

**COMPARATIVE PERFORMANCE ASSESSMENT OF TWO IRRIGATION
SCHEMES IN BUNO BEDEL ZONE, OROMIA, ETHIOPIA**



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**COMPARATIVE PERFORMANCE ASSESSMENT OF TWO IRRIGATION
SCHEMES IN BUNO BEDEL ZONE, OROMIA, ETHIOPIA**

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Adama Science and Technology University

June 2023
Adama, Ethiopia

DECLARATION

I declare that this Master Thesis entitled “**Comparative Performance Assessment of Two Irrigation Schemes in Buno Bedele Zone, Oromia, Ethiopia**” is my own work. That is, it has not been submitted for the award of any academic degree, diploma, or certificate in any other university. All sources of materials that are used for this thesis have been duly acknowledged through citation.

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Date

RECOMMENDATION

I, the advisor of this thesis, hereby certify that I have read the revised version of the thesis entitled “**Comparative Performance Assessment of Two Irrigation Schemes in Buno Bedele Zone, Oromia, Ethiopia**” prepared under my guidance by Adugna Ibsa Aga submitted in partial fulfillment of the requirements for the degree of masters of science in Water Resources Engineering (Specialization in irrigation Engineering). Therefore, I recommend the submission of a revised version of the thesis to the department following the applicable procedures.

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APPROVAL PAGE

I, the advisor of the thesis entitled “**Comparative Performance Assessment of Two irrigation Schemes in Buno Bedele Zone, Oromia, Ethiopia**” and developed by Adugna Ibsa Aga; hereby certify that the recommendation and suggestions made by the board of examiners are appropriately incorporated into the final version of the thesis.

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We, the undersigned, members of the Board of Examiners of the thesis by Adugna Ibsa Aga have read and evaluated the thesis entitled “**Comparative Performance Assessment of Two irrigation Schemes in Buno Bedele Zone, Oromia, Ethiopia**” and examined the candidate during the open defense. This is, therefore, to certify that the thesis is accepted for partial fulfillment of the requirement of the degree of Master of Science in Water Resources Engineering (Specialization in Irrigation Engineering).

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ACRONOMIES

AI	After Irrigation
BMC	Billion meter cube
CA	Command Area
CE	Conveyance Efficiency
DA	Development Agency
CWR	Crop Water Requirement
ETB	Ethiopian Birr
ET _o	Reference evapo-transpiration
ET _c	crop evapo-transpiration
FAO	Food and Agricultural Organization
FC	Field Capacity
FGD	Focus Group Discussion
FSS	Financial Self Sufficiency
GRI	Gross return on investment
GPS	Global Positioning System
GTP	Growth and Transformation of Plan
Ha	Hectare
HHs	House hold survey
IWMI	International Water Management Institute
IWR	Irrigation Water Requirement
KII	Key Informative Interviews
m.a.s.l	Meter above sea level
Mha	Million Hectares
MoA	Ministry of Agriculture
MC	Moisture Content
MoWIE	Ministry of Water, Irrigation and Energy
NGOs	Non-Governmental Organizations
NMSA	National Meteorology Service Agency
OIDA	Oromia Irrigation Development Authority
O & M	Operation and Maintenance

OPUCA	Output per Unit Command Area
OPUIA	Output per Unit Irrigated Area
OPUIS	Output per Unit Irrigation Water Supply
OPUWC	Output per Unit Water Consumed
PWP	Permanent Wilting Point
Q	Discharge
RIS	Relative Irrigation Supply
RWS	Relative Water Supply
SC	Sample Cillection
SIA	Sustainability of Irrigated Area
SSI	Small Scale Irrigation
TAW	Total Available Water
US\$/ha	United State per hectar
US\$/m ³	United State per meter cubic
USDA	United State of Agriculture
WDPR	Water Delivery Performance Ratio
WUA	Water Use Association
WUC	Water User Commite

ABSTRACT

Comparative performance Assessments of irrigation schemes is an instrument to demonstrate bench marks for both lands and water productivity, and to identify performance gaps and suggest improvement options. Accordingly, the objective of this study was to evaluate and compare the performance of Gella and Gepha community managed small scale irrigation schemes using selected comparative performance indicators. Primary data were gathered by field measurements, household surveys, focus groups, and key informant interviews. Secondary data were taken from various written publications. CROPWAT8.0 computer program was used to calculate the crop water requirement and irrigation requirement. To test the soil FC, PWP, TAW %, and TAM (mm/m), soil samples were taken by auger. Additionally, soil for bulk density test was collected by core samplers, and soil infiltration rate was determined by double-ring Infiltrimeters. Flow velocity is measured with a current meter at 36°05'36" and 21°51'53" longitude, 8°25' 22" and 8°92'88" latitude, and 1513 and 1498 m elevation for Gella and Gepha, respectively using area velocity method and mid-section method. With the exception of wheat production, which was assessed by the field sampling method, data on output, prices and the productivity of land and water were gathered through questionnaires. Then the schemes were assessed using water supply, physical, agricultural output and financial indicators. As a result, the conveyance efficiency of Gella and Gepha main canals was 94.12 and 95.58 % respectively. The values of relative water supply and relative irrigation supply were 2.2 and 2.6 for the Gella, whereas they were 1.9 and 2.3 for Gepha scheme respectively. The results showed that both schemes withdrew excess water. Moreover, the irrigation ratio and sustainability of the irrigated area showed 0.97 and 1.05 for the Gella scheme and 0.96 and 1.12 for the Gepha schemes respectively. The Output per unity irrigated area was 342744.4 and 298880.4 ETB/ha, and the Output per unity per unity command area was 661007 and 562268.75 ETB/ha for Gella and Gepha schemes respectively. The Output per unity water supply and Output per unity per unity water command area were 37.17 and 49 ETB/m³ for Gella and 33.5 and 43.9 ETB/m³ for Gepha respectively. Therefore, the Gella SSI scheme performed better in terms of land productivity than it did in terms of water productivity due to the water indicators values are the same value at both irrigation schemes. Accordingly, it's crucial to compare the schemes using indicators of land productivity rather than water productivity. The Gella SSI scheme performed better and can be used as a benchmark based on these indicators.

Keywords; SSI Scheme, performance, efficiency, irrigation ,Water and land

1. INTRODUCTION

1.1 Background

Ethiopia is certainly considered one among few African international locations endowed with abundant water resources. The country has 12 river basins with an annual runoff volume of 124 BMC of water and an estimated groundwater potential of about 30 BMC (Mekonen et al., 2022).

The potential of irrigable land in Ethiopia is around 8.5 Mha. From these potential land resources, around 4 Mha could be developed using surface water sources and 4.5 Mha are using groundwater and rainwater management (Awulachew and Ayana, 2011; Belay et al., 2022).

The overall area irrigated under irrigation schemes is around 1.5 Mha, from these total irrigation potential, around 7 to 8 % of the irrigated area has been developed by medium and large irrigation scheme (Mekonen et al., 2022). Although, the small-scale irrigation development seems increasing at a faster rate, a lot remains to be done in medium and large scale irrigation development (MoWIE, 2015; Belay et al., 2022).

As Tesfaye (2020) reported, small-scale irrigation schemes in Ethiopia cover a large portion of the total irrigation schemes developed in the country, and about 69 % of the irrigated area is covered by traditional and modern small-scale irrigation schemes. In this country, small-scale irrigation is the primary contributor to food security and developments in rural livelihoods.

These schemes play an essential role in changing the living standards of smallholder farmers (MoWIE, 2015). However, the small-scale irrigation schemes in the country perform below capacity due to some of the challenges and problems related to poor awareness of irrigation water management and irrigation scheduling techniques, water saving and water measurement techniques, and operation and maintenance of irrigation facilities (Dejen et al., 2012; Haile & Kasa, 2015; Adugna & Ayana, 2020; Tesfaye, 2020).

As Abera (2018) reported in his thesis small scale irrigation evaluation of farmer-managed, in the case of the Fultino SSI scheme in Ada'a Barga district, Oromia, in the irrigation development, more emphasis is given to the construction of infrastructure while the management aspect of irrigation (performance evaluation) is often neglected. For community-based (farmers' managed) small-scale irrigation systems to be successful, the interaction of both performance and physical aspects of irrigation is very important to evaluate the whole irrigation scheme.

Performance assessment of irrigation systems plays a vital role in evaluating how far the current performance achievement differs from the formulated goals and objectives of the systems during design (Elshaikh et al., 2018). This is a useful means to identify success or limitation areas of the system for improving its performance (Adugna & Ayana, 2020; Nuru et al., 2020). Effective irrigation management requires reliable performance assessment; good farm irrigation management assures correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff, and minimum deep percolation except for that required for salt management, minimum erosion, and optimal return on irrigation investment (Renault, 1999). With the progressively increasing physical infrastructure of irrigation projects, special attention should be given to the performance of the systems.

As Molden et al. (1998b) stated, performance is assessed for a variety of reasons: to improve system operations, to assess progress against strategic goals, as an integral part of performance-oriented management, to assess the general health of a system, to assess the impacts of interventions, to diagnose constraints, to better understand determinants of performance, and to compare the performance of a system with others or with the same system over time.

1.2 Statement of the problem

Oromia Region is giving more emphasis to irrigation development to increase production and productivity and ensure food security in the region. Even concrete achievements were made in the region for irrigation development; however, the performance is not satisfactory; some of the constructed schemes have totally failed, while others are performing below their capacity (Abera, 2018; Adugna & Ayana, 2020). According to Awulachew (2010), Due to a number of issues, including poor operations and maintenance (sedimentation impacts and smallholders' lack abilities) and inadequate structural design and construction, the performance of many irrigation systems in Ethiopia is far below its potential. Buno Bedele zone is found in Oromia Regional State, west-south of Ethiopia. In this area, there are vast small-scale irrigation schemes; about 65 modern small irrigation schemes were constructed by the regional GOs and NGOs, and about 250478 ha of irrigable potential are presented (Buno Bedele Zone irrigation office report, 2023).

Most of the irrigation schemes in this area have high potential for irrigation. However, on-field irrigation water management and performance are very poor. These problems are common for most irrigation schemes in the area.

No one has considered the performance of the scheme from both government and non-government agents. But they are focusing only on its' construction. Due to these problems, some of the schemes constructed in the area have totally failed, while others are performing below their capacity. It is important to conduct a comprehensive performance assessment on selected schemes to identify performance gaps and suggest improvement options. For this purpose, the Gella and Gepha small-scale irrigation schemes were selected.

Buno Bedele Zone, Dedesa Woreda, is home to the small-scale irrigation systems known as Gella and Gepha. There have been 10 and 8 years, respectively, of operation for the Gepha and Gella SSI schemes. The schemes' performances are now being underutilized, and they have not been fully functioning as expected. More generally, there are several reasons why irrigation schemes don't work well in the current situation. Disregard the irrigation system's ineffectiveness in the area, benchmarking of the results and assessment of SSI schemes are unknown; this is especially real by using comparing performance metrics. However, the area needs research on the performance of the irrigation system. But until now, there have been no significant studies on the performance assessment of the SSI scheme.

Therefore, this study displays the generality of a comparative performance assessment using selected indicators as a device to assess the performance of the Gella and Gepha irrigation schemes for better irrigation management of water and benchmark the results.

1.3 Objective

1.3.1 General Objective of the Study

The General goal of this research was to evaluate the performance of Gella and Gepha small scale irrigation schemes using comparative performance indicators.

1.3.2 The specific Objective of the Study

-  To measure Water supply indicators, External indicators and Physical indicators, and evaluate the performance of the schemes.
-  To assess performance gaps, causes and effects of poor performances of the irrigation schemes.
-  To recommend possible solution for identified gaps.

1.4 Research Question

This study was conducted to answer the following questions:

- ✓ What are the levels of performance of the irrigation schemes in terms of selected indicators?
- ✓ What are the gaps, causes, and effects of poor performance in irrigation schemes?
- ✓ What improvement options can contribute to the improvement of performances?

1.5 Importance of the Study

This study was gave information on the performance of the current irrigation schemes. The research would make an important contribution to understanding the disadvantages and best achievements across the system. It was further gave an insights into the impacts of intervention and give directions for policy makers. It was gave information for further improvement and investment approaches for implementing agents (GOs, NGOs, research centers, contractors and others stakeholders). It was also used as a benchmark and entry point for development work and future studies.

1.6 Scope of the Study

Only the Buno Bedele zone area of Gella and Gepha small-scale irrigation schemes was studied. The main limitation of the research was evaluating the performance of the schemes only using comparative performance indicators. The hypothesis was that evaluating performance comparatively identifies performance gaps. The comparative indicator groups, such as physical, agricultural output, water supply indicators, financial indicators and organizational indicators were studied.

2. LITERATURE REVIEW

2.1 Irrigation Performance Evaluation

Evaluations are helpful for a variety of analyses and activities, especially those that are crucial to enhancing management and control. Periodic data collection from the system can be used to evaluate management strategies and track field changes over the course of an irrigation season or from year to year (FAO, 1989). There is a need to pinpoint the regions where farmer-managed irrigation schemes fall short of their promise because so many of them don't operate as well as they could. As a result, it's critical to objectively assess their success or failure and pinpoint the particular areas that require improvement (Jorge, 1993).

In many developing nations, public organizations strive to help farmer-managed irrigation systems operate better through better management. Additionally, effective management requires the use of measures and procedures that allow for the evaluation of system performance in relation to management goals (Oad and Sampath, 1995). Therefore, accurate assessments of system performance are crucial for better irrigation policy and management choices. Small-scale irrigation appears to have great potential for growth because to its affordability, targeted audience, and capacity to be sustained thanks to beneficiary empowerment. Experience has shown us that there are still many obstacles and limitations that prevent the use of small-scale irrigation.

2.1.1 Concept of Performance

Any irrigation system's performance is determined by how well its measurements reflect the intended objectivity; as a result, it's crucial to gauge the system's success or failure in this regard and pinpoint any areas that require improvement (Cakmak et al., 2004).

The degree to which the land and water resources in irrigation schemes are intended for allocation to various users and their geographical and temporal distribution during the planning and operation stages, irrigation scheme's objectives can be stated as the performance of irrigation water management (Gorantiwar and Smout, 2005). The effectiveness of irrigation is the outcome of a wide range of operations, including planning, designing, building, operating infrastructure, maintaining it, and applying water to land (Small and Svendsen, 1990). Globally, farmers develop their own methods for controlling their irrigation systems (Gorantiwar and Smout, 2005).

Based on the agricultural conditions and the farmers' available resources, their management requirements produce a variety of levels of performance (Smith, 1998; Imbenzi, 2014). According to traditional belief, water will be used effectively when it is scarce due to physical, economic, or legal restrictions (Bekele and Tilahun, 2006). Irrigation system performance must be closely monitored in order to conserve water resources. And they must be assessed frequently to make sure the systems are well maintained and operating as intended (Ascough and Kiker, 2002).

According to Asia Small's studies for A Framework for Evaluating Irrigation Performance, The objective the results of a system's performance assessment determine how the evaluation is undertaken. Periodic assessments are sometimes carried out to examine the system's operational state and recommend adjustments. In other instances, the assessments are specifically designed to change how some system actors behave. The three primary types of performance assessments are operational performance monitoring, intervention assessment, and accountability assessment (Small, 1990; Aryastana et al., 2001). The intended audience for the assessment's conclusions, the assessment's time frame, and the amount of time required examining field data, and the standards utilized to make judgments all differ (Elshaikh et al., 2018). Ethiopia rarely conducts irrigation performance evaluations because there is a lack of field-level data. There have been some prior attempts to assess the effectiveness of some irrigation projects at the scheme level (Belete, 2006; Yusuf and Tena, 2006; Mekonen and Awulachew, 2009; Seleshi et al., 2011). The creation of aggregate indicators is necessary to measure irrigation development success under the restrictions of limited data availability.

In order to evaluate the effectiveness of irrigation in Turkey, Yercan et al. (2004) used physical performance indicators. These indicators primarily reflect how well established plans are put to use in achieving their goals. These types of indicators are helpful in nations like Ethiopia, where it is difficult to carry out in-depth scheme-level performance assessments due to a lack of measured data (Seleshi et al., 2011). The effectiveness and sustainability of irrigation systems can be assessed and tracked at various levels by assessing this indicator (Elshaikh et al., 2018).

2.1.2 Properties of performance indicators

Scientific basis: The indicator should be based on an experimentally measured, statistically tested causal model of that component of the irrigation process it describes. These are only a few of the desired characteristics of performance indicators given by Bos (1997).

The indicators must be quantifiable, which means that the data required to do so must be readily available or technologically feasible (measurable). Reproducible measurement is a requirement. Reference to a target value: Given the definition of a performance indicator, this is obviously true. It suggests that the goal values and tolerances for the indicator can be determined to be relevant and appropriate. The level of technology and management should be correlated with these target values and their margin of error (Bos et al., 1991). Providing unbiased information is preferable; performance indicators shouldn't be created from a limited ethical vantage point. This is actually very challenging because even technical measures include value judgments. Especially for regular management, performance indicators should be technically possible and simple for agency workers to utilize given their level of skill and motivation. Ease of use and cost effectiveness. Additionally, the expense of using indicators should be well within the agency's resources in terms of money, equipment, and human resource commitment.

2.1.3 Performance Assessment Importance

According to Boss (1997) and Boss et al. (2005), the goal of performance evaluation is to gauge a manager's ability to respond to two straightforward questions: "Am I doing things right?" and "Am I doing the right thing?" Identifying management strategies and systems that can be successfully adopted to assess the situation, increase irrigation efficiency, and boost productivity is the primary goal of analyzing the performance of irrigation systems (Ayana & Awulachew, 2008). The actual value of one or more parameters chosen as indicators of the system's goals is used to determine the performance level of an irrigation system (Murray-Rust & Snellen, 1993).

According to Molden et al. (1998), performance is assessed for a variety of reasons, including enhancing system operations, gauging a system's overall health, evaluate the effectiveness of interventions, pinpoint constraints, and better understand performance determinants. Performance evaluation is also a critical part of performance-oriented management. Additionally, it must have information that enables the manager to choose if the variation is acceptable (Wondatir, 2016). According to Boss et al. (2005), performance assessment provides the following key benefits: Different user groups' water use and consumption can be measured and weighed in relation to one another. The moment at which these levels will be reached is shown by a time series of performance indicators that are plotted with regard to the relevant critical value or benchmark value. For the production of food and fiber, the use of various resources (land, water, money, knowledge, etc.) is quantified and compared to desired values.

One can identify harmful impacts. When compared to goal values, the effects of management decisions on resource usage and crop yield can be observed. Stakeholder communication is enhanced by the methodical disclosure of the irrigation and/or drainage project's real performance. Although there is growing concern about performance evaluation in the irrigation sector as water resources are under more strain globally, there is also growing concern about making improvements to current irrigation systems to ensure their sustainability (Murray-Rust & Snellen, 1993).

2.1.4 Irrigation Performance Indicators

A set of acknowledged and approved parameters are necessary to conduct irrigation scheme performance evaluation. According to Rust and Snellen (1993), performance indicators must comprise a measure of both quality and quantity, be accompanied by acceptable standards or permissible tolerances, and quantify the value of a specific item, such as field canal discharge. The authors came to the conclusion that the architecture of the primary system has a significant impact on the services it offers and the suitable performance standards.

