Performance Assessment Irrigation Schemes According to Comparative Indicators: A Case Study of Shina-Hamusit and Selamko, Ethiopia

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Abstract- Performance of Shina-Hamusit and Selamko Irrigation Scheme of Dera and Farta district, respectively in South Gondar zone, Ethiopia were evaluated using some selected comparative indicators, classified into four groups, namely, agricultural, economic, water-use and physical performance by International Water Management Institute (IWMI). Overall activities in primary data collected included: field observation, interviewing beneficiary farmers, discharge measurements in the canals. In addition to primary data, secondary data were collected from the secondary sources, and included total yields, area irrigated per crop per season or per year, crop types, and cropping pattern. The results of performance with respect to both land and water productivity indicate that Shina-Hamusit scheme performs better. Analyses of water-use performance showed that relative water and relative irrigation supply values were calculated as 1.55 and 1.31 at Shina-Hamusit and 1.87 and 0.81 at Selamko, respectively, indicating that water distribution is not tightly related to crop water demand. Physical performance, evaluated in terms of cropping intensity, irrigation ratio and sustainability of irrigated land, were good. Economic performance indicators showed that Selamko scheme had a serious problem about the collection of water fees, but not at Shina-Hamusit.

Index Terms- comparative indicators, irrigation project, performance evaluation

I. Introduction

Water resources are renewable; however, these natural resources are limited. So as to acquire the highest efficiency from existing resources, it is necessary to efficiently make use of the resources concerned. Efficient use of limited water resources, especially for agricultural irrigation, will both enhance producer's yield per unit of water and hinder such negative effects on environment as drainage, salinity and increase in the level of underground water, resulting from overuse of water (Ucar *et al*., 2010).

Within the next two decades, many countries are expected to face insufficient water resources to satisfy their current agricultural, domestic, industrial and environmental water demands. The world population is forecasted to grow by about 30% by the year 2025, reaching 8 billion people. As a result of improved communications, globalization and more urbanization, the living standards are also expected to increase. This means competition among the agricultural, industrial, domestic and other users will increase in unprecedented levels. Therefore, water management of irrigated agriculture is very important in meeting the food requirement of the increasing world population (Takeshi and Abdelhadi, 2003; Konukcu *et al*., 2004a and b).

Irrigation is of major importance in many countries. It is important in terms of agricultural production and food supply, the incomes of rural people, public investment for rural development, and often recurrent public expenditures for the agricultural sector. Yet dissatisfaction with the performance of irrigation projects in developing countries is widespread. Despite their promise as engines of agricultural growth, irrigation projects typically perform far below their potential (Small and Svendsen, 1992). A large part of low performance may be due to inadequate water management at system and field level (Cakmak *et al*., 2004).

Food security in developing nations is aggravated by the rapid population growth and the consequent demand for food. Exacerbating this increased food demand, there has been a significant rise in prices of food products in the world market. Consequently, to better meet the demand for food and reduce the impact of inflated food prices, substantial investments in modifying existing farming systems or establishing new ones will be necessary (FAO, 1997).

As an extreme example, many parts of Ethiopia have faced food insecurity for the past three decades. In addition to and as a consequence of increases in population, continuous land degradation, excessive deforestation, erratic and unreliable rainfall and other factors have eroded assets and crippled coping mechanisms of farm households. Recurrent drought has had a long lasting effect on the livelihood of agricultural communities and the whole economy. As a consequence, both acute and chronic hunger and malnutrition occur among many Ethiopians even when there are good harvests during normal times (Catterson *et al*., 1999).

As a dramatic change to a mostly rain-dependent farming system, irrigated agriculture was thought to be one of the solutions to enhance food security in the country. Since its initial promotion, irrigated agriculture in Ethiopia still only comprises a small fraction of total cultivated area; of the 5.3 million hectares that can be irrigated, only 0.64 million hectares are irrigated (Seleshi *et al.*, 2010).

