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HYDRAULIC PERFORMANCE EVALUATION OF SHIMBURIT IRRIGATION SCHEME IN SELECTED INDICATORS E/GOJJAM ZONE, AMHARA REGION, ETHIOPIA.

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BAHIR DAR UNIVERSITY

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SCHOOL OF GRADUATE STUDIES

FACULTY OF CIVIL AND WATER RESOURCE ENGINEERING

MASTER'S THESIS

ON

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BY

GETACHEW KIFLE W/EYESUS

June 2023 G.C.
Bahir Dar, Ethiopia

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Getachew Kifle W/Eyesus

A Thesis submitted in partial fulfillment of the requirements for the Degree of Master of Science in Hydraulic Engineering in the Faculty of Civil and Water Resource Engineering.

Advisor: Dagnenet Sultan Alemu (Associate Professor)

Co-Advisor: Abebech Abera (Assistant Professor)

Bahir Dar University

DECLARATION

This is to certify that the thesis entitled “HYDRAULIC PERFORMANCE EVALUATION OF SHIMBURIT IRRIGATION SCHEME IN SELECTED INDICATORS E/GOJJAM ZONE, AMHARA REGION, ETHIOPIA”, submitted in partial fulfillment of the requirements for the degree of Master of Science in Hydraulic Engineering under Faculty of Civil and Water Resource Engineering, Bahir Dar Institute of Technology, is a record of original work carried out by me and has never been submitted to this or any other institution to get any other degree or certificates. The assistance and help I received during the course of this investigation have been duly acknowledged.

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Approval of Thesis for defense

I hereby certify that I have supervised, read, and evaluated this thesis titled "HYDRAULIC PERFORMANCE EVALUATION OF SHIMBURIT IRRIGATION SCHEME IN SELECTED INDICATORS E/GOJJAM ZONE, AMHARA REGION, ETHIOPIA" prepared by Getachew Kifle under my guidance. I recommend the thesis to be submitted for oral defense.

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Approval of thesis for defense result

I hereby confirm that the changes required by the examiners have been carried out and incorporated in the final thesis.

Name of Student Getachew Kifle W/Eyesus Signature ________ Date June 13, 2024.

As members of the board of examiners, we examined this thesis entitled "HYDRAULIC PERFORMANCE EVALUATION OF SHIMBURIT IRRIGATION SCHEME IN SELECTED INDICATORS E/GOJJAM ZONE, AMHARA REGION, ETHIOPIA"by Getachew Kifle W/Eyesus. We hereby certify that the thesis is accepted for fulfilling the requirements for the award of the degree of Masters of Science in "Hydraulic Engineering".

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LIST OF ACRONYMS

A	Area
ARIS	Annual Relative Irrigation Supply
ARWS	Annual Relative Water supply
Cm	Centimeter
CROPWAT 8	Crop water Requirement estimation model window 8
CWR	Crop water Requirement
Ea	Application Efficiency
Eo	Overall Efficiency
Ec	Conveyance Efficiency
Es	Storage Efficiency
ET_C	Evapotranspiration
ET_O	Reference Evapotranspiration
FAO	Food and Agriculture Organization
Fc	Field capacity
GOs	Governmental organizations
Ha	Hectare
Hr	Hour
IR	Irrigation ratio
IWMI	International Water Management Institute
Kc	Crop Coefficient
Ky	Yield Reduction Factor
m	meter
m^3	Cubic meter

MAD	Maximum Allowable Depletion
mm	millimeter
MOWR	Ministry of Water Resource
NGOs	Non-Governmental Organizations
OPUCA	Output per unit Command Area
OPUIA	Output per unit Irrigated Area
OPUIS	Output per unit Irrigation supply
OPUWC	Output per unit Water consumed
PWP	Permanent wilting point
Q	Discharge
RF	Rainfall
RIS	Relative Irrigation supply
RWS	Relative Water supply
Peff	Effective Rainfall
SSI	Small Scale Irrigation Scheme
SERAR	Sustainable Agriculture and Environmental Rehabilitation of Amhara Region
T	Time
TAW	Total Available Water
USDASCS	United Nations Development Agency Soil Conservation Science
Wds	Weight of Dry Soil
Wd	Depth of Water delivered
Wf	Depth of Water Diverted
Wn	Depth of Water Required
Ws	Depth of Water Stored
W	Weight of wet Soil
Za	Applied Depth
Zr	Root Depth