Over the years, efforts have been made to create suitable assessment models that could assess irrigation performance using the irrigation parameters and variables. The volume balance model among them serves as the foundation for the majority of design and field evaluation techniques. Data from the field and the lab have demonstrated this. According to Walker and Skogerboe (1987), it makes it simple to define infiltration rates over the entire field and may be simply expanded to include indicators of uniformity and efficiency criteria. According to James (1988), the efficacy with which water is diverted, carried, and applied, as well as the sufficiency and uniformity of application in each agricultural field, define the performance of an irrigation system.

Focus was placed on the performance evaluation of the schemes in response to the inadequate performance of the current irrigation system. However, there are several points of view when it comes to irrigation performance. Few of these criteria also take into account the viewpoint of farmers (Gowing et al., 1996). Therefore, it is crucial to continually monitoring the effectiveness of surface irrigation systems in order to raise the systems' performance. Yashima (1997) asserts that a performance indicator is an answer to the query, "How is it now?" The indicator is typically stated as the difference between actual and desired performance. The performance of their management at the start of performance assessment will be evaluated by irrigation

managers using this indicator. As mentioned by Burt and Styles (1999), Murray-Rust and Snellen (1993) described the framework for using performance indicators and identified two methods for applying them in the irrigation industry:

- Attempts to develop indicators which allow the performance of one system to be compared to similar systems elsewhere
- The use of indicator to compare actual results with what was planned.

Bos et al. (1994) remarked that it is easier to characterize system performance when the system is broken up into smaller sub-systems and their performance is evaluated. True performance indicators have both a planned value and an actual value, which makes it possible to calculate the degree of deviation. Therefore, it is preferable to describe indicators as a ratio of the actual measured situation to the anticipated scenario wherever possible (Bos, 1997). A manager may need to choose the next course of action based on the size of the variance, which is represented by the well-known head-tail dimension of many irrigation systems. When equality is part of the aim set, almost all operational performance indicators may and should be employed in a spatial context. According to Bos et al. (1994), employing performance indicators in a spatial dimension also enables managers to pinpoint the exact regions where issues are developing and where to take corrective action. Effectively describing system performance involves breaking the system down into multiple sub-systems and evaluating the performance at these smaller levels. The common efficiency terms used for on-farm irrigation system evaluation include application efficiency, uniformity and storage efficiency, recently complementary terms such as runoff ratio and deep percolation ratio are being applied (Jurriens et al., 2001).

According to Ayana & Awulachew (2007), using performance metrics, irrigation scheme effectiveness is assessed. A performance indicator is a description of actual achievement in relation to one of the objectives of an irrigation system. Those indicators are grouped based on their importance. A performance indicator is a declaration of actual advancement toward one of an irrigation system's objectives. An irrigation system could be thought of as having two sets of objectives: one for water delivery and the other for water use.

The findings from its irrigated region are the primary focus of the first set, while the water delivery system's characteristics of performance are the primary focus of the second (Oad & Sampath, 1995). According to Bos (1997), the performance measures now used by the Research Program on Irrigation Performance Within this program field, measurements and data collection

are used to quantify and test about 40 multi-disciplinary performance indicators. These metrics cover water distribution, efficient water usage, maintenance, sustainable irrigation, environmental factors, socioeconomic aspects, and management. He clarified that not all of the indications discussed should be used in all circumstances.

2.1.4.1 Water Supply Indicators

According to Kloezen and Garcés-Restrepo (1998), internal performance evaluation is predicated on the existence of well-defined management goals and operational targets.

Most frequently, internal process indicators link performance to management objectives for irrigation systems, such as timing, length, water flow rate, area cultivated, and cropping patterns of the irrigation season (Molden et al., 1998). Comparing the outputs and effects of irrigated agriculture on household life and the surrounding environment is one method for conducting cross-system or scheme comparisons. A fundamental concern of water delivery systems is to provide the volume of water necessary to meet the crop's water needs for irrigated crops (Molden & Gates, 1990). The relative water supply, relative irrigation supply, conveyance efficiency, and water delivery performance ratio are only a few examples of internal indicators.

I. The water delivery performance ratio

The difference between the total amount of water supplied to the scheme and the gross irrigation water requirement is known as the water delivery performance ratio (WDPR), and it provides information about the relationship between the amount of water delivered and the amount of water that needs to be delivered (Ayana & Awulachew, 2010).

By comparing the volume of water actually delivered to the volume intended for delivery, it will be estimated. A manager and planner can establish the degree to which water is actually supplied relative to what is expected over a chosen period and at any site in the system with the aid of the delivery performance ratio (DPR). Over time, WDPR can be deemed adequate if the water delivered is sufficient to meet crop water needs, and the regional variation of the delivery performance ratio reveals the degree of equity in the system (Molden et al., 2007)

II. Relative water supply (RWS)

One of the primary indicators used to determine the suitability of the water supply for agricultural production is the annual relative water supply (Clemmens and Molden, 2007).

It is the ratio of total annual water diverted (irrigation plus rainfall) to the annual crop water requirement. RWS shows whichever the water supply is short or in excess of demand. It narrates how well irrigation water supply and demand are matched (Agide et al., 2016).

III. Relative Irrigation Supply(RIS)

This is the ratio of irrigation supply to demand throughout the course of a year or season. A key production restriction in many irrigation projects is the lack of irrigation water. Crop water demand and effective rainfall are divided by 12 to determine the annual irrigation demand. Effective rainfall must, by definition, never be greater than the crop's water needs. The RIS value is 0 when effective rainfall is equal to agricultural water needs. The RWS and RIS values show whether or not the supply is sufficient to meet the demand. A RWS and RIS value of one or higher denote an adequate irrigation supply, whereas a value of less than one denotes an insufficient supply.

IV. Conveyance Efficiency

Conveyance efficiency is the ratio of the total volume of water diverted into the irrigation system to the amount of water supplied at the turnouts of the main irrigation conveyance network. Canal seepage and evaporation are the causes of water losses. These when farms are located far from water sources and the main canals are long and unlined, irrigation water losses in the conveyance system might make up a sizable portion of the total water losses. The amount lost is based on the soil type, seepage rate, and operation and maintenance standards (Thokal et al., 2014).

Yewendwosen and Zinabu (2015) state in their Case Study of Wondogenet, Southern Region, and Ethiopia: that the main canal, secondary canal, and tertiary canal were in decreasing order of conveyance efficiency. The higher infiltration rate of the soil may be the cause of the secondary and tertiary canals' inferior conveyance efficiency. Due to the lack of lining in the majority of secondary and tertiary canals, there was a higher loss of irrigation water before it reached the fields, which indicates that the conveyance efficiency of the schemes was reduced (Ayana and Bekele, 2011).

2.1.4.2 agricultural performance indicators

Irrigation Agriculture performance indicators gives the information on yield per unit area per season and shows the potential of that land production under set of environmental and other supplementary input services (Lakmali et al., 2015). The relative yield indicator gives the ability

of a particular system to produce over the expected yield at optimum conditions. When the water is a scarce resource, agricultural productivity per unit water delivered, as indicated by water productivity, gives a good picture on performance of the system with respect to production (Belay et al., 2022). This addresses the direct impact of operational inputs in terms of such aspects as area actually irrigated and crop production, over which an irrigation manager may have some but not full responsibility (Marinus and G Bos et al., 1993; Tesfaye, 2020).

1. Output unit per irrigated area

According to Molden et al. (1998), the output per unit of irrigated area is a key indication of land productivity when the area is at higher prices. In the irrigation season, it can be estimated as the total value of production per harvested area. The areas that were irrigated during irrigation seasons are included in the harvested/irrigated area. The amount of land harvested annually is influenced by cropping intensity. In this situation, the area is the total of all the areas planted with crops during the year. According to Molden et al. (1998), this indication is unaffected by cropping or irrigation intensity.

2. Output per unit command area

Since land is a major production bottleneck, this is more pertinent. It measures how much agricultural output there is for each notional square foot of irrigated land. The calculated figure shows the command area's degree of productivity during the production year as well as the number of times it was cultivated. Smaller values of this indicator may also indicate less intense irrigation, whereas a high value result indicates effective intensive irrigation (Molden et al., 1998).

3. Output per unit irrigation supply

It is one of the indicators of water productivity that shows how productive the entire annual irrigation water that has been diverted from a source is. The total value of production per unit of water diverted from the headwork to the command area throughout the irrigation seasons is used to determine this crucial metric when water is in short supply (Molden et al., 1998).

4. Output per unit Water Consumed

According to Molden et al. (1998), Consumed water is defined as the ET_c or process consumption from solely irrigated crops (ET); it excludes various losses and water depletion from the hydrological cycle. The computed price is now no longer low due to water losses but

rather low due to the climatic characteristics of the area. It used to be possible to have a look at the water intake of vegetation at the scheme in relation to the amount of irrigation water that was diverted and added, stage through evapotranspiration. It helps with irrigation control by allowing for the assessment of evapotranspiration losses.

2.1.4.3 Physical performance Indicators

Physical performance indicators are related to changing or losing irrigated land in the command area for different reasons. Among those reasons, water scarcity and input availability are the central reasons why lands in the command area are not fully under irrigation in a particular season. From physical performance, irrigation ratio is the main indicator (Marinus G. Bos et al., 1993; Tesfaye, 2020).

A. Irrigation Ratio(IR)

The irrigation ratio is the ratio of the presently irrigated area to the irrigable command area. Sener et al. (2007) cautioned that an excessive irrigation ratio may be carried out by means of powerful water transport inside the scheme. There isn't any irrigation water rate that encourages farmers to apply the irrigation water successfully with the purpose of growing the irrigable land inside the scheme. Dejen et al. (2012) and Alemayehu (2018) at Golgota and Godana irrigation schemes, respectively, have found similar reasons for the greater irrigation ratio, which could be explained by means of three factors: beneficent water availability, absence of irrigation water price, and higher land productiveness, encouraging farmers to make investments in extra areas. In order to elevate irrigation performance and the irrigation ratio, on-farm trends and practices need to be cautiously monitored and evaluated. Training and extension of farmers and irrigation managers in technical and economic considerations are also vital to the augmentation of the irrigation ratio (Deirmenc et al., 2003).

B. Sustainability of irrigated area (SIA)

The sustainability of an irrigated area is the ratio of the presently irrigated area to the irrigated area while it is being designed (Bos et al., 2005). It is a beneficial indicator for assessing the sustainability of irrigated agriculture. Lower values of this indicator could suggest abandonment of lands that had been to begin with irrigated and, hence, imply contraction of irrigated places over time. On the other hand, values better than team spirit suggest enlargement of the irrigated location and could suggest greater sustainable irrigation.

Dejen et al. (2016) suggested that the degree to which the initially irrigated area of schemes is sustained years after the implementation of a scheme is a crucial difficulty for the achievement of an irrigation scheme. In principle, neither extension nor shrinkage is desired, in particular in cases where irrigations schemes are properly deliberate and command areas have been described primarily based totally on land suitability and water. The main elements that could contribute to the shrinkage of irrigated land might be water shortage (unreliability), loss of infrastructure, and renovation of infrastructure.

2.1.5 Organizational set up irrigation management

A group-based irrigation system implies an organization in charge of operation and management, and organizational performance is an important factor in the sustainability and productivity of irrigation systems (Limperiere, 2004).

1. Water user's associations (WUAs)

The Water User Association is a user-based organization that aims to manage the irrigation system for its members, mostly on a nonprofit basis. The real length of a WUA is frequently dependent on the irrigation system. For example, a WUA may be responsible for one tertiary block that is subdivided into smaller units of Water User Groups (WUAs), or one WUA may be responsible for the entire system (Aarnoudse et al., 2018). As Aarnoudse et al. (2018) reported, the function of WUAs includes:

- The allocation of water within the irrigation system
- Operation and maintenance (O&M) of the system and
- The cost recovery of O&M is achieved through the collection of irrigation fees from its members.

According to FAO (1996), developing, operating, and maintaining an irrigation scheme almost always requires joint action by the water users. In conventional irrigation schemes, farmers could get together to construct a diversion weir throughout a river or dig a canal entrance, due to the fact that those were matters they couldn't accomplish on their own. Without a capacity for organization and decision-making among the users, it was simply not possible to complete a scheme. This potential helped customers broaden an organization capable of running and preserving the scheme. In a current scheme wherein the maximum amount of instruction and production is achieved with the aid of a central authority agency, the water customers have an awful lot less fun organizing them.

2. Factors influencing WUAs

Studies have diagnosed the most crucial elements that form WUA performance. Often a distinction is made between external and internal factors, in which external factors refer to the physical, socioeconomic, and political environment while internal factors describe the water management organization itself (IFAD 2001; Ghazouani et al., 2012), cited in Aarnaoudse et al. (2018).

3. Strengthen water user association

Policy makers and donor agencies have tried five main channels to strengthen conventional WUAs:

-  WUA policy and legal instruments
-  WUA bylaws
-  Contracts and formal agreements with WUAs
-  Training of WUA members
-  Introducing monitoring and evaluation (Aarnaoudse et al., 2018).

2.1.6 Benchmarking the result of irrigation performance assessment

Benchmarking simply involves comparison, either internally with prior performance and designed desirable targets to be accomplished, or externally versus similar programs or organizations pursuing comparable goals (Malano & Burton, 2001; Tesfaye, 2020; Belay et al., 2022). As Adugna & Ayana (2020) reported in their study on Comparative Performance Evaluation of Koftu and Fultino Small Irrigation Schemes in East Shoa Zone, benchmarking is a management technique that is already used in both the public and private sectors to identify performance gaps in one scheme in comparison to the others. Benchmarking or contrasting several schemes also involves altering or enhancing performances and switching to a better plan in response to the results of indicators.

The basic worry of system comparison, or benchmarking, is how to interpret the results to say that system A is better than system B (Molden et al., 1998). Accordingly, employing nine indicators per system, if the results showed that the higher values of the water supply indicators showed a more generous supply of water, productivity on the land may be more important. Whereas, if the water supply indicators show a lower value, it indicates a more constrained water supply, and values of productivity per unit of water are more important.

2.1.7 Irrigation Development and performance assessment in Ethiopia

2.1.7.1 Irrigation Development

Irrigation in Ethiopia practiced since ancient times producing subsistence food crops. However, modern irrigation systems were started in the 1960s with the objective of producing industrial crops (sugar and cotton) on large-scale farms by private investors in the Awash area (Awulachew, 2007). Modern small-scale irrigation development and management started in the 1970s initiated by the Ministry of Agriculture in response to major droughts, which caused wide spread crop failures and food insecurity (MOA, 2011). Any country may significantly increase productivity and lessen vulnerability to climate volatility by developing irrigation and agricultural water management. Despite having an abundance of rainfall and water resources, Ethiopia's agricultural sector has not yet completely benefited from water management and irrigation technologies (Hags et al., 2009). In Ethiopia, there is a potential for 7.5 Mha of irrigable land (Mekonen et al., 2022). According to Awulachew and Ayana (2011) and Mekonen et al. 2022, out of these potential land resources, 4 Mha might be developed using surface water sources and 3.5 Mha using groundwater and rainwater management.

2.1.7.2 Performance Evaluation of Small Scale Irrigation Schemes

The performance of the schemes varied with the quality of the scheme design, the experience of the communities in irrigation agriculture, access to reliable markets, the level of institutional support by government institutions, and the organizational capacity of the respective communities (Tilahun, 2014). Many large-scale irrigation schemes in the least developed countries are out of reach of smallholder farmers (Maatooq, 2016). However, in Ethiopia, small-scale irrigation schemes are the primary contributors to food security and developments in rural livelihoods (Tesfaye, 2020). More beneficial irrigation water allocation needs a good evaluation of irrigation water demand, cropping pattern, designated area, and project head operation (Imbenzi et al., 2014; Nuru et al., 2020).

According to MoA (2011), improved small-scale irrigation schemes (200 ha) in Ethiopia were constructed mainly by the government, NGOs, and other donors to increase crop production and productivity. In some places, traditional small-scale irrigation systems are constructed by community members. Similar to medium and large-scale irrigation schemes, the number of small-scale irrigation schemes is very low compared to poorly designed and functional schemes (Awulachew, 2006; Mekonen et al., 2022).

The schemes are underperforming due to a lack of experience in design, operation, and maintenance, limitations on modern irrigation water management (irrigation scheduling techniques, water-saving irrigation technologies, and water measurement techniques), and low irrigation performance (MoA, 2011). The evaluation of existing functional and non-functional small-scale irrigation schemes is relevant for improving their performance and increasing productivity (Belay et al., 2022). Ayana and Bekele (2011) state that, 86.5 % of Ethiopia's 312 irrigation projects were in operation throughout the study period, which was used to assess the irrigation efficiency of small-scale systems. Not all functional schemes, or those servicing less than the intended command area, were nevertheless working to their full potential. As a result, 26 % of the irrigation capacity was not used, and only 74 % of the command area was planted with irrigated crops.

The internal workings of irrigation systems have received a lot of attention in the work on irrigation performance assessment. Numerous internal process indicators link performance to management objectives, such as water timing, duration, and flow rate; irrigation area; and crop patterns. This kind of examination is done primarily to help irrigation managers provide better water distribution services to customers. If performance is not up to par, either the process must be adjusted to achieve the target or the target itself must be changed (Molden et al., 1998). Targets are set in relation to the systems management objectives.

2.1.7.3 Methods of Irrigation Performance Evaluation

In Ethiopia, many types of research have been conducted to assess the performance of irrigation schemes by different researchers at a different place by using different indicators and different methods (Seleshi et al., 2011). As Nuru et al.(2020) conducted on the Jawi and Homacho SSI in west Hararge, the net crop water requirement of Jawis scheme is greater than the net crop water requirement of Homacho scheme due to more perennial cropping intensity (Chat) in Jawis scheme. And the net irrigation water requirement of Homacho irrigation scheme is greater than that of Jawis irrigation scheme due to three additional perennial crops grown in the Homacho irrigation scheme. Agide et al. (2016) assessed the water delivery performance of ten schemes in Ethiopia selected from four Regional State by using performance indicators like relative irrigation supply, irrigation intensity, cropping intensity, field irrigation adequacy, and equity and field application efficiency.

Accordingly, the irrigation schemes were clustered into three typologies (modern, semi-modern and traditional) based on the mode of water abstraction, conveyance system, flow control, on-farm management, drainage facilities and irrigation organizations. The results of this study indicated that by relative irrigation supply semi-modern schemes were diverted the highest amount of water than others; while the modern schemes were received the highest water at farm level, whereas the lower value by both relative irrigation supply and field relative delivery recorded by the traditional schemes. Finally, apart from of their typologies, all study schemes undergo lack of proportion of water demand and supply (Seleshi et al., 2011).

And also, Dezen et al. (2012) evaluated the performance of two community-managed irrigation schemes named as Golgota and Wedecha schemes located in central Ethiopia using three groups of comparative indicators and fuzzy set concept were employed to analyze farmers' utility of irrigation service. Accordingly, the performance level of Golgota scheme was better than Wedecha scheme with respect to both agricultural and physical indicators. While by water supply indicators, both schemes supplied more water than demands (Seleshi et al., 2011). On the other hand, the Golgota scheme utility levels were found to be higher, except canal sedimentation problems. Ayana and Awulachew (2008) assessed the performance of six (five governments and one community managed) schemes based on management and cropping patterns using irrigation water use performance and outputs performance indicators.

As results by water delivery performance ratio Bilate Irrigation scheme perform better than other schemes, while based on the outputs of performance indicators, Wonji estate scheme is better product than others.

