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Performance Evaluation of Small Scale Irrigation System in Case of Degero and Gura Daso, Nejo District, West Wallaga, Oromia, Ethiopia

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Abstract: Performance evaluation is a practical tool to examine the achievement of irrigation management in the scheme to meet the growing food demands of the population and make viable water distribution for schemes. Therefore, this study was conducted to assess the performance of small-scale irrigation schemes using water use (input-related) physical and main output-related irrigation performance indicators from the long list of irrigation performance indicators, by using Degero and Gura Daso small-scale irrigation as a case study. This research was carried out starting from January 2022 for the irrigation season. In this study, primary and secondary data were gathered and engaged for the study purpose. For data analysis and manipulation activities, CROPWAT 8.0, GIS, Climwat2 software, and Statistical tools were employed. Then, the schemes were evaluated using groups of performance indicators such as water use, and physical and agricultural outputs. The results obtained showed that the values of relative water supply and irrigation supply were 1. 36 and 2.28 for the Degero scheme, whereas 1.16 and 2.06 for the Gura Daso scheme, respectively. This water use performance indicator shows that there was excess supplied water relative to the demand and it's possible to increase irrigation area by effective utilization of water. Physical indicators such as irrigation ratio, sustainability of the irrigated area, and the effectiveness of infrastructure showed 0.25, 0.42, and 0.4 for the Degero Scheme, 0.57, 1.33, and 0.8 for the Gura Daso scheme, respectively. Also, the values of the output per cropped area were 3084.2 and 3847.4US$, ha. Similarly, the output per unit irrigation diverted water was 0.41 and 0.69 US$, ha for Degero and Gura Daso schemes, respectively. The output per command area was 1542.1 and 4394US$, m^3 for the Degero and Gura Daso schemes, respectively. Likewise, the output per unit of water delivered and water consumed was 0.53, 0.83, and 0.73, 0.86 US$ for the Degero and Gura Daso schemes respectively. As the result showed, the Degero scheme was less performed relative to the Gura Daso scheme. Generally, in both schemes, the currently irrigated area was less than the designed command area. In the end, the following ideas were recommended: Water diversion and conveyance efficiencies in the Degero scheme are very low. Therefore, the diversion and conveyance system should be improved through the maintenance of broken irrigation infrastructures, especially sluice gates at head works and flumes at secondary canals.

Keywords: SSI Scheme, Performance, Efficiency, Water, Land, Output, Irrigation, Indicator

1. Introduction

Water is a necessity for life and is a substance significantly required. Each living thing wants it at various scales and for diverse needs. Human beings need water for their domestic, agricultural, and industrial purposes [1]. Water is an important asset for rural development; both shortage and mismanagement of water pose a serious and developing threat to life and practical advancement. As water is a constraining figure in most of the world, expanding yield and maintaining food production depends basically on irrigation [2]. In this manner, security and improvement of water resources are fundamental for irrigation facilities. With the expanding population and request for nourishment, sustainable production increase from irrigated agriculture must be accomplished. With limited freshwater and land resources and increasing competition for those resources, irrigated agriculture around the world must create its utilization of these resources [3]. Irrigation practice is one of the critical variables that play a major part in the financial improvement of numerous countries [4]. Similar to countries within the different portions of the world, the majority of the population of Ethiopia is dependent on rain-fed agricultural production for their source of income [5]. However, estimated crop production is not sufficient to fulfill the nourishment necessities of the country because it is practiced through rain-fed agriculture. In this manner, irrigation practice in different scales (i.e. small, medium, or large) and types (i.e. diversion, storage, gravity, or pumped) has been getting profound centering in logical investigation [6]. Irrigated agriculture needs successful administration as compared with rain-fed farming. The water system advancement has a coordinated connection with the development and the work of the irrigation plot. However, the water system execution of developing nations like our country Ethiopia is not to the expected standard. Some researchers have conducted execution issues of water system practices in Ethiopia and concluded that most small-scale water system plans have low beneficial capacity [7]. Performance assessment could be a key component of execution management. Performance evaluation of an organization covers a more extensive extent of performance indicators. For the most part, IWMI created two types of indicators to assess irrigation frameworks: process (inside), and comparative (outside), indicators [8].

The aim of applying comparative indicators is to assess yields and impacts of irrigation administration practices, interventions over different systems and framework levels, as well as to compare different irrigation seasons and technologies with one another whereas process indicators are utilized to survey actual irrigation execution relative to the system's particular management objectives and operational target [9]. Evaluating and improving the performance of the existing schemes is an attractive way for sustainable development and is used as a benchmark or point of entry for further irrigation development. The performance assessment is seen as the information framework that advances the execution management process successfully and productively [10]. It gives different partners (system directors, farmers, and arrangement producers) a much better understanding of how a system works. It is also, utilized to decide issues and identify ways and means of improving framework execution. Performance assessment could be a viable apparatus to look at the accomplishment of irrigation management at the scheme to meet the developing food requests of the populace and make practical water distribution for schemes [11].

Hence, this study was conducted to survey the execution of small-scale irrigation schemes utilizing water use (input-related), physical, and main output-related irrigation performance indicators from the long list of irrigation execution indicators by using Degero and Gura Dasso small-scale irrigation.

2. Materials and Methods

2.1. Location and Description of the Study Area

Degero and Gura Daso small-scale irrigation project is located in Nedjo woreda, west Wallaga zone of Oromia regional state. It is geographically located between 9º35´00´´and9º45´00´´ N latitude and 35º12´00´´ and 35º30´00´´ E Longitude and has an elevation of 1,821 m.

