Hydraulic Performance Evaluation of Community-Managed Irrigation Scheme, North Shewa, Amhara, Ethiopia

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Research Article

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Abstract

Background: Irrigation scheme performance assessment is vital to evaluate the impacts of irrigation practices, to identify performance gaps and to improve system performances. However, irrigation performance assessment has not been carried out for Yelen irrigation scheme since its operation. Therefore, this study has been done with the purpose of identifying and understanding the current level of irrigation performance of Yelen irrigation scheme. The indicators of adequacy, efficiency, dependability, deficiency and equity were used to determine hydraulic performance. Primary data were collected through flow measurement using current meter and Parshall flume, transect walk, household surveys and group discussions, whereas Secondary data were collected from different sources. CROPWAT 8.0 model, SPSS, Microsoft excels and GIS software was used to analyze the data. Water delivery indicators were evaluated from the amounts of water which was actually applied and which should have been applied.

Results: According to the results of the study, the value of adequacy, dependability, efficiency, deficiency and equity were found to be 0.84, 0.26, 0.93, 0.17 and 0.34 respectively. Generally, the performance of the irrigation system is poor. It mainly resulted due to water scarcity, illegal water abstraction, sedimentation of canals and inadequate operation and maintenance provisions.

Conclusions: Therefore, adequate maintenance and suitable management approaches are required to improve the irrigation system performance. Under the water scarce situations, improving the performance of water delivery systems can offer an opportunity to realize field level water savings.

Background

There is a dramatic increase in irrigated area across the globe. Most of this expansion has occurred through capital investments in infrastructure for the capture, storage and distribution of water and in the conversion of rain-fed areas into irrigable land (Murray-Rust and Snellen 1993). 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. It is widely recognized that irrigated agricultural development is a strategic tool that can feed rural populations and help to reduce the flow of the rural population to the already crowded urban centers of developing countries (Murray-Rust and Snellen 1993). Performance of many irrigation systems is significantly below their potential due to a number of shortcomings; including poor design, construction, operation, maintenance, and ineffective water control and measurement structure installation (Degirmenci et al. 2003; Aklilu 2006). Water is a natural resource of strategic importance, which directly affects economic and social development. As competition for water increases, the irrigation sector often blamed for its high and inefficient use of water and commonly held responsible for urban water shortages. However, when competition over water intensifies, irrigation usually becomes the residual human use after other needs have been met (Molle and Berkoff 2009). On farm irrigation, to be efficient in the use of water and labour must serve from a supply that is flexible in frequency, rate, and duration comparable to a domestic system, and operated under the direct control of the irrigator at or near the point of application (Merriam et al. 2007).

Irrigated agriculture, in the world, has an important role in human nutrition and in increasing the economic development of rural areas. Therefore, irrigated areas are constantly increasing. As important as increasing

the irrigated area is the efficient, equitable and dependable delivery of water and the efficient and uniform application to the fields of the water delivered (Korkmaz and Avci 2012). According to Solomon (1984), besides the amount of irrigation water delivered to the fields, uniform distribution of this water is also important. Non uniform irrigation results in some parts of the irrigated land receiving less water than necessary and other parts receiving more than is needed. These studies are generally carried out at scheme or canal level. In this study, irrigation performance in the Yelen irrigation project at zone of North Shewa, Amhara, Ethiopia, was evaluated based on farmers' irrigations in the irrigation season of October to December 2020. Hydraulic performance was determined according to the internal/process indicators of adequacy, dependability, equity, efficiency and deficiency.

Irrigated agriculture faces a number of difficult problems. One of the major concerns is the generally poor efficiency with which water resources are being used for irrigation. The other evident problem is the growth of alternative demands of water for urban and industrial needs. These uses place a higher value on water resources and, therefore, tend to focus attention on wasteful practices. The interventions so far made in Amhara region focuses on the development of new irrigation schemes and upgrading the physical infrastructures of existing traditional irrigation schemes (Wondatir 2016). As per the report by Wondimkun and Tefera (2006), the performance of many irrigation schemes in Amhara region is far below their potential mainly due to inefficient irrigation water management, poor maintenance and problems associated to input supply and marketing.

In Yelen irrigation project, there is high competition for irrigation water use among the upstream and downstream irrigation units, due to on-farm and off-farm water distribution problems. Therefore, there is a possible rise in a potential risk of low irrigation efficiency due to inappropriate methodologies. The infrastructure of irrigation system lacks the capacity to deliver irrigation water, problems of operating gates and maintenance of canals, management gaps (i.e. water delivery scheduling and water fee collection rates), water scarcity, poor water management, siltation, flooding and erosion. The critical problem in the scheme is frequent water related conflicts resulting from the unregulated and incorrect allocation of irrigation water. Water user association of the scheme is too weak to manage the system in a sustainable approach. Some of these problems may be due to inadequate and defective conveyance, distribution, control and measurement structures.

Particularly in North Shewa zone, little or no attention was given for evaluation of the performance of already established irrigation schemes. Yelen small-scale irrigation project is one of the scheme in North Shewa Zone, where no research on the performance evaluation of the project was done yet. As a result, the actual performance level of the irrigation scheme in the study area was not known. Relating to irrigation activities, there are visible structural and water application defects in this study area. A few studies have explored evaluation of the irrigation scheme performance, however considering the importance, the work done in past is insignificant. Therefore, the objective of this study was to: (1) investigate the situation of existing irrigation practices at Yelen irrigation scheme, (2) evaluate the performance of water delivery of the irrigation Scheme, and (3) identify the performance gaps and suggests remedial measures of the scheme.