2.1.7.4 Performances Gaps in irrigation System

The kinds of performance indicators selection were based on the function of the performance evaluation activity. There are 4 types of capability performance gaps that can occur in irrigation performance assessment systems (Douglas and Juan, 2009; Mekonen et al., 2022; Belay et al., 2022).

i. Technological Performance Gaps. This occurs when an irrigation system's infrastructure is unable to provide services that meet a specific hydraulic performance criterion. Changing the kind, design, or state of physical infrastructure is typically the solution to technology performance gaps.

ii. The second kind of performance gap is the point at which a discrepancy between the intended and actual implementation of management practices occurs. This involves issues with how people operate gates, keep canals clean, and report information. This is referred to as a performance gap in the implementation. Typically, a situation of this nature necessitates modifications to processes, supervision, or training.

iii. The third kind of performance gap is a gap between management goals and actual accomplishments. The size of the area covered by irrigation in a given season, crop intensity, irrigation efficiency, water delivery schedules, and water charge collection rates are a few examples of management aims. This is referred to as an accomplishment gap. Such issues are typically resolved by either altering the objectives (especially by making them simpler) or enhancing management's ability to accomplish them, such as by expanding the available resources or reforming organizations.

iv. The fourth type of performance problem concerns impacts of management. There is a discrepancy between what people believe irrigation's final consequences should be and what actually happens. These are performance gaps that affect factors like the economic and agricultural viability of irrigated agriculture, productivity per unit of water, the reduction of poverty, and environmental issues like salinity and water logging.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Dedesa Woreda is located in the Buno Bedele zone of Oromia Region in southwest Ethiopia. It is named after the Dedessa River, a Tributary of the Abay River. The area is situated about 420 km by road distance from southwest of Addis Abeba at longitude and latitude of 36°39'59.99"E and 8°04'60.00"N, respectively with 1290 -1950 m.a.s.l elevation.

The area is bounded on the south by the Gumay woreda, on the East by Limu Kosa, on the North by Gechi and Borecha Woreda, and on the West by Satama Woreda as indicated on Figure 3.1. In comparison to other woredas in the Buno Bedele Zone, this one has a higher potential for irrigation and suitable transport facilities to carry irrigation produce to the local market. Grazing land, forest land, and cropland are the three primary types of land use. This area is well situated between Jima, the major town in the Jima Zone, and Bedele, a major town in the Buno Bedele Zone. There are diversified economic activities in the area. Crop cultivation and animals' rearing are the most known activities in the area. Lowland areas of this Woreda are experienced by different types of cereal crop, those mostly used for consumption, and cash crops, those mainly used for commercial purposes. They all include sesame, maize, finger millet, cowpea, sorghum, groundnut, Niger seed, sweet potato, sugarcane mango lemon and etc. But the amount of production of each item may vary based on the adaptation of the weather system of the agro ecological zone.

Semi-lowlands are known for coffee, teff, maize, sorghum, barley, wheat, pearl, and millet. The Highlands are well known for different types of crops, vegetables, and fruits like field peas, fenugreek, linseed, rapeseed, potato, tomato, and avocado. The dominant cash crops that are harvested by those settled people in the study areas are coffee and chat, after the Oromo of Hararghe settled in Didessa Valley. About 80 km² of the study area is covered by coffee and tea (G/Wolado, 2018)). The annual mean temperature for most parts of the area is 9 °C –29 °C and the average annual rainfall is about 670-856 mm. The climatic condition of the area includes: Dega 16 %, Woina Dega 60%, and Kola cover 24 % of the district, respectively (Geda, 2020).

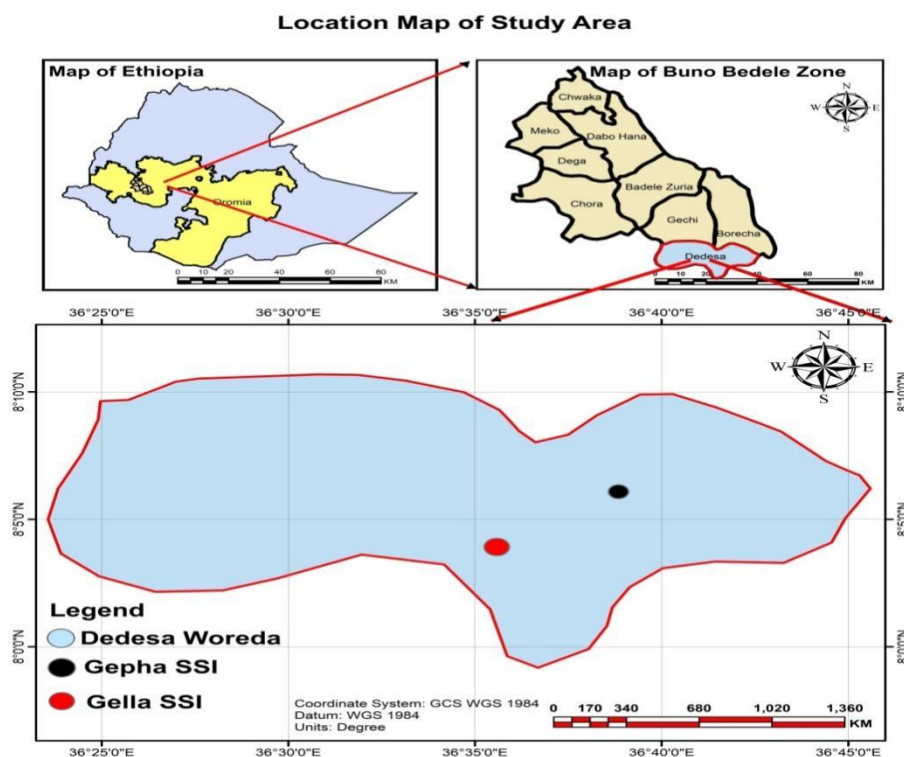


Figure 3. 1 Location map of study area

3.1.1 Gella Small Scale Irrigation Scheme

The Gella small-scale irrigation scheme is located in Buno Bedele Zone, Dedesa Woreda in Gella Kebele. Gella Kebele is 36 km from the town of Bedele and 5 km from Denbi, the largest town in the Dedesa Woreda. The Gella small-scale irrigation project is named after the Gella River, which is the Dedesa River Tributary. This scheme was constructed to help Hararghe villagers in the Dedesa Watershed avoid starvation. The scheme weir has an average elevation of 1513 meters above sea level. The scheme has a designed command area of 70 ha and was constructed by the Oromia Irrigation Development Authority in 2013.

AGP Expert created the scheme's design and budget source, and the Oromia National Regional Government entered into a contract with the Oromia Irrigation Development Authority (OIDA).

The main canal is approximately 750 meters long and features both lined and unlined secondary canals. The lined secondary canal is 800 m long, whereas the unlined secondary canal is 525 m long. The secondary-lined canals were hydraulically in good condition, as usual, during data collection. Currently, the actual beneficiaries of the scheme are 150 households known as members of water user associations. Water distribution operations managed by water user

associations are classified into seven groups. Irrigation water was distributed in rotation among the seven groups, and farmers' irrigation water time for application was based on field size. Because there was no flow measurement structure at the farm gate, they were free to irrigate until they had received enough water. In terms of scheduling, all seven groups received water turn-by-turn, and the technique of water distribution was rotational. This can take up to 13 days for one cycle.

3.1.2 Gepha Small Scale Irrigation Scheme

The Gepha SSI scheme is also located in Buno Bedele Zone, Dedessa Woreda, and Gepha Kebele, 8 km from the town of Woreda Denbi and 52 km from the town of Bedele, in the south-west direction of the Bedele-Adis Ababa main road. The scheme-designed command area is 80 ha and was constructed by the Oromia irrigation development authority in 2015 on the Gepha River. The design and budget source of this scheme also were made by AGP experts. Currently, the actual beneficiaries of the scheme have increased from 170 households during design to 180.

The soil has a dominant clay texture. The main canal was built with lined masonry, and the structure has both lined and unlined canals. The scheme, on the other hand, used stone or soil to manage water at the division box and field application. The main canal was in good hydraulic condition during the field survey. However, each of the two secondary canals wasn't in good condition. This is a result of minor maintenance issues, sediment buildup in the canals, vegetation growth, and a lack of flow-controlling infrastructure. In this irrigation scheme wheat covered 61 % of the command area during the research period. In terms of scheduling, water users in the scheme are divided into eight groups; all eight groups receive water in turn, and the technique of water distribution is rotational. In the scheme, each group has a minimum of 15 and a maximum of 25 members. Those WUAs were increased from 160 during irrigation design to 180 in 2022/2023 due to wheat production.

3.1.3 On field water management performance

Soil data, reference evapotranspiration, rainfall, CWR and IWR were all examined for this type of study. Based on the shallow depth of the wheat root zone, soil samples were taken from 0–30 cm, 30–60 cm, 60–90 cm, and 90–120 cm depths. The outflow and inflow of water in the canals was then measured to assess conveyance efficiency from open ditches.

3.2 Methods of data Collections

Quantitative and qualitative approaches were used in this investigation. The information was gathered from both primary and secondary sources.

3.2.1 Primary Data

Household surveys, interviews, Groups discussions, observations, fieldwork for flow measurements, sample collection for soil characterization, and wheat production were the main methods used to acquire the primary data for this study. A committee of WUAs, the Buno Bedele Zone Irrigation Office, the Dedesa Woreda Agricultural and Natural Resource Office, members of the Gella and Gepha Kebele, developmental agents (DA), and key informant interviews regarding the effectiveness of the schemes were some of the groups with which discussions were held. Regular field observations were also conducted to assess the situation's effectiveness and identify any issues.

I. To evaluate the water delivery performance of both irrigation schemes using performance indicators: observations about field measurements were done to determine the structural integrity of system components and their ability to transmit flows.

Discharge Measurement: Excellent irrigation management aimed to provide adequate flow distribution over the fields and within the canal network. The canal discharges should provide all of the water required for the agriculture farm. Poor flow division causes discharges to be high in some canals and too low in others. This can lead to water-related disputes between farmers. To evenly and sufficiently distribute water to the fields, it is necessary to measure the canal outflow. To estimate discharges into the canals, it is necessary to compute conveyance efficiency and losses in a number of different ways. A current meter was used to gauge the flow velocity for this study.

Canal Discharge Measurement; The irrigation canal's actual carrying capacity was measured using the current meter at 36° and 21° longitudes, 8° and 8.49° latitudes, and 1513 and 1498 m elevations for Gella and Gepha, respectively. The measurements were taken one time per week for successive three months at different points through canals in order to record chronological and geographical fluctuations flows water used for irrigation through the canals beginning February 10 to May 10 of the 2023 irrigation season at the main canals of both irrigation schemes due to sedimentation and temreture condition . One reach was used to measure the canal discharges for the secondary canal, and point reaches were created starting at the intake of the

systems and spaced 200 m apart through the main canals. An area-velocity method was employed to compute the discharge at the selected point using the mid-section method of discharge computation. First, the sizes of the canals were measured using a tape meter. Since both irrigation schemes have rectangular sectional structures, as shown in Figure 3.3, the cross-sectional areas were determined by multiply the canal's width by its depth of flow. The wetted widths of the canal cross-section were then divided into three vertical segments. The flow depth was also measured at selected points through canals, while the flow revolutions were recorded using the current meter and stopwatch for the duration of 25 seconds. Then, the actual discharge of each segment was computed by multiplying the average area of the segment with its velocity of flow. Finally, the average actual carrying capacity of the canal was computed by adding the average discharge at each segment as suited on equation 3.4. The amount of water supplied or diverted was measured at the main canal intake to determine the average total supplied discharge of water. The current meter was used to measure the flow rates through the canal as suited on Figure 3.4, and the flow rate was calculated from the propeller rotation speed (n), which was recorded by the control unit at three different points along the canal's flow length.

A depth of 60 % below the water's surface was used to measure the average velocities of each segment. Equations based on the average number of rotation speeds were then used to calculate the mean flow velocity; the flow velocity at the monitoring point was estimated using equations (3.1, 3.2, and 3.3).

$$V = 1.93 + n * 31.17 \dots\dots\dots 0 \leq n \leq 1.98 \quad (3.1)$$

$$V = 0.19 + n * 32.05 \dots\dots\dots 1.98 < n < 10.27 \quad (3.2)$$

$$V = - 14.09 + n * 33.44 \dots\dots\dots 10.27 \leq n < 15 \quad (3.3)$$

Where, V is stream velocity, cm/sec and n is number of propeller rotation per second.

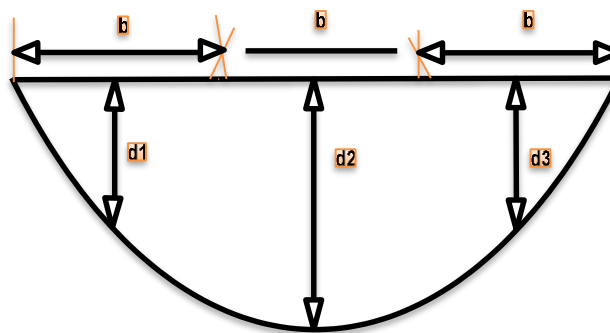


Figure 3. 2 Partial view of canal flow cross section

$$Q = \sum \Delta q_i \quad (3.4)$$

$$\text{Where; } \Delta q_i = A_i * V_i, \quad (3.5)$$

$$\text{Then } A_i = b \frac{d_1 + d_2}{2} \quad (3.6)$$

$$V_i = \frac{v_1 + v_2}{2} \quad (3.7)$$

Where; V_i is velocity of i^{th} segment of canal (m/sec)

A_i is wetted cross area of i^{th} segment canal (m^2)

b_i is base of i^{th} segment canal (m)

d_1 & d_2 are flow depth at inlet and outlet at each cross section (m)

v_1 - v_2 are velocity at each inlet and out let cross section (m/s)

Q is the discharge (m^3/s)



Figure 3. 3 Partial view of water flow measuring through current meter

II. for Evaluations of soil water related performance of both irrigation schemes; An auger and cone sampler were used to collect soil samples to determine soil texture, FC, PWP, TAW %, TAW (mm) and soil bulk density. The soil's basic infiltration capacities were measured using double-ring infiltrometers. The CROP WAT8.0 program used the maximum infiltration rate for CWR and IWR. Small amount of soil is taken from a field and used as a representative sample of the soil in that particular field as part of the soil sampling procedure. The four corners of the field are identified for the traverse method, and diagonal sampling is carried out. Locations are ordered using the zigzag approach so that they form a zigzag pattern. During the irrigation season, samples should be taken from specified (selected) fields). Accordingly, 60 undisturbed soil samples at different depths up to 120 cm root depth were collected from six farm plots (one

from the head, middle, and tail from both schemes), and from one plot, five samples were collected to determine soil physical properties as shown in Figure 3.6.



Figure 3. 4 Partial view of soil sampling

The physical attributes of the soil, like textures, FC %, PWP %, and TAW %, were determined. To evaluate the soil bulk density of the area, soil samples were collected by a cone sampler from the desired points at the head, middle, and tail of the schemes

III. to assess organizational structures and irrigation water management at both schemes; the full count of beneficiaries (330 HHs) in the chosen command area for Gella and Gepha was 150 HHs and 180 HHs, respectively were calculated by sampling method. Yamane's (1967) simplified equation (3.8) was used to calculate the size of representative samples. Finally, the computed samples were used to conduct a household survey.

$$n = \frac{N}{1+N(e^2)} \quad (3.8)$$

N is the population size or sample frame, n is the sample size, and e is the level of precision.

For both schemes, the computation was done using a 95 % confidence interval, a 10 % precision level, and a 50 % degree of variability (P).

Accordingly:

$$n = \frac{330}{1+330(0.1^2)} \quad (3.9)$$

The stratification of approximately 60 and 64 HHs for Gella and Gepha SSI schemes was done based on the number of responders and their relative location to the users of the head, middle, and tail irrigation systems.



Figure 3. 5 Partial view interview and discussions with members of the WUAs

These participants were chosen from the HHs beneficiaries list using stratified systematic random sampling techniques, in which the total number of survey participants in each area was determined by a proportional percentage of the block's total number of beneficiaries, and simple random selection method was used to choose respondents every channel reach. Female-headed homes were specifically included during this sampling and distribution period.

Household survey: moment of interview farmers at the time were not motivated to appear at the place in accordance with the request. Due to this, we were unable to complete the number of HHs interviews that we had intended. Due to these problems, total of 52 (which 25 from Gella and 27 from Gepha) HHs were interviewed. Males make up 75 percent of the respondents, while females make up 25 percent. Through a questionnaire, issues related to water management experience, their felling owing to the construction of the irrigation scheme, canal cleaning, organizations, community-level issues and experiences, and so on, were collected using questionnaires.

V. For evaluation of production per hector and it's price of both irrigation systems;

Yield samples from Wheat farmers in the two irrigation schemes were collected to calculate the effectiveness of the irrigation schemes due to the fact that wheat is a new crop for the irrigation schemes and the absence of wheat product information from the users as suited on Figure 3.5.

For this sampling wheat the area of wheat land first measured by tape meter and the area of the measured land was calculated. Accordingly, from Gella and Gepha SSIs at the head, middle and tail the area at each reach head was measured and calculated. Due to these, at the Gella SSI scheme at the head, middle, and tail the area measured were 400m², 560m² and 500m² respectively. And also for those area, around 340, 320 and 240 kg of wheat produced. And also at the Gella SSI scheme at the head, middle, and tail the area measured were 400m², 560m² and 500m² respectively. And also for those area, around 308, 275 and 220 kg of wheat produced. For an average area of 487 m² for each of the two irrigation schemes during the study period, about 3 kuintal and 2.7 kuintal of wheat were produced at Gella and Gepha, respectively, according to the sampling analysis of the wheat production. However, the Water Users Association and the Dedesa woreda Office of Agriculture and Natural Resource proposed different crop productions and price for 2022/2023 irrigation schemes production.



Figure 3. 6 wheat sampling

3.2.2 Secondary Data

For Evaluation of water delivery performance indicators: secondary data from the Bedele meteorological station included long-term average weather information like the average monthly minimum and maximum temperatures, rainfall, relative humidity, wind speed, and sunshine hours were collected. Additional secondary data, such as growing season length, areas under total command, irrigable land, and irrigated land, agricultural output, irrigation scheme cost, and production price and so on were gathered through Questionnaires from Zonal and Woreda Agricultural Offices and WUAs. Kc, Ky and maximum root depth of crop were obtained from research papers.

3.3 Data Analysis

3.3.1 Soil laboratory results analysis.

The physical parameters of the soil were determined, including textures, field capacity percent, permanent wilting point percent, and total available moisture contents percent and total available moisture content (mm/m).

1. Soil Texture

The proportional amounts of sand, silt, and clay make up the soil texture. Soil texture was examined using a laboratory working procedures with hydrometric method at Jima Agricultural Research Center. Then the results were cross-checked with the soil textural classes determined using the USDA soil textural triangle (Bouyoucos, 1951).

2. Soil FC and PWP Moisture Content

The soil's FC and PWP were also determined in Jima Agricultural Research center laboratory using pressure plate apparatus. After one day of saturation, soil samples were put under pressures of 1/3 bar (for field capacity) and 15 bar (for permanent wilting point) until there was no longer any change in the soil's moisture content. After obtaining soil moisture measurements, the soil's available water-holding capacity was determined for both irrigation schemes. Allen et al. (1998) were used to compute the total available water (TAW %) for crop use in the root zone.

$$\text{TAW (\%)} = \sum(\text{FC \%} - \text{PWP \%}) \quad (3.9)$$

Where; TAW (%) stands for total available water in percent, FC % is the percentage of soil moisture at field capacity, PWP % is the percentage of soil moisture at the permanent wilting point and The entire volumetric water content is provided by Allen et al. (1998).

$$\text{TAW} = 1000(\theta_{\text{FC}} - \theta_{\text{PWP}}) * Z_r * \text{BD} \quad (3.10)$$

Where; TAW is volumetric total available water in the root zone (mm/m), θ_{FC} is volumetric moisture content at field capacity (m^3/m^3) and θ_{PWP} is volumetric moisture content at permanent wilting point (m^3/m^3), Z_r is root zone depth (cm) and BD is bulk density of the soil (gm/cm^3).