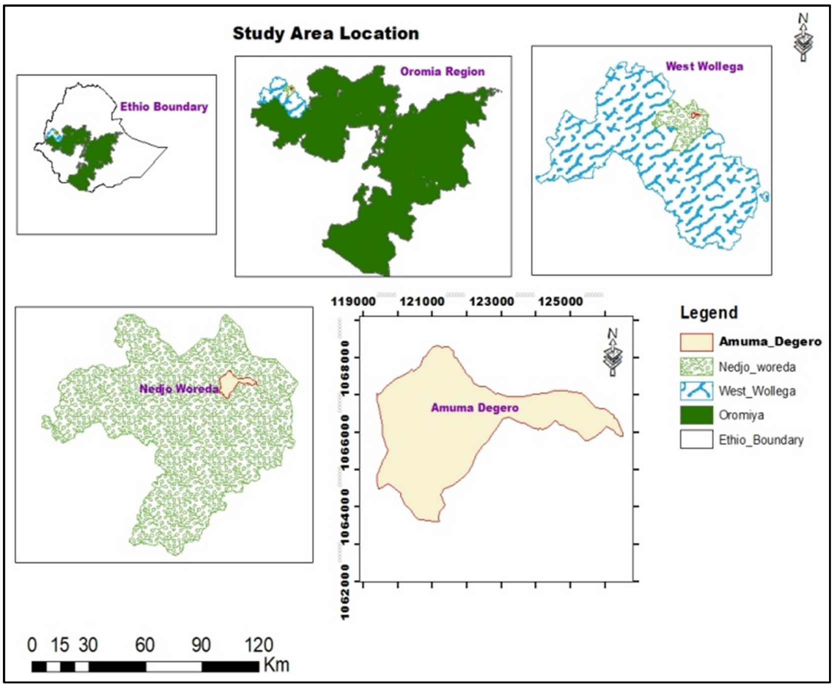

Figure 1. *Location map of the study area.*

2.2. Data Collection and Analysis

For implementing this study, several data were collected primary or secondary data depending on the assessment of efficiency and productivity of the area. This data were collected by using different techniques literature surveys, field survey, formal group discussion, informal group discussion, and through questioner survey to get available real-time data to cover the study period.

2.3. Data Collection Method

This research was carried out starting from January 2022 of the irrigation season. In this study, primary and secondary data have been gathered and engaged for the study purpose. For field data collection and measurement purposes; a Double-ring infiltrometer, Auger, Tape Meter, stopwatch, camera, and sensitive balance were used during the study period.

2.4. Primary Data Collection

The collection of field data including the measurement of canal inflow and collection of soil samples from the different parts of the farm for determination of soil textural classes, soil moisture content, and specific gravity. This Primary data collection will include field observation to observe and investigate the method of water application and practice related to the water management technique of stakeholders. Also, the layout and geometry of the physical features of the canal were collected. The data collection was carried out by coordinating with the irrigation Engineer, canal operator, and another stakeholder of the irrigation project.

2.4.1. Soil Sampling

The collection of the soil sample is done from three places of the farm depending on the root zone depth of the crop at the upper, middle, and dawn of the farmland before and after irrigation from each scheme for determination of soil physical properties; soil texture, Total moisture content, Field capacity (FC) and Permanent Wilting Point (PWP).

For the determination of soil textural class two composite soil samples at the specified depths were taken at each stratum (head, middle, and tail).

For the determination of the overall available water (TAW) amount in the soil; the field capability (FC) and permanent wilting point (PWP) of the soil were decided by using taking composite soil samples from each stratum. The investigation was carried out through a pressure plate device in the laboratory. The total accessible soil moisture for the plant is between FC and PWP. The magnitude of the overall accessible moisture is a work of soil surface and structure and shows the capacity of the soil to have water extricated by the plant. TAW is the total amount of water a crop can extract from its root zone. Before a wilting point is reached, a plant is already suffering from water stress. Readily available water (RAW) uses the fraction (P) of the total saturation that can be safely removed before stress occurs. Based on soil parameters of textural class, FC, PWP could specify the value of depletion fraction (P) from FAO recommendations.

2.4.2. Soil Infiltration Rate

The soil infiltration rates of the two schemes were characterized by utilizing a double-ring infiltrometer device. Penetration is the process of the section of water downwards from the air medium to the soil, or from the soil surface into the soil medium. This phenomenon has a greater practical importance in irrigation and rain-fed farming systems. Infiltration characteristic of the soil is one of the dominant variables influencing irrigation application. When adequate water is connected and maintained at atmospheric pressure, the flux (i.e. the volume of water passing through a unit cross-sectional zone per unit time) flowing into the soil profile is termed as infiltration rate. The infiltration rate is very fast at the beginning of water application, but it decreases quickly with the progress of time and eventually approaches to steady value. The consistent infiltration rate that reaches after a few passed times from the beginning of irrigation is named the essential infiltration rate. This value, basic infiltration rate, was used as input data for the CROPWAT 8.0 model, for the computation of crop water and irrigation requirements.

2.4.3. Water Flow Rate Measurement

Water flow rate estimation could be important information for irrigation scheme execution assessment activities, and computation of conveyance efficiency and losses [12]. There are diverse methods to measure the flow of water within the rivers, and canals. For this study floating method is used. For the floating method to determine the canal flow, equipment such as a floating ball, meter stopwatch, and Ruler is used. For the Degero SSI scheme, the main canal does not have much length since it's divided into two secondary canals at a short (100m) distance from the diversion head. So the measurement is taken from the inlet of the inlet canal and a distance of 100m. i.e. at the place it's divided into two secondary canals and for the secondary canal, the measurement is taken at the inlet and at the place where it reaches to command area.

For the Gura SSI scheme, the measurement is taken at the inlet and outlet of the canal for determination of actual discharge. During the measurement of canal discharge for both schemes, at least three trials are done. i.e. T1, T2, and T3 [13].

$$Q = AV \tag{1}$$

Where V=L/T

L-floating length

T-Time to travel given length

A= cross-sectional area

2.4.4. House Hold Survey and Key Informant Interviews

Issues related to production frameworks, organizations, community-level issues, and experiences have been collected through questionnaires, key informant interviews, and focus group discussions.

