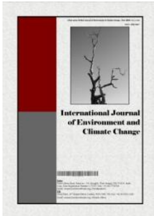

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Hydraulic Performance Assessment of Mychew Small Scale Irrigation Scheme, North Ethiopia

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Authors' contributions

This work was carried out in collaboration between both authors. Author ETK designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Author MA managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Performances assessment of irrigation schemes network is very essential in taking different water management strategies. However, the performance of Mychew irrigation scheme was not assessed and hence, this research was undertaken to assess the hydraulic performance of Mychew small scale irrigation scheme. Moreover, identification of the cause and effect for mal-functionality of irrigation structures was also another objective of this study. Hence, comprehensive field observations, measurements and focus group discussions were held to investigate hydraulic performance, cause and effect of failed hydraulic structures. Simple descriptive statistics was employed for analysis of the data collected from focus group discussions and observations. Eight performance indicators were used to assess the performance of this irrigation scheme. Several factors such as sedimentation, design problem, damage of sluice gates, abstraction of irrigation water by unwanted plants has been identified for mal-functionality of different structures. There were problems in irrigation adequacy (0.75) and equity (0.28) of irrigation water was categorized as poor, while good and fair for dependability (0.08) and irrigation efficiency (0.79), respectively. The

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average water surface elevation ratio, delivery performance ratio, and delivery duration ratio of the main canal during the monitoring period was less than one, greater than 5% and 150%, respectively. The highest sediment accumulation was observed at head and middle reaches of the irrigation scheme than the tail reaches. Generally, there were a number of irrigation structures which was mal-functioned in this irrigation scheme. Now it needs sustainable solution to improve the performance of the irrigation scheme. Therefore, it was recommended that water should be fairly distributed spatially and temporally. Additionally, capacity building and awareness creation to concerned bodies holds the key to bring a difference in irrigation water management in this irrigation scheme.

Keywords: Adequacy; equity; dependability; water surface; delivery performance.

1. INTRODUCTION

Ethiopia is predominantly an agricultural country where more than 80% of population depends on agriculture [1]. It has abundant rainfall and water resources, its technologies of water management and irrigation agricultural system does not yet fully benefit from the technologies of water management and irrigation [2]. Meanwhile, it is already suffering from food shortage because of rapid population growth [3] and chronic drought occurrence in most part of the eastern and northern part of the country. There is a dire need of utilizing these resources on emergent bases particularly, in those areas where the duration of the growing period is short and the precipitation is erratic.

Hence, to solve the scarcity of irrigation water public and non-governmental organizations have constructed different irrigation schemes of various capacity and scales. Small-scale irrigation schemes provide to be more viable in Ethiopia and play a vital role in improving the livelihoods of the small land holder farmers [4]. Improving the performance of irrigation schemes for different interventions is key issue for improving increased crop production and productivity of irrigated lands confronted water scarcity. Many irrigation schemes, particularly in least developed and emerging countries, are characterized by a low level of overall performance [5].

Even though much study has been done in Ethiopia on irrigation performance assessment of schemes focusing mainly on the hydraulic, structural, water service and maintenance issues of the irrigation system [4,6,7,8] such kind of studies are limited to Tigray, particularly in the area where this study has been carried out.

The farmers at Mychew irrigation scheme are able to irrigate and harvest crops twice a year. However, due to lack of awareness and frequent training for water application, management, operation and maintenance, for water users and water committee, the optimum crop yields are not being harvested. Additionally, expertise of district, development agent and or other body didn't envisage and plan appropriate crop water requirements and irrigation scheduling. Based on these problems farmers are spent more hours a day to watered the irrigate field. Hence, this study was designed to assess the hydraulic performances of Mychew small scale irrigation (SSI) scheme in central zone of Tigray, Ethiopia.

The study provides important information to the system managers, farmers, district expertise, funding agency and policy makers for better understanding of how a system can be operated and maintained. Besides, policy makers can take this opportunity to benefit other farmers that are not part of this study area.

1.1 Objectives

The objectives of this study were; 1) to assess the hydraulic performance of the irrigation scheme; 2) to identify the main causes and effect of failed hydraulic structures and 3) to create awareness amongst all stakeholders to enhance crop production and productivity.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The study was conducted in Kola Tembien district specifically at Adiha Tabia, Mychew SSI scheme. Kolla Tembien district is found in the central zone of Tigray region 95 km far to the west of Mekelle. It encompasses 27 Kebele (Tabia) and 93 villages (Kushet) occupying an area of 1389.70 ha. It has about 147,800 population size out of which 49.5% are female and 50.5% are male [9].

Mychew SSI scheme is a perennial flow river in the district which is located in regional state of Tigray at Tabia Adiha, Kushet Tahtay Skin. It is about 125 km and 25 km away from the regional town of Mekelle and Abi Adi, respectively. Its' catchment size is 150 km^2. Geographically, it is situated at latitude of 13.76° (N), and longitude 39.098° (E) (Fig. 1). The average elevation of the study area is 1640 m.a.s.l [10]. The total length of the lined canal is 3.09 km while the unlined canal is about 2.45 km.