3. Soil Bulk Density

The soil's bulk density profile was calculated using undistributed soil samples taken using core samplers with internal diameters and heights of 4.8 cm, 4.4 cm, and 4.6 cm from the head, mid,

and tail reaches, respectively. Then Jima Agricultural Research Soil Laboratory conducted the analysis. The bulk density was calculated using equation 3.11 from Jaiswal, 2003.

$$BD = \frac{W_s}{V_s} \quad (3.11)$$

Where; BD is soil bulk-density (g/cm^3) W_s is mass of dry soil (g) and

V_s is volume of soil in the core (cm^3) and $v = A \times h$ (3.12)

Where; A is area of the core (cm^2) h is the core's height in centimeters. The area of the core was calculated as equation 3.13, because the core was circular.

$$A = \pi \frac{d^2}{4} \quad (3.13)$$

Where; d is the core's interior diameter in centimeters.

4. Soil Infiltration test

In order to calculate the total crop water demand by CROPWAT 8.0 Model, the infiltration rate of the soil was required and measured using double-ring Infiltrimeters on the field. The measurement was conducted on different plots (six farm plots that were purposefully selected from the head, middle, and tail of both schemes). The installation of the double ring Infiltrimeters were installed as predented on figure 3.7.



Figure 3. 7 Double ring infiltrrometer instalation

The two schemes' rates of soil infiltration were determined using double-ring Infiltrimeters. Double-ring Infiltrimeters of 30 and 60 cm diameter were installed by hammering both rings into the root zone. The tests were started by pouring water into the internal ring.

Additionally, water was also added the same depth into the space between the two rings. The water within the external ring was used to prevent a lateral spread of water from the inner ring Infiltrimeters (FAO, 2002). A pointed rod was used to record the inner cylinder's water level. The pointed rod was set at the desired level, to which water was added. A stopwatch was also used to record time. The water level in the inner ring of the measuring rod was recorded at an interval of ten minutes for the first hour and after that at a twenty-minute interval, and as duration increased, the interval also increased. At the same time, the dropped water level in the inner ring on the measuring rod was recorded with a time interval until the constant infiltration depth was reached per sample plot.

Although the infiltration rate decreases rapidly as time passes and even approaches a constant value, it is initially highly rapid at the beginning of water application. The basic infiltration rate of the soil is defined as this constant water depth as the duration rises. The inner ring soil was continuously recorded until the soil's infiltration rate was attained, but it ultimately started to stabilize. The basic infiltration rate of the soil is defined as this constant water depth as the duration rises. Until the fundamental infiltration rate of the soil was reached, the practice of recording the water level in the inner ring was continued. This value was used as input data for CROPWAT8.0 Program to compute the total crop water demand.

3.3.2 Determination of CWR and IWR

CROPWAT 8.0 computer program; is a practical tool to carry out standard calculations for reference evapotranspiration, effective rain fall, crop water requirement and irrigation requirements (Joss, 2010).

Reference Crop Evapotranspiration (ET_o); values measured or calculated using CROPWAT8.0 model based on monthly climatic data: rainfall, minimum and maximum temperature, relative humidity, sunshine hours and wind speed were used to determine ET_o.

Effective Rainfall (R_{eff}); Effective rainfall refers to that portion of rainfall that can effectively be used by crops. This is to say that not all rain is available to the crops as some is lost through runoff and deep percolation. It was computed using CROPWAT 8.0 model, USDA Soil Conservation Service method according to (FAO, 2009).

Crop Water Requirement (CWR); the crop water requirements for different crops in the study area were computed using the CROPWAT 8.0 model, which is well-known and simple to use.

CROPWAT 8.0 calculated crop water requirements using computed monthly ETo values with crop, rainfall, and soil data. Using the CROPWAT 8.0 model, the water need of crops was calculated by taking into consideration the growth periods (initial, development, mid-season, and late season). The program estimates (ETc) were calculated using an equation 3.14 as (FAO, 1989).

$$ET_c = (ETo * Kc) \quad (3.14)$$

Where: Kc stands for crop coefficients (dimensionless), ETc stands for crop evapotranspiration (mm/day), and ETo stands for reference evapotranspiration (mm/day). The value of Kc for numerous crops obtained from (FAO 56, 1998) for the initial, middle, and final growth stages, respectively, is Kc-init, Kc-mid, and Kc-en and the values are represented on Table 3.1.

Table 3.1 values of crop parameter

Crop	Factors	Growth Stages				Total
		I	D	M	L	
Wheat	Kc	0.3		1.15	0.35	
	LGP	15	35	45	20	115
	Ky	0.2	0.65	0.55		1.05
	Z(m)	0.3			1	
	H(m)					1
	P	0.2		0.3	0.3	
Onion	Kc	0.7		1.05	0.95	
	LGP	25	30	35	10	110
	Ky	0.2	0.4	0.45	0.6	
	Z(m)	0.45		0.45	0.45	

	H(m)					0.95
	P	0.6		1.05	0.8	
Tomato	Kc	25	30	30	20	105
	LGP	0.4	1.1	0.8	0.4	1.05
	Ky	0.25		1		
	Z(m)					0.60
	H(m)					
	P	0.45		0.45	0.45	
Potato	Kc	0.5		1.15	0.95	
	LGP	20	25	30	20	95
	Ky	0.4	0.8	1	0.7	1.1
	P	0.4		0.4	0.7	
	Z(m)	0.3		0.60		
	H(m)					0.6
Pepper	Kc	0.6		1.05		0.9
	LGP	25	30	35	20	110
	Ky	1.4	0.6	1.2	0.6	1.1
	Z(m)	0.25		0.80		
	H(m)			0.70		
Green Maize	Kc	0.4		1.15	0.75	

Requirements (IR); refers to the amount of water that must be delivered through the irrigation system in order for the crop to receive its entire crop water requirements. The irrigation water requirement is calculated after the effective rainfall is computed. CROPWAT 8.0 calculates a daily water balance of the root zone in order to determine the irrigation water requirement (Harare, 2002) and is computed by (equation 3.15).

$$IWR = (ET_c - R_{eff}) \quad (3.15)$$

3.3.3 Cropping Pattern

Through household questionnaires, the cropping patterns of the irrigation seasons were gathered and examined during fieldwork. In addition to cropping patterns, farm size, yields, and market price were also collected for the surveys of 25 and 27 irrigation users from the head, middle, and tail of the Gella and Gepha SSI schemes, respectively. Additionally, numerous conversations with woreda experts and rural development agents were held to double-check the information gathered. In order to gather information and compare the results of the data, meetings with development agents, the administration of Kebele, and WUCs were also held. Finally, for the scheme's water supply, physical, Agricultural Output, and financial indicators, the collected data were compared with the yearly reports of the WUAs and Woreda Agricultural Office.

3.3.4 Internal Indicators Analysis

The main purpose of the water supply performance evaluation was to identify whether there is an adequate supply done or not to meet the demand or crop water requirement. Indicators used to measure the performance of water delivery for this study were listed below;

3.3.4.1 Water delivery performance ratio (WDPR)

This relates the amount of water actually diverted to the scheme versus the amount of water needed at peak period to be supplied, i.e. actual water supplied to the scheme divided by peak irrigation water requirement. It was computed to evaluate actual carrying capacity of the canals relative to peak consumptive demand at 36°05'36" and 21°51'53" longitude, 8°25' 22" and 8°92'88" latitude, and 1513 and 1490 m elevation for Gella and Gepha, respectively. It was calculated to assess the canals' real carrying capacity in relation to peak consumption demand accordingly, the water delivery performance ratio is calculated by Allen et al. (1998) formula.

$$WDPR = \frac{\text{the canal's actual carrying capacity}}{\text{peak consumptive demand}} \quad (3.16)$$

Where; the canal's actual carrying capacity is the canal's current discharge capacity at the system head, and peak consumptive demand is the season peak crop irrigation requirement represented as a flow rate at the irrigation system's head. By comparing canal capacity to peak consumption demand, water diverted capacity is meant to illustrate the extent to which irrigation infrastructure

affects crop intensity. Lower or higher values are not necessarily better, but they should be understood in the context of the irrigation system and in conjunction with other indicators.

3.3.4.2 Relative Water Supply (RWS)

The total amount of water used (irrigation water plus total rainfall) is related to the amount of water required by the crop in a given period of time. The total amount of water distributed over the period for irrigation systems was requested from the administration of the respective system. Plant water requirements were estimated based on weather data obtained from perimeter weather stations using the Cowpat 8.0 program and relative water supply is calculated by Allen et al. (1998) equation.

$$RWS = \frac{\text{total water supply}}{\text{crop water demand}} \quad (3.17)$$

Where; Total supply of water is irrigation supply plus effective rainfall in (m³), Crop water demand is potential evapotranspiration or the evapotranspiration each crop under well-watered circumstances in (m³) or is the actual evapotranspiration demand of the crops, determined using CROPWAT8.0 model for a given cropping patterns. For that Cropping intensity during study period, crop water demand and irrigation demand were calculated as follows: Crop water demand = CWR maize × (Area of maize/Total area) + CWR onion × (Area of onion/Total area) + [CWR tomato × (Area of tomato/Total area) + CWR pepper × (Area of pepper/Total area) + CWR cabbage × (Area of cabbage/Total area) + CWR wheat*(Area of wheat/Total area)]. The same procedure was applied for effective rain fall and irrigation demand.

3.3.4.3 Relative Irrigation Supply (RIS)

Irrigation water is a scarce resource in many irrigation systems and represents a major constraint on production. This indicator is useful to assess the level of irrigation water deficit/abundance in relation to irrigation needs (Molden et al., 1998). RIS is the ratio between the total amount of irrigation water supplied and the amount of irrigation water required (net irrigation demand, i.e. Evaporation from crops minus actual precipitation.

$$RIS = \frac{\text{irrigation supply}}{\text{irrigation demand}} \quad (3.18)$$

Whereas crop ET less actual rainfall equals irrigation demand (m³), irrigation supply (m³) is the area's departure toward irrigation. Using CROPWAT 8.0 models, the net water demand and crop

irrigation demand were determined (FAO, 2009). FAO Penman-Monteith is used to determine baseline evapotranspiration (ET_o) on a monthly basis (FAO, 2009).

3.3.4.4 Conveyance Efficiency (Ec)

To evaluate the conveyance efficiency of the main canal for this particular study, the length of the canal was marked at 200 m length based on canal shape, canal size, and canal slope. In order to calculate the flow (discharge) rate, for the assessment of water conveyance losses and water conveyance efficiency, the average values of input and outflow for all measurements for each of the chosen points are used (Shonka 2017).

$$EC (\%) = \frac{Q_{out}}{Q_{in}} * 100\% \quad (3.19)$$

$$L = (Q_{in} - Q_{out}) \quad (3.20)$$

Where; L is stands for conveyance loss (l/s), Ec is for conveyance efficiency (%), and Q_{in} and Q_{out}(l/sec) for inflow and outflow (respectively) in the designated canal reach length.

3.3.5 External Indicators Analysis

3.3.5.1 Agricultural Output /Land and water indicators Analysis

Production per unit command area, production per unit irrigated area, production per unit irrigation water supply, and production per unit water consumption are the four primary comparative performance indicators (Beshir and Bekele 2004; Awulachew and Ayana 2008; Mekonen et al., 2022). These indicators are used to compare the outcomes of irrigated agriculture. The most significant inputs for agricultural production are water and land. These four main external performance indicators were related to land and water unit output.

A. Land productivity Indicators

It was used to evaluate the productivity of land if the land is a constraint relative to water, expressed as output per unit land. Two indicators can express the land productivity.

1. Output per unit Irrigated Area (ETB/ha)

It is computed as the total value of production per harvested area in the irrigation season and calculated by Allen et al. (1998) equation.

$$OPUIA = \frac{\text{value of production}}{\text{Irrigation Cropped Area}} \quad (3.21)$$

2. Output per unit Command Area (ETB/ha)

This indicator quantifies the value of production that obtained per unit command irrigable area and Allen et al. (1998) formula's were used.

$$\text{OPUCA (ETB/ha)} = \frac{\text{production price}}{\text{command area}} \quad (3.22)$$

B. Water productivity indicators

This indicator evaluates the contribution of the irrigation to the economy in relation to consumption of the scarce resource water. Water productivity can be expressed in terms of monetary values per unity of water (Molden et al., 2007), and evaluated by two indicators.

3. Output per unit irrigated supply (ETB/m³)

The water productivity indicator calculated as the total value of production per unit water diverted from the headwork to the command area throughout the irrigation seasons.

$$\text{OPUIS (ETB/m}^3\text{)} = \frac{\text{Production price}}{\text{water supply}} \quad (3.23)$$

4. Output per unit water consumed (ETB/m³)

Consumed water is the actual evapotranspiration or process consumption from only irrigated crops (ET); it excludes other losses and water depletion from the hydrological cycle. The computed value does not affected by water losses through the system but only affected by the climatic feature of the area. It used to observe water consumption of crops at scheme level through evapotranspiration relative to the diverted and delivered amount of irrigation water. It has a contribution for irrigation management aspects; to take measurements those minimize evapotranspiration losses and Allen et al. (1998) formula's were used.

$$\text{OPUWC (ETB/m}^3\text{)} = \frac{\text{production price}}{\text{Volume of water consumed by ETc}} \quad (3.24)$$

The value of production, assessed at local or global prices, is the output of the irrigated area in terms of gross or net value of production. Production from irrigated agriculture is the main factor to compare systems in this study. As a result, agricultural output production values were calculated using local prices and then converted to US dollars in order to standardize and compare the results with those of other global studies.

3.3.6 Physical Performance Indicators

The two important physical performance indicators, Irrigation ratio and Sustainability of irrigated area were calculated.

1. Irrigation Ratio (IR)

IR is the ratio between currently irrigated areas to the command (nominal) areas to be irrigated. According to reports by Tesfaye (2020) and Mekonen et al.(2022), Lower utilization of the given irrigable area would be existed due to different constraints; i.e. lack of irrigation infrastructure, shortage of irrigation water, lack of interest on irrigation due to less return and market problems, and reduced productivity due to (soil nutrient depletion, lack of improved technologies, lack of inputs and water logging) Etc. Furthermore cropping intensity is an illustrative for land utilization capacities. The cropping intensities from 100 to 200 % are considered good, while lower ratio indicates poor intensities (Burton et al., 2000).

$$IR = \frac{\text{current irrigated area}}{\text{command area}} \quad (3.25)$$

Where; Irrigation Ratio (IR) represents the amount of land that is irrigated throughout the irrigation season (ha). The designated (nominal) irrigable area (ha) is the command area.

2. Irrigated Area Sustainability

Sustainability of irrigated area is the ratio of currently irrigable area to irrigable command area. This important indicator mainly used to observe the status of the irrigation systems either contracted or expanded. Lower values of this indicator would mean abandonment of lands which were initially irrigated; and hence, indicate contraction of irrigated area over time may be showed due to different reasons, i.e. water shortage or their own low interest of the farmers. On the other hand, values higher than 1 indicate expansion of irrigated area and would imply more sustainable irrigation.

$$SIA = \frac{\text{Current irrigated area}}{\text{irritial irrigated area}} \quad (3.26)$$

Where: SIA is Sustainability of irrigated area

The portion of the land that can currently be irrigated is known as the currently irrigable area. Initial irrigation is intended for irrigable land (ha).

3.3.7 Organizational setup and performance for irrigation water management

Sample questionnaires were constructed for both irrigation schemes to answer organizational condition and performance questions for irrigation water management and scheme maintenance, and data were collected from 52 irrigation water users 25 from Gella and 27 from Gepha SSI scheme.

3.4 Materials

The followings are the materials used to collect necessary information.

A current meter, staff gauge, seabor balance, auger, Core sampler, double-ring Infiltrimeters, measuring tape time watch, hammer, plastic bag, and GPS were used to collect the data.

4. RESULTS AND DISCUSSIONS

4.1 Soil Textural Class Results

To investigate the soil physical properties of the irrigation scheme's, soil samples were taken at depths of 0–30, 30–60, 60–90, and 90–120 cm. The USDA Soil Textural Triangle method was used to determine the textural classification of the soil in the research area based on particle size distribution. Soil texture distributions were similar for both SSI schemes in the study areas, as shown in Table 4.1 and Appendix Table 1. The clay soil was the most common soil type in the scheme's command area. According to laboratory results, the leading soil textural class in both SSI schemes, from head to tail, is clay texture. The only difference was the amount of clay, silt, and sand percentage.

soil textural class

Table 4. 1 soil textural class

Scheme	Soil depth(cm)	Particle size distribution			
		Clay (%)	Silt (%)	Sand (%)	Texture
Gella	0 – 30	51	18	31	Clay
	30 – 60	44	23	33	Clay
	60 – 90	46	20	34	Clay
	90- 120	45	23	32	Clay
Average		46.5	21	32.5	Clay
Gepha	0 – 30	54	28	18	Clay
	30 – 60	53	30	17	Clay
	60 – 90	52	34	14	Clay
	90- 120	51.5	32	16.5	Clay
Average		52.625	31	16.34	Clay

4.2 Soil Field capacity, Permanent wilting point and Bulk density results

The parameters such as the FC, PWP, and TAW of the study area soil are presented in Table 4.2 and Appendix Table.1 and vary both in soil depth in the root zone and spatially through command areas. By analyzing the water content of the soil at field capacity to the permanent wilting point, it is possible to calculate the moisture content of the soil. Hence, the dominant soil texture under both the Gella and Gepha irrigation schemes is clay, and the results of available moisture contents were 174 and 126 mm/m, respectively.

According to FAO (1985), the available moisture content of clay soil texture ranges between 175 and 250 mm of water depth per one meter of soil profile depth. Accordingly, the results of the study area laboratory are less than the values of the FAO recommendation for clay soil. In comparison, the water holding capacity of Gella scheme soil was higher. However, the water holding capacity at both irrigation schemes was poor relative to the recommended value. Generally, the water holding capacity relies on its texture and structure, as well as its organic content. The soil's poor water holding capacity can have an impact the irrigation schedule and productivity of the irrigation scheme. Therefore, it is preferable to employ the FAO-recommended values for inputs in the CROPWAT8.0 model for the computation of crop water requirements.

The bulk densities (BD) of the irrigation schemes the top, middle, and bottom reaches of the canal were 1.12, 1.11, and 1.56 g/cm³ for Gella and 1.14, 1.52, and 1.5 g/cm³ for Gepha, respectively as indicated on Table 4.2. In the bottom reach of the Gella, higher values of bulk density were recorded, which indicates the soil was more compacted than in the head and middle canal reaches of the irrigation scheme. Generally, in the three canal reaches of the irrigation schemes, the bulk density was in the recommended range of 1 to 1.8 g/cm³.