2.5. Sampling Techniques

Totally 230HHs (150 HHs in Degero and 70 HHs in Gura Daso) beneficiaries have been used as a sample frame/population/ for the determination of sample size. [9] Discovered a simplified formula to calculate sample sizes.

$$n = \frac{N}{1+N(e)^2} \quad (2)$$

Where
n= Sample size,
N= Population size/sample frame,
e= Level of precisions

For this study the calculation has been carried out through using 95% confidence interval
(α=5%), 10% precision level and 50% degree of variability (P).

$$n = \frac{220}{1+220(0.1)^2} = 69\text{HHs}$$

2.6. Secondary Data Collection

For both (the Degero and Gura Daso) SSI schemes the long time average climatic data of mean monthly minimum and maximum temperature and rainfall were collected from the Nejo meteorological station and the remaining data of relative humidity, wind speed, and sunshine hours were generated from CLIMWAT 2 software. Additional secondary data on total command area, irrigable area, irrigated area, crop yield, and price were collected from Woreda and Zonal agricultural experts, Design documents, and from respective stakeholders.

2.7. Data Analysis Techniques

For data analysis and manipulation activities CROPWAT 8.0, GIS, SPSS, Climwat2 software, and Statistical tools were employed. Finally, the selected performance indicators were computed.

2.8. Determination of Crop Water and Irrigation Water Requirement

Determination of Crop Water and Irrigation Water Requirement CROPWAT 8.0 computer program was used to estimate the total water requirements of major grown crops in the irrigation schemes. FAO (1992) Penman-Monteith strategy was chosen to calculate the reference crop evaporation (ETo). The program gauges (ETc) are based on the equation recommended by [14].

$$ET_c = ET_o * kc \quad (3)$$

Where; Kc= crop coefficients, changes with a crop developing stages. The value of Kc of each major crop was taken from FAO I & D 24 (1992) and 56 (1998) papers. The determination of irrigation necessity was made after the estimation of effective rainfall by the USDA Soil Preservation Service Strategy [9].

In order to compute the irrigation water requirement, CROPWAT 8.0 computes a daily water balance of the root zone. Computed as [12];

$$IWR = ET_C - Rf_{eff} \quad (4)$$

To estimate the overall crop water requirement at the scheme level, input information of real irrigated range by crop scheme level, input information of real irrigated range by crop sort included. For the determination of the irrigation schedule of the irrigation schemes and to make a comparison with the current irrigation practices; moisture content, field capacity, Permanent wilting point, and depletion fraction at each growing stage data were collected. Farmer's irrigation practices were determined; such as irrigation methods, irrigation frequency and interval of irrigation, and application depths. During the determination of the sum of water connected to the field, the normal water flow rate to the farm channel and individual time was recorded, with the estimate of the areas being irrigated. The whole volume of water applied to the field was obtained by increasing the discharge rate with the inflow time. The depth of water connected to the field was obtained by separating the whole volume of water connected to the zone irrigated. The irrigation intervals at each growth stage of the main grown crops were determined procedurally through equations (1), (2), and (3).

Through the decided irrigation intervals; CROPWAT 8.0 decided the specified depth of applications at each development stage. At last, the irrigation plans of primary crops at both irrigation schemes were determined.

2.9. Performance Indicators

Generally, different groups of performance indicators; Water use performance indicators, agricultural performance indicators, and physical sustainability performance indicators; have been used in this study to assess and compare the performance of the two small-scale irrigation schemes at system levels.

2.9.1. Water Use Performance Indicator

Water distributions of the diverted amount of water at the head to the entire irrigation framework can be measured by water conveyance performances of the existing irrigation infrastructures. I computed the conveyance efficiencies of the main canals and secondary canals for each scheme.

A. Relative Water Supply (RWS)

It is the ratio of total water provided by irrigation (I) and rainfall (P) to total water requested by crop (i.e. Real crop evapotranspiration (ETc) [15].

$$RWS = \frac{Total\ water\ supply}{Total\ crop\ water\ demand} \quad (5)$$

Where;

Total water supply = surface diversion plus effective rainfall (m^3),

Crop water demand = potential ET, or the ET under well-water conditions for each crop (m^3).

B. Relative irrigation supply (RIS)

$$\text{RIS} = \frac{\text{Irrigation water supply}}{\text{Irrigation water demand}} \quad (6)$$

Where;

Irrigation supply = only the surface diversion for irrigation (m^3),

Irrigation demand = the crop ET less effective rainfall (m^3).

2.9.2. Agricultural Performance Indicator

A. Output per cropped area (USA$/ha)

It is computed as the total value of production per harvested area in the irrigation seasons. The harvested /Irrigated/area includes the areas that were irrigated in the irrigation seasons.

$$\text{OPCA (USA\$}/ha\text{)} = \frac{\text{production}}{\text{irrigatedcropped area}} \quad (7)$$

B. Output per unit command (birr/ha)

It is computed as the total value of production per command area in the irrigation seasons.

$$\text{OPUCA}\left(\frac{\textbf{USA\$}}{\text{ha}}\right) = \text{production/command are} \quad (8)$$

Where, OPUCA-Output per unit command

C. Output per unit of irrigation diverted water (birr/m^3)

$$\text{OPUDW} = \text{production/Diverted irrigation supply} \quad (9)$$

Where, OPUDW-Output per unit of irrigation diverted water

D. Output per unit of water delivered (birr/m^3)

It evaluates the value of production per unit delivered irrigation water to the head of farm inlets within the irrigation seasons. It is the net irrigation water delivered to the farm and it does not incorporate losses in transport systems.

$$OPUWD = \frac{production}{Volumeme\ of\ water\ deliverd} \quad (10)$$

Where

OPUWD-output per unit of water delivered

E. Output per unit consumed water (birr/m^3)

$$\text{OPUCW} = \frac{\text{volume of production}}{\text{volume of water consumed by ET}} \quad (11)$$

Where, OPUCW-Output per unit consumed water

Value of Production is the output of the irrigated area in terms of gross or net value of production measured at local or world prices. In this study the production values were decided through local cost and at last it was changed over to US$; to standardize and to compare the results relative to other research discoveries within the world.