Materials And Methods

Research Site

The mean minimum and maximum temperature of the study area is 13.5 and 27.7°C, respectively. The monthly mean minimum temperature varied from 9.6°C in December to 16.9°C in July. The monthly mean maximum temperature varied from 24.3°C in December to 31°C in June. The rainfall distributions in the study areas showed a 'unimodal rainfall pattern and unreliable 'belg rainfall exists in the project area. The main rainy season is summer ('*Meher* or *Kiremt*'), which extends from July to Early September. Duration of *belg* rain, which is unreliable, is from March to April. The mean annual rainfall that the project area received is 712mm. The values of mean monthly rainfall, Tmax and Tmin are shown in Fig. 1. The sunshine hours duration at the project area ranges from 6.4 (August) to 9.2 (November) hours/day. The mean annual sunshine hour duration is 7.7hrs. The relative humidity (RH) at the project area also varies from 30% (June) to 57% (January) and the mean annual RH is 46%. The wind speed at project area ranges from 164km/day (August) to 192 km/day (June) which is high and likely to cause damage to the crops.

Description of Yelen community managed irrigation project

Yelen irrigation scheme is an intake irrigation project, located in Kewet Woreda in North Shewa Zone of the Amhara region. The study area is about 10km from the Woreda capital (Shewa Robit) and the Woreda capital is 95km from zone capital Debre Berhan and 795 km from the regional capital, Bahir Dar. The project lies on Addis Ababa-Dessie main road a short distance extended to the west and an estimated 7km gravel road from the asphalt road to the project. The total command area of the project is estimated to be 180ha. The study area is located at 10° 4' 51.6" N Latitude and 39° 53' 13.2" E longitude at about 1245 m.a.s.l average elevation. In traditional agro ecological classification system the project, area lays in kola agro ecologic zone.

Water for the scheme is supplied from an intake structure on the Sewer River (after spring water joins to it) which has a base flow of 60L/s, by allowing 12L/s release for downstream users and ecological services. The primary contour canal on the right side of the river course is 1.6km long. The secondary canal is 1.761km long leads water from the main canal into the command area, running down slope. Nine, tertiary canals of total length 5.516km run on contours, serve standard size irrigated plots by means of field ditches. Surface drains remove surplus irrigation water, and runoff from rainfall. The slope of the main canal ranges from 0.29-0.49% where as that of the command area ranges from 2–4%. This helps the farmers to irrigate the command area satisfactorily. The irrigation scheme has total 720 household beneficiaries. Farmers have been organized into compulsory Water Users' Associations (WUAs), which collect fees for maintenance of the canals and formulate bylaws. It was constructed in 2012 by Bureau of water Resource Development with a total investment cost of 7.1 million ETB for its life span of about 30 years.

Data and methods

This research was carried out for one irrigation season starting from October to December 2018. The choice of these months was, because, there is high availability of water and large numbers of fields are irrigated during the season than others irrigation season (February to June). The data collection was carried out with the DA on the selected small-scale irrigation project assigned by the Woreda (Kewet) Agricultural Office. For the study, all the necessary secondary data were collected from the wereda's agricultural office, and from Debre Brihan,

agricultural research center and during professional field visits. During the field visits, DAs and farmers were consulted about the general conditions of small-scale irrigation. Data collected included both primary and secondary data.

Primary data collection

Various types of primary data were collected through formal and informal survey approaches. Farm household interview and group discussions were practiced for gathering information and analysis. Measurement of plot size was also conducted. Soil samples were collected at each of the nine locations for the determination of different soil parameters and the rate of the soil infiltration test was done in the study area. Additionally, GPS data were also recorded for the purpose to set different points at the correct position on the systematic layout of the study area.

Flow measurement was taken in order to evaluate water delivery indicators. Frequent field observations (transect walk) were made to observe and investigate the method of water applications, and practices related to water management techniques made by the assigned persons and farmers. The field visits were paid plot-by-plot to observe the current water management situations in the scheme. Observations into various plots helped the researcher to know their status and identify constraints in sustaining the services of the schemes to the targeted communities.

Discharge measurement

Discharge measurement is a relevant data for evaluation of scheme performance indicators, such as determination of delivery performance indicators, which are based on required flows (Q_R) and actual water delivered (Q_D). Synthetic Propeller type Current Meter and three inches Parshall Flume was used for discharge measurement at field offtakes (Fig. 4).

Current meter was reading revolution and finish reading at 30 second. Number of propeller rotation (n) per second was calculating. The discharge was calculated using Equa.1.

$$Q = A \cdot V \quad (1)$$

Where;

Q = discharge of water in m^3/s ,

A = canal cross-section in square meter,

V = mean velocity of flow of water in m/s .

$$A = W \cdot D \quad (2)$$

Where;

A = rectangular cross-sectional area, m^2 ;

W = wetted width of section of canal, m ;

D = depth of flow of water in canal, m.

The dimensions were measured using tape meter.