Water development by constructing small earthen dams in the country is believed to bring changes in the way of life of the local communities in the area. The major problems related with such kind of projects are that their negative impact on the environment and human health. Irrigation projects have the potential to degrade the land, the soil and waste the valuable resource-water if they are mismanaged. In recognition of both the benefit and hazards assessment and evaluation of irrigation schemes performance has now become a paramount importance not only to point out where the problem lies but also helps to identify alternatives that may be both effective and feasible in improving system performance. Performance evaluation of irrigation projects is not common in the country. Lack of knowledge and tools used to assess the performance of projects adds to the problem (Mintesinot *et al.*, 2005).

South Gondar zone is one of the Amhara National Regional zones in the country where micro earthen dams of irrigation projects are constructed and ongoing. Shina-Hamusit, Selamko, Gaunta-Lomidur and East Estie irrigation projects are the functional schemes except the Ibinat (due to lack of reservoir water), and Ribb irrigation dam is the ongoing whereas the Gumera irrigation dam is the finished feasibility study. This study is to evaluate the performance of the two small scale irrigation schemes.

II. MATERIALS AND METHODS

Description of the Study Area

The study was carried out at two modern small-scale irrigation schemes in the Amhara National Regional State (ANRS) specifically in South Gondar Administrative Zone (SGAZ): the Shina-Hamusit and Selamko micro earthen dams at Dera and Farta Woreda, respectively, were serving for relatively longer period of time in the basin. The study schemes are selected based on site accessibility and availability of water in the reservoir.

Shina-Hamusit irrigation scheme- The Shina-Hamusit micro-earth dam project is situated in Metsele Kebele of Dera Woreda, adherent to Fogera Woreda in the south. It can be reached via the road leading to Gondar about 35 km away from Bahir Dar. From the village Hamusit, the Shina community is located about 9 km away in a northwesterly direction. The location is $11^0$55'N latitude and $37^0$60'E longitude. The altitude is 1560 m.a.s.l. The topography is Woinadega agro-ecological zones. The annual rainfall is ranging between 1000 mm and 1500 mm. The rainy season is from March to November. The dominant crops grown in the Woreda are Tef, Barely, Wheat, Finger Millet, Rice, Maize, Sorghum, Faba bean, Pea, Lentil, Goya, Niger seed, Linseed ,Ethiopian mustard and Sun flower. Root crops such as Potato and Sweet potato, and vegetables such as Shallot and Garlic are also produced in the Woreda (Dera Woreda Planning and Economic Development Case Team, 2011) (Eguavoen *et al.*, 2011). The irrigation system is gravity and the command irrigated land is 105 ha.

Selamko irrigation scheme- Selamko irrigation scheme is located in Farta woreda around South Gondar Administrative Zone. The scheme is located 3 km from Debre Tabor town. The geographical location is $11^0$53'N, $38^0$02' E with an elevation of 2519 m.a.s.l. The annual rainfall is ranges from 1500 – 2000 mm. The average annual temperature is 17^0C. The major crops growing are: potato, wheat, barley, teff, millet, faba bean, lentil and chickpea. It is hundred percent woynadega agro-ecological zones. The command area is 63 ha (Eguavoen *et al.*, 2011).

Data Collection

Primary data- canal water flow, production cost and productivity were measured from Respective sites.

Secondary data collected- Secondary data were collected from the documents kept by the responsible bodies or officials at each irrigation project from Woreda Agricultural Offices and Farmers training centers. Moreover, a participator approach discussions were held with beneficiary farmers and development agents (DA). The same data were also collected using questionnaire surveys from the water users (10% WU from the total water user). The questionnaires also were made to get the perception of the farmers about the water distribution within the project. The Secondary data included total yields, farm gate prices of irrigated crops, area irrigated per crop per season or per year, crop types, production cost per season or per year, and cropping pattern.

Climatic data of each irrigation projects were collected from the nearby weather stations. Bahir Dar National metreology agency was the sources of the climatic data for both irrigation projects.

Performance Evaluation

Performance of the Scheme was evaluated using four selected comparative indicators: agricultural, economic, water-use and physical performance by International Water Management Institute (IWMI) (Molden *et al.*, 1998).

