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Article

PERFORMANCE EVALUATION OF SMALL-SCALE IRRIGATION SCHEME: CASE STUDY OF SELAMKO IRRIGATION SCHEME, UPPER BILUE NILE - ETHIOPIA

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Abstract: The study was conducted to evaluate the performance of Selamko small scale irrigation scheme using internal and external performance indicators. The irrigation scheme command area was 63 ha and during the study season the irrigated area was 42ha. Over all activities in primary data collected included: field observation, discharge measurements in the canals, soil moisture before irrigation and after irrigation and depth of water applied at the field and interviewing beneficiary farmers. Secondary data were collected from secondary sources that were South Gondar Small Scale Irrigation coordination office, SGBoWR and WUA of the scheme. In order to evaluate the irrigation water, use efficiency of the scheme, nine farmer fields were selected from the scheme in relation to their location: at the head, middle and tail end water users. The internal process indicators which include conveyance efficiency and application efficiency were used to evaluate the performances of the scheme. From the analyses of internal performance indicators, the conveyance efficiencies were found to be 56.9% at the main canal, 57.09 at secondary canal 1 and 54.55% at secondary canal 2. The canals supply less water than the demand of the delivery points. And the application efficiencies were estimated to be 56.994%. The overall efficiency was 35.268%. The output per command area has to be calculated as 60198.14Birr/ha and 89738.1Birr/ha at 2016/17 and 2015/16 irrigation season respectively. The output per cropped area were estimated as 90297.62 Birr/ha and 99621.1 Birr/ha at 2016/17 and 2015/16 irrigation season respectively. The output per water consumed has to be determined as 17.66 Birr/m3 and 20.14 Birr/m3 at 2016/17 and 2015/16 irrigation season respectively. The water supply and irrigation supply were found as 1.71 and 1.47 respectively. From the analysis of physical performance of the scheme, during the study period, the irrigation ratio of the scheme was 66.67% and the sustainability of the scheme is 62.69% but in 2015/16 irrigation season, the irrigation ratio was 84.7% and sustainability of the scheme was 90.08%. During the study period the total effectivity of scheme infrastructure was 20.69%. It displayed that high system maintenance is required. Generally, the performance of the irrigation scheme is poor. Therefore, scheme monitoring, capacity building of the users and the water user associations, providing the flow control measurement structures, adequate operation and maintenance of the system are required to improve the irrigation scheme performance.

Key words: Selamko, scheme, indicators, performance.

1. Introduction

Performance evaluation is a practical tool to assess the successes of irrigation management at the scheme to meet growing challenges; increasing demand for irrigation to meet the growing food demands of the population: the competition for water allocation from high priority non-agricultural sectors and technical infeasibility (Bos et al., 2005). It is necessary to retrofit new techniques and approaches to existing management practices to improve the performance of the scheme. In recognition to both the promise and hazards associated with irrigation, evaluating irrigation performance has now become of paramount importance not only to point out where the problem exists but also helps to identify alternatives that may be both effective and feasible in improving system performance (Kedir et al., 2007)

Performance of conveyance structure system of irrigation scheme is used to the productivity of irrigation development. But Performance evaluation of irrigation projects is not crucial things in the country and Lack of knowledge and access used to assess the performance of projects adds to the problem (Behailu et al., 2005). Inadequate scheme can bring productivity problem to the beneficiaries. Therefore, the performance of the irrigation scheme must be evaluated.

Performance of most irrigation schemes is significantly below their potential. A large part of low performance may be due to inadequate water management at system and field level (Cakmak et al., 2004). This includes low-cost recovery and low water use efficiencies induced by area-based water allocation and poor water delivery performance. Not only efficiency, but also the sustainability of the irrigation schemes is in question.

There are no significant studies regarding performance evaluation of small-scale irrigation schemes in the region. Selamko small-scale scheme is operated and managed by the water users themselves with little involvement of government agencies in some cases. Even though this irrigation scheme is a functional scheme but the performance was not evaluated. Thus, evaluation of the performance of this irrigation scheme is very crucial to identify the factors that promote and inhibit the performance which can be assessed against key indicators.

Selamko small scale irrigation scheme is gravity fed and involves small earth dam. Most of the scheme conveyances are fortified by the community with water control and measurement structures. Field irrigation methods are unleveled basins and short furrows in this irrigation scheme. There is no significant rule and regulations between the water user association of the head user and tail user with respect to water control, water use efficiency, irrigation time, operation and maintenance of the scheme. In this scheme, the conveyance system of operation and maintenance performance is highly dependent the commitment of the community.

Therefore, this thesis is aimed to investigate and evaluate the performances of irrigation system in Selamko small scale irrigation scheme. The evaluation of the performance of this small-scale irrigation system will be carrying out clearly identify the main cause of the performance evaluation and other related problems and to forward the output of the evaluation.

2. Study Area

Selamko micro-earth dam irrigation scheme is located in Farta woreda, South Gondar Administrative Zone of the Amhara National Regional State. The scheme is located 5km from the North-East side of Debretabor city. The watershed of this area is part of the Abay Basin and more particularly part of Lake Tana sub-basin or sub watershed of Ribb which is situated on the South Eastern side of Lake Tana. The project including the watershed is located from 11050′53 " N and 11o53′37 " N latitude and 38000'34" E and 38002'35" E longitude with an elevation of 2501m.a.s.l.

Selamko micro-earth dam project constructed by Commission for Sustainable Agriculture and Environmental Rehabilitation in Amhara Region (Co- SAERAR) from 2003-2005 and being to harvest water in this year.

Selamko small scale irrigation was implemented to irrigate 63 ha of land but now it irrigates only 42 ha of land during the study period. The irrigable area of the scheme is 67ha. The project was expected to fulfill the food self-sufficiency of the local community by using irrigation.

The reservoir harvests water from catchment area and Selamko stream, which is Perennial River. The dam has 21 m height at elevation range from 2479 m to 2500 masl including free board. The Spillway is reinforced concrete and has masonry chute type spillway with a bridge and two supporting piers located in the upper right flank designed to discharge maximum of 13 m3/s with a nominal crest length of 15 m and crest level of 2498 m amsl but the length of spillway at the bridge is16 m.