2.9.3. Physical Performance Indicators

Under this, two important physical performance indicators were selected to measure the sustainability and irrigation intensities of the systems.

A. Rate of irrigation (Irrigation ratio)

It's computed by the ratio between currently irrigated areas to the command (nominal) area to be irrigated; to quantify the level of utilization of the potential irrigable area for irrigated agriculture for a particular production time period.

$$\text{Rate of irrigation(RI)} = \frac{\text{Irrigated land(ha)}}{\text{Irrigable land}} \quad (12)$$

B. Effectively of infrastructure

It was computed by ratio of functioning structure to total structure [13, 16, 17].

$$\text{EI} = \frac{\text{functioning structure}}{\text{total structure}} \quad (13)$$

3. Result and Discussion

3.1. Soil Textural Class Identification

The soil textural class of both irrigation schemes was determined based on the particle size distribution by using the USDA SCS Soil Textural Triangle method. As stated in Table 1, the soil texture distribution was the same at the Degero irrigation scheme. I found clay soil type in the head and middle of the scheme. However, the sample of soil taken from the tail part at depth (30-60cm) resulted from sandy clay, while the soil sample at depth (0-30cm) is clay type. In the Gura Daso irrigation scheme silt clay soil type was more dominant in the head and middle of the scheme, but silt clay loam was dominant in the tail part of the scheme.

Table 1. *Soil textural class of Degero SSI.*

Irrigation schemes	Canal reaches	Soil depth (cm)	Clay (%)	Silt (%)	Sand (%)	textural classes
Degero SSI	Head	0-30	53.3	13.3	33.3	Clay
		30-60	57.1	14.2	28.5	Clay
	Tail	0-30	46.66	13.33	40	Clay
		30-60	40	13.3	46.6	Sandy clay
Gura SSI	Head	0-30	35.4	41.9	22.6	Silt clay
		30-60	38.7	35.5	25.8	silt clay
	Tail	0-30	20	60	20	silt clay loam
		30-60	20	53.3	26.6	silt clay

3.2. Field Capacity and Permanent Wilting Point

The parameters such as the field capacity, permanent wilting point, and total available water content of the study area soil are presented in Table 2 and vary both in soil depth in the root zone and spatially through command areas.

Table 2. *Soil FC, PWP and TAM of the IS.*

Irrigation schemes	Canal reaches	Soil depth (cm)	FC (%)	PWP (%)	TAM (%)	TAM (mm/m)
	Head	0-30	38.4	23.2	15.2	152
Degero SSI		30-60	40.3	25.4	14.9	149
	Tail	0-30	38	23	15	150
		30-60	40	25.2	14.8	148
Average			39.25	24.1	15.1	151
Gura SSI	Head	0-30	41.5	26	15.5	155
		30-60	44.2	27.5	16.7	167
	Tail	0-30	43.8	28	15.8	158
		30-60	42.9	28.5	14.4	144
Average			43.5	27.9	15.6	156.1

3.3. Determination of Soil Infiltration Rate

The soil infiltration rates of the two schemes were determined by using a double-ring infiltrator meter apparatus. The basic infiltration rate for the Degero SSI Scheme was 2.8 mm/hr, 3.8 mm/hr, and 3 mm/hr at the head, middle, and tail end of the test plot, respectively. The basic infiltration rate for the Gura Daso SSI Scheme was also 6 mm/hr, 5.2 mm/hr, and 5 mm/hr at the head, middle, and tail end of the test plot, respectively.

3.4. Flow Measurements

3.4.1. Degero SSI Scheme Flow Measurement

Table 3. *Flow measurement of Degero SSI.*

Canal	Area of MC m^2		Velocity MC m/s		Discharge of MC (m^3/s)		Discharge of MC (l/s)	
	At inlet	At out let	At inlet	At outlet	At inlet	At outlet	At inlet	At outlet
MC	0.05	0.045	0.58	0.53	0.031	0.024	31	24
SC1	0.07	0.044	0.48	0.47	0.033	0.021	32.7	20.8
SC2	0.05	0.05	0.52	0.5	0.03	0.24	25.5	23.5

Key terms: MC-main canal, SC1-secondary canal 1, SC1-secondary canal 2

3.4.2. Gura Daso SSI Scheme Flow Measurement

Table 4. *Flow measurement of Gura SSI.*

Canal	Area of MC m^2		Velocity MC m/s		Discharge of MC (m^3/s)		Discharge of MC (l/s)	
	At inlet	At out let	At inlet	At outlet	At inlet	At outlet	At inlet	At outlet
MC	0.053	0.045	0.58	0.53	0.031	0.024	31	24

Key terms: MC-main canal

3.5. Rainfall Data Analysis

In the schemes under the study, the minimum and maximum rainfall occurs in the months of December (5mm) and August (350 mm), respectively. While the average total annual rainfall of the study area is 1788 mm, on the other hand, the average total annual effective rainfall amount of the study area is 1003.1 mm.