Table 4. 2 Soil FC, PWP and TAW of both schemes

Scheme	Soil depth(cm)	Parameters				Av. BD (gm/cm ³)
		FC %	PWP %	TAW%	TAW(mm/m)	
Gella	0 -30	41.71	26.92	14.79	43.37	1.12
	30 – 60	40.85	26.1	14.75	44.25	1.11
	60 – 90	40.79	26.57	14.22	41.66	1.56
	90 – 120	41.26	26.53	14.73	43.19	
	Total	164.61	106.12	58.49	174	
Gepha	0 -30	41.69	29.21	10.69	32.07	1.14
	30 – 60	41.13	28.77	9.19	27.57	1.52
	60 – 90	42.56	29.73	10.37	31.11	1.5
	90 – 120	39.56	29.55	11.75	35.25	
	Total	164.94	117.26	42	126	

Note; FC is field capacity, PWP is permanent wilting point and TAM is total available moisture in mm/m.

4.3 Soil Infiltration test result

The results computed in the Gella and Gepha SSI schemes are shown in Figure 4.1, Figure 4.2, and Appendix Table 10. The average basic infiltration rate of the Gella and Gepha SSI schemes were 5.86 cm/hr and 5.90 cm/hr, respectively, after 3.3 and 2.67 hrs. of field testing.

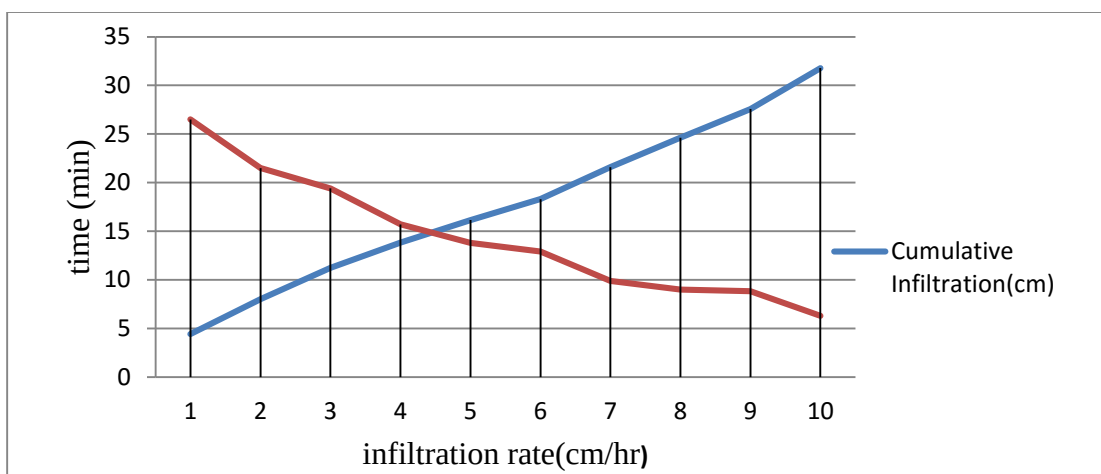


Figure 4. 1 Gella infiltration rate

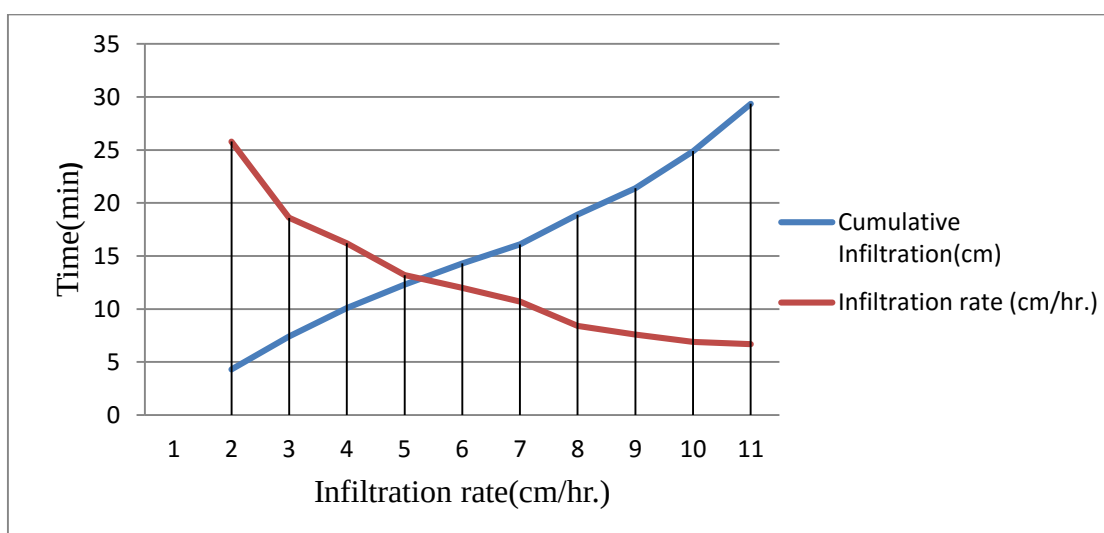


Figure 4. 2 Gepha infiltration rate

As previously stated, the soil laboratory results revealed that the predominant soil texture in both study areas is clay. According to FAO (2002), the fundamental infiltration rate of a clay soil texture is in the range of 1–7 cm/hr, as shown in Appendix Table 17. It is classified as a soil with low infiltration rate that is the characteristics of the clay- textured soil. Hence, the experimental soil infiltration rate field results were within the range of FAO recommended value and agreed with the soil textural class laboratory results. As a result it is better to use the average recommended values for inputs in CROPWAT model, i.e. 5.86 cm/hr for clay soil of Gella scheme and 5.90 cm/hr for clay soils for Gepha Scheme. At both irrigation schemes the cumulative infiltration rate increased when the basic infiltration rate is decreased.

4.4 Crop Water and Irrigation water requirement results

4.4.1 Rainfall Data(graphical representation)

Rainfall data for both irrigation schemes was gathered from the neighboring Bedele meteorological station, which has the same agro-climatological conditions as the research sites. The min and max rainfall amounts the research area includes 5.6 mm and 212.6 mm, respectively. While the typical annual rainfall in the research area is 855 mm, its average annual effective rainfall quantity is 664 mm. The variety of rainfall distribution in time and space is continuous for four months, from May to September. However, in May, there is an unanticipated distribution in time and space.

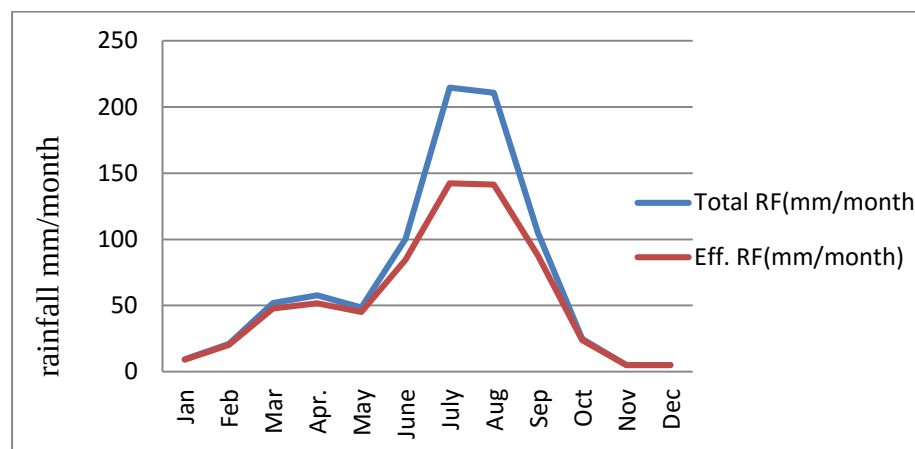


Figure 4. 3 the study areas mean monthly rainfall and effective rainfall values

4.4.2 Determination of Reference Evapotranspiration (ET_o)

The ET_o values of both SSI schemes were calculated using the method stated in the methodology chapter. In Appendix Table 12, the computed meteorological data values are summarized. The daily min and max ET_o values for both SSI schemes were 4 mm/day and 5.3 mm/day respectively. In this study area, monthly ET_o average values are higher than the mean monthly effective rainfall, except from July to August, when it is lower, as shown in Figure 4.3. This indicates that additional water supply is required from September to the June to meet agricultural water requirements. Thus, irrigation water is necessary in the study's areas from September to June to meet crop water demands.

4.4.3 Cropping Pattern results

According to field surveys, the majority of farmers in both SSI schemes produced crops twice a year, using irrigation.

The first is from September to December, and the second is from January to April, when wheat covers a substantial portion of the command area. Farmers choose crops depending on water availability, crop yield, and market value. Major crops grown in the first irrigation seasons in Gella were onion, tomato, cabbage, potato, pepper, and maize and the main crops grown in the first seasons of irrigation the Gepha were onion, tomato, cabbage, potato, pepper, and maize. According to the results of the household survey, tomatoes and onions covered the most land in the first irrigation season at the Gella scheme, with 20 ha and 25 ha, respectively. Wheat, on the other hand, was the current dominant crop in both irrigation schemes, covering approximately 43 and 51 ha during the second irrigation season at both Gella and Gepha SSIs, respectively, owing to the government's emphasis on wheat production, as shown in Table 4.3 and Appendix Tables 14 and 15. The observation shows that Gella and Gepha had cropping intensities of 192.8 and 188.12 %, respectively. Therefore, the cropping intensity of the Gella scheme is better than the cropping intensity of the Gepha system due to good irrigation water management. The Gepha SSI scheme's lower cropping intensity number indicates that poor on field irrigation water management and farmer willingness to the irrigation project.

The Gepha Water Users Association had a highly positive attitude toward the irrigation project, especially at the upper and middle reaches of the irrigation scheme. They use water responsibly in contrast to Gella Tail's organizations of water consumers. Due to these circumstances, the cropping intensity at the head and middle reach of the Gella SSIscheme was greater than at the tail and Gepha SSIscheme.

Table 4. 3 Cropping patterns of Gella and Gepha SSI

Crop types	Gella SSI scheme				Gepha SSI scheme			
	Season I		Season II		Season I		Season II	
	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)	Area (%)	Area (ha)
Tomato	29.85	20	7.14	5	31.50	23	12.5	10
Onion	37.39	25	10	7	32.87	24	15	12
Cabbage	14.9	10	4.3	3	20.54	15	6.25	5
Potato	10.40	7	-	-	5.48	4	-	-
Maize	-	-	14.3	10	-	-	-	-
Pepper	7.46	5	-	-	9.6	7	-	-
Wheat	-	-	64.3	43	-	-	66.25	50.5
Total	100	67 ha	100	68 ha	99.98	73	100	77.5 ha

4.4.4 Determination of CWR and IWR

The CROPWAT 8.0 software calculated the crop's water needs based on information about the climate, the soil, and the crops.

The National Meteorology Services Agency provided the meteorological input data needed to run the computer model for the nearby station to the study area, Bedele station, in order to estimate the crop water requirements (CWR) and irrigation water requirements (IWR) of the primary crop grown in irrigation areas during irrigation season. Crop coefficient (Kc), maximum root depth (m), crop height, critical depletion (fraction), and yield reduction factor (Ky) values were adopted from FAO Irrigation and Drainage paper 56 (Appendix Tables .10). Crop type, planting date and length of growing period (LGP) were also collected from users through a household survey. The crop water requirement (CWR) and irrigation water need (IWR) for each irrigated crop in the 202/2023 cropping seasons were calculated by using equation 3.7. Accordingly, the results of ETo ETc, R.eff and IWR are summarized on Table 4.4, 4.5 for Gella and Gepha respectively. Due to the high crop intensity and water users' positive attitudes toward the irrigation infrastructure, the values at this irrigation scheme were high.

Table 4. 4 CWR and IWR of Gella SSI

Crop type	Season I				Season II			
	Area (ha)	ETc mm/season	R.eff mm/season	IWR mm/season	Area (ha)	ETc mm/season	R.eff mm/season	IWR mm/season
Tomato	20	452.68	99.55	365.16	5	483.88	30.764	350.27
Onion	25	492.66	126.68	395.046	7	519.94	156.43	363.12
Cabbage	10	505.99	101.6	411.98	3	545.49	172.78	367.9
Potato	7	392.09	47	343.74	-	-	-	-
Maize	-	-	-	-	10	349.04	93.01	290.20
Pepper	5	366.3	79.2	291.61	-	-	-	-
Wheat	-	-	-	-	43	397.22	202.5	207.7
Total	67				68			

Based on these table the water crop water demand were calculated as $452.68 \times (20/67) + 492.66 \times (25/67) + 505.99 \times (10/67) + 392.62 \times (7/67) + 366.3 \times (5/67) = 462.77\text{mm}$ for the first irrigation season, the result is 462.77 mm/season. To convert the depth of water demand to CWR volume, multiply it by the entire irrigated area, yielding 310055.9 m^3 per season. The depth of CWR for the scheme's second cropping season is 415.68 mm/season, and $282662.4 \text{ m}^3/\text{season}$ by volume of water was needed using the same procedure as the first irrigation season.

The scheme's total CWR for the eight-month irrigation seasons per year was estimated as 592718.3 m³ per year, which was the sum of the two irrigation seasons. The scheme's whole irrigation demand was calculated both cases way as the total CWR, and the results were 375.56 mm/season, i.e., 251625.2 m³ per season for the first irrigation season and 253.38 mm per season of depth, while irrigation infrastructures were expected to deliver 172298.4 m³ season volume of irrigation supply at the farm level for the second irrigation season. The total irrigation need for both seasons in a year is 423923.6 m³.

Table 4. 5 CWR and IWR of Gepha SSI

Crop type	Area ha	Season I			Area Ha	Season II		
		ETc mm/season	R.eff mm/season	IWR, mm/season		ETc mm/season	R.eff mm/season	IWR, mm/season
Tomato	23	481.54	76.092	408.20	10	537.23	126.99	408.82
Onion	24	471.34	108.02	383.32	12	529.58	134.44	393.92
Cabbage	15	484.908	108.02	384.44	5	549.48	145.65	402.69
Potato	4	481.95	98.43	405.25	-	-	-	-
pepper	7	469.98	99.2	331.61	-	-	-	-
wheat	-	-	-		51	505.17	207.98	297.32
Total	73				77.5			

Where, CWR is crop water requirement, R.eff is Effective rainfall, IWR is the irrigation water requirements.

Similar to Gella SSI, overall crop water requirements or requirement for the 2022/2023 irrigation season was similarly determined by multiplying the CWR of each crop by its area coverage and dividing by the entire area under crop throughout the cropping season.

Table 4. 6 summary of the total volume of CWR and IWR for both schemes

Scheme name		Cropped area, ha	CWR m ³ /season	IWR m ³ /season
Gella	Season I	67	310055.9	251625.2
	Season II	68	282662.4	172298.4
	Total	135	592718.3	423923.6
Gepha	Season I	73	348786.7	282802
	Season II	78	402377	259911.6
	Total	151	751163.7	542713.6

Where; CWR is crop water requirement, IWR is the irrigation water requirements

Accordingly, the results in a depth of water requirement of 477.79 mm/season, which is then multiplied by the amount of each crop type's total cropped area that must be irrigated to produce a volume of 348786.7

m³ for the first irrigation season. The identical procedure is used for the IWR's first and second irrigation seasons.

4.5 Flow Measurement results

4.5.1 Gella SSI scheme discharge flow results

The flow record process was started in the second irrigation season of 2022/2023 irrigation year. Accordingly, the main canal of the scheme had an average capacity of 99.7 l/s, measured at an average length of 200 m, with a loss of 5.8 l/s per 200 m as indicated on Table 4.7, and the average discharge of the secondary lined canal at the head was 73.4 l/s as presented in Table 4.9.

Table 4. 7 Average observed discharge in MC of Gella SSI

Gella Main canal								
Month	Length (m)	Area (m ²)	Velocit y (m/s)	Qin (m ³)	Qout (m ³)	loss	CE %	Loss %
February	200	0.234	0.405	0.09486	0.08736	0.0075	92.1	7.9
March	200	0.234	0.441	0.1034	0.10040	0.003	97.86	2.93
April	200	0.230	0.434	0.1002	0.092245	0.0079	92.07	7.93
Average	200	0.233	0.427	0.0997	0.09384	0.00586	94.12	5.88

While the flow rate of using a current meter, measure the main canal on a weekly basis for three months, was 0.427 m/s and the average canal cross-section area was 0.233 m², due to the sedimentation of the intake structure, as shown in Table 4.7 and Figure 4.4, the flow fluctuation was decreased in this case. The highest flow, recorded in March, was 103.4 l/s. Due to the impacts of sedimentation, the main canal's supply capacity was reduced after one month. In addition, an unlined canal's average input discharge rate of 52 l/s was noted. Sisay et al. (2009) revealed an average water loss of 2.58 l/s per 100 meters from the lined main canal of the Blue Nile, which has a flow rate capacity of 43.21 l/s. These results for the lined main canal were significantly higher than similar research findings in Ethiopia.

4.5.2 Gepha SSI scheme flow rate measurement

At the average canal length, the main canal's average input discharge was measured at 146.7 l/s per 200 m, with an average area and velocity of 0.249 m² and 0.583 m/s, respectively as suited on Table 4.8 and Figure 4.4. The reason why the flow fluctuation was so significant in March is that by the time I got there, I would have cleaned every canal using the water users' power to accurately gate the discharge flows.

Accordingly the flow fluctuation be high in these months.

Table 4. 8 Average observed in the MC of Gepha SSI

Gepha Main canal								
Month	Length (m)	Area (m ²)	Velocity (m/s)	Q _{in} (m ³)	Q _{out} (m ³)	loss	CE %	Loss %
February	200	0.250	0.596	0.149	0.142	0.007	95.1	4.9
March	200	0.253	0.624	0.158	0.152	0.006	96.42	3.58
April	200	0.243	0.529	0.133	0.1267	0.0063	95.23	7.65
Average	200	0.249	0.583	0.1467	0.140	0.0067	95.52	4.48

While in this irrigation scheme, a maximum flow 158 l/s were recorded in March with an average water loss of 7 l/s per 200 meters due to canal cleaned. Contrarily, it was found that the two lined canals' average inflow discharges was 116.80 l/s, per 200 m of canal length as indicated on Table 4.10. Unlined canals also existed, with typical average lengths of 155 m and discharge rates of 77 l/s. it is impossible by comparing lined canal with unlined canal due to many losses at unlined canals naturally.

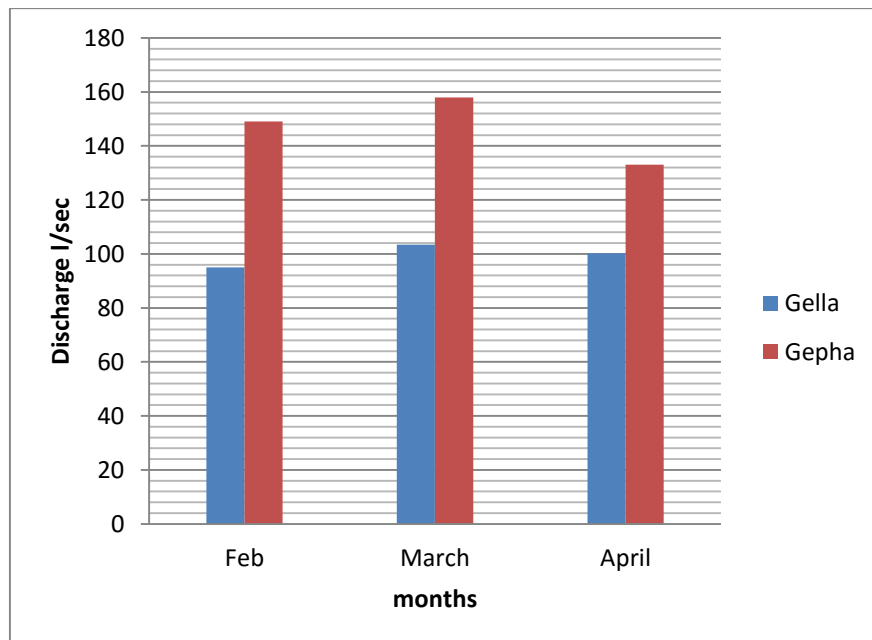


Figure 4.4 Discharge of main canal at both schemes

4.6 Water Supply Indicators results

4.6.1 Conveyance Efficiency results

The quantity loss of water through the main canals from the source of the Gella and Gepha SSI projects was measured as the average conveyance efficiency of main canals at each reach point of 200 m in length. These values were determined to be 94.12 and 95.58 % per 200 m, respectively as suited on Table 4.7 and 4.8. The average conveyance efficiency of the main canal of the Gepha scheme was greater Gella and was similar to the conveyance efficiency values recommended for clay soil for lined canals. According to FAO (1989), for medium canal lengths between 200 and 2000m, it is recommended to have clay soil conveyance efficiency greater than 95 % and be regularly maintained.