Velocity was measured without affecting canal operations, using SABA universal current meter F1 with propeller 125 mm on rod 20 mm diameter. The velocity was calculated using Equations 2.3 to 2.3.3 or can read from standard table.

$$V = k \cdot n^{\frac{1}{n}} \quad (3)$$

$$V = 31.17 \cdot n^{1.93}, \text{ if } 0.00 < n < 1.98 \quad (4)$$

$$V = 32.05 \cdot n + 0.19, \text{ if } 1.98 < n < 10.27 \quad (5)$$

$$V = 33.44 \cdot n - 14.09, \text{ if } 10.27 < n < 15. \quad (6)$$

Where;

k and $\frac{1}{n}$ represent the coefficient of the propeller type, constant values equal to 31.17, 1.93, 32.05, 0.19, 33.44, and -14.09 ,

n = number of propeller rotation per second, and

V = the flow velocity of the water (cm/sec).

The flow velocity was measured with current meter at a depth of (0.6*d) from the water surfaces at each vertical section; where 'd' is the depth of the respective canal section, because measured depth of water from each canal section was below 60cm. For each farm fields taking reading up to the end of irrigation times at every 30 minute intervals. Then after for analysis taking the average value of readings. To determine amount of water applied to the field, the average water depth in the flume and respective irrigation time was recorded. The values of discharge of the water applied were determined from standard Tables for corresponding depths of a specific size of Parshall flume. Eqa.7 (Merkley 2006; Gertrudys 2006; Bos, 1989; Worku et al. 2018) may express the depth-flow relationship free flow condition.

$$Q = k h_1^n \quad (7)$$

where: Q = the flow rate in m³/s,

h₁ = upstream flow depth in the converging inlet section, in m,

k = the free flow coefficient, and n = the free flow exponent,

[IMAGE-C:\Workspace\ACDC\ImageHandler\3cThe values of k and n are functions of the dimension of the constriction and measurement unit chosen. The value of the constant of k and n for three-inch Parshall flumes and for metric unit were 0.1771 and 1.55, respectively. The minimum and maximum discharge and head range of three-inch Parshall flume were 0.77 l/s and 32 l/s and 0.03 meter and 0.33 meter, respectively (Gertrudys 2006).

Household's survey and group discussion

A questionnaire survey from water user is a useful tool to collect primary data needed for performance assessment. In community-managed schemes, relevant data such as land holding, cropping pattern and intensity, degree of satisfaction with irrigation service, crop characteristics; i.e., planting date and length of growing period, etc., are hardly available from primary sources through questioner.

Issues regarding the perception of the farmers about the water management of irrigation schemes in study area, related to WUA Organization, users problems and experiences, and the overall situations at the scheme were collected through questionnaire, and group discussions. A household survey in the irrigation scheme was conducted using a structured questionnaire regarding the water management of irrigation schemes in the community. For the farm household survey, 21 households were randomly selected from the head, middle and tail reaches for interview. From the respondents, males account 17 and females' 4. Generally 26 questions were prepared, and 18 respondents were interviewed. In the irrigation scheme, group discussions with organized groups were the main sources of information on the water management of SSI projects. Group discussions were held with WUA committees (nine), development agents and Kebele administrators. For group discussion purpose, generally 12 types of questions were prepared. The discussion was carried out for half a day (6 hrs.).

Data from secondary sources kept by the responsible bodies or officials on the irrigation project, Woreda Agricultural Offices, design document, Irrigation Offices at Zonal, National Meteorological Services Agency and research Centers were collected as much as possible. For Yelen community managed irrigation scheme, the longtime average climatic data of mean monthly minimum and maximum temperature, rainfall, relative humidity, wind speed and sunshine hours were collected from Shewarobit meteorological station. Additional secondary data include cropping pattern, command area, Crop coefficient, the maximum rooting depth, area irrigated; crop characteristics; i.e., planting date and length of growing period (LGP), date of irrigation and irrigation application method were obtained from responsible bodies or officials.

Data Analysis Techniques

Hydraulic performance evaluation

The success of an irrigation water delivery system can be measured by how well it meets the requirement of users served by it. In this study water, delivery performance was evaluated based on farmers and system manager's point of view. From the farmer's point of view, the system is effective only when the water supply is adequate and dependent. Whereas the manager achieves satisfaction when the system is able to conserve water (efficiency) and distribute the water in an equitable manner. A measure of deficiency at various points will help the manager to govern the system more effectively.

Nine measurement points were selected at different field offtakes on delivery systems for the study; each three at the head, middle and tail end of the irrigation system. Flow measurements were made on daily basis from which average monthly flows were determined. Based on the settled water delivery plan, the measurements of actual discharges in each field offtakes were taken on an average of 3 days per field offtake per month totally almost 27 days per month. At each measuring points (field offtakes) the amount of irrigation water diverted to

the fields was estimated in mm depth (Q_D), by multiplying the measured flow rate by the duration of irrigation and dividing it by the field area (Korkmaz and Avci 2012). Flow was measured by the use of Parshall flume. Each measuring point serves a different command area. A set of field measurements was taken for a period of three months in one irrigation season. The water requirement for each site was obtained by multiplying the crop water requirement for each crop with the area of the sites. Adequacy indicator (P_A) (delivery performance ratio), equity indicator (P_E), deficiency (P_{DF}), efficiency (P_F) and Reliability indicator (P_R) were the main indicators of hydraulic performance used in this study. The indicators were determined for each offtake as well as for a group of head, middle and tail offtakes. The purpose of these indicators was to evaluate whether the system delivers water at the required rate at the right place and time and to assess whether the water delivery service is healthy or not (Dejen et al. 2015).

