to 15% of loss of water in the canal is accepted. When the result was compared to this, it is unacceptable range. The conveyance water loss of the main canal as evaluated during this study is presented as shown below (Fig. 7).

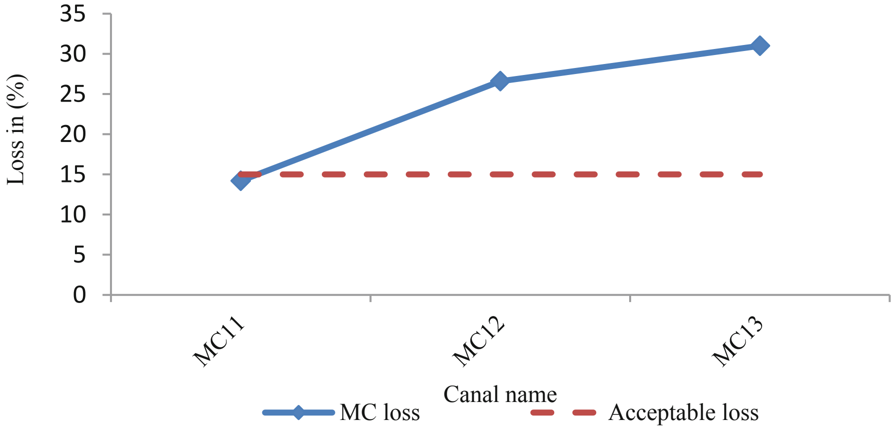

Fig. 7. Main canal water loss with acceptable loss value

The above Figure shows that large amount of water was lost in the downstream of main canal (MC13). The reason for losses in the main canal is mainly related to unauthorized diversions of water by farmers into field ditches, siltation and weeding, seepage, weak section of canal embankment and overtopping of the water from the canal.

The secondary canals conveyance efficiency in the upper, middle and downstream of irrigation scheme was 70.5, 67.6 and 64.3% respectively. The average conveyance

Table 9. Conveyance efficiency (Ec in %) of secondary canals

Day	SC1	SC2	SC3	SC4	SC5	SC6	SC7
17/03/18	65.3	64.6	68.0	62.9	72.5	72.1	69.9
24/03/18	65.4	69.4	76.7	71.9	62.7	–	–
31/03/18	61.8	70.8	61.5	73.9	69.0	67.6	66.4
07/04/18	68.6	74.6	80.2	67.6	66.2	–	–
14/04/18	76.7	76.9	66.1	68.1	68.1	64.4	66.9
21/04/18	72.7	75.9	68.1	71.5	63.7	–	–
28/04/18	62.1	78.7	74.1	66.6	65.5	61.6	62.4
05/05/18	79.6	77.2	76.1	71.8	68.4	64.0	63.6
12/05/18	74.9	71.8	70.1	64.8	60.5	–	–
12/05/18	74.5	71.32	72.9	68.5	66.5	65.4	62.8
29/12/18	56.7	78.2	68.9	70.0	67.1	63.5	63.7
05/01/19	66.5	66.7	65.4	67.7	67.7	58.6	61.3
12/01/19	68.9	64.4	53.4	61.7	51.9	63.9	59.3
19/01/19	66.7	67.1	54.4	66.8	57.1	54.5	60.5
Average	68.8	72.3	69.4	68.2	65.4	64.6	64.0
Secondary canal Ec (%) = 67.5							

efficiency of the secondary canal has 67.5%. According to [12] report the minimum recommended secondary canal water conveyance efficiency was 75%. Therefore secondary canals conveyance efficiency of Quashni irrigation scheme was below recommended value as shown in Table 9 (Fig. 8).