Due to grass vegetation, soil sedimentation, and the use of a traditional gate for the division box and field application, the conveyance efficiency through the secondary canal in the Gella SSI system declined to 91.96 % per 200m as indicated on Table 4.9. On the other hand, Gepha's scheme's conveyance efficiency was calculated using an unlined canal and two secondary line canals. The average conveyance efficiency for secondary-lined canal was 89.54 % as indicated on Table 4.10. Both irrigation schemes' average conveyance efficiencies were below the FAO-recommended line canal value.

Table 4. 9 Gella secondary canal conveyance Efficiency

Gella secondary canal								
Month	Length (m)	Area (m2)	Velocity (m/s)	Qin (m ³)	Qout (m ³)	Loss	CE %	Loss %
February	200	0.205	0.332	0.068	0.062	0.006	91.2	8.8
March	200	0.209	0.455	0.0953	0.0893	0.006	93.7	5.6
April	200	0.208	0.365	0.076	0.069	0.007	91	9
Average	200	0207	0.384	0.0797	0.0734	0.0064	91.96	8.03

The secondary canals in Gella, however, had relatively greater conveyance efficiency than the secondary canal in Gepha. Control gate malfunctions, canal damage, and soil settling were the main reasons or substantial losses or poor conveyance efficiency in both irrigation schemes. Based on the soil types and maintenance quality, which are the same for both schemes within the study area, the conveyance efficiencies differed inside the scheme as well as between schemes, as shown in Figure 4.7.

Table 4. 10 Gepha Conveyance Efficiency at secondary canal

Gepha secondary canal								
Month	Length (m)	Area (m ²)	Velocit y (m/s)	Qin (m ³)	Qout (m ³)	loss	CE %	Loss %
February	200	0.214	0.495	0.106	0.096	0.01	90.85	9.29
March	200	0.215	0.636	0.137	0.129	0.008	94	6
April	200	0.209	0.540	0.113	0.106	0.007	89.38	10.62
Average	200	0.213	0.557	0.1187	0.110	0.0087	89.9	10.1

When comparing the conveyance effectiveness of both schemes, the main canal of Gepha performed better than the main canal of Gella. However, at secondary canals, the Gella secondary canal's conveyance efficiency outperformed that of the Gepha secondary canals. The main canal at the Gella project was soil-sediment. However, throughout the fieldwork period, problems with grass vegetation and silt deposition in secondary canals could be seen on Gepha's scheme.

In general, the conveyance efficiency data analysis at both irrigation schemes outperformed other study results recorded in different parts of the country. According to Bayan (2017), the average conveyance efficiency (Ec) of the Mada Batu Small Scale Irrigation Scheme's main canal was 64.77 %. And also the conveyance efficiency of Gella and Gepha SSI schemes were higher than the conveyance efficiency of Gota and Shiny were found to be 77.89 and 57.75% (Tesfa Getenet, 2020). However, the small-scale irrigation schemes in Gella and Gepha had conveyance efficiencies of 94.12 and 95.58 % for their main canals, respectively, and 91.96 and 89.9 for their secondary lined canals. According to this comprise, both Gella and Gepha irrigation schemes are in good condition.

4.6.2 Estimation of the total diverted water

The entire amount of water that was diverted during the irrigation year had to be calculated using the average main canal discharge, operating hours per day, and months per year of irrigation season. The average operating hours per day and months per year of irrigation seasons of the main canal operation were collected through interviews during fieldwork with gate operators and water committees, whereas the actual carrying discharge of the main canals was measured and presented in tables 4.6 and 4.7. Water that was diverted during the 2022/2023 irrigation seasons

was calculated from the average main canal discharge by multiply it by the study areas' annual irrigation season months and by the average daily operational hours.

Although the Gella SSI scheme's operating hours were 13 hours in accordance with the design scheme, farmers typically practice ten hours of irrigation water diversion during the eight months of irrigation seasons each year. Therefore, taking into account an average canal outflow o Gella, the scheme's total amount of diverted water came to 1120792.8 m³. However, under the Gepha SSI scheme, the total irrigation water assigned for the whole irrigation season each year is 1249475.5 m³ as indicated on table 4.8.

4.6.3 The Water Delivery Performance Ratio results (WDPR)

Performance of Water Delivery Ratio evaluates the system's capacity to meet peak water demand during a specific cropping season in a given study area. The main canal has enough capacity in the study area for the Gepha and Gella SSI systems to handle peak water demand at intakes. Considering the fact that the main canal's average actual discharge capacity at the system head was 99.7 l/s for the Gella SSI scheme and 146.74 l/s for the Gepha SSI scheme, respectively, this amount represented the main canal's current capacity's average measured discharge during the period of both irrigation schemes' three-month irrigation seasons. Accordingly, the Gella and Gepha irrigation schemes' water delivery performance ratios were 1.9 and 1.7 respectively as represented on Table 4.11.

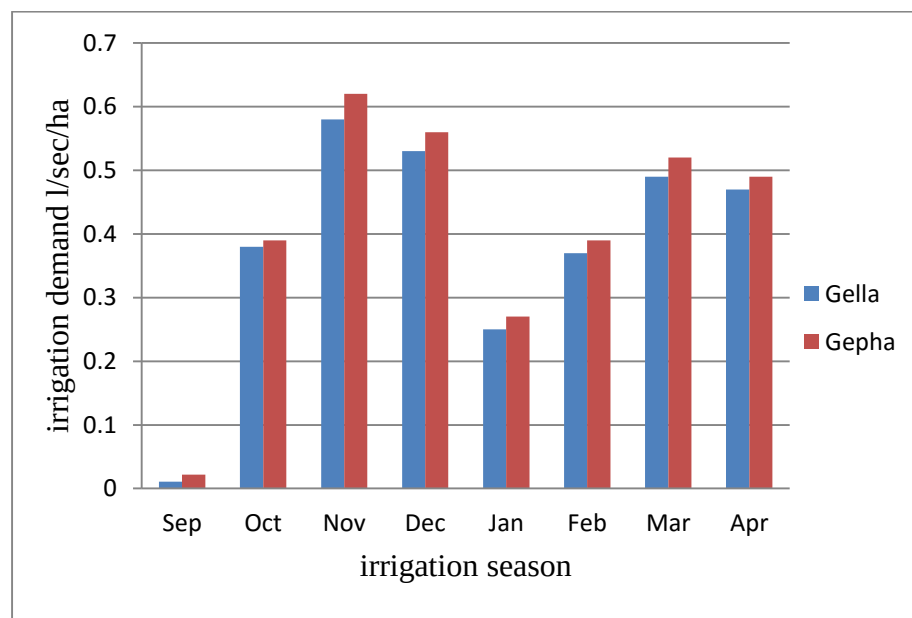


Figure 4.5 The irrigation water demands

The Gella and Gepha SSI schemes' peak irrigation needs for the 2022/2023 irrigation season were 0.58 and 0.62 l/s/ha, respectively, in November as suited on Figure 4.7. The Gella scheme's highest demand for consumption was 62.6 l/s. However, the Gepha scheme's highest consumption demand was 66.5 l/s. These result shows, the main current canal's capacity at the intake was high enough to meet the area's peak agricultural water needs. Therefore, the canal capacity was not a constraint to meet peak crop water demands.

4.6.4 Relative Water supply results (RWS)

For a specific cropping pattern and irrigation seasons, the total crop water demand, irrigation demand, total precipitation, and crop irrigation demand were calculated by the CROPWAT model to determine the relative water supply of the Gella and Gepha SSI Schemes. The values of RWS for the Gepha and Gella SSI schemes were 1.9 and 2.2, respectively, as shown in Table 4.11 and Figure 4.8. Gella's bigger value than Gepha's indicates that there is more water available at the top of the Gella scheme. The findings of both schemes showed that the total water supply was greater than the total crop water demand, and the relative water supply demonstrated the accessibility of water in relation to crop water demand. Both irrigation schemes had RWS values greater than one. This shows that the total amount of water provided to the farmed area provided for the demands of the crops, while a value of less than one indicates a water shortage (Molden et al., 1998).

Table 4. 11 Water supply indicators at each reach point

Schemes	Indicators	Head	Middle	Tail	Average
Gella	RWS	2.3	2.2	2.1	2.2
	RIS	2.7	2.6	2.4	2.6
	CE %	97.8	94.12	86.8	94.12
Gepha	RWS	2	1.94	1.84	1.94
	RIS	2.3	1.95	1.92	2.3
	CE %	95.58	81.01	78.98	95.58

However, the relative water supply of the two irrigation schemes was lower than in the countryside's earlier research done by Yusuf (2004) in the Doni and Betu Degega irrigation systems; the relative water supply ratios for each irrigation scheme were 2.32 and 2.24, respectively. But, the present study's findings were greater than those of the esteemed investigations by Dejen et al. (2012).

They carried out research on the Wedecha and Golgota projects, calculating the relative water supplies to be 1.32 and 1.25, respectively.

4.6.5 Relative Irrigation Supply result (RIS)

The RIS indicator is calculated using equation 3.15 and is the proportion of irrigation supply to irrigation demand (total water demand minus effective rainfall). The relative irrigation scheme values of the Gella and Gepha SSI schemes were 2.6 and 2.3 respectively, as shown in Table 4.11. We can deduce from the outcome that for each of the two methods, RIS values are higher than RWS values. It suggests that the main source of water supply for agriculture in the area is irrigation. The RIS values for two irrigation schemes can be seen to be greater than one.

This result indicated that the scheme head's additional irrigation supply was sufficient to meet demand. With these supply amounts and the potential for effective rainfall, it may irrigate more agricultural land. The absence of farm gate discharge regulation and the fact that irrigation water fees are determined by irrigated area size rather than discharge rates are significant contributors to an excess irrigation supply. As a result, with the help of effective rainfall and accessible irrigation water supplies, it is possible to expand or irrigate the additional land.

Table 4. 12 Water supply indicators

Parameters	Gella	Gepha
Total water diverted, m3	1120792.8	1249475.5
Effective rain fall, m3	168801.4	208450.1
Total water supply, m3	1289594.2	1457925.6
Crop water demand, m3	592718.3	751163.7
Irrigation demand, m3	423916.9	542713.6
RWS	2.2	1.94
RIS	2.6	2.3
WDPR	1.9	1.7

4.7 Physical Indicators results

The command area, initially irrigated areas, and currently irrigated areas of the two schemes' physical indicators were gathered, and the results of the indicators are reported on Table 4.12.

4.7.1 Irrigation Ratio result

This physical indication only takes the irrigated area into account or cultivated in one irrigation season rather than the annually irrigated area on the same plot of land relative to the designed command area of each scheme. As explained in Table 4.12 and Figure 4.9, the irrigation ratio values of the Gella and Gepha SSI schemes showed that 97.14 % and 95.95 % of the designed irrigable land have been irrigated, respectively as indicated on Table 4.13. This value shows that the cultivated areas of both schemes during the irrigation season were less than the designed command area. However, from the results, the Gella SSI scheme was better.

Hence, the cropping intensity of the Gella scheme, a value of 192.8 %, is reasonably better than the Gepha scheme cropping intensity of 188.12 %. The lower cropping intensity value of the Gepha SSI scheme is indicative of less utilization of the irrigable land. In addition, the main reasons for the low irrigation ratio at the Gepha scheme are also connected with poor on-farm water management and farmer willingness of irrigation.

Table 4. 13 command area and values of physical indicators of schemes

Parameter	Gella	Gepha
Currently irrigated area (ha)	68	77.5
Annual irrigated area (ha)	135	151
Designed command area (ha)	70	80
Initially cultivated area (ha)	65	69
Irrigation ratio %	97.14	95.95
Sustainability of irrigated land (%)	104.6	111.6
Cropping intensity(%)	192.8	188.12

Abebe (2015) computed the irrigation ratio of the Shina-Hamusit and Selamko schemes as 96 % and 94 % of the irrigated land, respectively, which is less than the values of Gella and Gepha SSI schemes.

4.7.2 Sustainability irrigation area

An irrigated area's sustainability reveals whether it is expanding or contracting relative to the nominal area that was first irrigated. Both irrigation schemes have seen an increase in the area under irrigation since they were first implemented, as shown in figure 4.9. According to Table 4.13, the first created areas for Gella and Gepha were 65 and 69 ha, respectively, whereas the command area throughout the design period was 70 ha and 80 ha for each. The command area is currently shrinking to 68 ha and 77.5 ha, respectively, from the designed command area.

On the other hand, the area that is currently being irrigated is growing beyond the original established area. This demonstrates that inadequate irrigation water management and scheduling, along with a decline in supply reservoir capacity, are causing the command area of these schemes to shrink from its intended nominal command area. As a result, the sustainability of the irrigation systems in Gella and Gepha was 104.6 and 111.6%, respectively. Values above 100 %, however, indicate an expansion of the irrigated area and would point to a more sustainable design (Dejen et al., 2012). Therefore, both irrigation schemes were better in terms of the sustainability of irrigated land indicators.

4.8 Agricultural Output Indicators results

The agricultural outputs were computed from two cultivation seasons, and the required data includes crop types, area coverage of each crop, average yield, and each crop's price. The output yield each crop's value is based on soil and crop management, appropriate agricultural technologies applied, and irrigation water supply infrastructure. As an existing condition, the following yield value was collected from the users through interviews during the data collection period: The cultivated area and area coverage for each crop of the irrigation season, intensity, yields, and value of production for the two schemes for the agricultural year 2022-2023 are summarized in Tables 4.14 and 4.15.

Table 4. 14 productivity and cost of Production in Gella SSI in 2022/2023

Season I(2022)						Season II(2023)				
Crop types	Area (ha)	Yield (qt/ha)	Yield (qt)	Price(E B/qt)	Total income (ETB)	Area (ha)	Yield (qt/ha)	Yield (qt)	Price(ET B /quint)	Total income (ETB)
Tomato	20	145	2800	4500	13050000	5	145	725	5000	3625000
Onion	25	80	1750	5000	10000000	7	85	560	5500	3272500
cabbage	10	125	1250	1200	1500000	3	130	360	1800	702000
Potato	7	85	560	1800	1071000	-	-	-	-	-
	-	-	-	-	-	10	90	900	1200	1080000
Gr.Maize										
Pepper	5	45	200	1600	360000	-	-	-	-	-
Wheat	-	-	-	-	-	43	60	2150	4500	11610000
Total	67				25981000	68				20289500

Table 4. 15 productivity and cost of Production in Gepha SSI scheme in 2022/23

Season I(2022)						Season II(2023)				
Crop types	Area (ha)	Yield (qt/ha)	Yield (qt)	price (ETB/q)	Total income(ETB)	Area (ha)	Yield(qt/ ha)	Yie(qt)	price (ETB/ qt)	Total income (ETB)
Tomato	23	130	3220	4500	13455000	10	140	140	5000	700000
Onion	24	75	1800	5000	9000000	12	80	960	5500	5280000
cabbage	15	115	1800	1200	2070000	5	115	575	1800	1035000
Potato	4	70	340	1800	504000	-	-	-	-	-
Pepper	7	30	280	1500	315000	-	-	-	-	-
Wheat	-	-	-	-	-	50.5	55	2805	4500	12622500
Total	73				2534400	77.5				19637500

4.8.1 Output per unit harvested area result (ETB/ha)

The production per unit harvested area expresses each irrigated area's response or return under the current conditions. The total of the areas irrigated during the 2022/2023 irrigation year at each scheme's first and second irrigation seasons, or yearly cropped area, was calculated. For the duration of the two irrigation seasons, the outputs per unit harvested area for the Gella and Gepha SSI schemes were 342744.4 and 298880.4 ETB/ha, respectively, based on the data gathered from each irrigation scheme. The difference was 43864 ETB/ha, which was an excellent value for a given amount of space. Based on the results in Tables 4.13, 4.14, the output per unit harvested area at the Gella scheme was better. This value shows there is more intensive cropping at the Gella SSI Scheme, thereby increasing the annual irrigated area in relation to the designed command area. This can also be associated with the strong irrigation management setup at the Gella irrigation scheme. Due to this, the OPUA of the Gella and Gepha irrigation schemes was 6854.9 and 5977.6 US\$/ha, and these values were greater than the results obtained in the countryside, with results of 3,714.93 and 3,545.81 US\$ per ha for Koftu and Fultino (Adugna and Ayana, 2020).

4.8.2 Output per unit of command area result (ETB/ha)

Instead of using data from the area that is currently being irrigated, this indicator assesses the productivity of the system from its command area.

The outputs per unit of command area for both seasons for the Gella and Gepha SSI schemes were 661007 and 562268.75 ETB/ha, respectively, according to the data gathered from each irrigation scheme and presented in tables 4.14 and 4.15. The output per unit command area at the Gella scheme was better than at the Gepha scheme, according to the results, since the Gepha SSI scheme had not been able to meet the expected intended command area in comparison to the Gella SSI scheme, which was a result of the different cropping intensities. The results of Gella and Gepha scheme was 13221.14 and 11245.4 US\$/ha is greater than the results obtained in countryside with the results of 5,765.57 and 3,925.42 US\$/ha (Adugna and Ayana 2020). Based on the results obtained, Gella and Gepha were in excellent condition in terms of land productivity compare to the other results.

4.8.3 Output per unit of water supply result (ETB/m³)

The results of this indicator were 41.3 and 36 ETB/m³ for the Gella and Gepha small-scale irrigation schemes correspondingly. As a result, the Gella SSI scheme's output per unit of irrigation water supply was also higher, according to the results. This is due to the relatively excess supply of irrigation water at the Gepha SSI scheme at the head, which results in lower output per unit of irrigation water diverted. In contrast, the higher value of output per unit irrigation water supply at the Gella SSI Scheme implies effective utilization of limited water resources. Generally, the Gella scheme was better on both land and water productivity. In comparison to other research findings in the countryside, the production per water supply in Gella and Gepha of 0.83 and 0.72 US\$/m³ seemed greater than 0.23 and 0.1 US\$/m³ for Koftu and Fultino SSI schemes (Adugna and Ayana, 2020). And also this outcome is likewise greater than the results of 0.38 and 0.37 US\$/m³ that were investigated in Malaysia and Burkina Faso, respectively (Molden et al., 1998).

4.8.4 Output per unit water consumed result (ETB/m³)

This indicator evaluates the productivity of the schemes from its command area rather than from the currently irrigated area. According to the data collected from each irrigation schemes and explained in table 4.14 and 4.15, the outputs per unit of command area were 661007 and 562268.75 ETB/ha for Gella and Gepha SSI schemes, respectively. The output per unit of water consumed for the Gella and Gepha SSI schemes was 45 and 38 ETB/m³, respectively.