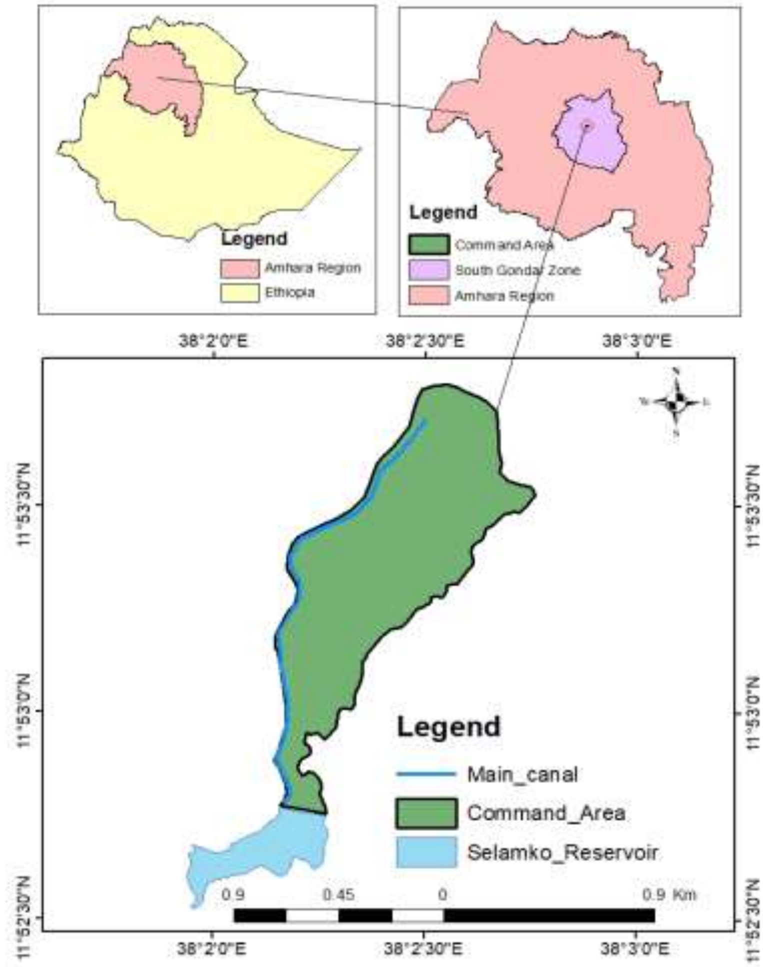

Figure 1. Map of the study area (Selamko irrigation scheme).

3. Materials and Methods

3.1 Field data acquisition

The study was conducted during the dry season and while crops were being cultivated, from late November 2016 to late April 2017. During the study period, daily visits and observations were made at study site.

The flow rates of water released for irrigation were recorded for the season at different points along the main canal, secondary canal and field canals. The individual discharge measurements were recorded in one-minute intervals by current meter (SEBA hydrometer F1) at main canal and secondary canals. Using parshall flume the field canal discharges were recorded.

Soil samples were collected from the study site and soil moisture was monitored at Bahir Dar institute of technology soil mechanics laboratory. Measurements were taken in clusters of three in each of three areas, the head, the middle, and tail of main canal (Figure 2a). These measurements were performed twice, directly before and after irrigation. Plots for measurements were chosen at random within each section, and measurement points within the plots were selected to be surrounded by onion plants.

Socioeconomic data were also collected during the study period and 2015/16 irrigation season. A survey, with the assistance of an enumerator, was conducted during the harvest period at the site. All farmers and WUAs participated in the survey. When the farmer harvested and the survey had been completed, an area measurement of the corresponding plot was also performed.

3.2 Performance Evaluation

Evaluation of the performance of Selamko irrigation scheme with regard to performance indicator was an important aspect of the methodology. The internal performance indicators computed were conveyance efficiency, application efficiency, and overall scheme efficiency. For this purpose, a total of nine farmers' fields were selected from the scheme, i.e., three from the Head (H1, H2, and H3), three from the middle (M1, M2, and M3) and three from the tail (T1, T2 and T3) end water users of the scheme. The external performance indicators computed were agricultural irrigation performance (output per command area, output per cropped area and output per water consumed), water delivery performance , water use performance and physical performance during the study season but in 2015/16 irrigation season the computed external indicators were agricultural irrigation performance (output per command area, output per cropped area and output per water consumed) and physical performance indicators (irrigation ratio and sustainability of the scheme) because the recorded data for other were not found from the south Gondar small scale irrigation coordination office.

3.3 Primary data collection

Primary Data collection methods include a survey, semi-structure interviews and focus group discussions. The field survey was carried out to inspect physical conditions of the scheme components, operation and maintenance activities and management situation.

Repeated field visits were made to investigate method of water applications and closely observe practices related to water management techniques used by irrigators.

Primary data at field level were collected from farmer's field from irrigated (the head, middle, and downstream water user) of the study area.

The field survey was carried out to inspected physical conditions of the scheme components, operation and maintenance activities and management situation. Data was collected at household and community level and talk with a number of stakeholders who were directly involved in the scheme such as farmers, water user associations, government offices, operators, and agriculture extension officers. The methods used consists mainly of direct field observations by spending time within the command area and with the irrigators' community and combination of a variety of working methods helping to get access to the many aspects of the scheme's functioning.

To determine the amount of water applied by the farmers to their fields, the average head water passed through the main, secondary and field canals and the width of the canal were recorded.

3.4 Secondary Data Collection

Secondary data were collected from the South Gondar Zone Agricultural and Rural Development Office, Water Resource Offices and small-scale irrigation coordinating offices.

More over participatory approach discussions were held with beneficiary farmers and development agents (DA). The same data were also collected using questionnaire surveys from the water users. The questionnaires also were made to get the perception of the farmers about the water distribution within the project.

The secondary data collected total yields, farm gate prices of irrigated crops, area irrigated per crop per season, production cost per season, incomes generated by the irrigation associations and cropping pattern. Climatic data of the irrigation projects were collected from the nearby weather stations. Debretabor metrology station was the sources of the climatic data for the irrigation projects.

3.5 Data Analysis

Different methods of data analysis were used to achieve the goal of the study. In this study the evaluation of performance of Selamko irrigation scheme had used different performance indicators. Data collected to evaluate the performance of the scheme were analyzed descriptively. The data collected through questionnaires were analyzed descriptively using tables and percentages. In addition, depending on the nature of the questionnaires some of the data were summarized with narrative reports

3.6 Methods to Measure Performance Indicators

3.6.1 Conveyance efficiency (EC)

There are main canal and secondary canals conveyance structure of the scheme. The conveyance efficiency was measured on the main canal and 2 secondary canals at two different points (at outlet and inlet of canals). And on field canals selected purposively from head, middle and end of the command and at two different points for each canal by parshal flume. The discharges were calculated from the velocities of the water flowing in the main canal and secondary canal using current meter. To take the data more reliable, the flow measurement was taken five times on the same location within an interval each irrigation stage (initial, developmental, medium and late stage) and average flow was taken for computation of conveyance efficiency (Bantero et al., 2008).

Measurement of canal water flow at the diversion of the irrigation scheme will be done by velocity-area method. The cross-sectional area of the canal was estimated by measuring the average depth and width of this same canal section. Then the discharge can be calculated using

$$Q = A \times V \qquad 3.1$$

Therefore, the amount of conveyance loss will be known and the conveyance efficiency is determined. The conveyance efficiency was, then, calculated as: -

$$\text{Conveyance Efficiency} = \frac{\text{Canal outlet Discharge}}{\text{Canal inlet discharge}} * 100 \qquad 3.2$$

$$Ec = \frac{Vc}{Vd} * 100$$

Where; Ec is conveyance efficiency (%)

Vc is water flowing at outlet of the canal (m3/sec) and,

Vd is water flowing inlet of the canal (m3/sec),

The same procedure will be used to measure conveyance efficiency in the secondary canals.