Comparative indicators

Agricultural performance- Four indicators related to the output of different units were used for the evaluation of agricultural performance. These indicators were calculated as follows (Molden *et al*., 1998):

$$\text{Output per unit of land cropped} \left(\text{US\$}/_{\text{ha}}\right) = \frac{\text{SGVP}}{\text{Irrigated cropped area}} - - - - - (6)$$

$$\text{Output per unit command area} \left(\text{US\$}/_{\text{ha}}\right) = \frac{\text{SGVP}}{\text{command area}} - - - - - - - - - - (7)$$

$$\text{Output per unit of irrigation supply} \left(\text{US\$}/_{\text{m}^3}\right) = \frac{\text{SGVP}}{\text{Diverted irrigation supply}} - - (8)$$

$$\text{Output per unit of water consumed} \left(\text{US\$}/_{\text{m}^3}\right) = \frac{\text{SGVP}}{\text{Volume of water consumed by ET}} \quad (9)$$

Where, SGVP is the output of the irrigated area (US$) in terms of gross or net value of production measured at local or world prices. Irrigated cropped area (ha) is the sum of areas under crops during the time period of analysis. Command area (ha) is the nominal or design area to be irrigated. Diverted irrigation supply (m^3) is the volume of surface irrigation water diverted to the command area, plus net removals from groundwater. In our case, groundwater contribution was not taken into account. Volume of water consumed by ET (m^3) is the actual evapotranspiration of crops. ET was calculated with following equation (Doorenbos and kassam, 1986):

$$ET = K_c * ET_o \text{ ------------------------------- } (10)$$

Where, ET_o is reference evapotranspiration (mm) were calculated with Cropwat 8 program (FAO, 1992) and K_c is the crop coefficient developed for the main crops using FAO guidelines (Doorenbos and Kassam, 1986) and adjusted for regional conditions (Sener, 2004). Volume of water consumed (m^3) was calculated multiple of each ET values with their cultivated area.

Standardized Gross Value of Production (SGVP) is developed for cross-system comparisons regardless of where they are or what kinds of crop are grown. SGVP was calculated as described in Molden *et al.* (1998).

$$SGVP = \left(\sum_{crops} (A_i\, Y_i)\frac{P_i}{P_b}\right)P_{world} \text{ ----------------------- } (11)$$

Where, A_i is the area cropped with crop i (ha), Y_i is the yield of crop i (kg/ha), P_i is the local price of crop i (US$/kg), P_b is the local price of the base crop (the predominant locally grown and internationally traded crop) (US$/kg), and P_{world} is the value of base crop traded at world prices (US$/kg).

Water use performance- Two types of indicators, relative water supply (RWS) and relative irrigation supply (RIS) were used for evaluation of water use performance (Levine, 1982 and Perry, 1996):

$$\text{Relative water supply} = \frac{\text{Total water supply}}{\text{Crop water demand}} \text{ ----------------- } (12)$$

$$\text{Relative irrigation supply} = \frac{\text{Irrigation supply}}{\text{Irrigation demand}} \text{ ---------------- } (13)$$

where, total water supply (m^3) is diverted water for irrigation plus rainfall, crop water demand (m^3) is the potential crop evapotranspiration (ET_p), or the real evapotranspiration (ET_c) when full crop water requirement is satisfied. Irrigation supply (m^3) is surface diversions and net groundwater drafts for irrigation, irrigation demand (m^3) is the crop ET minus effective rainfall. Irrigation requirement and net crop water requirement calculated by Cropwat 8 program (FAO, 1992). The reference evapotranspiration (ET_o) is calculated on a monthly basis using the Penman-Monteith (Allen *et al.*, 1998). The monthly value of effective rainfall (P_e) was calculated using the US Bureau of Reclamation's method (Smith, 1992). RWS and RIS values indicate whether there is an adequate supply done or not to cover the demand.

Discharge determination- In both schemes the discharges of irrigation water diverted from the schemes were determined by volumetric method (float method). The diversion at Shina-Hamusit was cleaned and completely opened at the beginning of October 2012/13 and at Selamko started at September 2012/13. To calculate the total amount of water diverted to the total irrigated areas within a season, the total flow time of irrigation water in the main canal were recorded and multiplied by the respective discharges.