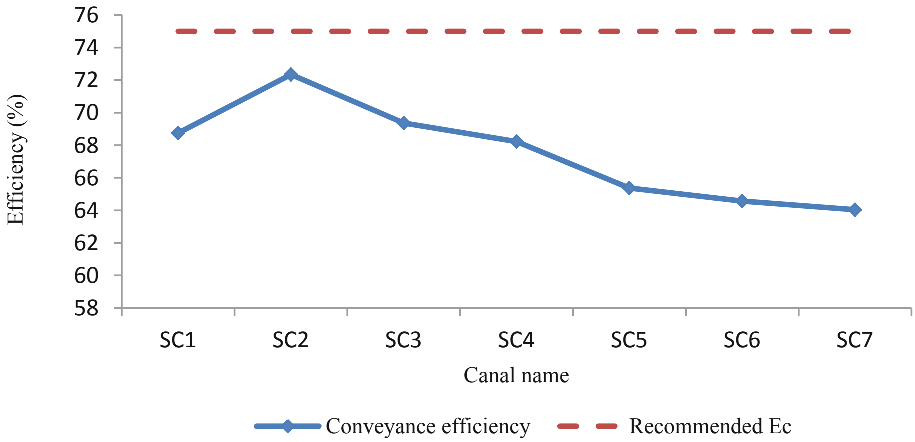

Fig. 8. Conveyance efficiency of secondary canals with recommended value

The water loss was in the upper part 29.5%, 32.4 in the middle and 35.7% in the downstream of secondary canals. The reason for this loss occurs in the secondary canals is due to seepage, evaporation and overtopping flow of water (Fig. 9).

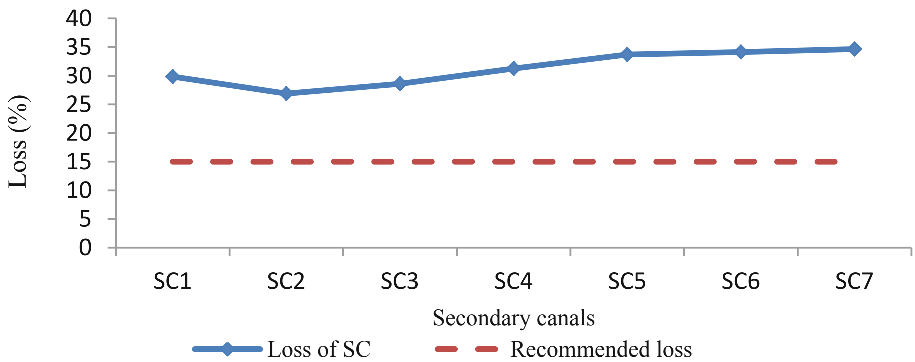

Fig. 9. Secondary canals water loss with acceptable loss value

Application Efficiency

From the result application efficiency of selected farmers' fields at the Quashni irrigation scheme was found to vary from 33.68% to 78.21% with an average of 55.5% in the first season and vary from 24.5.3% to 68.2% with an average of 47% in the second irrigation season. As shown in the Table 10, the water application efficiency of the farmers was 59.4% at the head, 49.7% at the middle stream, 44.6% at downstream users of the schemes. Therefore, average application efficiency of the scheme was 51.3%. As compared to the design application efficiency of the scheme it was reduced by 18.7%.

Table 10. Application efficiency of the scheme

No	User name	1st season Ea (%)	2nd season Ea (%)
1	U/S	67.3	51.6
2	Middle user	53.3	46.1
3	D/S	46	43.3
Average		55.5	47
Scheme Ea (%) = 51.3			

FAO (2003) reported that the attainable application efficiency in US according ranges from 55%–70%, value below this limit would normally be considered unacceptable. Therefore from the result application efficiency in Quashni irrigation scheme are not between the acceptable limit. The reason for poor water application efficiency may be as small scale irrigations were associated to lack of technical capacity of farmers resulted from absence of extension workers and the required trainings, the type of irrigation system employed which was predominantly wild flooding and furrow irrigation, the slopes of irrigable fields, absence of knowledge of irrigation time and scheduling by farmers and more (Figs. 10, 11, 12 and 13).