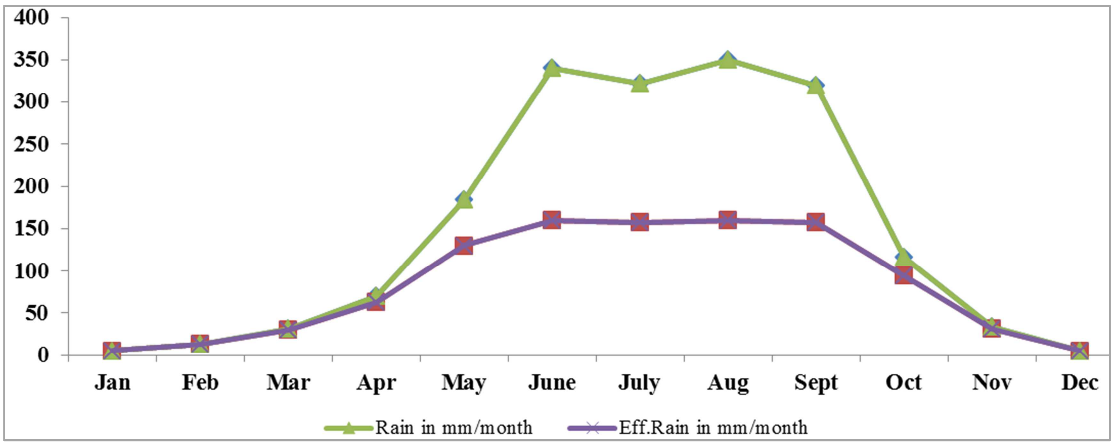

Figure 2. *Rain fall and Effective rain fall Diagram.*

3.6. Determination of Reference Evapotranspiration

***Table 5.** Metrological data and Reference Evapotranspiration.*

Month	Min Temp C°	max Tem C°	Humidity %	Wind speed km/day	Sunshine Hrs	Rad MJ/m²/y	ETo mm/day
January	11.9	27.6	49	95	8.5	19.9	3.96
February	113.4	28.8	49	112	8.5	21.3	4.51
March	14.4	29.2	49	121	3	13.8	3.85
April	14.2	28.7	52	112	8.1	22	4.82
May	13.9	25.7	74	78	2.9	13.7	3.04
June	13.2	23.4	84	69	4.3	15.6	3.02
July	13	21.8	87	104	3.6	14.6	2.75
August	12.8	22.1	86	78	2.5	13.2	2.57
September	12.4	23.3	80	78	5.8	18.1	3.33
October	12.8	24.4	75	104	7	19.1	3.59
November	12.7	24.9	67	104	7.3	18.4	3.53
December	12.1	26.5	57	104	7.9	18.7	3.7

3.7. Determination of Crop Water and Irrigation Water Requirement

Crop Water Requirements were computed by CROPWAT 8.0 software based on climate, soil description, and crop characteristics data.

***Table 6.** Crop water requirement and irrigation requirement of Degero SSI scheme.*

Crop type	Season I				Season I			
	Area in (ha)	ETc in mm/season	Eff.RF mm/seas	IWRmm/se	Area in (ha)	ETc (mm/season)	Eff.RF (mm/seas)	IWR mm/se
Tomato	8.25	517.6	134.9	406.4	5.8	448	495.4	104
Onion	5.4	313.6	120.2	209.7	4.6	331	232.4	143
Cabbage	4.35	457.7	129.4	344.4	3	410	444.1	109
Potato	12	439.2	138	337.9	5.3	451	300.5	218
Maize	-	-	-	-	11	406	274	204

The total crop water demand or requirement for the 2021/22 irrigation seasons of the Degero SSI scheme was computed as: CWR tomato*(Area tomato/Area total) + CWR Onion*(Area onion/Area total) + CWR potato*(Area potato/Area total) + CWR cabbage*(Area cabbage/Area total) + CWR maize*(Area maize/Area total).

The result is 428.03 mm/season for the first cropping season of the scheme. To change the depth of water demand to the volume of CWR multiply it by the total irrigated area and equal to 128,409 m^3 /season. Also, the depth of CWR for the second cropping season of the scheme is 410.97 mm/season and 123,291 m^3/season volume of water was required. On the other hand, the total irrigation requirement of the scheme was also calculated in the same way as the total CWR as stated below:

IWR tomato*(Area tomato/Area total) + IWR Onion*(Area onion/Area total) + etc and the result is 334.59 mm/season i.e. 100,377 m^3/season for the first season and also, 168.3 mm/season of depth, i.e. 50,490m^3/season volume of irrigation was required for second cropping season. To fulfill the irrigation requirement of scheme 172,238.4m^3/season volume of water supply was expected to be delivered at the farm level by irrigation infrastructures. So, it's enough for an actual irrigated area.

***Table 7.** Crop water and irrigation requirement of Gura Daso SSI scheme.*

Crop type	Season I				Season II			
	Area in (ha)	ETc mm/sn	Eff.RF mm/sn	IWR mm/seas	Area in (ha)	ETc (mm/season)	Eff.RF (mm/seas	IWR mm/seas
Tomato	12.5	518.6	131.8	409.5	6.72	459.6	469.4	124.4
Onion	2.4	314.1	116.5	211.8	3.48	341	209.3	159.5
Cabbage	3.7	458.9	125.9	348	2.76	419.9	417.1	122.5
Potato	5.4	443.4	124	350.5	11.1	421	390.8	136.2
Maize	-	-	-	-	-	-	-	-

The total crop water demand or requirement for the 2021/22 irrigation seasons of the Gura Daso SSI scheme was computed as:

CWR tomato*(Area tomato/Area total) + CWR Onion*(Area onion/Area total) + CWR potato*(Area potato/Area total) + CWR cabbage*(Area cabbage/Area total).

The result is 471.69 mm/season for the first cropping season of the scheme. To change the depth of water demand to the volume of CWR multiply it by the total irrigated area and equal to 113206.8 m^3 /season. The depth of CWR for the second cropping season of the scheme is also 420.06

mm/season and 100,814.4 m^3/season by volume of water was required.

On the other hand, the total irrigation requirement of the scheme was also calculated in the same way as the total CWR as stated below:

IWR tomato*(Area tomato/Area total) + IWR Onion*(Area onion/Area total) + etc and the result is 366.92 mm/season i.e. 88,060.8 m^3/season for the first season and 134.68 mm/season of depth, while 32,323.63m^3/season volume of irrigation was required for second cropping season. To fulfill the irrigation requirement of scheme 124416m^3/season volume of water supply was expected to be delivered at the farm level by irrigation infrastructures. So, it's enough for an actual irrigated area. Also, it's required to calculate for total designed command area to determine the overall irrigation requirement of the scheme. So, it was calculated as follows: -

IWR of all crops (Tomato + Onion + Cabbage + potato) * Total command area and the result is 554,316m^3/season. Since the total water supply is less than the total IWR it is not enough for the irrigation scheme. To fulfill the irrigation requirement for the total command area night storage is strongly needed. But the night storage of the scheme does not store water because of seepage, for sustaining this scheme seepage-preventing mechanism such as Asphalt lining, and geo-membrane is needed. Therefore, the summary of the volume of crop and irrigation requirement of both of the schemes was calculated and given in table 8.