The total command area is 186.5 ha from this the irrigation potential is 54.75 ha. The total irrigation beneficiaries were 83 out of these 15.66% were females and remains 84.34% were males. The main fruit trees, vegetables and cereals which found in this scheme are orange (*Citrus sinensis*), and Mango (*Mangifera indica*), pepper (*Piper nigrum*), and maize (*Zea mays*), respectively [9].

2.2 Data Collection and Sources

For this assessment the data were collected from primary and secondary sources. The primary data were collected through direct measurement of fields. For example, soil characteristics, overview of the irrigation structures together with their water control and measurements, discharging through branch off-take canals, actual water surface elevation in the main canal were measured from the field. Comprehensive field survey such as transect walk was held through different components of the scheme to understand irrigation practices, sources of irrigation water, its water distribution system and their cropping patterns. Moreover, discuss with the focused group and key informants was undertaken to identify the root causes and effect of failed irrigation structures.

The secondary data were collected from Relief Society of Tigray Bureau (REST), district Kola Tembien Water Resource, Mine and Energy office (KTWRME), district Kola Tembien Agricultural Rural Development office (KTARD) and National Meteorological Agency of (NMA) Ethiopia. Design document of the irrigation scheme, irrigated crops, actual command areas and climate data are major data which were utilized in the study.

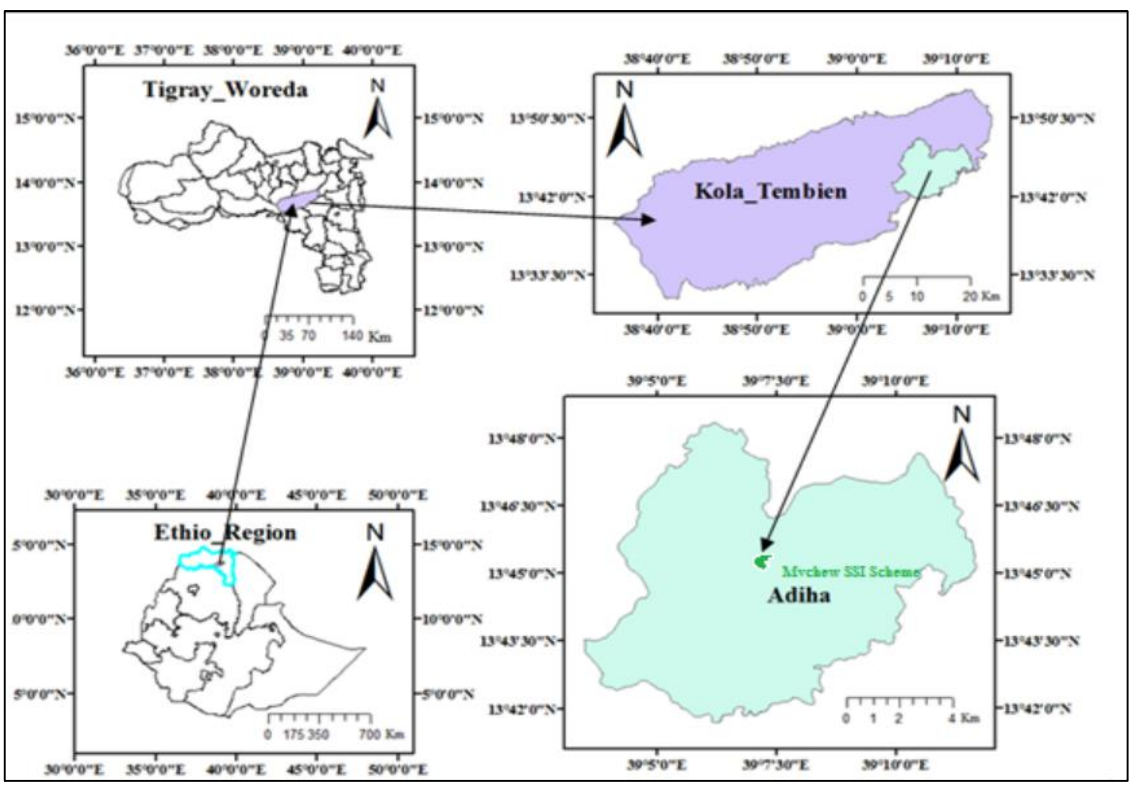

Fig. 1. Map of the study area

2.3 Sampling Methods

The sampling techniques used in this research are first clustering method (scheme was classified into head, middle and tail reach base on length of irrigation canals and irrigated area) to take soil sample, measure irrigation water delivery and water surface elevation (WSE)), second randomly sampling method base on [11] for focus group discussion (FGD) with irrigation water users (IWUs). The third sampling technique was purposely sampling method; it was used for cross checking the causes and effects of the mal-functionality of the irrigation structures with district experts who have the irrigation profession and water committee.