ABSTRACT

Evaluation of irrigation system plays a fundamental role in improving surface irrigation and in providing information used to advise irrigators how to improve their system operation. Hence, This study was conducted to evaluate the existing hydraulic performance of Shimburit small irrigation scheme in selected indicators at Debere Elyas Woreda, East Gojjam zone, Amhara Region. Internal and external performance indicators were used for evaluation. To achieve the objectives, primary and secondary data were collected. Primary data collection includes measuring discharge at different points of main, secondary, tertiary and field canals, soil moisture before and after irrigation and depth of water applied. The secondary data collection includes determination of crop types, total yields, prices of irrigated crops, area irrigated per crop per season and cost of production. From our result of the internal performance indicators analyses, the conveyance efficiency, application efficiency, storage efficiency and overall efficiency were found to be 79.14 percent, 68.9 percent, 33.01 percent and 54.53 percent respectively. From the analyses of external indicators, the outputs per crop area were found as 180 quintal and 540,000 birr per hectare, the value of outputs per command area of the scheme were 103.81 quintal and 294,300 birr per hectare and the output per unit irrigation supply of 0.017 quintal and 49.82 birr per cubic meter, output per water consumed was 0.039 quintal and 116.85 birr per cubic meter. The irrigation ratio of the scheme was found to be 0.6 which means 60 percent of the command area was under irrigation during the study period. Water distribution equity, reliability and water saving, continuous monitoring and maintenance is required for its long-term sustainability; Nevertheless, the results of the study can be considered in proposed water saving plans for improving the performances of the scheme. It provides to the system managers, farm staff and policy makers a better understanding of how a system can be operated.

Keywords: Shimburit; hydraulic performance; internal and external performance Indicators.

Table of Contents

List of Tables

List of Figures

1. INTRODUCTION

1.1. Background

Agriculture is the core driver for Ethiopian economy; base for food and food self -sufficiency. About 16 percent of the Ethiopia's government expenditures are dedicated to this sector. Agriculture directly supports 85 percent of the population's livelihoods, 41.6 percent of gross domestic product (GDP) and over 80 percent export value (Cia & Barham, 2009).

Agriculture in Ethiopia is mainly dependent on rain fed systems, and this dependency has put the majority of the Ethiopian population at the mercy of meteorological variability. With increasing meteorological variability due to changing climate, it is highly probable that the rain fed agriculture of Ethiopia is vulnerable to its effects (Dejen et al., 2012).

Irrigation development has been identified as an important tool to stimulate economic growth and rural development, and is considered as a cornerstone of food security and poverty reduction in Ethiopia. Increased availability of irrigation and less dependency on rain-fed agriculture is taken as a means to increase food production and self-sufficiency of the rapidly increasing population of the country (Awulachew et al., 2010).

The irrigation development is increased when the construction and the function of irrigation scheme increased. However, despite water resources and irrigation potential in Ethiopia best owed, the area developed under irrigation is less than its potential. Even those developed irrigation schemes do not perform well as planned and expected because of several inter related factors. One of the factors of the irrigation potential is the performance of conveyance structure is not well functional. Therefore, improving the performance of the irrigation scheme is one of the issues of development of irrigation in developing countries and also crucial due to relatively low performances (Awulachew et al., 2011).

Water scarcity is a potential constraint to produce more foods to meet the demands of increasing world population. One possible approach to conserve this scarce resource might be through improving the performance of existing irrigation schemes (Tebebal & Ayana, 2015).

Although availability of water for agriculture is a top priority to farmers in developing countries, less attention is given to the quality of irrigation services and efficiency of water utilization.

Water is delivered to the fields with any sound assessment of irrigation demands and depends on availability (Dejen et al., 2012).

Irrigation enhances agricultural production and improves the food supply, income of rural population, opening employment opportunities for the poor, and supports the national economy by producing industrial crops that are used as raw materials for value-adding industries and exportable crops (Awulachew et al., 2011).

Performance assessment is used to identify the present status of the scheme with respect to the selected indicators and will help to identify ‘why the scheme is performing so’ which in turn imply means of improvement. Of course performance evaluation needs relevant and reliable data which is rarely measured in Ethiopia (Awulachew et al., 2011).