Table 4. 16Agricultural output indicators for both schemes

Indicators	Scheme name		
	Gella	Gepha	Unit
OPUIA	342744.4	298880.4	ETB/ha
OPUCA	661007	562268.75	ETB /ha
OPUWS	41.3	36	ETB /m ³
OPUWC	45	38	ETB /m ³

The result shows that the output per unit of water consumed was relatively higher in the case of the Gella SSI scheme; this is due to the difference in cropping intensity, where the ratio of annually irrigated area to command area was higher.

The cropping intensity of Gella (192 %) was higher than Gepha (188 %) while the large portion of the harvested area was covered with high value crops onion and tomato at Gella than Gepha scheme. Therefore, the main reasons due to the poor water and land production in Gepha could be attributed to purely water management at the scheme level and farm level rather than various aspects of agriculture, such as land appropriateness and soil fertility, which are nearly the same for both schemes under the studies

The results of 2.6 and 1.2 US\$/m³ output per unit of water consumed in the Gella and Gepha SSI schemes were higher than the results obtained in Koftu and Fultino (Adugna and Ayana, 2020). Generally the values of water productivity indicators computed from Gella had shown higher performance. This implied there was better water management and crop selection experiences that leads to better water productivity functions.

According to Table 4.16's results for agricultural indicators, the values of OPUIA at the Gella SSI scheme appear to be higher than those at the Gepha irrigation scheme.

The Gella Small Scale Irrigation Scheme has produced better and more significant results than just this indicator alone.

At the Gella Small Scale Irrigation Scheme, those values were attained through effective irrigation water management and irrigation scheduling. Accordingly. In comparison to Gepha Small Scale Irrigation Scheme, Gella was superior.

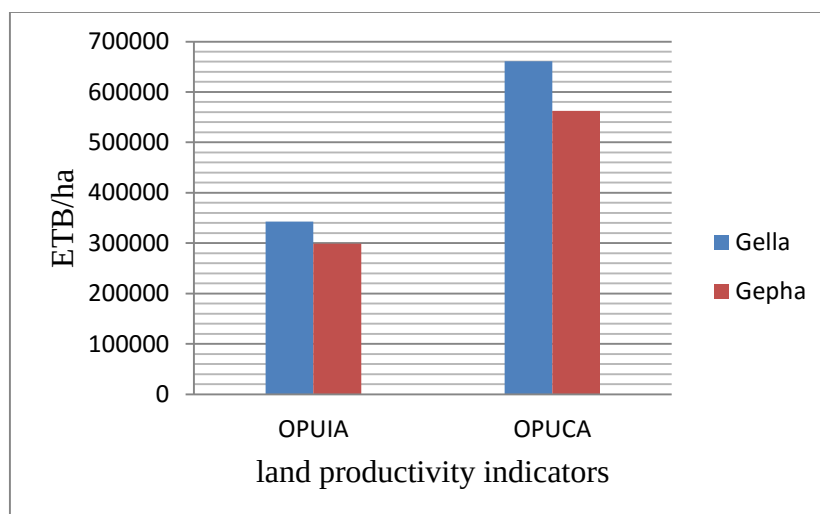


Figure 4. 6 Land productivity indicators

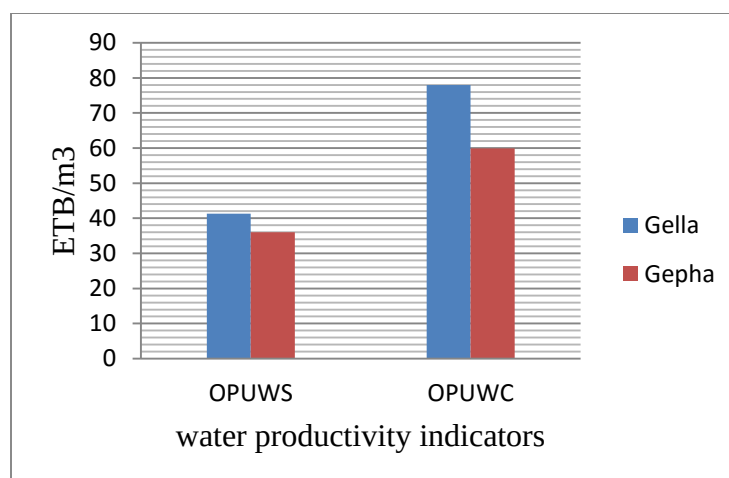


Figure 4. 7 Water productivity indicators

4.9 Organizational setup

4.9.1 Organizational Structure of WUAs

After the construction of small-scale irrigation once finished, the government assigned Schemes for the community through collaborative management by both the community and government to fulfill their respective obligations. The water users are responsible for operation and minor maintenance and major maintenance and rehabilitation works can be beyond the capability of the consumer government's responsibilities. Today, the main duties of water user associations are to distribute water and manage its distribution, ensure the scheme's upkeep by planning activities and mobilizing resources, and settle water-related disputes in accordance with their rules. However, neither event is currently able to carry out its obligations in reality under the Gella and Gepha SSI schemes.

For improved irrigation system maintenance and operation systems and levels of distribution, the WUAs have an executive committee, a subcommittee, and water user teams. Each irrigation system has a seven-person executive committee in charge of running and maintaining the irrigation systems. The WUA committee is made up of a secretary, two members, a control and monitoring committee, a cashier, and a chairman and vice chairman.

The highest body is the general assembly where all irrigation system constituent get together to discuss the most important topics and make decisions that are ultimately based on the bylaw. The general assembly is in charge of setting up irrigation schedules and allocating water. The general assembly's direction and the bylaws are monitored and controlled by the controlling and monitoring committee, which also assesses whether the implementation process is taking place in accordance with them.

The Agricultural and Rural Development Office drafted the bylaw with the primary goals of maintaining infrastructure for irrigation and guaranteeing equitable distributing water to the recipients. Depending on how the schemes are laid out, the organizational structure and management duties of the committees are further dispersed. The water users teams (WUTs) 'Abbaa Bishaanii', which includes a variety of water user groups 'Garee itti Fayyadamtoota Bishaan jallisii', are made up of all water consumers in irrigation systems.

In the corresponding territory units or water user teams, subcommittees are in charge of managing water distribution and coordinating maintenance tasks. They typically answer to the executive committee and are required to notify the board of any violations of the water distribution by-laws. However, due to organizational shortcomings, they were unable to efficiently carry out this duty as required by the bylaws. Generally, the Gella SSI scheme has 7 WUTs and 14 "Garee Bishaanii," each of which contains 10–13 users. While Gepha has 8 WUTs and 8 WUGs, each WUG contains 15–25 users ("miseensota itti Fayyadamtoota Bishaan jallisii"). On the other hand, about 25 and 23% of the WUAs were women respondents in the Gella and Gepha irrigation schemes, respectively.

4.9.2 Bylaws

The SSI program needs internal bylaws that have been well established, contain clear rules and regulations formulated and agreed upon by beneficiaries, and protect the interests of all irrigators in order to be managed effectively and sustainably. Compared to Gepha, a WUA in Gella has bylaws that are significantly better drafted and defined, even so implementation problems.

After two years of operation, the Gepha WUA bylaw was established. The productivity and viability of the scheme were impeded by establishment gaps. Although Gepha's WUA was established in 2017, it does not have a documented and detailed bylaw. Beneficiaries were frequently bound by cultural laws. The bylaws' provisions have not yet been fully applied as a result of committee members' resistance and the inadequate functionality of WUAs at organizational levels.

The charges against those who were found guilty of violating the WUA committee members' decisions, breaching canals, abusing their power to use water before their turn, and abusing their turn have not been fully brought. Numerous unlawful water withdrawals and canal breaches occurred in Gepha SSI, but none of them were prosecuted in compliance with the bylaw. The water user association committees in Gepha also acknowledged, during group discussion, which they hadn't yet been provided with any knowledge of any information regarding the new IWUA declarations.

4.9.3 Fee Collections

For both irrigation schemes, an estimate of the water fee would be made according to the legislation based on the standardized area of agricultural land ($25 \text{ m} * 50 \text{ m} = 1250 \text{ m}^2$); for this area, 35 ETB/season would be paid for members and 55 ETB/season for non-members, and a variety of taxes would be paid for one irrigation season. The WUAs Committee did not measure the amount of irrigated arable land in each household; therefore, their calculations were based on a rough estimate, which varied from farmer to farmer.

Additionally, they did not collect water fees using legitimate receipts. Gepha SSI systems generally lacked billing transparency, which was incompatible with legitimate financial systems. As a result, it's essential to establish a uniform system for recording expenses and to produce official documentation for each payment.

4.9.4 Conflicts and Conflict managements

The majority of disputes in irrigation schemes involved irrigation beneficiaries, particularly head and tail users. However, disputes between users upstream and downstream at various system levels were less of an issue at the Gella schemes. User disputes in the irrigation system: 55 % of respondents to the Gepha SSI scheme reported such issues. 56 % of the respondents reported user conflict in Gella, where it was generally better. The main sources of issues in the Gepha SSI project were water theft and rivalry brought on by an increase in water customers.

Table 4. 17 Beneficiaries response on conflict over irrigation water

	Gella		Gepha	
	Frequency	%	Frequency	%
Yes	14	56	12	45
No	11	44	15	55
Total	25	100	27	100

4.9.5 Degree of Participation of WUAs in Operation and Maintenance

The sense of ownership and sustainability are positively impacted by users' participation during the planning and building phases. But the primary informant interview showed that neither the planning nor the construction phases of the Gepha irrigation schemes involved the beneficiaries. The scheme's farmers were unaware of how crucial irrigation development was to the region. Beneficiaries had no interest in effectively exploiting the irrigation infrastructure that had been built for them as a result. Users haven't yet performed any operation or maintenance tasks, even though the government assigned them to them as minor maintenance and operation duties. However, beneficiaries periodically clean canals by sprinkling weeds and sediment with them. Both within and among beneficiaries of the same irrigation schemes, participation varied. Farmers typically favor cleaning the neighboring canals from their field plots.

However, the WUAs have been taking part in the small maintenance and operation of irrigation structures as they gain more knowledge and experience in irrigation water management. As a result, 36 and 29 % of respondents in the Gella and Gepha SSI schemes, respectively, paid close attention to irrigation maintenance and operation. Gella WUAs were therefore successful in controlling irrigation water.

Table 4. 18 Perceptions of respondents on the maintenance condition of irrigation infrastructures

Maintenance conditions	Gella		Gepha	
	Frequency	%	Frequency	%
Good	9	36	8	29
Medium	8	32	9	36
Bad	5	20	6	22
Very Bad	3	12	4	13
Total	25	100.0	27	100.0

4.9.6 Water allocation and Water Distribution

Quantity of water allotted for each field in the size of each irrigation systems was taken into account of the farm plots and followed a strict rotational schedule in the water team called "Abba Laga." The types of crops and their water needs were not taken into account. Without any technical assistance from the irrigation assistant, the WUA committees design the schedule based on educated guesses.

Table 4. 19 Main criteria used to scheduling irrigation

Scheduling criteria	Gella			Gepha		
	Frequency	%	Rank	Frequency	%	Rank
Condition of the plant	2	8	3	14	50	1
Fixed time periods	16	64	1	7	26	2
Water supply	7	28	2	6	24	3
Total	25	100.0		27	100.0	

Data source; HHs field survey

Table 4. 20 Levels of water distribution

Levels	Gella		Gepha	
	Frequency	%	Frequency	%
Very fair	2	8	6	23
Fair	15	60	14	51
Unfair	8	32	7	26
Total	25	100	27	100.0

Water allocations and a tight rotation method created and carried out by committees of water user associations are consequently subject to numerous design and implementation restrictions.

The attribution was determined solely based on speculation as it relates to design. The size of each plot was taken into account when determining the amount and duration of the water supply, rather than the specific crops' water needs. This is where constructing a fair water distribution system becomes problematic.

Gaps and Causes of Poor performance of the Irrigation schemes

4.9.7 Performance Gaps of the Irrigation Schemes

By physical indicators; Irrigation Ratio at both irrigation scheme the value of the observed result was less than one. This value shows there is the constraining irrigation land from both irrigation schemes. Poor on-farm water management, ineffective irrigation scheduling methods, and canal sedimentation are the primary causes of low irrigation ratios and the sustainability of the irrigated area in both schemes. For the Gepha Scheme, farmer willingness is an additional contributing factor. As observed from production indicators in both irrigation schemes, there was a considerable gap in land productivity indicators (OPUIA and OPUCA) between the Gella and Gepha irrigation schemes. The results of the OPUA of Gella and Gepha were 342744.4 and 298880.4 ETB/ha, and the difference values between both schemes were 43864 ETB. The land productivity of the Gella scheme was greater than that of the Gepha scheme. The Gella scheme had a higher level of land production than the Gepha scheme.

In Gepha, the gaps were due to poor irrigation water management and farmer willingness to participate in irrigation projects. Organizational indicators show that WUAs in Gella have more clearly stated and defined rules than those in Gepha. The lack of written and specific regulations in the Gepha organization has resulted from a deficiency in the organization's facilities. The beneficiaries were also guided by their personal cultural beliefs and the ineffectiveness of the WUAs, which prevented a thorough implementation of the legislation's rules. The absence of fee collection transparency in both SSI systems made them incompatible with lawful financial systems. As addressed in the literature, there are four different types of performance gaps that exist in irrigation management, according to Douglas and Juan (1990). Out of this, depending on what emerges in the scheme, the third and fourth performance Gaps were found in this study. The third Gap developed when there was a discrepancy between management objectives and actual results, which included water delivery timetables, and the fourth Gap was management impacts. There is a discrepancy between what people believe irrigation should be most effective at and what actually happens.

4.9.8 Causes of the Irrigation Schemes' Poor Performance

The same problems of low performance at both irrigation schemes are caused by the sedimentation of canals and vegetation. Particularly in Gepha secondary canals, the canals' short

cross-sectional area causes them to overflow. And also there are no flow-controlling structures present. Ineffective fee collection methods, improper irrigation schedules, etc.

4.10 Improvement Options for Poor Performance of the Irrigation schemes

The following improvement alternatives are created for the enhancement of the performance of the two irrigation performance assessments.

4.10.1 management improvement

❖ Training on Irrigation water management

When extra water is applied at the farm level, irrigation production productivity rises with irrigation water users' assumptions. Farmers felt let down by the volume of discharges they were receiving at the farm gates as a result. As a result, training was given to users to provide greater knowledge regarding irrigation water management. The improvement of irrigation performance also depends on educating farmers and irrigation managers about technical and financial issues.

4.10.2 infrastructure improvement

✚ Fixing Schedule for operation and maintenance of the canals

There isn't a specific schedule for clearing canals; therefore, it makes sense that people clear and maintain canals as needed at any time. Both of these characteristics of the irrigation schemes poor maintenance, excessive water diversion at the head, and unequal water distribution at the tail are severe issues with the Gepha Scheme. The currently irrigated area at both schemes is smaller than the intended command area. This is mostly caused by poor irrigation water management. Both irrigation networks' secondary canals were mostly overgrown with grass, weeds, and soil. Water user associations are unable to complete their operation and maintenance responsibilities. Because the water user associations can't perform, the operation and maintenance work on the regular basis.

✚ Repair and Re-install control gate at Division box and field application

At division boxes and turnouts, there Metal sheets (flow control) gates put within the irrigation system. However, half of them broke down, and some of them were stolen. Because of them, additional water was lost and wasted. In order to reduce those water losses and distribute water fairly among scheme water users, the repair and re installation of control gates at division boxes and field applications are crucial.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusions

In order to evaluate and raise the production level of scarce resources, such as water and land, to increase returns and identify practices that lead to higher performance, comparative performance evaluation of irrigation schemes is very important. The extension of physical infrastructure has received the majority of attention from interventions implemented so far in Ethiopia to decrease poverty and boost productivity, the creation of small-scale community controlled irrigation schemes. Indicators for benchmarking results and identifying improvement gaps have not received much attention when analyzing the success of current programs on a seasonal basis, particularly for community-managed projects.

This study compares the effectiveness of typical small-scale, community-managed irrigation schemes in the Oromia Region of Ethiopia using the Gella and Gepha SSI projects as case study. A transect walk, fieldwork for flow measurements, infiltration rate tests, soil sample collection, a home evaluation, and discussion have all been done as part of the study to identify the systems. The performance was then evaluated utilizing groups of IWMI equivalent metrics, such as financial, physical, and agricultural indicators as well as water supply indicators.

Accordingly, Gella and Gepha SSI schemes were gave a service for 10 and 8 years operational period respectively. The Designed command area of Gella and Gepha SSI schemes were 70 and 80 ha and the land holding of beneficiaries for both irrigation schemes were ranges from 0.25 ha to 0.75 ha. Both irrigation schemes has no tertiary canals, instead farmers uses field canals and directly from secondary canals. Furrow type irrigation method and Rigid rotational irrigation schedule has been practiced in both irrigation scheme. The soil textural structure at both irrigation schemes were clay texture, the only diffirence is the percentage of sand, silt and clay. The water holding capacity of Gella Small Irrigation Scheme was greater than Gepha water holding capacity.

In both irrigation schemes, the beneficiary's contribution to canal clearing was minimal. The WUA's organizational capabilities and legal enforcement of regulations were inadequate as a result of illicit water extraction and unequal water distribution in irrigation schemes. Beneficiaries receive water allocations in actuality, and both schemes for irrigation have flaws in their fee collection mechanisms. The user fees that were collected have not yet been applied to annual maintenance tasks in Gepha SSI scheme.

Additionally, the results of the irrigation ratio indicators for both irrigation schemes were less than 1. This shows the irrigated area was less than the command-designed area. The minority of canals at both irrigation schemes were covered by weeds, grass, and soil. The water user associations do not perform the operation at regular times. However, Gella SSI scheme was better in land and water productivity than the Gepha SSI scheme. The reason was due to higher cropping intensity practiced in Gella Scheme. While at Gepha scheme, the poor irrigation water distribution and low cropping intensities were contributed for low land and water productivity. The output per unit command area is higher than the output per unit harvested area at both irrigation schemes were indicating that the cropping intensity at each scheme is higher than 100 %. On the other hand, the output per unit water consumed is higher than output per unit water supplied at both schemes and the excess water supplied was higher at Gella scheme. The Gross Return on Investment of the Gella SSI Schemes was higher than Gepha's Gross Return on Investment due to service year and higher crop intensity at Gella scheme.

Accordingly, based on comparative performance indicators, Gella SSI scheme was performing better and could be benchmarked for the Gepha scheme by outputs performance and relatively better supply of water at the system head. Since there was excess supply at the head of the systems, no water supplies limitation at both schemes. Therefore, it is important to compare the scheme based on the land productivity indicators rather than water productivity. Based on these indicators, Gella scheme performed better.

5.2 Recommendations

Some recommendations are provided for the enhancement of the schemes' functionality and for the direction of future work based on the results stated within the study area.

-  If sufficient training and technical support on distribution and irrigation scheduling has been given, the water available at the head of the systems may be used to irrigate more area.
-  The schemes' maintenance work should be done on a regular basis.
-  It is crucial to implement and adapt the new IWUAs proclamations No. 84/2014 for the benefit of beneficiaries and relevant stake holders.