2.4 Irrigation Water Delivery Measurements (IWD)

In the study, irrigation water in the canal was measured by calibrated Parshall flume and 90 degree V notch. The flow measurements were taken from nine off-take canals which were located at head, middle and tail reach of the irrigation scheme. The discharge of canals resulting from the depth-flow relationship of parshall flumes were calculated in free flow conditions. The measurements were taken at the branch off-take canals just after abstraction points along the distribution canals. Based on the settled water delivery plan, the measurement of actual discharges in each branch off-take canals taken on 15 days per three months (five days/month) and then converted into an average monthly rate.

2.5 Water Surface Elevation (WSE) Measurements

Actual water surface elevation (AWSE) of the main canal was measured from five monitoring stations classified into 0.5 km intervals of the head and also five monitoring stations classified to 300 m intervals of middle and tail reach.

2.6 Measurements of Sediment Accumulation

Measuring of sedimentation accumulation in the irrigation canals were based on the division of reaches and measure 5 m by its width and depth. In this measurement five samples were taken from 5 m at the interval of 1 m to each other and finally display the result its average for irrigation scheme. In this irrigation scheme most part of the irrigation canal was found at the head than tail so four samples were taken from head reach and three from middle and tail reach. Initial depth was measured before cleaning of the canal, while final depth of the canal was taken after cleaning the silt or sedimentation from September 13 to 14, 2016. Additionally, the soil samples were taken from the irrigation scheme. Two composite soil samples were taken from each reach.

2.7 Data Analysis

Hydraulic performance of the irrigation system was evaluated using eight internal performance indicators. It was investigated based on the data that were collected during September to November, 2016 in one irrigation season. The choice of these months was arranged due to the fact that, in this irrigation scheme most of fields are irrigated. A water delivery performance indicator was designed to evaluate on the main canal at head, middle and tail reaches. The main canal system performance with respect to water delivery indicators were estimated based on the monthly required and delivered discharge. Additionally, infiltration rate of soil was evaluated using double ring infiltrometer. The soil physical and chemical characteristics were analyzed at Mekelle soil research center, Tigray, Ethiopia.

2.8 Hydraulic Performance Indicators

Hydraulic performance indicators were concerned with the assessment of the water supply function of the irrigation system. Water delivery performances at field level were determined according to the indicators of adequacy, equity, dependability and efficiency. There are three volumes of water that need to be considered in the hydraulic performance indicators. These are intended volume of water (Q_{int}), actual supplied volume of water (Q_{ac}) and effective volume of water (Q_R). The number of irrigations in one season (T) was taken as the time period; and number of fields (R) was taken as the sub-region. The coefficient of variation (CV) was estimated through the ratio of standard deviation to mean. These indicators have been proposed by [12]. The results where compared with performance standards.

2.9 Maintenance Indicators

Maintenance performance assessment of irrigation scheme would provide an insight to the future of maintenance situations. It was estimated through the indicators recommended by several authors [12,13] maintenance requirements of the system were evaluated by water surface elevation ratio, delivery performance ratio, delivery duration ratio and effectiveness of the infrastructures.

3. RESULTS AND DISCUSSION

3.1 Soil Characteristics

The soil characteristics of the study area at the head and middle reach of the irrigation scheme is dominated by sandy loam, while tail reach is by sandy soils (Table 1). The maximum rain infiltration rate of the head, middle and tail reach are range from 28 – 29.33 mm/day, 29 -29.51 and 29.8 – 30.12 mm/day, respectively.

Irrigation water requirements of the scheme for the growing season were estimated using CROPWAT 8 program [14]. Crop water requirement were computed for different crops in the command area and then total sum of irrigation water requirements of the main canal and the potential for each branch off-take canal was designed. The volume of water required (Q_R) to feed the main and branch canals at each measuring station estimated as corresponding with the product of irrigation requirement and the command area served for irrigation practice by assuming an irrigation efficiency of 55 per cent from [10] design document.

3.2 Evaluation of Hydraulic Performance

Based on the investigation, from September to November, 2016, the average values of actual monitored discharge and required in the secondary and branch off-take canals are summarized in Tables 2 and 3 respectively.

3.3 Adequacy Indicator (P_A)

According to the irrigation performance standards table, the spatial adequacy of irrigation water in Mychew irrigation scheme was laid to poor classification at all months (September, October and November). While comparing the adequacy based on the months it decreased numerically, which is 0.78, 0.75 and 0.72 for September, October and November, respectively. This variation shows, the canal and other irrigation physical structures were inappropriate maintained during the irrigation preparation stage while after irrigation started the irrigation canals were easily got filled with silt which came from farm land or by water users themselves to control water flow from one farm to other by traditional methods such as soil, stones, wooden logs etc… it helps in filling the irrigation canals with silt and causes decreased flow of irrigation water into the next user.

There was temporal variation of adequacy in Mychew irrigation scheme (Table 4); it decreased toward the tail reach that is 0.86, 0.82 and 0.57 at head, middle and tail reach, respectively. This is because there were different water abstraction in head and middle of the next off-take canal and it was normal characteristics of the small scale irrigation schemes.