It is always equitable for the manager to see that he is giving a fair share of water to users throughout the system, (Mattamana et al. 2013). Equity expresses the degree of variability in relative water delivery from point to point over the irrigated area (Korkmaz and Avci 2012). A measure of equity would be the average relative spatial variation of the ratio of the amount delivered (Q_D) to the amount required (Q_R) over the period of interest. Eqa. 8 gives it.

$$P_E = \frac{1}{T} \sum_T CV_R \left(\frac{Q_D}{Q_R} \right) \quad (8)$$

Where, CV_R spatial coefficient of variation of the ratio $\frac{Q_D}{Q_R}$ over the region R, T is number of month. The closer the value of P_E is to zero, the greater the degree of equity in delivery. Performance was said to be good when the value of P_E is between 0.00 and 0.10, fair when it is between 0.11 and 0.25, and poor when it is more than 0.25.

In any type of irrigation systems, it is useful to have the concept of efficiency to enable comparison of different management strategies for a particular system, since efficiency shows to foresee how the water resource would be conserved. Resource conservation plays an important role in water delivery. System managers should always be thoughtful that the water delivered should not be greater than the requirement. If the system is supplying more than the requirement, it indicates the non-conservation of the resources. A measure of this would be the spatial and temporal average of the ratio of Q_R to Q_D . Efficiency embodies the ability to conserve water by matching irrigation application with crop water requirements as given by Eqa. 9.

$$P_F = \frac{1}{T} \sum_T \left(\frac{1}{R} \sum_R P_F \right) \quad (9)$$

Where; $P_F = \frac{Q_R}{Q_D}$ (If $Q_R \leq Q_D$)

Otherwise, $P_F = 1$

R is number of offtakes. If p_F is equal to or close to 1.00, this means that water in the system is being used efficiently, but if the value is less than 0.70, it means that water in the system is not being used efficiently.

Performance is said to be good when the value of P_F is between 0.85 and 1.00, fair if it is between 0.70 and 0.84, and poor if it is below 0.70.

The primary interest of the farmer is to get adequate water for irrigation. The amount of water required depends upon type of crop, cropped area, period of cropping, application losses, and cultural practices, such as land preparation and salt leaching. Adequacy is a measure of the delivery of the required amount of water for optimal plant growth. For a single offtake, it is the ratio of delivered (Q_D) to required (Q_R) delivery in terms of flow rate or volume. Adequacy can, however, also be determined for an irrigation system as a whole or for subsystems, (Dejen et al., 2015). In this case, it is aggregated for a service area R averaged over a period of consideration T . For a region and for a period T , Eqa.10 can measure the adequacy attained by a system.

$$P_A = \frac{1}{T} \sum_T \frac{1}{R} \sum_R \left(\frac{Q_D}{Q_R} \right) \quad (10)$$

If $Q_D \leq Q_R$,

Otherwise, $P_A = 1$, in another expression when the amount delivered Q_D exceeded the amount required Q_R , the amount delivered is accepted as adequate without considering the amount of the excess, and the ratio Q_D/Q_R is taken as 1.00.

A value of 1.00 or close to 1.00 for P_A shows adequacy of water delivery, while a value less than 0.80 for P_A shows inadequacy of water delivery. Performance is evaluated as good when P_A values are between 0.90 and 1.00, fair when between 0.80 and 0.89, and poor when below 0.80. P_A is the spatial and temporal average of the ratio of amount delivered to amount required.

The second concern of the farmer is the dependability. The farmer should not only get the required amount, but also should get it in time, (Mattamana et al. 2013). If water is not available at the right time, it may lead to total crop failure. Reliability is defined as temporal uniformity of the ratio of the delivered amount of water to be required or scheduled. A system that dependably delivers an inadequate amount of water may be more desirable than one that delivers on the average an adequate yet unpredictable supply, (Mattamana et al., 2013). A farmer can plan for a dependable delivery of an inadequate supply of water by planting or growing different crops or adjusting other farming inputs. Reliability of water delivery can be taken as the temporal variability of the ratio of the amount of water required that occurs over a region. Eqa.11 measures this.

$$P_R = \frac{1}{R} \sum_R CV_T \left(\frac{Q_D}{Q_R} \right) \quad (11)$$

Where; $CV_T \frac{Q_D}{Q_R}$ = temporal coefficient of variation of the ratio $\frac{Q_D}{Q_R}$ over the period T .

The water delivery is uniform over the given time period and thus is more dependable when the value of P_R approaches zero. Performance is said to be good when the value of P_R is between 0.00 and 0.10, fair when it

is between 0.11 and 0.20, and poor when it is above 0.20. If water does not arrive at farms in an adequate and timely amount, crop yields may suffer and farm net returns may decrease. The degree of the deficiency is another parameter that the farmer is more concerned, so that he can take precaution measures to meet it. Knowledge of the amount of deficiency is a quantitative measure of the un-satisfaction of the farmer. Assessment of deficiency is given as the ratio of water deficiency to the required amount. A measure of deficiency is considered as the temporal and spatial average of the ratio of ($Q_R - Q_D$) to Q_R (Binoy et al. 2012) as expressed by Eqa.12.

$$P_{DF} = \frac{1}{T} \sum T \left(\frac{1}{R} \sum R \frac{Q_R - Q_D}{Q_R} \right) \quad (12)$$

$$P_{DF} = \frac{Q_R - Q_D}{Q_R}, \text{ (if } Q_R > Q_D \text{)}$$

Otherwise, $P_{DF} = 0$

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

Method Of Analysis

The materials used in the present work are, auger, core samplers, shovels, stop watch, measuring tapes, pegs or dyes, Oven dry, plastic bags, weight balance, current meter, Parshall flume, markers, short note, double ring infiltrometer apparatus, hammer, float, stainless steel hammering cross, steel rings, sacks, CROPWAT version 8.0, Arc GIS10.7, Microsoft spreadsheets, Microsoft excels optimizer, Questionnaires, SPSS, and Garmin GPS etc.