Physical performance- Physical indicators are related with the changing or losing irrigated land in the command area by different reasons. It was calculated using the equation (vermillion, 2000):

Cropping intensity- is an indicator used to assess the degree to which irrigated crops are grown in the command area. It is determined as:

$$\text{Cropping intensity} = \frac{\text{annualy cropped area}}{\text{cultivable area}} \text{ -------------- } (14)$$

More intensified cropping is indicative of more utilization of the available land resources for crop production. It is also related to availability of water for irrigation. In areas where irrigation water is scarce, values less than 100% are apparent; while in areas with excess water resources, much higher values are possible. In the current study, actual cropped area was determined for the agricultural year 202/13 from the local agricultural office which was also supplemented by field interviews with sample farmers.

$$\text{Irrigation ratio} = \frac{\text{Irrigated land}}{\text{Irrigable land}} \text{ ------------------------ } (15)$$

$$\text{Sustainability of irrigable land} = \frac{\text{Irrigated land}}{\text{Initial irrigated land}} \text{ -------------- } (16)$$

Where, irrigated land (ha) refers to the portion of the actually irrigated land (ha) in any given irrigation season. Irrigable land (ha) is the potential scheme command area (Vermillion, 2000).

Economic performance- Economic indicators deal with how much fee collected from water user, yearly maintenance and operation expenditure and whether system self–sufficient or not. The economic performance indicators used in the evaluation were calculated using the following equation (Vermillion, 2000):

$$\text{The effectiveness of fee collection (EFC)} = \frac{\text{Collected fee}}{\text{Total fee}} ----------- (17)$$

$$\text{Financial self} - \text{sufficiency (FSS)} = \frac{\text{Annual fee revenue}}{\text{Total Annual expenditure}} --------- (18)$$

where, effectiveness of fee collection represents how portion of fee collected from water users whereas financial self-sufficiency represents the collected fee from water users either sufficient or not sufficient for operation-maintenance (O-M) cost in each year.

III. RESULTS AND DISCUSSIONS

Assessment of the performance of Shina-Hamusit and Selamko community-managed irrigation systems were evaluated using comparative indicators to assess the external performance.

Comparative Performance Indicators

Performance of the Scheme was evaluated using some selected comparative indicators, classified into four groups, namely, agricultural, economic, water-use, and physical performance by International Water Management Institute (IWMI) (Molden *et al.*, 1998).

Agricultural performance- Twelve main crops in Shina-hamusit and ten in Selamko scheme were taken into account among which rice and potato was taken as the base crop, respectively because they were the most tradable and cultivated crop. The irrigated area in Shina-hamusit is 100.5 ha and total command area is 105 ha. While in Selamko the irrigated area is 59.13 ha and the command area is 63 ha. The area allocation for each crop, intensity, productivity and SGVP values were calculated for the two schemes for the year 2012/13 by local prices (Table 1 & 2). Standardized SGVP were calculated for different units (Table 3).

Table 1 Crop area allocation, productivity and SGVP values of different crops by 2012/13 local prices in Shina-hamusit Scheme

Crop type	Area, ha	Intensity, %	Annual area, ha	Annual area, %	Productivity, ton/ha	Total Production, Ton	Price, US$/ton	SGVP (US$)
(1)			(2)		(3)	(4)=(2)x(3)	(5)	
Maize	40	117	46.6	32	6	280	1045	292182
Potato	12	100	12	8	8.7	104	285	29754
Sweet potato	13	158	20.55	14	7	144	190	27332
Onion	15	100	15	10	8	120	285	34200
Oat	7	201	14.1	10	4	56	3610	203604
Teff	3.5	100	3.5	2	1.4	5	2660	13034
Vetch	6.5	100	6.5	5	7	46	570	25935
Tomato	3.5	100	3.5	2	30	105	950	99750
Barely			7.1	5	2	14	855	12141
Vetch			6.5	5	3	20	342	6669
Garlic			5	4	9	45	2850	128250
Cabbage			3.6	3	12	43	950	41040
Total	**100.5**		**143.95**	**100**		**982**		**913,891**