Table 8. *The summary of the total volume of CWR and IWR for both schemes.*

Scheme name		Cropped area (ha)	CWRm^3/season	IWRm^3/season
Degero	Season I	30	128,409	100,377
	Season II	30	123,291	50,490
Gura Daso	Season I	24	113206.8	88060.8
	Season II	24	100814.4	32323.63

3.8. Water Use Performance Indicator

The main purpose of water delivery systems is to carry the diverted water from the source to the required area i.e. cropped area. The following indicators, i.e. conveyance efficiency, RWS, and RIS were used as parameters to evaluate and characterize the performance of irrigation projects distinctly and used to see the variation of the indicators spatially through the schemes and between schemes.

3.8.1. Conveyance Efficiency

The results of the flow rate measurement at two reaches for the main canals and one reach for the secondary canal revealed that the conveyance efficiency indicator varied within schemes at different points and spatially between schemes. The overall conveyance efficiency of main canals and secondary canal values at reach two, which indicate the amount of water lost through the canals from the source, of Degero and Gura Daso SSI schemes were found 86.1% and 90.4% per 100m and 400m, respectively.

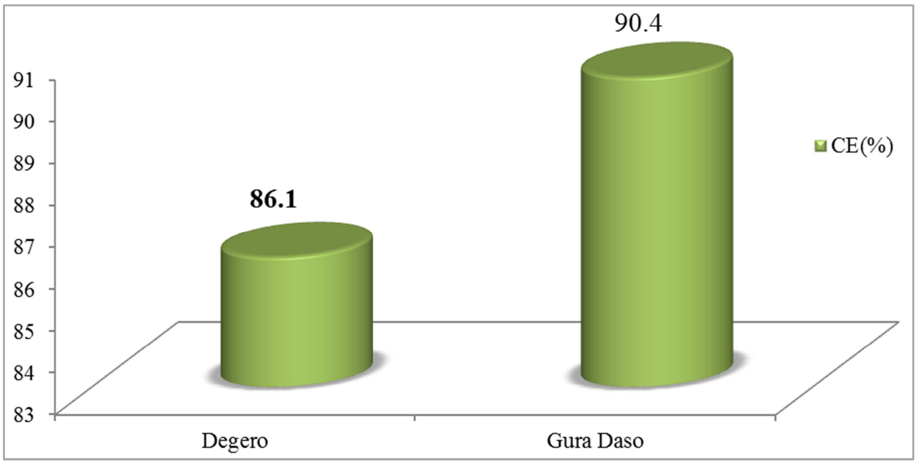

Figure 3. *Conveyance Efficiency of both schemes.*

3.8.2. Relative Water Supply (RWS)

The values of RWS for the Degero and Gura Daso SSI schemes were 1.36 and 1.16, respectively as explained in Figure 4. This value indicated that the supplied water was sufficient for the crop water demand, i.e. neither surplus nor deficit.

3.8.3. Relative Irrigation Supply

This indicator is the ratio of irrigation supply to irrigation demand (total water demand minus effective rainfall) and is determined based on Equation 6. As shown in Figure 4, the relative irrigation scheme values of the Degero and Gura Daso SSI schemes were 2.28 and 2.06, respectively. This value showed that there was sufficient irrigation supply from the scheme head and met the demands of both schemes.

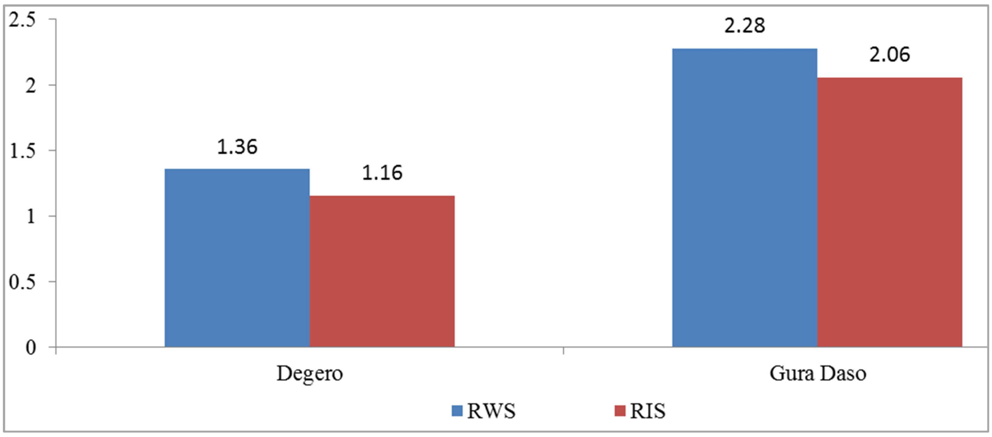

Figure 4. *Water use indicator.*

3.9. Agricultural Output Indicators

The agricultural outputs were computed from two cultivation seasons and the data required includes crop types, area coverage of each crop, average yield, and price of each crop. The output yield value of each crop is based on the soil and crop management, appropriate agricultural technologies applied, and irrigation water supply infrastructures. The major agricultural output performance indicators employed for this study include output per cropped area, output per unit of command area, output per unit of irrigation diverted water, output per unit of water delivered, and output per consumed water [10].

3.9.1. Output Per Cropped Area (US$/Cropped Area)

The results of this indicator were 3084.2 and 3847.4US$/cropped area for the Degero and Gura Daso SSI schemes, respectively. The result showed the output per cropped area was higher in the Gura Daso SSI scheme. This value showed there is more intensive cropping at the Gura Daso SSI Scheme.