3.6.2 Application efficiency (Ea)

The application efficiency was calculated at field level and was collected from farmer’s field from irrigated (the head, middle, and downstream water user) of the study area.

Soil sample primary data is important to determine the initial moisture content of bulk density, and hence using sampling auger undisturbed soil samples were collected to determine the soil bulk densities and disturbed samples was taken to determine the soil the moisture contents (Figure 2b).

Initial moisture content of the soil and moisture content after irrigation was determined by taking soil sample at the same depth before and after irrigation. For moisture content determination soil samples was taken to the laboratory 9 times at three growth stages of the crops (initial stage, developmental stage and maturity stage) per plot.

Soil Sampling and Analysis

Soil samples were collected for analysis of selected soil physical properties. The properties analyzed were particle size distribution, bulk density, soil moisture contents at field capacity and permanent wilting point before and after irrigation. Particle size distribution was analyzed using hydrometer method. Bulk density was determined using core method and water contents at field capacity and permanent wilting point were determined using pressure plate apparatus method. To determine soil samples of each selected farmland, twenty-seven soil samples before irrigation and twenty-seven soil samples after irrigation at three different depths were collected. Therefore, Soil samples were totally collected to determine the initial soil moisture contents before one-day irrigation and moisture contents after irrigation by using augur about 54 soil samples from the scheme with an interval of 20cm to a depth of 60 cm. It is over hoped that the effective root zone of the irrigated vegetable crop is not more than this depth. The maximum effective root zone of onion is 60 cm (Allen et al., 1998).

The dry bulk density of the soil was also being measured using the standard core sampler and weighing before and after drying the soil samples collected with core samplers in the regional soil laboratory. The bulk density of the soil can be determined by dividing the mass of the dry soil to the sample volume.

$$Bd = \frac{\text{Mass of natural soil in core sampler tube (gm)}}{\text{volume of core sampler tube(cm3)}} \text{ ----------------------------------3.3}$$

Bd = bulk density of the soil (gm/cm3)

Initial moisture content of the soil before irrigation and moisture content after irrigation was determined using gravimetric method. The samples were dried in an oven for 24 hrs at temperature of 105oC with the container cover removed. After drying, the soil and the container were again weighed and the weight of water determined. Therefore, for determining the soil moisture on a mass basis, the collected samples will be an oven dried, and then (in percent) stated by:

$$Wd = \frac{\text{Weight of moist soil} - \text{Weight of oven dry soil}}{\text{Weight of oven dry soil}} * 100 \text{ -------------------------------3.4}$$

Where: Wd soil moisture (soil water) content on dry weight basis %

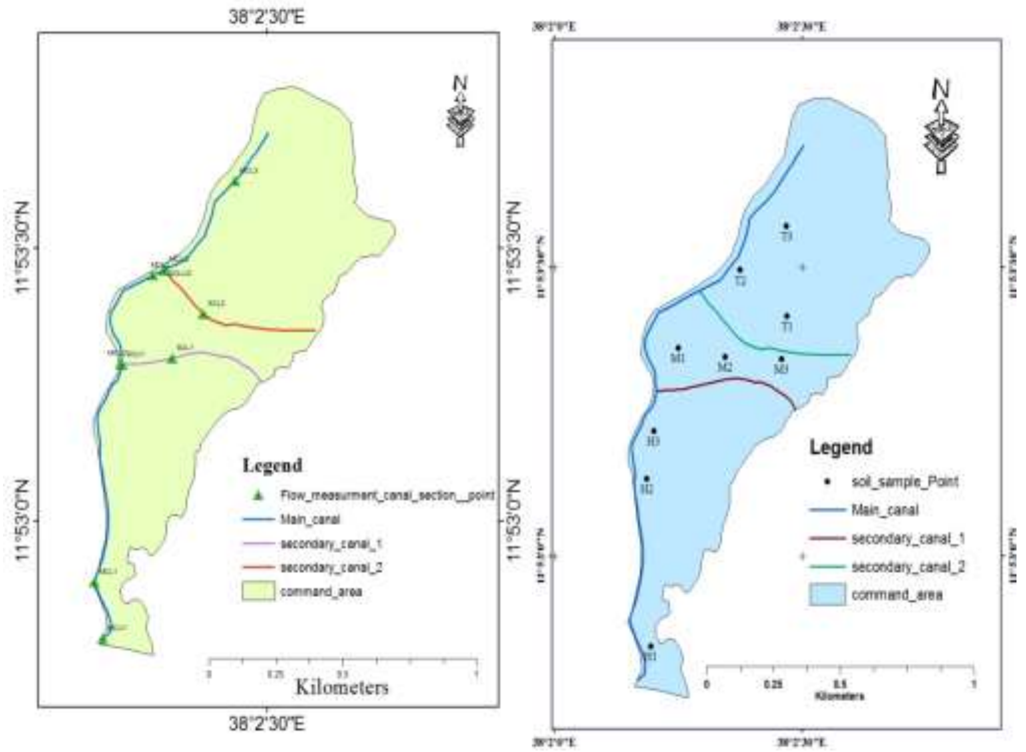

Fig.2 a) Flow measurement b) Soil sample location

Additional 27 soil sample were taken for physical characteristics of soil, field capacity and permanent wilting point determination.

The depth of water retained in the root zone of the soil before and after irrigation was determined (Equation 3.5).

The depth of water retained in the soil profile in the root zone was determined using the following equation given by (Murray-Rust and Snellen, 1993).

$$d= \sum_{i}^{n} \frac{Qf-Qi}{100} * Bdi * Di \text{ --3.5}$$

Where: d is depth of water retained in the soil profile

Qf is moisture content of the ith layer of soil after irrigation on oven dry weight basis (%)

Qi is moisture content of the ith layer of soil before irrigation on oven dry weight basis (%)

Bdi is bulk density of the ith layer of soil (gm/cm3)

Di is depth of ith layer

n is number of layers in the root zone (which is 3, i.e soil depth interval)

Amount of water applied to the field

In all the three crop growth stages, immediately after soil samples were taken, fields were irrigated and the amount of water applied is the irrigation water applied to each sample plot in selected irrigation events. To determine the amount of water applied by the farmers to the fields, a 50mm Parshall flume was installed at the entrance of each field of interest to measure the depth of water applied to the filed.

The measured water depth was changed to its respective discharge from the calibrated graph. During the determination of the amount of water applied to the field, the average water depth of irrigation water passing through the flume to the field and respective time were recorded with the size of the fields being irrigated (Appendix Figure 1)

The total volume of water applied to the field was obtained by multiplying the discharge rate with the inflow time. The depth of water applied to the field was obtained by dividing the total volume of water applied to the area irrigated (Kraatz and Mahajan,1975).