Table 2 Crop area allocation, productivity and SGVP values of different crops by 2012/13 local prices in Selamko Scheme

Crop type	Area, ha	Intensity, %	Annual area, ha	Annual area, %	Productivity, ton/ha	Total Production, Ton	Price, US$/ton	SGVP (US$)
(1)			(2)		(3)	(4)=(2)x(3)	(5)	
Potato	34.88	109	38.13	57	8	305	380	61000
Garlic	1.5	133	2.00	3	9	18	2850	27000
Maize	1.25	100	1.25	2	1.6	2	950	1000
Barley	12	100	12.00	18	2	24	855	10800
Bean	0.25	100	0.25	1	1.6	1	1045	220
Carrot	0.5	250	1.25	2	16	20	1900	20000
Shallot	0.75	183	1.38	2	8	11	3040	17600
Onion	6.5	119	7.75	11	12	93	3040	148800
Pepper	0.75	100	0.75	1	7	5	475	1313
Lentil	0.75	100	0.75	1	3	2	665	788
Cabbage			1.75	2	12	21	950	10500
Total	**59.13**		**67.25**	**100**		**502**		**299,020**

Agricultural performance indicators for the two schemes are shown in Table 3. The results of performance with respect to both land and water productivity indicate that Shina-Hamusit scheme performs better. Higher land productivity values at Shina-Hamusit are mainly due to the improved irrigation management in the scheme. This was also attributed to the cropping intensities and the type of crop grown in each area. The cropping intensity of Selamko (94%) was lower than Shina-Hamusit (137%). SGVP per command area is much lower than the other indicators are because of low cropping intensity (Şener, *et al*., 2007).

Although the amount of irrigation water supplied with respect to demanded is a bit higher at Shina-Hamusit, the water productivity values are still higher at this scheme. The differences are attributable to the cropping patterns and the abilities of farmers and system manager (Şener, *et al*., 2007). The reasons could be also attributed to other agricultural factors such as soil fertility and land suitability rather than purely water management.

Table 3 Agricultural indicators for Shina-Hamusit and Selamko schemes

Schemes	Output per unit land cropped (US$/ha)	Output per unit command area (US$/ha)	Output per unit irrigation water diverted (US$/m^3)	Output per unit water consumed (US$/m^3)
Shina-Hamusit	6,349	8,704	0.95	1.46
Selamko	4,446	4,746	0.62	1.15

Water use performance- Two indicators, Relative Water Supply (RWS) and Relative Irrigation Supply (RIS) were used in the evaluation of water use performance. The net crop water requirement (CWR) and the net irrigation requirement (IR) were computed for each irrigated crop for the 2012/13 cropping season (Oct-Apr) for Shina-Hamusit and (Sept-May) for Selamko. The crop coefficients provided with CropWat 8 computer program were used (input: planting dates and growth length in days) to calculate the crop water requirement at each growth stage. For Shina-Hamusit and Selamko the results of the computer program are presented in Table 4 and Table 5, respectively.

Table 4 Results of CWR and IR of Shina-Hamusit irrigation scheme

Crop type	Area, ha	Annual area, ha	Annual area, %	Effective Rainfall, mm/season	Crop water Requirement, mm/season	Irrigation requirement, mm/season
Maize	40	46.6	32	21.3	449.4	428.1
Potato	12	12	8	16.9	365.8	348.9
Sweet potato	13	20.55	14	19	407.8	388.8
Onion	15	15	10	41.1	530.3	489.2
Oat	7	14.1	10	28.3	463.2	434.9
Teff	3.5	3.5	2	36.2	363.3	327.1
Pepper	6.5	6.5	5	75.6	346.3	270.7
Tomato	3.5	3.5	2	75.9	417.6	341.7

Barely	-	7.1	5	41	391.7	350.7
Vetch	-	6.5	5	93.5	322.4	228.9
Garlic	-	5	3	45.7	459.3	413.6
Cabbage	-	3.6	2	39.2	563.5	524.3
Total	**100.5**	**143.95**	**100**	**533.7**	**5,080.6**	**4,546.9**