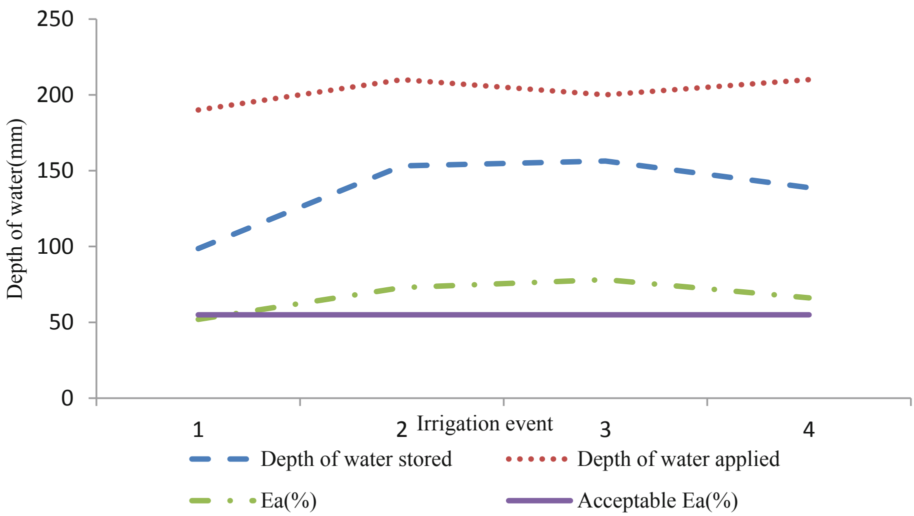

Fig. 10. First season upper user Ea with Acceptable Ea

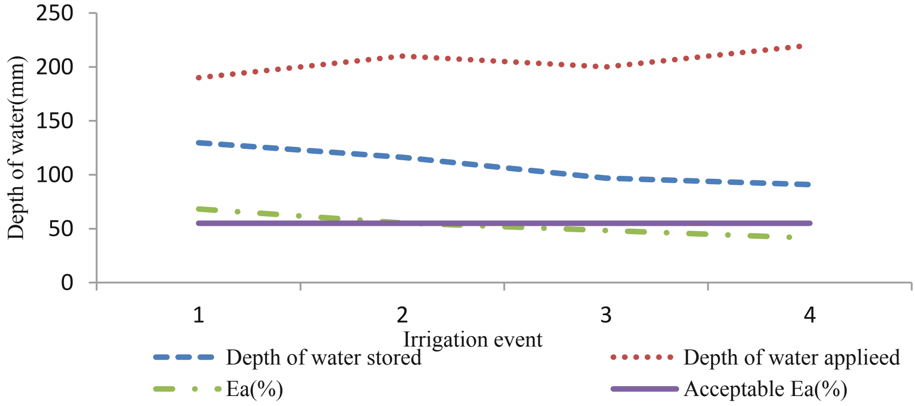

Fig. 11. First season middle user Ea with Acceptable Ea

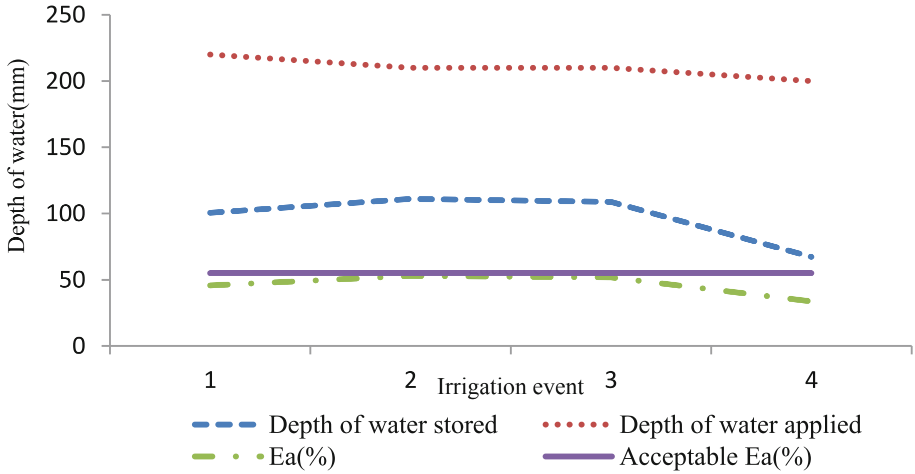

Fig. 12. First season downstream user Ea with Acceptable Ea

Overall Scheme Efficiency

The overall efficiency of the scheme is the ratio of water made available to the crop to the amount released at the headwork. The result indicated that the Quashni irrigation scheme was relatively poor. The overall efficiency of the scheme was not within the range of values (40–50%) commonly observed in other similar African irrigation schemes Savva and Frenken (2002). as compare to the design overall scheme efficiency it was reduced by 13.2%.