After determining the depth of water actually applied into the fields using a 50mmParsall flume and the depth of the water retained in the root zone of the soil based on the soil Moisture contents of the soils before and after irrigation and then the application efficiencies (Ea) in the selected fields was calculated, using

$$Application\ \ Efficiency(\%) = \frac{Water\ \ Retention\ \ in\ \ the\ \ soil\ \ due\ \ to\ \ irrigation}{Total\ \ water\ \ added\ \ to\ \ the\ \ field} * 100$$

$$Ea = \frac{d}{Df} * 100\%\text{---}3.6$$

Where d is Depth of water in the root zone and,

Df is Depth of water applied to the field,

The amount of moisture stored in the root zone of the crop was determined by deducting the percentage of the initial moisture content from the moisture content after irrigation. The purpose of calculating the amount of moisture stored in the root zone of the crop is to determine the water application efficiency of the scheme.

Overall scheme efficiency was calculated as the product of conveyance and application efficiency (Hailu and Shiberu, 2011).

$$\mathrm{Ep} = \frac{(\mathrm{Ec\ \ x\ \ Ea})}{100}\text{--}3.7$$

Where Ep is overall efficiency (%), Ec is conveyance efficiency (%) and Ea is the application efficiency (%)

3.6.3 Water delivery performance (WDP)

Water delivery performance is the ratio of the amount of the actual water delivered by the system compared to the target irrigation water amount. This serves as an indicator of the performance of the irrigation scheme to monitor productivity and equity. It shows changes in quality of service to water users and quantifies the uniformity and equity of water delivery (Bos, 1997). The water delivery performance indicator was calculated using equation 3.8,

$$\mathrm{WDP} = \frac{\text{canal capacity to deliver water at system head}}{\text{disigned(intended) discharge of water to be delivered}}\text{----------------------}3.8$$

The value of designed (intended) discharge of water was taken from the design document while actually delivered discharge of water (capacity to deliver water at the system head) was the present discharge capacity of the canal at the system head, and measured directly from the scheme with current meter at the canal head.

3.7 Irrigated agriculture performance indicators

The data was collected from the farmer, water user association and woreda stakeholders. Secondary data such as total yields, farm gate prices of irrigated crops, area irrigated per crop per season, crop types and yield per hectare was collected. Local prices of each cultivated crop were collected from the Agronomist Bureau of Agriculture and Rural Development.

The design feasibility study documents of the irrigation projects were collected from the South Gondar small scale irrigation scheme coordination office and were used as a source of information on the investment costs of the irrigation projects. For the irrigated agriculture performance indicators, three indicators related to the output of different units were used. They were used for the evaluation of the project performance in terms of the production it results in. The selected indicators used to evaluate irrigated agriculture performance according to Molden et al., (1998) were:

Output per cropped area was calculated as the ratio of production per irrigated cropped area,

$$\text{Output per cropped area (birr/ha)} = \frac{\text{production(birr)}}{\text{Irrigated area(ha)}} \text{----------------------3.9}$$

Output per command area as the ratio of production per Command area

$$\text{Output per unit command (birr/ha)} = \frac{\text{production(birr)}}{\text{Command area(ha)}} \text{------------------3.10}$$

Output per water consumed as the ratio of production in per volume of water consumed

$$\text{Output per unit water consumed (birr/m3)} = \frac{\text{production}}{\text{volume of water consumed by ETc}} \text{----3.11}$$

Where,

Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices,

Irrigated cropped area is the sum of the areas under crops during the time period of analysis,

Command area is the nominal or design area to be irrigated,

Volume of water consumed by ETc is the actual evapotranspiration of crops

FAO CROPWAT 8.0 computer model used to determine the crop water requirements (CWR), and monthly ET of the irrigated crops at field levels during irrigation season. ETc was estimated for the previous period using the previous meteorological data.

Volume of water consumed by ETc is the actual evapotranspiration of crops, ETc which is calculated by:

$$ETc = Kc \times ETo \text{ --3.12}$$

Where ETo reference evapotranspiration Kc the crop coefficient (dimensionless) (Molden et al., 1998).

3.8 Water use performance

Two types of indicators namely relative water supply (RWS) and relative irrigation supply (RIS) were used for evaluation of water use performance. RWS and RIS values indicate whether is an adequate supply done or not to cover the demand. Both relative water supply and relative irrigation supply were calculated by using the following formulas (Perry, 1996):

$$\text{RWS (\%)} = \frac{\text{TWS(m3)}}{\text{Croped demand(m3)}} * 100 \text{ ------------------------------3.13}$$

$$\text{RIS (\%)} = \frac{\text{Irrigation supply(m3)}}{\text{Irrigation demand(m3)}} * 100 \text{ ----------------------------3.14}$$

where RWS (%) is relative water supply, TWS (m3) is total water supply or diverted water for irrigation plus rainfall, crop water demand (m3) is the potential crop evapotranspiration (ETp), or the real evapotranspiration (ETc) when full crop water requirement is satisfied, RIS (%) is relative irrigation supply, irrigation supply (m3) is surface diversions and net groundwater drafts for irrigation, and irrigation demand (m3) is the crop ET minus effective rainfall. Irrigation requirement and net crop requirement calculated by CROPWAT 8 programs (FAO, 1992).

3.9 Physical performance Indicators

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. By using the equation (Vermillion, 2000):

$$\text{Irrigation ratio} = \frac{\text{Irrigated area}}{\text{command area}} \quad \text{---}3.15$$

$$\text{Sustainability of irrigable land} = \frac{\text{irrigated area}}{\text{Initial Irrigable area}} \quad \text{------------------------}3.16$$

The sustainability of Selamko irrigable area is used to an indicator to measure the performance of the scheme. Where, irrigated land refers to the portion of the actually irrigated land in any given irrigation season. Irrigable land is the potential scheme command area (Vermillion, 2000).

3.10 Effectivity of infrastructure

Effectivity of infrastructure quantifies effect of maintenance or it Shows areas with maintenance problems. Maintenance is needed to keep the system in operational condition. For this to occur, structures and water application systems must be operational as intended.

To determine the effectivity of the infrastructure of the irrigation system, all the infrastructures including gates, the drop structures, the division boxes, and farm bridges which are positioned on the main, secondary and tertiary canals were monitored. And these were compared to what was proposed in the design document with the following formula.

$$\text{Effectivity of infrastructure} = \frac{\text{Number of functioning structure}}{\text{Total number of structure}} \quad \text{------------------------------}3.17$$

4. Results and Discussion

4.1 Soil Physical Properties

The soil textural class in the project area is loam and clay loam for the selected farm lands of the scheme. The bulk density values ranged from 1.03 to 1.30 g/cm3. The bulk density values of the soils at both irrigation schemes were low as per the bulk density rating of indicating that there was no compaction that could limit infiltration of water into and through the soil and root penetration (Hailu and Shiberu, 2011).