Based on the results [15] on the performance of Hare irrigation Scheme; they concluded that poor adequacy was major common problems of the Hare irrigation scheme. The overall adequacy value of the system was found to be 0.64 which was due to incorrect water delivery scheduling, weak management of the committee to operate the system according to delivery schedules, sedimentation of canals, and inadequacy operation of the physical system components due to scant maintenance work. These factors influence the required benefits of the system.

3.4 Equity Indicator (P_E)

The results of equity are displayed in Table 4. The equity perceived more than 0.25 which are said to be poor in all months. This is due to unlawful water abstractions (lack of sound by law), nearly inoperative of water distribution structures, water losses along the main canal, improper operation and inadequate maintenance of the canal, poor management of the scheme and WUAs and fixed irrigation scheduling. Similar results were obtained in [5] who applied CV to evaluate the level of variability of irrigation supplies at off-takes. Based on the idea of Tariq *et al.* (2004) the practically acceptable value of CV in tertiary off-takes, is assumed to be of 10%. Then [4] concludes that Metahara Scheme, a CV of 32% was obtained, which was substantially higher than the target. This gives an insight into spatial non-uniformity of water distribution of the whole scheme.

3.5 Dependability Indicator (P_D)

Mychew SSI scheme dependability ranges from 0.04 to 0.14 and the overall dependability was 0.08 (good); but its rage is from good to fair. Hence, the dependability scheme was classified as good in head and middle reach. This means there was low variability of water distribution in these reaches. Because, these reaches were close to the irrigation structures and delivered irrigation water into their land based on their schedule. As contrarily, tail reach was far. This result shows the commitment or agreement of the water committee with farmers (IWUs) who found at tail reach was low proportional and the communication between them was not stronger to distribute irrigation water.

Based on the clarification of [16] farmers may be happier with a water delivery system in the irrigation scheme that delivers an inadequate supply which is reliable, than with the adequate supply which is not reliable. If the farmers are sure that the deliveries are according to the schedule communicated to them, they can plan their activities accordingly resulting in higher productivity. There is more cooperate the irrigation water user with their leaders' water users committee (WUC) at head and middle reach than tail reach to allocate the required irrigation water.

3.6 Efficiency Indicator (P_F)

The spatial and temporal average values of irrigation efficiency (P_F) are given in Table 5. The spatial average efficiency is more efficient in October and November. This is because the canals which were filled with silt were cleaned and additionally other irrigation structures maintenance which was important to convey and temporarily constructed some additional distributors.

The temporal irrigation efficiency was poor at tail while, good and fair at middle and head, respectively. The reason is that at head reach IWUs were delivered the required water into their farm properly and routinely silt cleaning from the irrigation canal. And the middle reach of this scheme was used for irrigation water appropriately and the canal depth was at approprate depth (good design) than head reach, and therefore, silt intered into the canal decrease at this reach than head.

Whereas tail reach most part of the irrigation canal was unlined and exposed into different water wastage. Similar results were found by researchers such as [17], average conveyance efficiency was found to be 75% in concrete-lined trapezoidal canal. The low irrigation efficiency attributed to the fact that almost all the observed irrigation block are lacking discharge control structures leading to a weak capacity of farmers to have adequate control on efficient water application as found Mychew SSI scheme at tail reach.

3.7 Maintenance Indicators

Water surface elevation ratio (WSER): The actual water surface elevation (AWSE) was averagely found to be 0.73m 0.66 m and 0.54 m for the head; middle and tail reaches, respectively (Table 6). The overall average WSER was 0.86 which shows eleven percent of WSE at full surface level (FSL) was reduced from the intended water depth of the main canal. The average WSER at head, middle and tail reaches of the main canal during the monitoring period was generally less than one, indicating the main canal was ineffective by weed and sedimentation problems. Similar result was found by [15] and summarized as the overall average WSER was found to be 0.91; and from their estimation, about seven percent of WSE at FSL was reduced from the intended water depth of the main canal.

Delivery performance ratio (DPR): The delivery performance ratio of this irrigation scheme is listed in Table 7. It has 0.14 at middle reach that is greater than 5%, showing the irrigation scheme needs maintenance in the middle reach. According to observations, focus group discussion, key informative and transect walks, animals were passed through this irrigation canal and destroyed every irrigation time and filled this canal with silts (Fig. 2 (a) and (b)). From these results, it needs more maintenance in November than the remained months (September and October). Because, irrigation canals were in function and initially cleaned in these months but in November, the irrigation scheme was prepared into the second irrigation season and they filled with silt.

Delivery duration ratio (DDR): The value of delivery duration ratio (DDR) for Mychew SSI scheme as per design documents, the intended duration of water delivery was 12 hours a day. However, because of the expansion of irrigated land, silting up of the canal systems, mal-functioning of control structures, inappropriate watering of main and secondary canals and shortage of irrigation water; mainly for tail end beneficiaries, actual duration of water delivery was increased to 18 hours a day. Therefore, the DDR this irrigation scheme is 150%; showing the water distribution system was not dependable and the system maintenance also insufficient. Generally, the scheme was need further maintenance. Comparable results found by [15] at Hara irrigation scheme similarly demonstrated that water distribution system was not dependable (133.33%) and the system maintenance was also insufficient.