Table 5 Results of CWR and IR of Selamko irrigation scheme

Crop type	Area, ha	Annual area, ha	Annual area, %	Effective Rainfall, mm/season	Crop water Requirement, mm/season	Irrigation requirement, mm/season
Potato	34.88	38.13	57	66.3	376.80	310.50
Garlic	1.5	2.00	3	99.8	417.50	317.70
Maize	1.25	1.25	2	66.0	408.40	342.40
Barley	12	12.00	18	179.4	410.60	231.20
Bean	0.25	0.25	1	40.3	263.50	223.20
Carrot	0.5	1.25	2	73.4	308.90	235.50
Shallot	0.75	1.38	2	59.1	351.50	292.40
Onion	6.5	7.75	11	99.8	460.10	360.30
Pepper	0.75	0.75	1	221.5	605.90	384.40
Lentil	0.75	0.75	1	100.9	431.70	330.80
Cabbage	-	1.75	2	157.3	501.20	343.90
Total	**59.13**	**67.25**	**100**	**1164**	**4,536**	**3,372**

Table 6 Water use indicators of the two schemes

Parameters	Shina-Hamusit	Selamko
Total rainfall, m^3	212,758.1	318,966.75
Total water diverted/ Irrigation supply, m^3	752,400	165,888
Total water supply, m^3	965,158	484,855
Crop water demand, m^3	623,836.12	259,174.78
Irrigation demand, m^3	576,303.82	203,585.92
Annual RWS	1.55	1.87
Annual RIS	1.31	0.81

The values of RWS and RIS in Table 6 are after accounting for the losses in the canal conveyance and distribution systems. RWS and RIS values were calculated as 1.55 and 1.31, and 1.87 and 0.81 at Shina-Hamusit and Selamko respectively, excess water supply and irrigation supply is supplied at both schemes. The difference vales between RWS and RIS are due to rainfall in both schemes. The RIS results indicated that excess irrigation water is supplied at Shina-Hamusit than Selamko, but in both schemes there is not a constraining water availability situation during the 2012/13 irrigation season for total demand. The low value of RIS (0.81) at Selamko is not considered as a problem rather the water user considered as rainfall supply, and is due to rainfall. It is better to have RIS close to 1 than a higher or lower value (Molden *et al*, 1998).

The water users give less attention to water saving issues and waste significantly large amount of water resources at Shina-Hamusit than Selamko. Farmers feel that excess irrigation water application would result in increased yield, and divert the water to the schemes as long as it is available. Lack of sound irrigation scheduling, lack of knowhow on actual crop water requirements, etc. 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 the crops in the schemes are satisfied. Similar results were also obtained from many researches around the world (Ray *et al*., 2002; Bandara, 2003). These values also imply relationship between the water supply and crop water demand was poor from the point of water distribution in the schemes (Şener, *et al*., 2007).

Physical indicators- Three physical indicators were used: irrigation ratio, sustainability of irrigation and cropping intensity. Data related to area of the land at the schemes is shown in Table 7.

Table 7 Data related to areas of land at the schemes

Parameter	Shina-Hamusit	Selamko
Currently irrigated land, ha	100.5	59.13
Irrigable (cultivable) land, ha	105	63
Initial irrigated land, ha	32.5	28

Annual area irrigated, ha	144	67.25
Cropping intensity, %	137	107
Irrigation ratio	0.96	0.94
Sustainability of irrigated land	3.09	2.11

The values of physical indicators for the two schemes are shown in Table 7. The Shina-Hamusit scheme, a value of 137% is reasonably good, while for Selamko a value of 94% is indicative of less utilization of the cultivable land for irrigated agriculture. Burton *et al*. (2000) state that cropping intensity values from 100% to 200% are considered good, while an inferior number is judged low.