Volumetric moisture content retained at field capacity varied from 27-32% and the permanent wilting point varied from 9- 13%. Furthermore, the total available water holding capacity of soils selected fields from the scheme ranged from 170 – 210 mm/m. In general the scheme soils are medium as per available water holding rating of (Hailu and Shiberu, 2011). The result depict that the relevant soil physical properties measured are not different to a great deal from each other with depth and across the different sampling points indicate that the soils of the study area is homogeneous. The detail of selected soil physical properties of the scheme is shown in Appendix Table 18.

4.2 Irrigation water distribution system

In Selamko irrigation scheme, WUAs was grouped into three groups in which the farmers are free to irrigate till they have received enough water. Irrigation management was carried out in rotation among the three groups in which the farmers are free to irrigate until they have received enough water. There is irregular irrigation interval in the scheme which varies from 5 to 6 days depending on the growth stage of the crops. Regarding the scheduling, all 3 groups get water turn by turn and the method of water distribution is a rotational type. A representative farmer assigned by the water user association throughout the year manipulates the gate at the head of the main canal to divert water from the dam intake. The distribution can be allocated one for specific period within a week. As far as the schedule of irrigation water allocation is for the peasant association they belong, farmers have the right to apply the water as much as they want. There is no any restriction how much water a farmer can divert for his field regardless of the size of his farm, especially for head end user. From field observation and results of the questionnaire, due to unwise use of water by the head end users and due to seepage problem of the main canal the tail end user faced water shortage frequently. The structure of the WUAs, there are 3 leaders at the head, middle and end users and 6 members in each irrigation users. Totally, 21 persons are the member of WUA. But there is no strong practical to manage the irrigation water distribution, it's orally organized.

4.3 Performance Evaluations

The parameters assessed for performance evaluation of Selamko SSIS were internal process indicator (conveyance and application efficiency) and external process indicator (Irrigated agricultural performance indicator, water delivery performance, water use performance indicator, and physical and maintenance performance indicator).

4.3.1 Conveyance efficiency

The results of the conveyance efficiency evaluation revealed that this indicator varied within a farm at different points, between farms within the scheme and between the schemes. The conveyance efficiency of the system was computed using equation (3.2) that to consider the total flow the canal delivered and the total inflow into the canal. The conveyance efficiency of the main and the secondary canals monitored during this study is mentioned below in Table 1

Table 1: Conveyance efficiency of the main canal and the secondary canal

Canal Section	Average Depth (cm)	Average Width (cm)	Total Area (m2)	Mean Velocity (m/s)	Discharge (m3/s	Conveyance efficiency (%)	Remark
MC Upper	15	60	0.1125	0.130	0.0205	54.31	Header
MC Lower	18	60	0.135	0.059	0.0111		
MC Upper	13.2	60	0.099	0.061	0.0085	58.42	Middle
MC Lower	15	60	0.1125	0.031	0.0049		
MC Upper	12	60	0.09	0.034	0.0043	57.96	Tail
MC Lower	10.8	60	0.081	0.022	0.0025		
SC1 Upper	9	30	0.045	0.086	0.0049	57.09	B/n Head & Middle
SC1 Lower	12	30	0.06	0.037	0.0028		
SC2 Upper	12	30	0.06	0.055	0.0041	54.55	B/n Middle &Tail
SC2 Lower	13.2	30	0.066	0.027	0.0022		

As seen from the above table the conveyance efficiency values of the main canal which indicate the amount of water lost during transportation of water from diversion point or source to the field canal of the scheme was found to be 54.31, 58.42 and 57.96 % at the head, middle and tail user sections respectively. The average conveyance efficiency of this canal is 56.9%. The amount of water lost at upper part of the main canal at the head user was 9.36 l/s or 809.546m3 per day. This shows that 45.69% loss of water has been occurred in the main canal at the head. The amount of water lost at the middle part of the main canal at the middle user was 3.52l/s or 58.554m3 per day. This showed that 41.58% loss of water occurred in the main canal at the middle. The amount of water lost at the tail part of the main canal at the Tail user was 1.79 l/s or m3 155.046m3 per day. This indicates that 42.03% loss of water occurred in the main canal at the tail. When the result was compared to (Renault et al., 2007) about 10 to 15 % of loss of water in the canal is admitted, It was found to be unacceptable range because as the efficiency indicated that large amount of water was lost. The reasons for losses in the main canal might be attributed to more seepage loss, illegal water diversion by the farmers overtopping of the water from the canal in each head, middle and tail users

Figure 3: Breached canal

The conveyance efficiencies of the secondary canals are 57.09 and 54.55% for the secondary canal 1 and secondary canal 2 respectively. The discharge loss of the secondary canal 1 and secondary canal 2 were estimated as 2.08l/s or 179.978m3 per day and 1.86l/s or 160.863 m3 per day respectively. The efficiencies of these canals are below the standard 75% for secondary canal (Brower, 2011). The reason of this loss is the breakage of the canal, sedimentation, the seepage of the canal, illegal use of water of the farmer.

The total average of the conveyance efficiency of the canal is 61.87; this is below the recommended value i.e. 70% poorly managed canals (Hailu and Shiberu, 2011).

4.3.2 Application Efficiency

Selamko irrigation project water was observed that farmers were applying water without the crop water requirements because they have not knowledge about it. Application efficiency describes how effective the irrigation system is in storing water in the crop root zone. The application efficiency of a given irrigation scheme tells us whether the irrigation water is stored in the intended soil profile or lost as surface runoff or deep percolation. To determine water application efficiency, moisture contents of the soil before and after irrigation of the sample plots was determined from the samples soil collected. And depth of water retained in the root zone was computed using moisture content before and after irrigation using equation 3.5

The application efficiency (Ea) was computed using equation (3.6) on the Head, Middle and Tail of the selected farmers' field is presented in the Table (2) below

Table 2: Application Efficiency of the selected farm lands

Field	Field Code	Applied Depth	Sum of stored depth	Application efficiency, Ea %
Head	H1	28.207	17.011	60.308
	H2	25.200	15.61	61.944
	H3	23.520	14.59	62.032
Middle	M1	21.073	12.2	57.894
	M2	32.637	18.418	56.432
	M3	25.267	14.297	56.583
Tail	T1	28.305	14.08	49.744
	T2	28.737	16.48	57.348
	T3	28.761	14.57	50.659

The application efficiency of the selected fields was found to vary from 60.308% to 62.032% with an average of 61.428%, 56.432% to 57.894% with an average 56.97% and 49.744% to 57.348% with an average 52.584% at the head, middle and Tail respectively. The total average application efficiency of the scheme from the selected fields was approximately 57%. The values obtained below the recommended value i.e 60% (Walker, 1989). Similar research conducted by Lesley (2002), showed that the application efficiency could be in the range 50% - 80 % however Roger, et al. (1997) stated that the application efficiency varies widely but it's possible to have high application efficiency. The detail of the application efficiencies for the selected fields in the scheme are shown in appendix tables 16 and 17. Comparing the three fields on the basis of their application efficiency, it was found the head end users have better in efficiency because the efficiency is greater than the recommended i.e. 60% whiles the tail end users are the least efficient.