Results And Discussion

Status of Irrigation Scheme and Irrigation Practices

Yelen community managed Irrigation scheme was constructed in 2012 and given a service for 7 years operational periods only. The design command area of Yelen community managed Irrigation scheme was 180ha, however, currently only 121.45ha was irrigated in the irrigation season. Around 720 households are involved in the scheme as beneficiaries with a land holding size varying from 0.13 ha to 0.5ha. The command area was categorized into nine water user groups (association) for operation and management purpose. Irrigation management was carried out in rotation among the nine groups in which the farmers are free to irrigate until they have received enough water. The distribution can be allocated day and night rotation or for specific periods (day's interval). From field observation and the results of the questionnaire, due to the unwise use of water by the head end users, the tail end users were facing water shortages frequently. Irrigation water management is a sole responsibility of the water users themselves in Yelen community managed Irrigation Scheme. Farmers are responsible for water diversion, distribution and scheduling at field levels.

Farmers practice different irrigation methods. Flooding type of irrigation method is widely practiced for the main crops, while at the initial stage of the growing period, farmers have tried to practice furrow irrigation

method. At initial stages of growing period, some farmers (onion and cabbage producers) are using short furrows having an average length of 8 meters with 0.45-meter furrow spacing. Spade is the equipment to open and close furrows while they are irrigating their crops. Regarding scheduling, all the nine groups get water turn by turn and the method of water distribution was a rotational type. There was an irregular irrigation interval in the scheme, which varied from 10 to 14 days depending on their rounds. The irrigation interval in the initial period of the crops commonly grown in the area is about 4-5 days; which increases from 10 to 14 days at the end of the growing season due to availability of water. Some farmers irrigate according to the schedule, but other farmers negotiate with other groups to use more or earlier irrigation water. If such farmers are granted water, then they usually have to wait until all the group members with the right to finish irrigation, after which they can irrigate their own field.

The main canal has a rectangular cross-section. The discharge of the main canal varies from time to time, along with the parent source. The maximum discharge capacity of the main canal of the Lemchek-Sewur irrigation project is 226 liter per second. Despite some breaching of canals by illegal users, hydraulically the structure was under good condition. Secondary canal leads water from the main canal into the command area with the maximum discharge capacity 187 liter per second. Hydraulically the structure was under good condition, but it was covered by weed, sand and soils and some parts were cracked (Fig. 3). Nine tertiary canals were almost all affected by sediment deposits.

The irrigation scheme has no water flow control gates at division boxes or turnouts; as an alternative farmer use local control materials (stone, soil, leaves, etc.) (Fig. 4). The crops that are grown in the study area are planted both in the rainy and dry seasons. During the rainy season, even if the rain is sufficient for the crop, irrigation water is supplemented when vegetable crops are transplanted. The farmers, including their family do all the farming practices themselves. However, during peak times like harvesting, farmers are forced to hire additional labor on daily wage basis. In the irrigation project, there is no rule or restriction on the farmers what type of crop to produce. The farmers have the right to choose the type of crop to grow as far as the crop is profitable and the water available is adequate to produce the selected crop.

Furthermore, the Yelen irrigation project is facing huge salinity problems, which are natural, and has close relationship with misuse of irrigation water, which is an aggravating salinity effect. Similarly, drainage structures are not in proper order. They are not functional and there is no drainage water flow out of the field. This in turn causes the accumulation of salty water on the soil surface resulting in a wide salinity challenge for the irrigation project. The main production constraint experienced by the farmers is the lack of availability of water and salinity problems. Some farmers develop hand-dug wells during water scarcity period. Consequently, farmers are forced to limit cultivated area of land under irrigation. Large portions of the area located at the tail end are left unproductive during the crop season, while the land near the head end are all irrigated during the entire crop seasons.

Nowadays the major management tasks of the water user association committee are; allocate water and controls water distribution, ensure the safety of the scheme through organizing operation and maintenance works, and mobilizing resources for these works and resolve disputes related to water and maintenance based on their bylaws. In the context of SSI schemes frameworks; Yelen's irrigation scheme WUAs were established after construction completed, during the first year of the implementation period of 2013. The association was

initially formed in cooperative forms as a multi-functional local institution with three main objectives, which were operation and maintenance of the scheme, input and credit supply and marketing of outputs, but not functional yet. Presently, the association is only trying to practice the water allocation issues with minimum achievements. The study area has no well-written and defined bylaws. Offenders who are found guilty of turn abuses, breaching canals, power abuse to use water out of their turn and failure to respect the decisions of the WUA committee members have not been fully charged. In the scheme, WUA committee was not collecting the water use fee using legal receipts; the system seems highly corrupted.