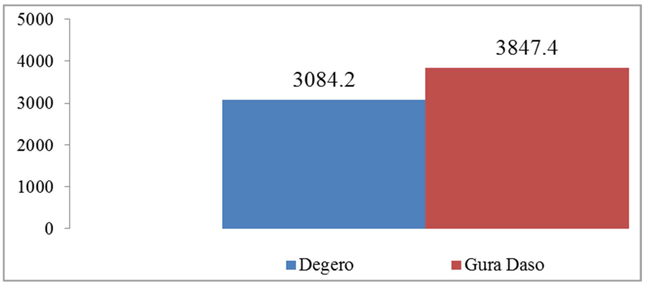

Figure 5. *Output per cropped area of both schemes.*

3.9.2. Output Per Unit of Irrigation Diverted Water (US$/m^3)

The results of this indicator were 0.41 and 0.69 US$/m^3 for the Degero and Gura Daso SSI schemes, respectively. Therefore, the results stated that the output per unit of irrigation water diverted was also higher in the Gura Daso SSI scheme; which means that the Gura Daso Scheme water supply was more productive than the Degero scheme. This is due to the relatively excess supply of irrigation water at the Degero SSI scheme at the head, which results in output per unit irrigation water diverted at a lower value.

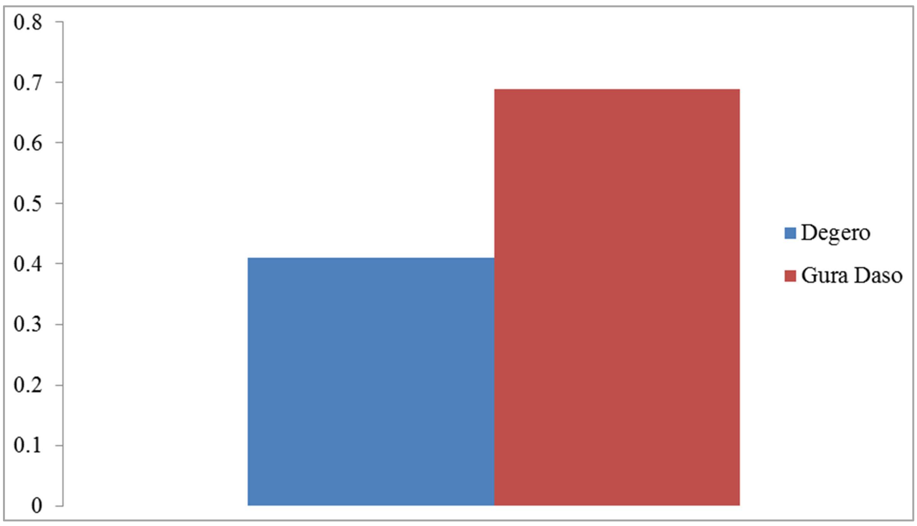

Figure 6. *Output per unit diverted water of both schemes.*

3.9.3. Output Per Command Area (US$/Ha)

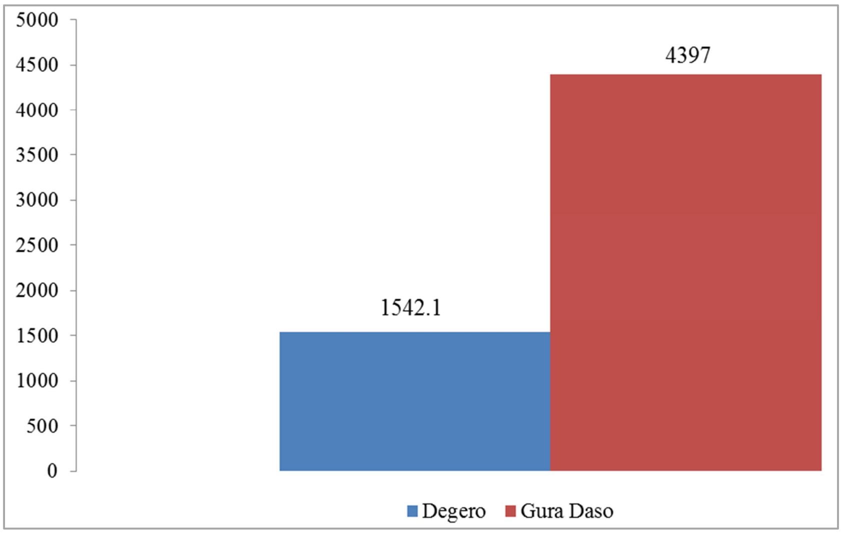

Figure 7. *Output per unit command area of both schemes.*

This indicator evaluates the productivity of the schemes from its command area rather than from the currently irrigated area. It was computed using equation 7. According to the data collected from each irrigation scheme and explained in table 10, and figure 7 the outputs per unit of command area were 1542.1 and 4397 US$ per ha for Degero and Gura Daso SSI schemes, respectively.

3.9.4. Output Per Unit of Water Delivered

Output per unit of water delivered was computed using Equation 10 and presented in Table 10 and Figure 8. The results of this indicator were 0.53 and 0.89 US$/m^3 for the Degero and Gura Daso SSI schemes, respectively.