The reason for small scale irrigation is associated to lack of technical capacity of farmer resulted from absence of extension workers and the required trainings, the type of irrigation system, wild flooding, and absence of knowledge of irrigation time and scheduling by farmers. It might be the losses of application efficiency include either evaporation from the soil and plant surface, runoff from the target site or deep percolation. To improving this efficiency might be scheduling irrigations based on soil moisture estimates or measurements which mean soil moisture levels can be tracked with soil sensors or weather crop ET estimates to determine when and how much irrigation is needed, consider installing an irrigation flow measurement to monitor the total volume of water discharged and conservation tillage practices such as no-till and strip tillage have been shown to improve soil water holding capacity.

4.3.3. Overall Scheme Efficiency

The overall scheme efficiency is the ratio of the water made available to the crop to the amount released at the head work. In other words, the product of conveyance efficiency and application efficiency is overall efficiency. In the present study the overall efficiency of Selamko small scale irrigation scheme commuted using equation (3.7) is 35.268%. The result indicates relatively poor because below the range of value 40-%50% (Hailu and Shiberu, 2011)

According to Konukcu (2007) irrigation losses can be due to operational losses from distribution system, seepage and evaporation losses from canals, deep percolation losses below the root zone and tail water losses at field end. Irrigation system should be need periodically inspected and properly maintained, and irrigation scheduling based on soil moisture estimates and measurements can improve the overall efficiency of the water use on the farm, water measurement data helpful with monitoring system performance and detecting well problems and recovery or reuse of runoff water (tail water) to the field. Regular irrigation system maintenance along with proper cultural and management practices can help to improve the overall efficiencies of water use on the farm land.

4.3.4. Water Delivery Performance

Water delivery is the value calculated as the ratio of actually delivered volume of water to the intended volume of water to be delivered. The intended amount based on the design document was 0.11m3/s. The actual discharge of the main canal is 0.021m3/s as measured using current meter five times. The water delivery performance is using equation (3.8), approximately 19.09%. It indicated that the actual water delivered is much less than the intended water volume because the water delivery of the scheme diverts to the field approximately 1/5 part of the designed discharge. The reason for this reduction is the illegal obstruction of flow across the canal and the absence of the clearance of the intake of the canal. It becomes the consequences of irrigated land decrease then the production yield of the scheme decreases.

4.3.5 Irrigated Agricultural Performance Indicator

This includes performance indicators, which are associated with the production. The major of such performance indicators included are output per command area, output per cropped area and output per unit water consumed. During study period, five main crops in Selamko irrigation scheme were taken into account among which onion was taken as the base crop because it is most tradable and cultivated crop. The irrigated area of the scheme was 42ha and the command area is 63ha.

In 2015/16 production season, there were six main crops in the scheme. At that period onion is the dominant crop. The irrigated area of the scheme was 56.75 ha and the command area is 63 ha.

4.3.5.1 Output per Unit Command Area

This indicator expresses the average return per design command area. It is an indication of whether all the command areas generating returns or not. The output per unit command area of the scheme was 60198.14 birr/ha during the study period but 2015/2016 production season the production per command area was 89738.1 birr/ha. There was variation between 2016/17 and 2015/16 irrigation season. The reason might be in the year 2015/16 the farmers used fertilizers (UREA and DAP). Because the farmer said that they have received the fertilizer from the woreda agricultural office and they have used to the crop land during 2015/16 but in 2016/17 irrigation season have not used fertilizer. So the soil of the command area might need some fertilizer nutrients. The detail of outputs per unit command area is shown in Figure 4 and Table 3

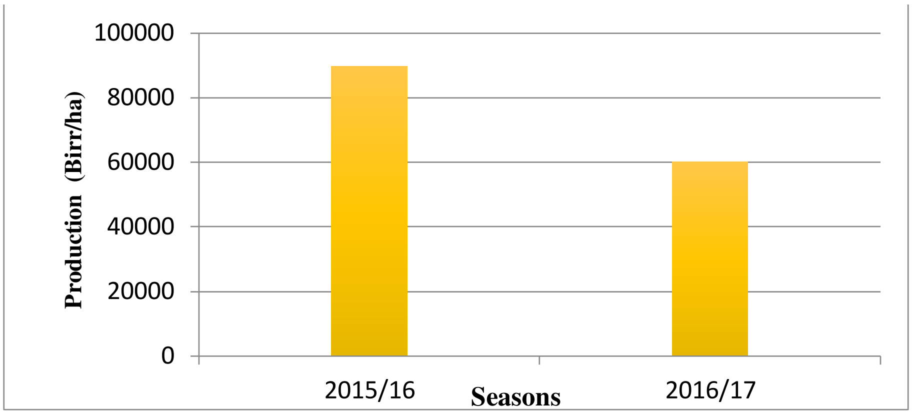

Figure 4: productions per unit command area

4.3.5.2 Output per Unit Cropped Area

The output per unit cropped area show the response of each cropped area on generating gross return. This parameter gives a clue about the management practice in every scheme. The output per unit cropped area was 90297.62 birr/ha during the study period but 2015/2016 production season the production per cropped area was 99621.1 birr/ha. The reasons might be the same as output per command area. Based on this information it is possible to say that the response or income per cropped area in 2015/16 is better than in 2016/17 irrigation season. The detail of outputs per unit cropped area is shown in Figure 5 and Table 3

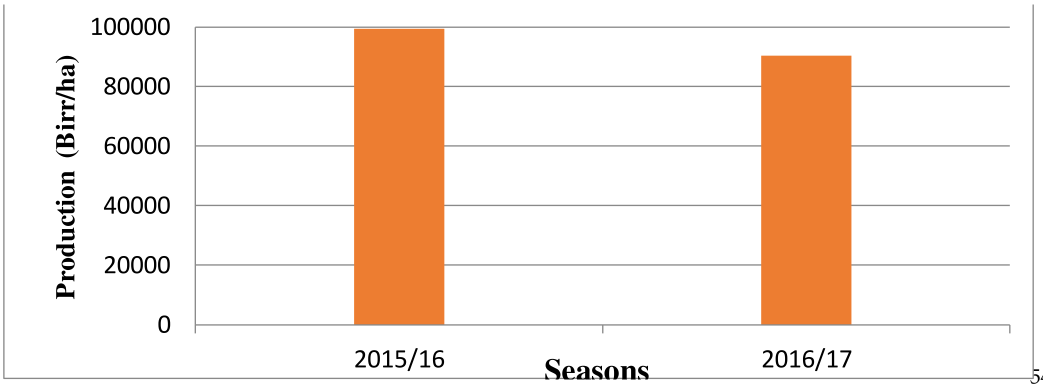

Figure 5: production per unit cropped area

4.3.5.3 Output per Unit Water Consumed

The output per unit water consumed is used to describe the return on water actually consumed by the crop. This indicator tells us how water is efficiently utilized by the scheme from economic point of view and gives due attention to the water consumed by the scheme. The output per unit water consumed of the scheme was 17.66 birr/m3 during the study period but 2015/2016 production season the production per water consumed was 20.14 birr/m3. The reason might be best described by poor cropping pattern and the water use efficiency. And it may be the institution was better in 2015/16 irrigation season but in 2016/17 irrigation season, I observed that almost there is no technical institutional support to the farmers. The detail of outputs per unit water consumed is shown in Figure 6 and Table 3.