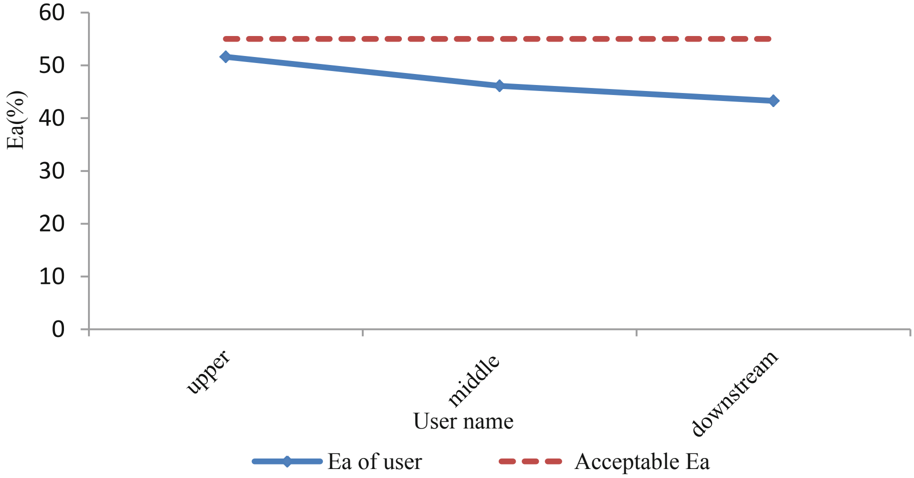

Fig. 13. Second season Ea with Acceptable Ea

Table 11. Actual average irrigation efficiencies of Quashni irrigation scheme

Internal performance indicators	% of efficiency
Conveyance efficiency	71.8
Application efficiency	51.3
Overall scheme efficiency	36.8

Table 11 shows the actual efficiency of the scheme to get overall scheme efficiency by the product of conveyance efficiency with application efficiency. In the present study the overall efficiencies of Quashni irrigation scheme was 36.8% see in the above table. Table 7 shows that designed irrigation efficiency obtained from designed manual. It uses for comparison of actual efficiency with designed efficiency of the scheme. Therefore, as compare to the design efficiency overall scheme efficiency was reduced by 13.2% (Table 12).

Table 12. Design irrigation efficiency of Quashni irrigation scheme

Efficiency	% of efficiency
Conveyance efficiency	90
Application efficiency	70
Overall scheme efficiency	50

(Source: Design manual)

3.5 External Performance Indicators

Relative Water Supply

The relative water supply depicts whether there is enough irrigation water supplied or not. Both the relative water supply and relative irrigation supply relate supply to demand, and give some indication as the condition of water abundance or scarcity, and how tightly supply and demand is matched. The relative water supply value below one normally indicates that the water applied is less than the crop demands and values above one indicate extra water is added to the root zone beyond plant demands. The relative water supply of Quashni irrigation scheme was found to be 1.24.

The result in Table 14 which is greater than one indicates that excess water was used beyond plant demands in the schemes. In order to maximize water use efficiency of the scheme, it is required that the amount of water supplied be reduced in the scheme.

Relative Irrigation Supply

The relative irrigation supply shows whether the irrigation demand is satisfied or not. The relative irrigation supply of Quashni irrigation scheme was found to be 1.1 which is almost 1. During the irrigation season water actually supplied from irrigation for the irrigated land satisfy crop water demand of the scheme. The irrigation requirement was completely to meet irrigation water supply for the irrigated crop area (Table 13).

Table 13. Different parameter used for external performance evaluation

Crop name	Irrigated Land(ha)	CWR (mm)	NCWR (mm)	IR (mm)	NCWR (m)	NCWR (m^3)	IS (m^3)	R.eff (m^3)	TWS (m^3)	Irrigation Demand (m^3)
Potato	52	413.9	179.35	302.5	0.17935					
Maize	68	464.3	263.1	336.4	0.2631	530,952	432,000	224,640	656,640	386,052
Total	120		442.45		0.44245					

3.6 Physical Performance Indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. The irrigation ratio of Quashni irrigation scheme was 0.84 which means about 16% of command area of the scheme was not under irrigation during the study period. The main reasons for this were the first secondary canal diverted water to right side of the scheme totally non-functional because of pressurized pipe installed underground was out of function.

Table 14. Result external performance indicators at Quashni irrigation Schemes

External indicator	Value
Relative water supply	1.24
Relative irrigation supply	1.12
Irrigation ratio	0.84

4 Conclusions

The Ec of the scheme was 71.8%, Ea 51.3% and overall scheme efficiency were 36.8%. RWS and RIS of the scheme were 1.24 and 1.12 respectively. Irrigation ratio of Quashni irrigation scheme found to be 0.84 which means 16% of the command area was not under irrigation during the study period. The reason of the less conveyance efficiency in canal was absolutely due to lack of proper maintenance of the watercourses hence it may be evaporation, seepage and leakage losses, presence of vegetation and sediments. The loss in conveyance was unavoidable unless the canal was lined or can be minimized with better canal management activities. Therefore the result shows that too low efficiency of the scheme. Irrigation water management requires determining when to irrigate and how much water to apply in each application. Knowledge of CWR and soil properties was essential for management of irrigation water. To enhance efficiency of irrigation and water management it is highly important to pay special attention to the following: adequate planning and proper design of the irrigation system, maintenance of the conveyance and distribution systems, including regular clearing of weeds growing along the main and secondary canals.

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