Table 1. Soil characteristics of the study area

Reach	Parameters						Texture			USDA textural Class	Max. rain Infiltration rate (mm/day)
	pH	EC Ms/Cm	OC %	CEC Meq/100 gm soil	AV.P ppm	TN %	Sand %	Silt %	Clay %		
Head	7.970	0.180	2.098	24.208	4.478	0.105	68	12	20	Sandy Loam	29.33
	7.780	0.160	2.003	24.243	4.391	0.100	84	4	12	Sandy Loam	28.92
Middle	7.450	0.140	2.193	15.478	5.382	0.110	78	4	18	Sandy Loam	29.51
	7.970	0.160	2.399	23.249	3.439	0.120	82	6	12	Sandy Loam	29.23
Tail	7.850	0.270	2.194	28.124	2.138	0.110	98	0	2	Sand'	30.12
	7.850	0.270	2.194	28.124	2.138	0.110	97	1	2	Sand'	30.09

Where: EC = electrical conductivity, OC = organic carbon, CEC = cation exchange capacity AV.P = available phosphors, TN = total available nitrogen

Table 2. Average required (Q_R) and delivered (Q_D) discharge on the secondary canal ($m^3\ s^{-1}$)

Reach	Head						Middle						Tail					
	Q_{R1}	Q_{D1}	Q_{R2}	Q_{D2}	Q_{R3}	Q_{D3}	Q_{R4}	Q_{D4}	Q_{R5}	Q_{D5}	Q_{R6}	Q_{D6}	Q_{R7}	Q_{D7}	Q_{R8}	Q_{D8}	Q_{R9}	Q_{D9}
Sep	0.13	0.11	0.18	0.17	0.17	0.15	0.17	0.12	0.16	0.14	0.15	0.12	0.30	0.23	0.04	0.03	0.11	0.03
Oct	0.13	0.11	0.18	0.15	0.17	0.14	0.17	0.13	0.16	0.13	0.15	0.14	0.30	0.26	0.04	0.02	0.11	0.02
Nov	0.13	0.11	0.18	0.15	0.17	0.14	0.17	0.13	0.16	0.13	0.15	0.13	0.30	0.21	0.04	0.02	0.11	0.02

where: Q_{R1}, Q_{R2}, Q_{R3} … Q_{R9} and Q_{D1}, Q_{D2}, Q_{D3} … Q_{D9} required and delivered discharge at 1, 2, 3… 9 of the supply canal incoming across the off-taking canal, respectively.
N.B. The delivery discharge measurements were taken twice per day and average as the delivery of one day. Totally five days per month were taken

Table 3. Average delivered and required discharge in the branch off-take canals ($m^3\ s^{-1}$)

Reach		Head						Middle						Tail					
		Q_{R1}	Q_{D1}	Q_{R2}	Q_{D2}	Q_{R3}	Q_{D3}	Q_{R4}	Q_{D4}	Q_{R5}	Q_{D5}	Q_{R6}	Q_{D6}	Q_{R7}	Q_{D7}	Q_{R8}	Q_{D8}	Q_{R9}	Q_{D9}
Month	**Sep**	0.018	0.024	0.017	0.024	0.02	0.024	0.003	0.004	0.003	0.004	0.004	0.004	0.009	0.006	0.006	0.008	0.004	0.007
	Oct	0.018	0.024	0.017	0.023	0.02	0.021	0.003	0.004	0.004	0.003	0.004	0.004	0.008	0.006	0.006	0.008	0.004	0.008
	Nov	0.018	0.023	0.021	0.022	0.02	0.023	0.003	0.003	0.004	0.004	0.004	0.004	0.008	0.001	0.006	0.008	0.004	0.008

Where; Q_D and Q_R is the delivered and required discharge in the branch off-take canals and in branch off-take of R_1 till R_9, respectively

Table 4. Average adequacy of water distribution, dependability of water supplied and equity of water distribution on the system

Month	Head			Middle			Tail			Spatial Average (P_A)	STDEV	CV_R (P_E)
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**			
Sep	0.89	0.94	0.89	0.73	0.86	0.82	0.78	0.85	0.27	0.78	0.20	0.26
Oct	0.85	0.84	0.85	0.76	0.84	0.93	0.87	0.65	0.20	0.75	0.22	0.29
Nov	0.83	0.82	0.83	0.78	0.80	0.85	0.70	0.64	0.20	0.72	0.21	0.29
Average (Temporal)	0.86	0.87	0.86	0.76	0.83	0.87	0.78	0.71	0.22	0.75		
Ave. Reach (P_A)	**0.86**			**0.82**			**0.57**			**0.75**		
STDEV	0.03	0.07	0.03	0.03	0.03	0.05	0.08	0.12	0.04			
CVT (P_D)	0.03	0.08	0.03	0.03	0.04	0.06	0.11	0.16	0.16			
Ave.CVT (P_D)	**0.05**				**0.04**			**0.14**		**0.08**		**0.28**