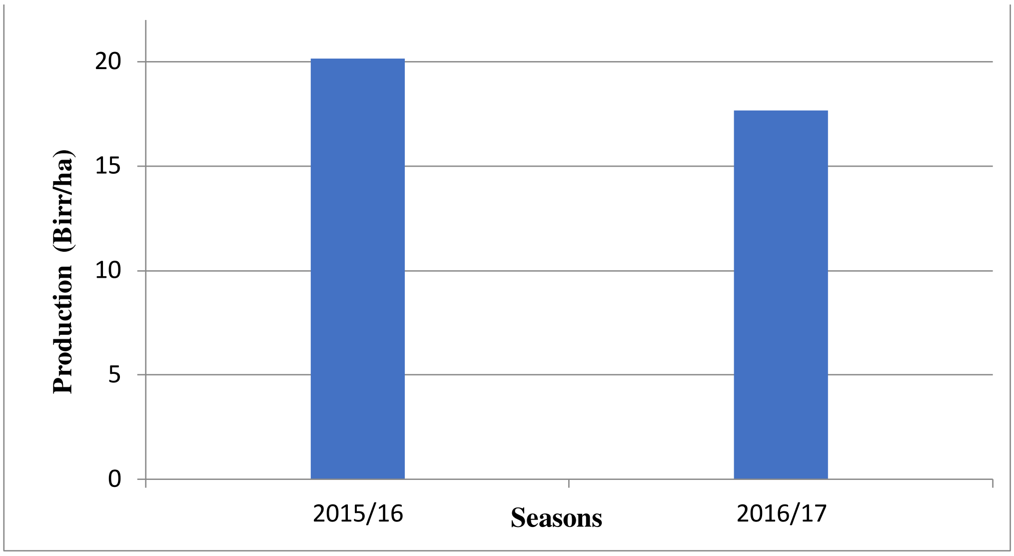

Figure 6: production per unit water consumed

Table 3: Indicative values of the production performance indicators

Irrigation Season	Output per command area (Br/ha)	Output per unit cropped area (Br/ha)	output per unit water consumed (Br/m3)
2015/16	89738.1	99621.1	20.14
2016/17	60198.14	90297.62	17.66

At Selamko small scale irrigation scheme, the major crops grown were onion, garlic, tomato, potato and cabbage among them onion is the dominant crop produced covering around 50% of the irrigated land and the other 50% of irrigated land is covered by garlic, potato, tomato and cabbage the area was 26.19%, 19.05%, 2.38% and 2.38% respectively during the study period. The agricultural performance indicators of the scheme in two irrigation seasons were relatively good at 2015/16. This result showed that the irrigated agricultural performances were better at 2015/16 than at 2016/17 irrigation season. Although the amount of irrigation water consumed with respect to demand a bit higher in 2015/16, the water productivity values are still higher in this year. The difference is attributable to the cropping patterns and abilities of system management in this year (Şener et al., 2007)

3.6 Water Use Performance

Two indicators, relative water supply (RWS) and relative irrigation supply (RIS) were used in the evaluation of the water use performance. The net crop water requirement (CWR) was computed for each irrigated crop for 2016/2017 cropping season (Nov –April end) for the scheme. The crop coefficients provided with CROPWAT 8 computer program were used to calculate the crop water requirement at each growth stage.

Table 4: Results of the CWR and IR of the scheme

Crop Type	cropped Area	Cropped Area (%)	CWR (mm/dec)	CWR (m^3)	IR (mm/dec)	IR (m^3)
Potato	8	19.05	443	35440	388.9	31112

onion	21	50.00	541.3	113673	464.5	97545
Garlic	11	26.19	498.3	54813	429.7	47267
Tomato	1	2.38	514.5	5145	446	4460
cabbage	1	2.38	572.7	5727	463.6	4636
Total	42	100	2569.8	214798	2192.7	185020

Table 5: water use indicators of the schemes

parameters	total rainfall (m3)	Total water diverted (m^3)	Total water supply (m^3)	crop water demand (m^3)	irrigation demand (m^3)	RWS	RIS
scheme	95004	272160	367164	214798	185020	1.71	1.47

The relative water supply depicts whether there is enough irrigation water supplied or not. The relative irrigation supply shows whether the irrigation demand is satisfied 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 value of relative water supply value more than one indicates the TWS is enough to meet the demand. Higher value of RWS indicates that there is excess water supply (Peria, et al., 2012). RIS is the fraction of irrigation supply to irrigation demand. The value of RIS more than one indicates that irrigation supply by the canal is enough to meet crop insist (Peria, et al., 2012). The value of RWS and RIS using equation (3.13 and 3.14) in Table 4.5 are after accounting for the losses in the canal conveyance and distribution systems. RWS and RIS were calculated using equation 3.13 and equation 3.14 as 1.71 and 1.47 respectively excess water supplies and irrigation supply of the scheme. The difference value between RWS and RIS are due to rain fall in the scheme because there was a rain fall at the scheme during the period at the end of February to the end of April. There is not a constraining water availability situation during the 2016/2017 irrigation season for total demand because RWS and RIS were greater than 1 (Molden et al, 1998). The water users give less attention for water saving and waste significantly large amount of water resources at the scheme. Farmers feel that excess irrigation water to the scheme is good for crops as long as it is available. Lacks of sound irrigation scheduling, lack of knowledge on actual CWR are some of the factors contributing to wastage of water.

Generally, the RWS and RIS values alone in this study indicate that water demands of crops in the scheme are satisfied. Similar results were also obtained from many researchers around the world and these value also imply the relationship between the water supply and crop water demand was poor from the point of water distribution in the scheme (Şener et al., 2007).

3.7 Physical Performance Indicator

Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. Three physical indicators were used: irrigation ratio, sustainability of irrigation and effectivity of infrastructures. Data related to area of land at the scheme is shown in Table 4.6 and the effectivity of the infrastructure is shown in Table 4.7.