Conflicts

on irrigation water occur in many stages; among users in the irrigation system, between users and WUAs, and between downstream and upstream users. However, at the irrigation scheme conflicts between upstream users and downstream users at different system levels was not as such a main problem. Concerning conflicts among users in the irrigation system, 61.1% of the respondents were faced the problem in this scheme (Table 1). Additionally, the conflicts also extended with WUAs committees; because the WUA committee members were biased to their relatives, selfishness and use their power in illegal ways. The main factors for conflicts in the study area were water theft, competition due to increasing number of water users and water scarcity. In addition, district level irrigation experts and DAs did not provide consistent support to WUAs committees in conflict management. As it is known, the task of water and conflict management systems has become more complex and cannot be controlled by the WUA committee alone.

Table 1
Beneficiaries response on conflict over irrigation water.

	Frequency	Percent,%
Yes	11	61.1
No	7	38.9
Total	18	100

Evaluation of Water Delivery (Hydraulic) Performance

The water delivery performance of the system was evaluated based on the monitored water flows at each of the nine-selected offtake. The monthly average actual water delivered at each offtake, was measured for a period of the three months (October, November, and December). The measurements of water delivered at each offtake were made on an average for 3 days per offtake per month by using three-inch Parshall flume. Water requirement for each site was obtained by multiplying the crop water requirement for each crop with the area of sites. The monthly values of water delivered (Q_D) and water requirement (QR) for irrigation were taken as basic variables; the number of irrigations in one season (T) was taken as the period; and the number of fields (R) were taken as the sub-region. From the computed performance indicator values, performance was classified as “good”, “fair” or “poor” according to the performance standards, (Molden and Gates 1990).

Estimated Water Required And Water Delivered

The different hydraulic performance indicators were estimated for each field off take and reach (head, middle, and tail) for three months, in one irrigation season. Water delivered at each of the selected nine delivery points and water required for each crops per month for a period of three months was estimated. The estimated values for each selected field offtakes for three months are given in Table 2.

Table 2
Values QD and QR for Each Month at Selected Field offtakes (mm).

Offtake code	Crop type	Area of field, ha	October		November		December	
			QD	QR	QD	QR	QD	QR
OH1	Onion	0.49	37.7	31.5	45.1	41.8	38	49.9
OH2	cabbage	0.4	31.9	24.7	39.8	31.8	25	38
OH3	maize	0.5	24.8	9.1	42.9	50.2	31	64.2
OM1	pepper	0.4	27.2	20.3	37.4	29.6	35	40.6
OM2	onion	0.4	29.9	27.2	33.6	36	29	43
OM3	onion	0.42	27.2	29.8	43.6	39.5	31	47.1
OT1	maize	0.5	8	8.5	39.1	47	35	60.2
OT2	onion	0.4	19.2	28.1	32	37.3	40	44.5
OT3	cabbage	0.48	21.6	28	20.6	36	22	43
OH=offtake at head users, OM=offtake at middle users and OT=offtake at tail users								

Water Delivery (Hydraulic) Performance Indicators

Water delivery performance levels were evaluated on spatial and temporal scales. The spatial indicators are meant for the water delivery performance over a region R; while the temporal indicators are for the water delivery performance in time T.

Adequacy

The adequacy indicator was estimated for each of the nine selected field offtakes and reach wise (head, middle, tail) for three months. The estimated values of adequacy for each of the nine locations and each of the three months along with the temporal and spatial mean values using Equa.10 are given in Table 3. The estimated values varied from 0.48 to 1.0. The temporal average value of adequacy varied from 0.68 for location OT₁ to 0.92 for location OH₁. Similarly, the spatial average value of adequacy during different months varied from 0.67 in December to 0.92 in October. The overall adequacy of the system was found to be 84%. The result indicates that the scheme was found under satisfactory condition. The temporal mean values of adequacy at different locations are shown in Fig. 4. The adequacy was good at site OH₁ (0.92) and OM₁ (0.95), poor for site OT₁ (0.78), OT₃ (0.68) and OH₃ (0.78), and fair for the others sites.

Spatial adequacy performance indicators are spatially averaged values of the indicators of water delivery performance of all field offtakes for different months. The average values of spatial adequacy for different

months are shown in Fig. 5. The spatial adequacy was good in October (0.92), fair in November (0.89), and was poor in December (0.67). The spatial adequacy levels were relatively inferior ranging from 'poor' to good' over the months. Generally, the major common problems of the system were incorrect water delivery scheduling, weak management of the committee to operate the system according to the delivery schedules, and sedimentation of canals.

Table 3
Temporal and Spatial Mean values of Adequacy.

	Head			Middle			Tail			
	OH ₁	OH ₂	OH ₃	OM ₁	OM ₂	OM ₃	OT ₁	OT ₂	OT ₃	Spa.Av.P _A
Month										
Oct	1.00	1.00	1.00	1.00	1.00	0.91	0.94	0.68	0.77	0.92
Nov	1.00	1	0.85	1.00	0.93	1	0.83	0.86	0.57	0.89
Dec	0.76	0.65	0.48	0.85	0.68	0.66	0.57	0.91	0.50	0.67
Temp.Av.PA	0.92	0.88	0.78	0.95	0.87	0.86	0.78	0.82	0.68	0.84