REFERENCES

- Abebe Shankut (2015). Performance Assessment Irrigation Schemes According to Comparative Indicators: Volume 5, P.9
- Abebe Shankut, Kindie Tesfaye, Fentaw Abegaz and Tilahun Hordofa, (2013). Determination of Water Requirement and Crop Coefficient for Sorghum at Melkassa, Ethiopia. Volume 7, P.10
- Abera Shanko, D. (2018). Performance Evaluation of Farmers Managed Small-Scale Irrigation: The Case of Fultino Small-Scale Irrigation Scheme in Ada'a District of East Shoa, Oromia.
- Adugna, M., & Ayana, M. (2020). Comparative Performance Evaluation of Two Small Scale Irrigation Schemes in East Shoa Zone, Ethiopia. October 2020. <https://doi.org/10.13140/RG.2.2.29167.87204>
- Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998).Crop Evapotranspiration. Guidelines for computing crop water requirements. FAO irrigation and drainage paper No.56.FAO.Rome.
- Ave, N. P. (2011). United States Department of the Interior Bureau of Reclamation. 2279, 904.
- Awulachew SB and Ayana M. (2011). Performance of irrigation: An assessment at different scales in Ethiopia. *Experimental Agriculture* 47: 57-69.
- Awulachew, S. B., Yilma, A. D., Loulsegged, M., Loiskandl, W., Ayana, M. and Alamirew, T. (2007). Water resources and irrigation development in Ethiopia.
- Balmuri V. 2014. Determination of Infiltration Rate Soils Using Single and Double Ring Infiltrometers and Study of Drought Analysis in Karim Agar District of Andhra Pradesh. Published Thesis paper Submitted to departments of Civil Engineering, National Institute of Technology, and Rourkela.
- Belachew muche mekonen, d. b. and m. f. m. (2022). the current irrigation potential and irrigated land in ethiopia : asian journal of advances in research the current irrigation potential and irrigated land in ethiopia : a review. *Asian journal of advances in research*, 13(2), 1–8.
- Belay, A. M., Belay Bahir, S. A., & Yimam Bahir, A. Y. (2022). Evaluating the Performance of Small-Scale Irrigation Schemes in Sub Humid Ethiopian Highlands; a case study in Mugie and Fesas. <https://doi.org/10.21203/rs.3.rs-1303002/v1>

- Beshir, A., and Bekele, S. (2006). Analysis of irrigation systems using comparative performance indicators: A case study of two large scale irrigation systems in the upper awash basin. Addis Ababa:
- Bos, M.G. (1997). Performance indicators for irrigation and drainage. *Irrigation and Drainage systems*, 11:119-137.
- Bouyoucos, G.H., 1951. A Calibration of the Hydrometer for Making Analysis of Soils. *Argon Journal* 43, 434–438.
- BURT, C. M. & STYLES, S. W. 2004. Conceptualizing irrigation project modernization through benchmarking and the rapid appraisal process. *Irrigation and Drainage*:
- Depeweg, H. (1999). Off-Farm Conveyance and Distribution Systems. *Land and Water Engineering. CIGR Handbook of Agricultural Engineering. Volume I. America Society of Agricultural Engineers (ASAE). USA.*
- Douglas L. V., Juan A. S. 1999. Transfer of Irrigation Management Services. Guideline: Irrigation and Drainage Paper. No. 58. FAO, Rome
- Dupriez and De l eener Irrigation water management methods and application, (2002). IWMI
- Smith LED (2004). Assessment of the Contribution of Irrigation to Poverty Reduction and Sustainable Livelihoods. *Int. J. Water Resource*.
- Eticha Shiberu, (2011). Performance Evaluation of Small scale Irrigation Schemes in Adami Tullu Jido Kombolcha Woreda, Central Rift Valley of Ethiopia. Haremaya University. P.75
- Fentahun Moges, M. (2019). Performance evaluation of golda small-scale irrigation scheme in Assosa Woreda, Benishangul Gumuz Regional state, Ethiopia, Hawassa University.
- FAO (Food and Agriculture Organization), (1989). Irrigation water management; Irrigation method; Training manual no. 5. P. 140
- FAO (1998). Crop Evapotranspiration-Guidelines for Computing Crop Water Requirements. FAO Irrigation and Drainage Paper, 56, Rome. P. 326
- FAO (1989). Guideline for Designing and Evaluating Surface Irrigation Systems. *Irrigation and Drainage Paper. No. 45.FAO, Rome*
- Geda, H. B. (2020). Causes of Climate Change and Its Coping Up Strategies in Case of Gechi Woreda, Bunno Bedelle zone, South Western Ethiopia. 66, 1–12.

- Gebremeskel Gebremichael Gebregziabher, (2013). Impact of small scale irrigation on the livelihood of rural farm households: Indira Gandhi National Open University. P. 112
- Hagos F, Makombe G, Namara RE, Awulachew SB (2009). Importance of irrigated agriculture to the Ethiopian economy: Capturing the direct net benefits of irrigation. Colombo, Sri Lanka: International Water Management Institute. 37p. (IWMI Research
- Hamdy, A. (2007). "Water use efficiency in irrigated agriculture: an analytical review." Water use efficiency and water productivity: WASAMED project: 9-19.
- Harare (2002) Crop Water Requirements and Irrigation Scheduling; Manual Module 4. P. 132Report 128).
- HASSEN, Y. K. 2004. Assessment of small scale irrigation using comparative performance indicators on two selected schemes in Upper Awash River Valley. Msc Thesis. Alemaya University, Ethiopia.
- IRMAK, S., ODHIAMBO, L. O., KRANZ, W. L. & EISENHAUER, D. E. 2011.Irrigation efficiency and uniformity, and crop water use efficiency
- Jason shvanda (2011). Stream gagging: measuring stream velocity and discharge. P. 42
- JURRIENS, M. & LENSELINK, K. 2001. Straightforward furrow irrigation can be 70 % efficient. Irrigation and Drainage: The journal of the International Commission on Irrigation and Drainage, 50, 195-204.
- Ministry of Water Resource, Irrigation and Electric),(2013-2015).Water and development quarterly bulletin, Addis Ababa, Ethiopia. MoWIE
- Molden, David J., R. Sakthivadivel, Christopher J. Perry, Charlotte de Fraiture, and Wim
- H. Kloezen. 1998. Indicators for comparing performance of irrigated agricultural systems. Research Report 20. Colombo, Sri Lanka: International Water Management Institute.
- Murray-Rust, D.H. and W.B Snellen. 1993. Irrigation system performance assessment and diagnosis. Colombo, Sn Lanka. International Irrigation Management Institute. 148 pp.
- Nuru, N., Ayana, M., & Umer, N. (2020). Comparative Performance Assessment of Two Small Scale Irrigation Scheme in West Harerghe, Oromia Regional State, Ethiopia. American Journal of Management Science and Engineering, 5(3), 24.

<https://doi.org/10.11648/j.ajmse.20200503.11>

Solomon Wondatir Taye (2016). Performance evaluation of irrigation schemes: a case study of jari and Aloma small irrigation schemes. Arba Minch University, Ethiopia. P. 166

Tesfaye, H., Dananto, M., & Woldemichael, A. (2019). Irrigation & Drainage Systems Engineering Comparative Performance Evaluation of Irrigation Schemes in Southern. 8(2), 8–12. <https://doi.org/10.4172/2168-9768.1000232>

WONDATIR, S. 2016. Performance evaluation of irrigation schemes: A case study of Jari and Aloma small-scale irrigation schemes, Tehuledere District, Ethiopia. Arba Minch University.

APPENDIX TABLE

Appendix Table 1 Soil Laboratory results

Scheme	plots location	Soil depth (c)	Sample Code	Particle size distribution				BD	Parameters	
				Clay %	Silt %	Sand %	texture		FC %	PWP %
Gella	Head	0 -30	GelH1	44.4	18	37.6	clay		43.56	28.63
		30 – 60	GelH2	38.4	26	35.6	Clay		42.69	27.32
		60 – 90	GelH3	40.4	28	41.6	Clay		41.85	26.58
		90 – 120	GelH4	41.07	23.93	35	Clay	1.12	42.7	27.51
	Middle	0 -30	GelM1	54.4	18	27.6	Clay		41.68	27.17
		30 – 60	GelM2	42.4	26	31.6	clay		39.52	25.96
		60 – 90	GelM3	44.4	16	39.6	clay		40.76	26.07
		90 – 120	GelH4	44	17.5	38.5	Clay	1.11	41.07	26.03
	Tail	0 -30	GelT1	54.4	14	31.6	clay		39.89	24.98
		30 – 60	GelT2	49.4	16	34.6	clay		40.35	25.02
		60 – 90	GelT3	54.4	18	27.6	Clay		39.75	27.06
		90 – 120	GelH4	53.01	17.09	29.90	Clay	1.56	40.03	26.05
Gepha	Head	0 -30	GepH1	56.45	27.36	16.19	Clay		44.23	32.15
		30 – 60	GepH2	58.87	29.67	11.46	Clay		42.39	30.62
		60 – 90	GepH3	59.06	30.55	10.39	Clay		43.31	31.38
		90 – 120	GepH4	58.13	27.90	13.97	Clay	1.14	43.00	29.98
	Middle	0 -30	GepM1	50.24	25	24.76	Clay		40.95	28.34
		30 – 60	GepM2	48	31.33	20.67	Clay		41.74	28.05
		60 – 90	GepM3	51.44	29	19.56	Clay		42.64	28.96
		90 – 120	GepH4	49.75	28.25	22	Clay	1.52	42.02	29.01
	Tail	0 -30	GepT1	53	34.4	12.6	Clay		39.88	27.14
		30 – 60	GepT2	49.7	32	18.3	Clay		39.25	27.63
		60 – 90	GepT3	48.34	31.5	20.16	Clay		41.73	28.84
		90 – 120	GepH4	50.12	32.23	17.65	Clay	1.5	42.09	29.65

Appendix Table 2 Discharges and conveyance efficiency of Gella main canal

Month	Observations	Area, m ²	Velocity, 0.6d, m/s	Qi m ³ /s	Qo m ³ /s	CE (%)	Loses %
February	200 m	0.234	0.376	0.088	0.080	90.17	9.83
	250 m	0.235	0.435	0.102	0.096	94.4	5.6
	300 m	0.236	0.403	0.095	0.087	91.73	8.27
Average	250 m	0.234	0.405	0.095	0.087	92	7.9
March	200 m	0.234	0.440	0.103	0.102	98.8	1.2
	150 m	0.2343	0.446	0.1045	0.103	98.88	3.49
	250 m	0.234	0.436	0.102	0.098	95.89	4.11
Average	200 m	0.234	0.441	0.1034	0.10040	97.86	2.93
April	200 m	0.225	0.430	0.099	0.093	94.12	5.88
	150 m	0.230	0.434	0.100	0.096	96.4	3.6
	250 m	0.231	0.438	0.101	0.087	85.7	14.3
Average	200 m	0.230	0.434	0.10019	0.092	92.07	7.93
Grand Av.	200 m	0.233	0.427	0.0997	0.094	94.12	5.88

Appendix Table 3 Discharges and Conveyance efficiency of Gepha main canal

Month	Observations	Area, m ²	Velocity, 0.6d, m/s	Qi m ³ /s	Qo m ³ /s	CE (%)	Loses %
February	200 m	0.243	0.564	0.1369	0.122	89.53	10.47
	200 m	0.253	0.610	0.1544	0.149	96.90	3.1
	200 m	0.253	0.616	0.156	0.153	98.97	1.03
Average	200 m	0.250	0.596	0.149	0.142	95	4.9
March	200 m	0.247	0.626	0.1544	0.152	98.8	1.2
	200 m	0.260	0.635	0.1656	0.162	97.87	2.13
	200 m	0.251	0.610	0.153	0.142	92.59	7.41
Average	200 m	0.253	0.624	0.158	0.152	96.42	3.58
April	200 m	0.244	0.504	200 m	0.1224	92.77	7.23
	200 m	0.243	0.543	250 m	0.132	95.4	4.6
	200 m	0.243	0.518	300 m	0.126	97.53	11.12
Average	200 m	0.243	0.529	0.133	0.1267	95.233	7.65

Appendix Table 4 Gella and Gepha Basic Infiltration rate

Infiltration rate at Gella SSI scheme			Infiltration rate at Gepha SSI scheme		
Time(min)	Cumulative Infiltration(mm)	Infiltration rate (cm/hr.)	Time (min)	Cumulative Infiltration(mm)	Infiltration rate (cm/hr.)
10	4.42	26.5	10	4.3	25.8
20	8.00	21.5	20	7.4	18.6
30	11.23	19.4	30	10.1	16.2
40	13.85	15.7	40	12.3	13.2
50	16.15	13.8	50	14.3	12.0
60	18.30	12.9	60	16.1	10.7
80	21.60	9.9	80	18.9	8.4
100	24.63	9.0	100	21.4	7.6
120	27.57	8.82	120	24.9	6.9
160	31.78	6.3	160	29.36	6.7
200	35.78	6.0	180	33.83	6.7
220	39.78	6.0	220	38.3	6.7
240	43.78	6.0	240	42.76	6.7

Appendix Table 5 ETO and climate data of the study area

Country	Ethiopia	Station				Bedele	
Altitude	1560	Latitude		8.450957 N		Longitude	36.3552268 E
Month	Min Temp°C	Max Temp°C	Humidity (%)	Wind km/day	Sun (hr.)	Rad(MJ/m ² /day	ETO(mm/day)
January	9.5	27	54	120	9.2	21.2	4.19
February	10.9	28.6	49	139	9.7	23.2	4.91
March	12.4	28.7	52	139	8.9	23	5
April	13.8	29.6	55	144	8	21.8	5
May	13.3	29.4	55	142	8.6	22.1	5
June	13.1	28	64	116	6.9	19.2	4.2
July	13.8	25	76	102	5.3	17	3.46
August	13.8	24.6	77	88	7.2	20.3	3.85
September	12.8	25.7	71	85	9.3	23.6	4.41
October	10.3	26.9	55	127	9.8	23.5	4.72

November	9	26.6	53	135	9.7	22.1	4.44
December	9	26.4	54	129	8	19	3.94
Average	11.8	27.2	60	122	8.4	21.3	4.43

Appendix Table 6 Crop Area coverage and planting date at Gella SSI scheme

Crop types	Gella SSI scheme					
	Season I			Season II		
	Area (%)	Area (ha)	Planting Date	Area (%)	Area (ha)	Planting Date
Tomato	29.85	20	01/09/2022	7.14	5	01/02/2023
Onion	37.39	25	05/09/2022	10	7	02/02/2023
Cabbage	14.9	10	08/09/2022	4.3	3	04/02/2023
Potato	10.40	7	10/09/2022	-	-	-
Maize	-	-	-	14.3	10	01/02/2023
Pepper	7.46	5	14/09/2022	-	-	-
Wheat	-	-	-	64.3	43	21/01/2023
Total	100	67 ha		100	68 ha	

Appendix Table 7 Crop Area Coverage and planting date at Gepha SSI scheme

Crop types	Gepha SSI scheme					
	Season I			Season II		
	Area (%)	Area(ha)	Planting Date	Area (%)	Area(ha)	Planting Date
Tomato	31.50	23	04/09/2022	12.5	10	11/02/2023
Onion	32.87	24	07/09/2022	15	12	12/02/2023
Cabbage	20.54	15	09/09/2022	6.25	5	04/02/2023
Potato	5.48	4	11/09/2022	-	-	-
Maize	-	-	-	-	-	08/02/2023
Pepper	9.6	7	13/09/2022	-	-	-
Wheat	-	-	-	66.25	50.5	25/1/2023
Total	99.98	73 ha		100	100	

APPENDIX FIGURE



Appendix Figure. 1 Poor on farm irrigation water management at Gepha Scheme



Appendix Figure. 2 Partial view of Water loss at Gella Main canal

Sapling Questionnaires

Sample question for the Gella and Gepha small scale irrigation schemes' management of irrigation water and maintenance of organizational setups and performance.

Enumerator name: _____ Farmer name: _____

Location: Head

Middle

Tail

House hold characteristics

1. House hold male _____ Female _____ Age _____ Educational Level _____

1.1. <20yrs

1.2. 20-60yrs

1.3 .>60yrs

The respondent's marital status:

2.1. Married

2.2. Widowed

2.3. Separated

2.4. Single

3. The household's degree of literacy:

3.1. Illiterate

3.2. Elementary only reading and writing

3.3. High school

Project Evaluation

Planning

4 Who came up with the concept to build the diversion weir?

➤ Local residents

➤ DA

➤ Project staff

➤ Other staff

➤ Others.....

➤ If it wasn't the locals, did you provide your approval for the structures to be built?

Yes

No If No Why?

5. How was the planning process?

• Discussion in groups

• DAs providing basic information

• Simple information provided by the PA leader

• Simple information provided by project staff

6. Have you participated in any project planning?

Yes

No

Design/ layout

7. Where did you decide on the project's or dam's location?

8. What do you think about the location of the diversion?

9. Did the site selection cause you any issues?

Yes

No

10. If so, what exactly went wrong? _____

Implementation

11. Do you help with the building of the irrigation canals and diversion structures?

Yes

No

- ✚ If so, how do you participate?
 - ✚ Freely and without compensation
 - ✚ By law (mass mobilization) without payment
 - ✚ By receiving payment in cash Through payment in the form of food assistance (EGS)
 - ✚ Through the use of FFW as payment
 - ✚ Both with and without payment
12. Do you still use the irrigation project? Yes No
- ✓ If not, why?
 - ✓ Do you understand the root of the issue? Yes No
 - ✓ If so, what kind of things?.
13. Design issue
- Do you notice any structural flaws? Yes No
 - Which structures, if any, exist?
 - the canals, the head work, and the canal structures
 - All
 - Other (indicate)
14. Do you see any seepage on the canal infrastructure (canals, headwork, etc.)? Yes No
15. Water management
- What factors should you take into consideration when deciding whether to irrigate crops?
 - a. Wait until you notice wilting signals on the leaves.
 - b. Examine the soil around the roots
 - c. irrigate when it's dry irrigate every day
 - Do you think your yield is reduced because you cannot apply enough water to your crop? Yes No
 - Who makes decisions on the sequence of using irrigation water? _____
 - What is the system of water allocation?
 - i. Proportional to the amount of land you have under irrigation.
 - ii. Equal division among members of the association
 - iii. Specify if any other system
16. Does the community have a system of rule for controlling water distribution default?
- Yes No
- ❖ Are there special considerations for crop-type and stage of growth during water allocation? Yes No
 - ❖ Are there any issues with the irrigation water application? Yes no
 - ❖ If so, what exactly are they? (Order them)
 - i. Conflict downstream
 - ii. Reducing the amount of time that irrigation water can flow
 - iii. .Administrative issue with water use
 - iv. Insufficient upkeep
 - v. Lack of training or operational skill

vi. Others.....

17. The dependability (reliability) of the irrigation water supplies, both in terms of flow rates and supply time.

- i. Good
- ii. Medium
- iii. Bad
- iv. Terrible
- v. Supply duration

❖ Good

❖ Moderate

❖ Bad

❖ Terrible

- vi. Is the distribution equitable?
 - A. Very fair
 - B. Fair
 - Unfair
 - D. Very annoying

18. If something is unjust, why is it unfair?

- ✓ Head customers'
- ✓ Corrupted officials/WUA
- ✓ Illegal users of water

19. The water sources' unreliability? Additional details_____

- How reliable are the water deliveries to supply water during scheduled irrigation turns?

- ✓ Very Good
- ✓ Very Bad
- ✓ very poor
- ✓ If the delivery is poor or really poor, why is that?

- ✚ Inadequate irrigation infrastructure
- ✚ Unauthorized water users Water supply services that are poorly coordinated
- ✚ The water sources are unreliable
- ✚ Other

20. Do you have a variable flow control device at the farm entrance to manage the water flow to your field? yes No