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

Irrigation Season	Currently Irrigated Land (ha)	Command Area (ha)	Irrigable Land (ha)	Sustainability Of the Scheme (%)	Irrigation Ratio (%)
2016/2017	42	63	67	66.67	62.69
2015/2016	56.75	63	67	90.08	84.70

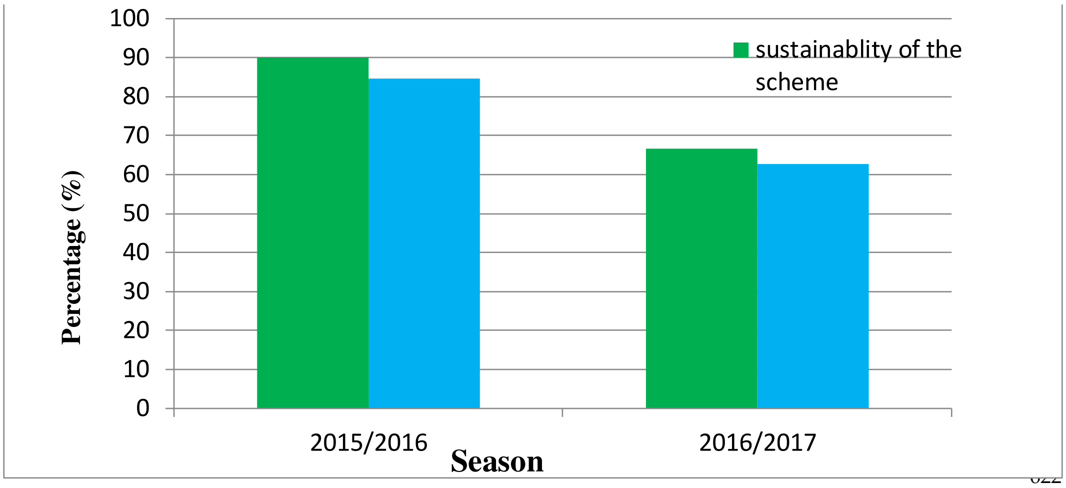

Figure 7: irrigation ratio and sustainability of the scheme

In Table 4.6, the irrigated area of 2015/16 was 56.75 ha but in 2016/17 were 42 ha. It is decreased by 14.75 ha irrigable land in study period. During the study period (2016/17), the irrigation ratio of the scheme was 66.67% which means that about 33.33% of command area of the scheme was under irrigation. The main reason for this according to the farmers is the water quality of the dam. There is a slaughter house in the nearby and waste of Debretabor city discharge into the river the mainly affects the water quality. Therefore, farmers are convinced that the water quality is deteriorating with time and some are not willing to use irrigation water. Consequently, irrigation area is reducing. I observed the water quality only by odder and color of irrigation water. The odder of irrigation water smelt rotten egg and the color was black, it might be indicated that there is high amount of sulfur. The other reason might be weak institutional set up of water association at the scheme because some farmers convinced that the water user association was not well control the users and irrigation land.

The initial irrigable area of the scheme is 67ha and the current irrigated area is 42 ha. The sustainability of the scheme for two irrigation seasons is 62.69%. I cannot be judge the sustainability of the scheme was decrease or increase by using the two irrigation seasons because sustainability is a long term process of irrigation system functions working or not. But this indicates and gives the direction of that from the sustainability of the scheme was decreasing in two irrigation seasons. In 2015/16 irrigation season, the irrigation ratio was 84.7% and sustainability of the scheme was 90.08%. It was relatively greater than 2016/17 irrigation season. This figure shows that there is plenty of land to be developed with the scheme while the resulting achievement is far from satisfactory. As the scheme built recently, the sustainability of irrigation is vulnerable.

Table 7: Effectivity of Selamko irrigation scheme infrastructure

	Types Of Structure	Total No of Structure Constructed	Number of Non-Functional Structure	Percent of Non-Functional
1	Head regulator	1	0	0
2	Gates on main canals and division box	18	16	88.89
3	Division boxes	7	5	71.43
4	Drops	3	2	66.67
5	Total	29	23	79.31

The total effectivity of scheme infrastructure using equation (3.17) was 20.69%. The total percent of non-functional structure was 79.31%. As observed in the assessment during the study period most of structures of the scheme were damaged either partly or fully. The farmers divert water from the canal to the field by using stone and soil to dump the section of the canal (see Figure 8). Physical effectivity of the irrigation infrastructure calls for need based O&M funding. This requires systematic maintenance and monitoring of the physical assets of the irrigation system and their current status on a continuous basis.

Figure 8: Farmers controlling structure using stone and soil at control of the canal

5. Conclusions

In this study, an attempt was made to evaluate the performance of Selamko small scale irrigation scheme at Amhara regional state, Abay basin of Ethiopia using internal and external indicators. The internal process indicators computed were conveyance efficiency, application efficiency and water delivery performance. The external indicators were including in this study were agricultural, water use and physical performances.

The assessment of the irrigation efficiencies in the scheme indicated that the availability of irrigation water may be constrained by quality of water and high amount of water was diverted to the farmer field. During the study period there was enough water from the reservoir during the dry time but the water was contaminated by effluents from the slaughter house and waste of Debretabor city. The water smelt rotten egg and the color was black. Some farmers applied enough water to the field but the production was low as compared to the applied water.

The conveyance of at all hydraulic levels showed some low values, the conveyance efficiency of the main and secondary canals was low due to lack of regular maintenance.

The application efficiency appeared to be good when we compare with application efficiency in the range of 50-70% for field irrigation observed in other African countries.

The water delivery performance of the scheme was very low which means the actual discharge of the canal was very less as compared to the intended discharge of the canal. This might indicate that some part of the water intake of the dam may blocked by some trash material or debris. Recent studies have also indicated that reservoir sedimentation has might affect the storage.

In irrigation agricultural performance of the scheme, output per unit command area and output per unit cropped area were greater in the first irrigation season that means in 2015/16, but output per unit water consumed was greater at the study period. This indicates that the production of the irrigation scheme decreases from time to time due to water use and command area of the scheme, although continuous data needs to be taken to confirm this.

The water use performance indicators are RWS and RIS of the scheme. There was enough water supplied to satisfy the irrigation demand. The result of the RWS and RIS was greater than one which indicated that enough water is supplied to the scheme. But the water users give less attention to water saving and waste significantly large amount of water resources at the scheme. Farmers feel that excess irrigation water is good as long as it is available. Lacks of sound irrigation scheduling, lack of knowledge on actual CWR are some of the factors contributing to wastage of water.

Physical performance indicators were considered the parameter of sustainability of the scheme, irrigation ratio and effectivity of infrastructures. It was found that the physical performance of the system very poor. Irrigation ratio and sustainability of the scheme was decreased during the study season. Some part of the structure was affected by sedimentation, some part was broken, some part was damaged by erosion, the weed growth at the structure, and some part of the command area was affected by salinity.

In general, due to lack of well irrigation management, improving water management and lack of irrigation system knowledge the performance of the irrigation scheme is low according to the observed results. During evaluation of the Selamko small scale irrigation, it was understood that farmers used their indigenous knowledge in execution of the irrigation farm; that means if they could have good access to water, they will over irrigate their land without understanding the implication of water loss and yield loss from the scheme.

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