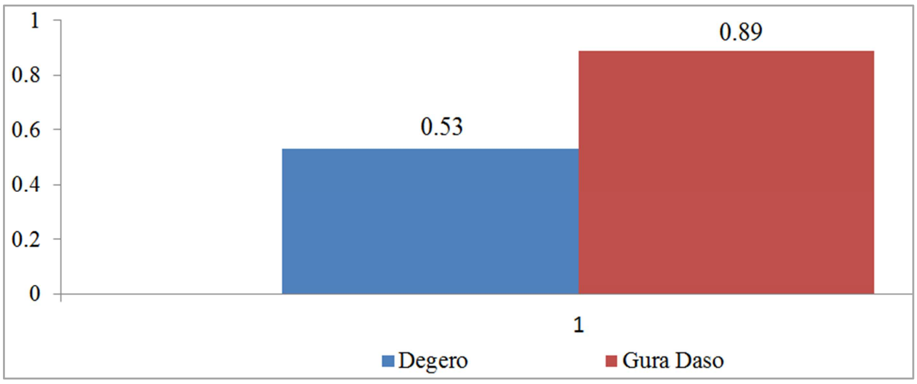

Figure 8. *Output per unit of water delivered of both schemes.*

3.9.5. Output Per Unit Water Consumed (US$/m^3)

The volume of water consumed is the actual evapotranspiration from irrigated areas [10]. Output per unit of water consumed was calculated by using equation 11. The output per unit of water consumed for Degero and Gura SSI Daso schemes were 0.73 and 0.86US$/m^3, respectively. The result shows that the output per unit of water consumed was higher in the case of the Gura Daso SSI scheme relatively; this is due to the difference in cropping intensity, where the ratio of annually irrigated area to command area was higher.

Table 9. *Agricultural output indicator for both scheme.*

Scheme name			
Indicator	**Degero**	**Gura Daso**	**Unit**
Output per cropped area	3084.2	3847.4	US$
Output per command area	1542.1	4397	US$
Output per unit of irrigation diverted water	0.41	0.69	US$
Output per unit of water delivered	0.53	0.89	US$
Output per unit water consumed	0.73	0.86	US$

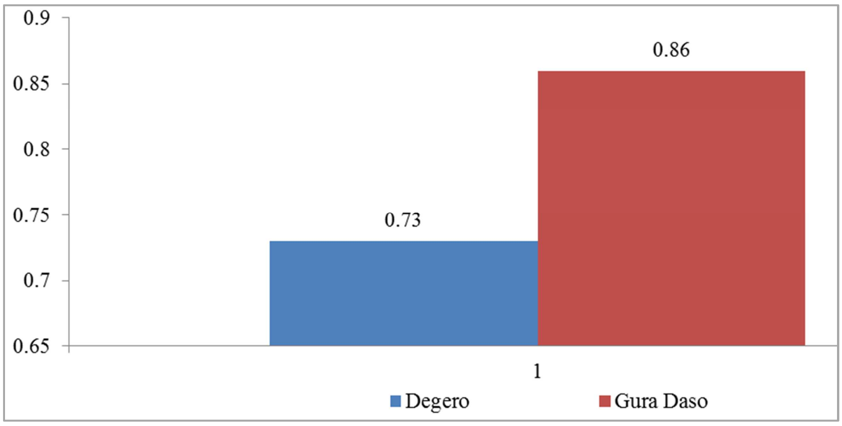

Figure 9. *Output per unit of water consumed of both schemes.*

3.10. Physical Indicators

The values of physical indicators for the two schemes are given in Table 10.

Table 10. *Data of command areas and value of Physical indicator of the scheme.*

Parameter	Degero	Gura Daso
Currently irrigated area (ha)	30	24
Annual irrigated area (ha)	60	48
Designed command area (ha)	120	42
Initially cultivated area (ha)	70	18
Cropping intensity (%)	50	114.2
Irrigation ratio	0.25	0.57
Sustainability of irrigated land (%)	0.42	1.33
Effectiveness of infrastructure	0.4	0.8

3.11. Improvement Options

Based on the results and field observations the following improvement options are made for the improvement of the performance of the schemes to utilize the designed potential at both schemes under the study;

1. Fixing the schedule for operation and maintenance of the canals At both schemes the currently irrigated area was less than the designed command area, and the results were very low at the Degero scheme. This is mainly due to the maintenance problems of the schemes where water does not reach the tail users and the majority of the structure fails. Because the management and water user associations can't perform the operation and maintenance work regularly. Additionally, in the Gura Daso SSI scheme, lack of regular operation and maintenance work was there, because of this the night storage of the scheme failed which resulted in low productivity of the scheme.

2. Training on irrigation water use efficiency

The low attitude of farmers toward deficit irrigation and lack of training on water use efficiency were the main causes for the contraction of the command area, especially in the Gura Daso scheme. In addition, users believe that productivity increases when excess water is applied at the farm level. Subsequently, farmers were dissatisfied with the amount of the discharges they were obtaining at the farm gates. Hence, the life of the community of the area depends on the scheme due to the small land holding relative to the population growth rate and moisture stress occurring in the area, if the training is not provided to the users, may create many problems shortly.

3. Creating fee collection strategies for maintenance work

In both scheme, there is no fee collection strategies which makes the scheme dependent on the government only for maintenance work. If the fee was collected from the water user the simple maintenance work such as seepage prevention mechanism by geo-membrane for night storage and other related was overcome by the water user; which led the scheme to self-sufficient.

4. Conclusions and Recommendations

4.1. Conclusions

Generally, in both schemes, the currently irrigated area was less than the designed command area, and the results were very low in the Degero scheme. This is mainly due to the maintenance problems of the schemes where water does not reach the tail users and the majority of the structure fails. Because the management and water user associations can't perform the operation and maintenance work regularly. Additionally, in the Gura Daso SSI scheme, lack of regular operation and maintenance work was there, because of this the night storage of the scheme failed resulting in low productivity of the scheme.

4.2. Recommendations

The following recommendations are made for the improvement of the performance of the scheme:

1) Water diversion and Conveyance efficiencies at the Degero scheme are very low. Therefore, the diversion and conveyance system should be improved through the maintenance of broken irrigation infrastructures, especially the sluice gate at head work and flume at the secondary canal.
2) In both schemes maintenance of night storage is required to improve land and water productivity.

3) Additionally appropriate cropping pattern with market linkage is crucial for both schemes. Setting formal way of fee collection mechanisms preparing legal receipts, and utilizing the collected money for maintenance works are relevant to creating transparency and increasing farmer's participation.

Data Availability

All information provided to this publication is presented in the full document.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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