Table 5. Average spatial and temporal irrigation efficiency of the scheme

Month	Head			Middle			Tail			Spatial Av. P_F
	R1	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	
Sep	0.78	0.74	0.84	0.75	0.77	1.00	0.65	0.66	0.65	0.76
Oct	0.77	0.75	0.97	0.75	1.00	1.00	0.67	0.7	0.55	0.80
Nov	0.80	0.95	0.88	0.84	1.00	1.00	0.69	0.7	0.53	0.82
Average PF	0.78	0.81	0.90	0.78	0.92	1.00	0.67	0.69	0.58	
Temporal Av. P_F	**0.83**			**0.90**			**0.64**			**0.79**

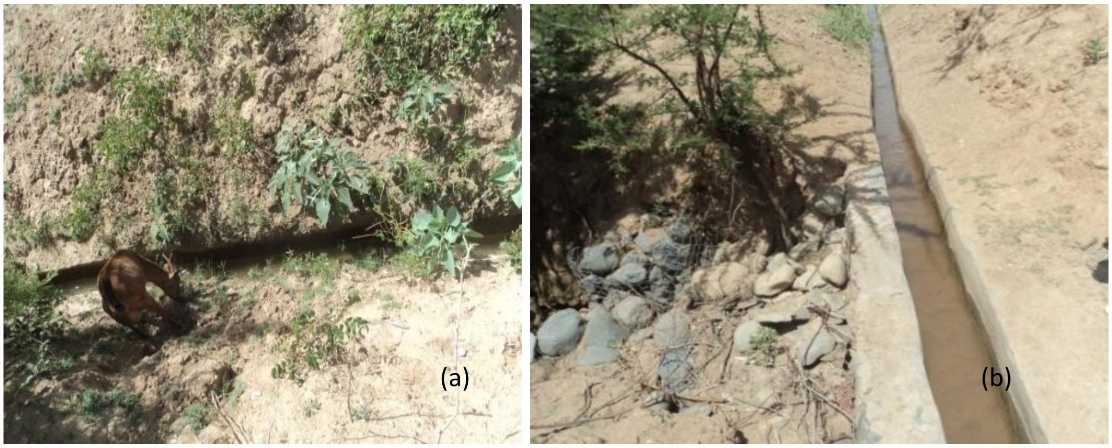

Fig. 2. Animal grazing on irrigation structures (a) and Mal-functioned (b)

3.8 Summary of the Cause and Effect of Low Hydraulic Performance Indicators

The main causes of low hydraulic performance indicators were poor water user association irrigation structures, irrigation water users and expertise. Even though these are the main causes there are also sub main causes. These cause and effect of the low hydraulic performance indicators are presented in Fig. 3 using the fish bone diagram.

3.9 Effectiveness of Infrastructure

In Mychew irrigation scheme the spill way sluice gates at the weir were not functional hence, are not effective yet. On the other hand, no failure was observed at main and branch canals. Based on the design document, the total number of structures was constructed on the main and branch canals were 93, however only 47 hydraulic structures are currently functional (Table 8). Therefore, the values of effectiveness of infrastructures were estimated to be 50.54%. These values suggest that maintenance activity of the systems were very poor. Based on [15] in Hare irrigation scheme, SNNPR, Ethiopia from 113 constructed irrigation structure only 18 structures were functional and its position was 15.9%.

3.10 Causes and Effect of Failed Hydraulic Structures

The failures of some irrigation structures were observed to be design problem. This was the variation of depth below the original ground level (OGL) was averagely found 1 m at the head and 0.5 m at the middle, it leads to sedimentation of canals from its surrounding, while, it was to be constructed by concrete conduits. These problems were not due to curt away of the soil from the irrigation canals. But it was due to design problems and they dug to the natural ground and construct irrigation canal below the OGL (Fig. 4 (a) and (b)).

The tertiary unlined canals which were constructed by the individual farmers has a problem in its dimension (very wide) which creates an opportunity of water loss through percolation, evaporation and even flow to unwanted areas and additionally leads soil erosion. Generally, focus group discussion (FGD) and observation, improper operation and maintenance of canals which was strengthened by poor awareness on water users and water committee were also mentioned as a problem. These problems lead into illegal manipulation of canals and structures.

Apart from the structure mal-functioning factors, there were some unwanted plants (such as *Pterolosium stellatum* (Konteftefe), *Ziziphus spinachristi* (geba), *Acacia sieberiana and Acacia seyal* (Tsaeda cheia and Tselim cheia), *Ficus sur* (Sagla), *Balanites eagyptica* (Meki'a), *Syzygium guinensis* (Li'ham) and *Ficus vasta* (Da'ero) whereas the planted trees were *Euphorbia tirucalli* (Knchib), *Eucalyptus camaldunes* (keyhkelamitos), *Grevilia robusta* (Gravila), Susbanyia, and Lusinya) in the farm land that absorbed the irrigation water and they are agents of the irrigation canal to become cracked.