Reliability

Reliability is a term used for the capacity of a water delivery system to meet prior expectations. Reliability actually encompasses two elements: reliability of the delivery amount and reliability of the timing. The reliability indicator answer the question outlined: does the timing of the water deliveries match the water needs of the crops and the expectations of the users? (Molden and Gates 1990). The estimated values of reliability for each location during different months along with temporal average for different locations using Eqa.11 are given in Table 4. The mean value for different locations during different months varied from 0.62 to 0.95. The temporal average coefficient of variation of reliability varied from 0.13 for location OM₂ to 0.44 for location OH₃. The overall reliability of the system was found to be 0.26. The results indicate that the scheme was found under worst condition. Temporal average of coefficient of variation is shown in Fig. 7. Dependability of water delivery at the head, middle and tail field offtakes significantly varied from one offtake to the other. Particularly, dependability was very poor at five field offtakes in the head, middle and tail reaches, and fair at others field offtakes. Generally, the dependability was unsatisfactory at all field offtakes, which means that farmers were not able to obtain water for irrigation when they needed it for irrigation of crops. Moreover, the water delivery was not uniform over the given time period due to unauthorized abstraction of water by upstream users and theft of water by others or additional users and lack of water from source of water. The performance of the entire system in terms of dependability of water distribution was found in the unsatisfactory range; it performed poor over the season.

Table 4
Dependability& Equity.

	Head			Middle			Tail					
	OH ₁	OH ₂	OH ₃	OM ₁	OM ₂	OM ₃	OT ₁	OT ₂	OT ₃			
Month										mean	Std.d	CVR,P _E
Oct	1.00	1.00	1.00	1.00	1.10	0.91	0.94	0.68	0.77	0.93	0.36	0.39
Nov	1.00	1.00	0.85	1.00	0.93	1.00	0.83	0.86	0.57	0.89	0.38	0.43
Dec	0.76	0.65	0.48	0.85	0.68	0.66	0.57	0.91	0.50	0.67	0.41	0.60
mean	0.92	0.88	0.78	0.95	0.90	0.86	0.78	0.82	0.62			0.47
Std.dev	0.19	0.27	0.35	0.20	0.11	0.27	0.24	0.14	0.16			
CVT,PR	0.20	0.31	0.44	0.21	0.13	0.31	0.31	0.17	0.26	0.26		

Equity

Equitable water distribution is attained when the ratio of water delivery to water required in the outlets equal to one over the system (Molden and Gates 1990). It indicates the spatial distribution of a water delivery. The coefficient of variation (CV) of the ratio of delivered (Q_D) to required (Q_R) over an area R and time T as proposed by (Molden and Gates 1990) was used for the measure of equity in the system. The calculated values of spatial average coefficient of variation (CVR) using Eqa. 8 are given in Table 4. The mean value for different locations during different months varied from 0.67 to 0.93. The spatial average coefficient of variation of equity varied from 0.39 in October to 0.66 in December with the overall equity of the system to be 0.47. The result indicates that the scheme was found under worst condition. The variation of the values of the coefficient of variation for different months is shown in Fig. 8. The equity level in the system was 'poor' during all months, but it was worst in December. It is evident that there is significant problem about equity of water allocation from one month to the other month due to poor water user association. Some of the factors, which cause for uneven distribution of water along the scheme were unlawful water abstractions, water losses along canal network, limited water availability, and poor management of the scheme of WUAs and fixed irrigation scheduling.

Efficient

Efficient irrigation practice is very relevant topic at present, and there is much effort going into improving the performance of irrigation system; which is an important agronomic indicator for areas with limited water resources (Deng et al. 2006). The parameter shows how the water resource would be conserved (Mohsen et al. 2012) and knowing how the system conveyed the required amount water. The calculated values of the efficiency at different locations during different months using eqa. 9 are given in Table 5. The variation of temporal average and special average values of the efficiency are shown in Figs. 9 and 10, respectively. The calculated values of the efficiency varied from 0.37 to 1.0. The temporal average value for different offtakes varied from 0.79 to 1.0, showing satisfactory water delivery at all field offtakes. The overall efficiency of the

system was found to be 0.93. Thus, the overall performance of the scheme was good. The level of performance generally ranged from 'fair' to 'good'. The values were higher at tail end as compared to head reach. This indicates tail end user to be more efficient as compared to head end user with respect to water availability in the scheme. The water requirement at tail end was more than the water delivered. The spatial average values of efficiency varied from 0.85 in October to 1.0 in December. Thus, December was more efficient than October with respect to water availability in the scheme.

Table 5
Temporal and Spatial Mean Values of Efficiency.

	Head			Middle			Tail			
	OH ₁	OH ₂	OH ₃	OM ₁	OM ₂	OM ₃	OT ₁	OT ₂	OT ₃	
Month										Spat.Av
Oct	0.84	0.77	0.37	0.75	0.91	1	1	1	1	0.85
Nov	0.93	0.80	1	0.79	1	0.91	1	1	1	0.94
Dec	1	1	1	1	1	1	1	1	1	1
Temp. Av.	0.92	0.86	0.79	0.85	0.97	0.97	1	1	1	0.93

Deficiency

Delivery of less water than adequate requirement of water to the delivery points within the system results in shortage of water. The parameter will help the system managers and users to take corrective measurements for system improvements in the deficit water supply area. The calculated values of deficiency using eqa.12 are given in Table 6. The variation of average temporal and special values is shown in Figs. 11 and 12. The calculated value of the deficiency varied from zero to 0.52. The temporal average deficiency for different offtake varied from 0.08 to 0.38 with higher values for tail ender as compared to head reaches, indicating that water shortage for tail end user. The average values of special deficiency during different months varied from 0.08 in October to 0.33 in December. This shows higher deficiency level in the scheme during December. Moreover, the overall average value of the system was found to be 17%. The result indicates that the scheme was under good condition except tail end water users. The overall performance of the system was unsatisfactory at tail end users and at December month. The reason was water scarcity and canal water losses.