Irrigation ratio has also more or less similar purpose as that of 'cropping intensity' however this indicator considers only the area irrigated in one cropping season and not the cropping area on the same plot of land in a year. The irrigation ratio values of Shina-Hamusit and Selamko schemes show that 96% and 94% of the irrigable land has been irrigated, respectively. These values indicate that both schemes have a better performance. Sustainability of irrigation is indicative of whether the area under irrigation is contracting or expanding with reference to the nominal area initially developed. While the area under irrigation is expanding since its development in both schemes (Table 7).

Financial self sufficiency- Financial self-sufficiency indicates the revenue from the irrigation over the expenditure for operation and maintenance. The government covers the operation and maintenance of the Shina-Hamusit irrigation scheme and it is considered as subsidy; and currently at Selamko there is no water fee. The financial data used to calculate some of the parameters in this study was not documented, audited and checked by the responsible government offices. Therefore it is not possible to compare these schemes based on this indicator.

IV. CONCLUSIONS

In this study, the external performance of two community-managed irrigation schemes:

Shina-Hamusit and Selamko were assessed using comparative indicators. This indicators used are useful to evaluate the degree of utilization of resources such as land and water in producing agricultural outputs.

The comparative indicators used are agricultural, water use (supply) and physical financial. The results of performance with respect to both land and water productivity indicate that Shina-Hamusit scheme performs better. Higher land productivity values at Shina-Hamusit are mainly due to the improved irrigation management in the scheme and cropping intensity. Although the amount of irrigation water supplied with respect to demanded is bit higher at Shina-Hamusit, the water productivity values are still higher at this scheme. The differences are attributable to other agricultural factors such as soil fertility, land suitability and the cropping patterns rather than purely water management. RWS and RIS values were above 1 at Shina-Hamusit and Selamko (except RIS at Selamko (0.81)), respectively, excess water supply and irrigation supply is supplied at both schemes except RIS (0.81) at Selamko. The difference between RWS and RIS values are due to rainfall in both schemes. The RIS results indicated that excess irrigation water is supplied at Shina-Hamusit than Selamko, but in both schemes there have not a constraining water availability situation. Generally the RWS and RIS values alone in this study indicate that water demands of the crops in the schemes are satisfied. These values also imply relationship between the water supply and crop water demand was poor from the point of water distribution in the schemes.

- System manager should a yearly water budge plan that includes total and seasonal water requirement according to the crop pattern and farmer petition in the scheme area.

There is collection of water fee at Shina-Hamusit while at Selamko now there is no water fee, and this fee is not audited and documented by Woreda office (government officials). Water users at Selamko are responsible for the overall water management including maintenance of the main diversion and now they have not paid irrigation water fee since 2010/11. The reasons for this may be listed as follow: i) water fee is not collecting according to the used water amount by farmers, ii) weak committee iii) delay of payments by the farmers. Contradict to this, the collection of water fee will help for operation and maintenance and other managerial activities of the irrigation systems.

- Therefore for the successful fee collection the suggested solutions maybe i) institutional reforms for water management, ii) install of volumetric measurement, iii) taking of fee before irrigation and investment in infrastructure. Generally, institutional reforms for water management at the scheme are essential. The water users association (WUA) would have to be strengthened and capacitated through training for efficient water management and government should be enforce pricing policies.
- Comparative indicators are very good estimator and indicator of performance of irrigation projects as a whole but full, **reliable and consistent documentation system is a must**. And this type of study has to be adopted and practiced on some other small-scale irrigation projects in the country.

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APPENDICES

Appendix Table 1 Monthly climatic data and ET_o of Shina-Hamusit irrigation scheme

Country: Ethiopia Station: Bahir Dar
Altitude: 1920 meter(s) above m.s.l.
Latitude: 11.49 ^oC (North) Longitude: 37.31 ^oC (East)

Month	Min Temp, ^oC	Max Temp, ^oC	Humidity (%)	Wind Spd. (Km/d)	Sunshine (Hours)	Solar Rad. ($MJ/m^2/d$)	ET_o (mm/d)
January	8.6	26.8	50.3	0.7	9.4	20.2	2.98
February	10.4	28.5	44.7	0.7	9.7	21.9	3.39
March	12.8	29.7	42.5	0.9	9.1	22.5	3.74
April	15.0	30.1	42.9	1.0	9.0	23.4	4.06
May	15.5	29.4	52.2	0.9	8.4	22.4	4.03
June	14.9	27.0	66.5	0.9	6.9	19.7	3.65