Table 6. Water surface elevation (WSE) statuses of the main canal

Monitoring station	Linear distance (m)	Head				Linear distance (m)	Middle				Linear distance (m)	Tail				Over all	
		IWSE (m)	AWSE (m)	DEV. WSE	WSER		IWSE (m)	AWSE (m)	DEV. WSE	WSER		IWSE (m)	AWSE (m)	DEV. WSE	WSER	DEV. WSE	WSER
C1	20	0.80	0.73	0.07	0.91	2020	0.75	0.69	0.06	0.92	4020	0.70	0.47	0.23	0.67		
C2	420	0.80	0.72	0.08	0.90	2420	0.75	0.64	0.11	0.85	4420	0.70	0.52	0.18	0.74		
C3	820	0.80	0.75	0.05	0.94	2820	0.75	0.66	0.09	0.88	4820	0.70	0.54	0.16	0.77		
C4	1220	0.80	0.70	0.10	0.88	3220	0.75	0.68	0.07	0.91	5220	0.70	0.60	0.10	0.86		
C5	1620	0.80	0.76	0.04	0.95	3620	0.75	0.64	0.11	0.85	5540	0.70	0.58	0.12	0.83		
Average			**0.73**	0.07	0.92			**0.66**	0.09	0.88			**0.54**	0.16	0.77	**0.11**	**0.86**
Maximum			0.76	0.10	0.95			0.69	0.11	0.92			0.60	0.23	0.86		

Where; monitoring station is the part of irrigation canal which taken the measurement, linear distance is the distance from the intake canal to monitoring station, IWSE is intended water surface elevation, AWSE is actual/current water surface elevation, DES.WSE is deviation of water surface elevation, DEV.ESE = IWSE – AWSE, and WSER is water surface elevation ratio

N.B. The result was based on average level measurement of water depth at FSL in various main canal sections and linear distance was the distance from the intake of irrigation canal

Table 7. Delivery performance ratio of canal reach

Month	Head			Middle			Tail			Spatial Average
	R1	R2	R3	R4	R5	R6	R7	R8	R9	
Sep	0.05	0.05	0.05	0.05	0.05	0.05	0.04	0.04	0.04	0.05
Oct	0.02	0.05	0.05	0.05	0.05	0.06	0.05	0.03	0.04	0.04
Nov	0.02	0.05	0.05	0.05	0.82	0.05	0.04	0.03	0.05	0.13
Average (Temp)	0.03	0.05	0.05	0.05	0.31	0.05	0.04	0.04	0.04	
Average	**0.04**			**0.14**			**0.04**			**0.07**

Table 8. Functional and mal-functioned irrigation structures of Mychew SSI scheme

S.N°	Infrastructures	Functional	Malfunctioned	Total N° of Infrastructure	Effectiveness of Infrastructure (%)
1	Spill way gate	0	3	3	0.00
2	Drop structures	17	5	22	77.27
3	Off-take	30	4	34	88.24
4	sluice gate at the off-take	0	34	34	0.00
	Total	47	46	93	
	Position (%)	**50.54**	**49.46**		