Table 6
Temporal and Spatial Mean Values of Deficiency.

	Head			Middle			Tail			
	OH ₁	OH ₂	OH ₃	OM ₁	OM ₂	OM ₃	OT ₁	OT ₂	OT ₃	
Month										Spatial Av.
Oct	0.00	0.00	0.00	0.00	0.00	0.087	0.059	0.317	0.229	0.08
Nov	0.00	0.00	0.145	0.00	0.067	0.00	0.168	0.142	0.428	0.11
Dec	0.244	0.347	0.520	0.145	0.323	0.338	0.427	0.092	0.495	0.326
Tep.Av	0.08	0.12	0.22	0.05	0.13	0.142	0.218	0.184	0.384	0.17

Reach-averaged performance indicators

In addition to spatial and temporal indicators of water delivery, reach-aggregated indicators enable better understanding of water delivery performance. Average indicators of adequacy, efficiency, and deficiency in each reach are given in Figs. 14, 15 and 6 respectively. The average value of adequacy during different months on different reaches varied from 0.63 to 1.00. Adequacy was larger during October and November at head and middle reach. The lowest values were at tail end and during December. The adequacy during October was rated 'good' at head a middle reach and 'fair' at tail reach. During October, all farmers received adequate water for irrigation throughout all filed offtakes. The adequacy during November was 'good' at head and middle reach and 'poor' at tail reach, while during December, adequacy was 'poor' for all reach, because at this month the water availability was low due to increased water users and lack of water supply from the source.

The average value of efficiency during different months on different reaches varied from 0.66 to 1.00. The efficiency during October was good in middle and tail reach, and poor in head reach. The water requirement at head reach was lower than the water delivered, so that there is loss of water at head reach. However, during November and December the efficiency was good at each reach indicating that the water delivered was not greater than the requirement due to lack of water supply from the source. The average value of deficiency during different months on different reaches varied from 0.00 to 0.37. The deficiency during October and November was low in head and middle reach and high in tail reach. However, the deficiency during December was high at all reaches. In general, shortage of water was high at tail reach and during December.

Conclusions

The conclusions of the performance evaluation of Yelen community managed irrigation scheme located in Kewet Woreda in North Shewa Zone of the Amhara region using water delivery performance indicators may be listed as below.

- i) Beneficiary participation in the irrigation scheme was very low in canal clearing and regular maintenance. Weeds and soils covered the majority of tertiary canals. The reason being that the WUA's organizational,

function and legal enforcement of bylaws was weak. This also attributed to illegal water abstractions and unfair water distributions in the irrigation scheme. In the scheme, there were gaps in fee collection mechanisms. In addition, the collected money was not used for annual maintenance work. Thus, this situation hindered the motivation of farmers in participation and maintenance work.

ii) The dependability of water delivery was found to be poor. There was no significant problem with adequacy of water distribution at the field level for the prevalent cropping system. Water was not delivered to the fields at the targeted level of equity. However, the efficiency of the system was good, but the irrigation water management at the head reach was poor. In addition, deficiency of the system was found to be good except at tail end water users.

iii) The major reasons for poor performance of irrigation system were:

- (a) Malfunctioning of flow control and distribution structures,
- (b) Lack of proper maintenance of irrigation infrastructures,
- (c) Canals sedimentation,
- (d) Improper water delivery system,
- (e) Shortage of water,
- (g) Unfavorable irrigation scheduling,
- (h) Technical and financial problems associated with the beneficiaries,
- (i) Inadequate planning of maintenance works,
- (j) Lack of community participation and weak system administration,
- (k) Design failure of water distribution structures and over abstraction of water by upstream users in the irrigation scheme.

iv) In general, the performance of irrigation system was poor. The result of this study maybe used to identify performance gaps and take measurements for better improvement and sustainability of the irrigation scheme.

Declarations

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Authors' contributions

In the acquisition of the data, data collection, data coding and entry, data analysis, interpretation of the result, and writing has been substantially contributed by AS, TW have been involved in critically reviewing, revising the manuscript and made possible suggestion. All authors read and approved the final manuscript.

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The authors have no conflicts of interest to declare.

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Figures

Figure 1

Mean Maximum and Minimum Temperature and Rainfall.

Figure 2

Discharge Measurement Using Current Meter and Parshall Flumes.

Figure 3

Onion and maize fields using flooding irrigation method.

Figure 4

Canals covered by weed and mud.

Figure 5

Flow control using local materials.

Figure 6

Average Temporal Point Adequacy, P_A .

Figure 7

Spatial Average of P_A over Months.

Figure 8

Average temporal point of CVT

Figure 9

Estimated Average Values of CVR over Month.

Figure 10

Figure 11

Spatial Average of P_F over Months.

Figure 12

Average Temporal point Deficiency, P_{DF} .

Figure 13

Spatial Average of P_{DF} over Months.

Figure 14
Average Reach Wise Adequacy Indicator, P_A

Figure 15
Average Reach Wise Efficiency Indicator, P_F

Figure 16

Average Reach Wise Deficiency Indicator, P_{DF} .