July	14.2	23.9	76.0	0.8	4.5	16.0	3.00
August	14.1	24.3	82.5	0.7	4.6	16.3	3.10
September	13.4	25.4	72.5	0.7	6.4	19.2	3.49
October	13.5	26.5	60.9	0.7	8.6	21.9	3.80
November	11.3	26.6	54.5	0.7	9.4	21.6	3.46
December	9.0	26.5	50.8	0.6	9.8	20.9	3.09
Average	12.7	27.0	59.1	0.8	8.0	20.5	3.48

Pen-Mon equation was used in ET_o calculations with the following values for Angstrom's Coefficients: a = 0.25 b = 0.5

Appendix Table 2 Monthly rainfall data of Bahir Dar station

Month	Total Rainfall(mm/month)	Effective Rain(mm/month)
January	2.0	2.0
February	1.9	1.9
March	10.5	10.3
April	27.6	26.4
May	68.7	61.1
June	189.0	131.8
July	421.9	167.2
August	390.7	164.1
September	195.9	134.5
October	90.3	77.3
November	13.2	12.9
December	2.3	2.3
Total	1414.0	791.8

N.B. Effective rainfall calculated using the USSCS formulas:
Effective R. = (125 - 0.2 * Total R.)* Total R. / 125 (Total R. < 250 mm/month),
Effective R. = 0.1 * Total R. – 125 (Total R. > 250 mm/month).

Appendix Table 3 Monthly climatic data and ET_o of Selamko irrigation scheme

Country: Ethiopia Station: Debre Tabor
Altitude: 2500 meter(s) above m.s.l.
Latitude: 11.53 ^oC Deg. (North) Longitude: 38.02 ^oC Deg. (East)

Month	Min Temp, ^oC	Max Temp, ^oC	Humidity (%)	Wind Spd. (Km/d)	Sunshine (Hours)	Solar Rad. ($MJ/m^2/d$)	ET_o (mm/d)
January	8.2	23.0	39.2	1.1	8.6	19.1	2.70
February	9.4	24.5	35.9	1.2	8.6	20.3	3.04
March	10.2	25.0	33.3	1.2	7.2	19.7	3.14
April	10.4	24.6	43.0	1.3	6.9	20.1	3.42
May	10.1	24.1	46.9	1.1	4.8	16.9	3.00
June	10.4	22.0	68.4	1.2	6.0	18.3	3.22
July	9.8	19.1	80.7	1.1	4.2	15.5	2.76
August	10.0	19.8	97.4	1.2	5.2	17.2	3.11
September	9.4	20.6	74.2	1.1	6.3	19.0	3.29
October	8.5	21.8	58.8	0.9	7.5	20.3	3.31
November	8.0	22.3	49.9	0.9	8.0	19.6	2.99
December	7.0	20.3	43.2	1.0	8.9	19.7	2.69
Average	9.3	22.3	55.9	1.1	6.9	18.8	3.06

Pen-Mon equation was used in ET_o calculations with the following values for Angstrom's Coefficients: a = 0.25 b = 0.5

Appendix Table 4 Monthly rainfall data of Debre Tabor Station

Month	Total Rainfall (mm/month)	Effective Rain (mm/month)
January	14.5	14.2
February	5.6	5.5
March	29.8	28.4
April	51.4	47.2
May	96.2	81.4
June	172.1	124.7
July	421.0	167.1
August	444.0	169.4
September	197.5	135.1
October	49.7	45.7
November	23.2	22.3
December	6.4	6.3
Total	1511.2	847.4

N.B. Effective rainfall calculated using the USSCS formulas:
Effective R. = (125 - 0.2 * Total R.)* Total R. / 125 (Total R. < 250 mm/month),
Effective R. = 0.1 * Total R. – 125 (Total R. > 250 mm/month).