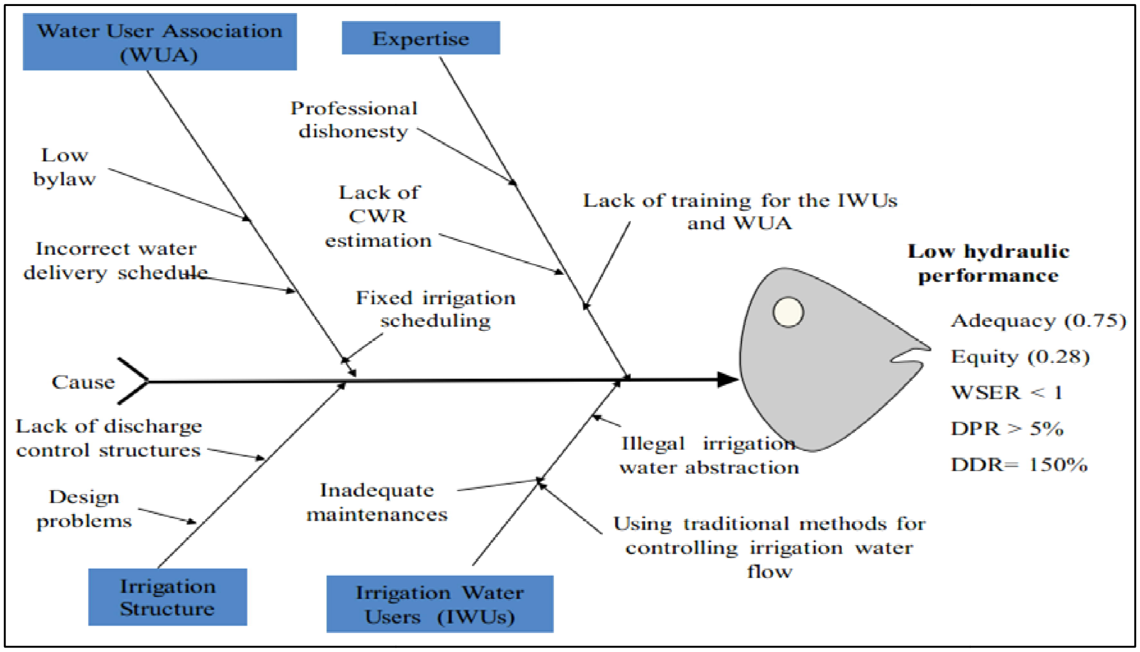

Fig. 3. The main cause and effect of failure hydraulic structures

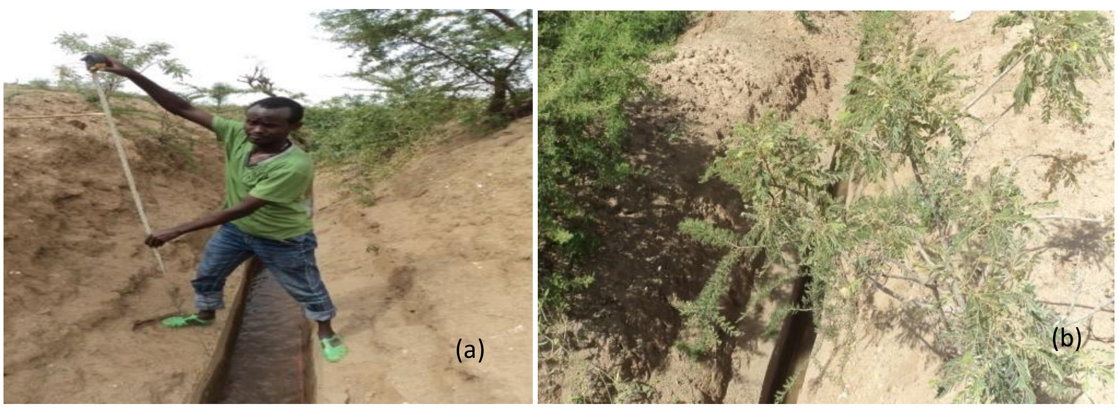

Fig. 4.The main cause of the mal-functionality due to depth of irrigation canal below OGL

Table 9. Sediment deposition of Mychew SSI scheme

Reach	Sample	Average (m^3/5m)
Head canal	S_1	3.650
	S_2	2.898
	S_3	2.093
	S_4	0.873
Middle canal	S_5	0.809
	S_6	0.819
	S_7	0.664
Tail (lower) canal	S_8	0.670
	S_9	0.659
	S_{10}	0.635
Average		**1.377**

3.11 Sediment Deposition in the Irrigation Canals

The sediment accumulation in Mychew at head varies between (S_1) 3.65 $\frac{m^3}{5m}$ to (S_4) 0.873 $\frac{m^3}{5m}$, middle from (S_5) 0.809 $\frac{m^3}{5m}$ to (S_7) 0.664 $\frac{m^3}{5m}$ and tail varies from (S_8) 0.67$\frac{m^3}{5m}$, and (S_{10}) 0.635 $\frac{m^3}{5m}$ (Table 9). This variation shows sedimentation accumulation decrease toward the tail reach. Generally, Mychew SSI scheme has an average sediment accumulation of 1.377$\frac{m^3}{5m}$.

4. CONCLUSION

The irrigation scheme at which this study has been carried out is located in semi-arid areas and here, it is known that water is the limiting factor for agricultural production. Hence, improving irrigation water management through identification of factors that hinder for efficient utilization is inevitable. Several factors such as flooding, sedimentation, cracking, design problem, improper operation and maintenance, abstraction of irrigation water by unwanted plants, deforestation, free grazing has been identified for mal-functionality of different structures. There were not initially constructed the flow control gates at off-take. Consequently, farmers were used stone and mud for control of water flow in canals.

The spatial adequacy was poor for all months while temporally fair at the head and middle but poor at tail reach. The overall equity value of the delivery system was poor. Dependability was classified as good for this irrigation scheme. Regardless of the spatial variability, the overall efficiency of this irrigation scheme was classified as fair.

The average WSER at head, middle and tail reaches of the main canal during the monitoring period was generally less than one, indicating the main canal was ineffective by weed and sedimentation problems. The estimated delivered performance ratio was greater than 5% which needs maintenance. Delivery duration ratio has 150%; showing the water distribution system was not dependable and the system maintenance was insufficient. The spillway sluice gates at weir were not functional and effective. On the other hand, no failures were observed at the main and branch canals. The amount of sediment accumulation more at the head than middle and tail reach.

Generally, in this irrigation scheme there were a number of irrigation structures which were mal-functioned due to aforementioned above reasons and now needs sustainable solution to improve the performance of the irrigation scheme.

5. RECOMMENDATION

- Irrigation water user association (IWUA) of this irrigation scheme was not well-organized, it has management target gaps. They should be reforming and giving training to them.
- Awareness creation and capacity building should be given to local administrations, development agent, IWUA and farmers on management of irrigation water and irrigation structures and crop water requirement and irrigation scheduling.
- In this irrigation scheme the main canals from the diversion till 500 meter should be constructed by tube not open canals because it was averagely 1 m below the OGL and also the soil is sandy loam which is easily exposed to siltation by rainfall, animals and human beings.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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