Improving the water utilization of the scheme, this requires improving the management skills of the users is one challenge to be tackled to ensure the sustainability of the schemes. In the country, water development for agriculture is a priority, but poorly designed and planned irrigation undermines efforts to improve livelihoods and exposes people and environment to risks. Recent estimates indicate that the total irrigated area in Ethiopia is 640,000 ha, around 4 to 5% of the existing cultivated area and 12% of its irrigation potential (Awulachew et al., 2010).

Poor management of irrigation water is one of the main reasons for the low water use efficiency in irrigation. As available water resources become scarce, more emphasis is given to efficient use of irrigation water for maximum economic return and water resource sustainability. This requires measuring how efficiently water is extracted from a water source and used to produce crop yield. Inadequate and often unreliable water deliveries in the main system cause farmers to face regular shortages in the water supply, resulting in reduced yields and incomes as well as in much smaller areas being irrigated than originally planned. At field level, inappropriate field layout and mismanagement also lead to further water losses and reduced yield. There is a need for research and capacity building to understand the complex issues of water use and water management, so as to develop national and local capacity to deal with water and land management issues to enhance food security, reduce poverty and speed up national economic development (Quaraishi & Muleta, 2013).

1.2. Statement of the problem

Historically irrigation was undertaken to meet human needs for food and computation was limited to neighboring irrigators sharing the same source of water. In the postindustrial era, population has increased dramatically and economies have diversified leading to computation for water among different sectors. Then with increasing computation, water is now viewed as a limited resource and the notion of water conservation has emerged (Nega, 2011).

Performance of most irrigation schemes is significantly below their potential. In Ethiopia, scheme performance is estimated on average 36% below design capacity, implying a loss of about 230,000 ha of irrigated land, leading to only 410,000 ha being irrigated from the total irrigated area of 640,000 ha. Small scale irrigation schemes account for 90% of this irrigation performance gap (Awulachew, 2019).

The performance of many irrigation schemes in Amhara region is far below their potential mainly due to inefficient irrigation water management, poor maintenance and problems associated with input supply and marketing (Wondimkun & Tefera, 2006).

Poor management of available water for irrigation, at both system and farm level has led to a range of problems and further aggravated water availability and has reduced the benefits of irrigation investments (Van Stappen, 1996).

Particularly in the East Gojjam zone little attention is given to the monitoring and evaluation of the performance of already established irrigation schemes. Out of these Shimburit small irrigation scheme, the one that covers 94.5 hectare of land has not been fully functional as expected and its performance is underutilized.

1.3. Objectives

1.3.1. General objective

The general objective of this study is to evaluate the hydraulic performance of Shimburit irrigation scheme in selected indicators, E/Gojjam zone, Amhara region, Ethiopia.

1.3.2. Specific objectives:

- ✓ To evaluate the hydraulic performance of Shimburit irrigation scheme by using internal indicators (conveyance efficiency, application efficiency, storage efficiency and overall efficiency).
- ✓ To determine the hydraulic performance level of the scheme by using external indicators (outputs per crop area value of outputs per command area)

1.4. Research questions

- ➢ What is the level of the hydraulic performance of Shimburit irrigation scheme with respect to internal performance indicators?
- ➢ What is the level of the hydraulic performance of Shimburit irrigation scheme with respect to output based external indicators?

1.5. Significance of the study

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

This study will provide information for the current hydraulic performance or efficiency of Shimburit irrigation scheme. The study will have a significant contribution to understand the weaknesses and best achievements of the whole system of the scheme. It will also give information for further improvement and investment approaches for implementing agents (GOs, NGOs, research centers, contractors, etc.). It can also be used as a benchmark and entry point for development works and future studies.

2. LITERATURE REVIEW

2.1. Irrigation practice

Irrigation is the supply of water to agricultural crops by artificial means, designed to permit farming in arid regions and to offset the effect of drought in semi-arid regions. Even in areas where total seasonal rainfall is adequate on average, it may be poorly distributed during the year and variable from year to year (Defries et al., 2000).

Nega (2011) stated that irrigation is a system application of water to allow all water to infiltrate and distribute both in space and times to meet the requirements for each parcel of the field.

Irrigated agriculture is the major consumer of freshwater worldwide, presently in the order of about 70%. However, water availability for agriculture continues to decline due to competing demands from other sectors such as municipal, industrial and recently environmental recreational requirements (Abuzar et al., (2017).

According to Wondatir (2016) irrigation projects cause serious damage to the environment like salinity and water logging, and in some instances aggravating community problems, due to different reasons such as social conflicts, the opportunities for transmission of aquatic disease vectors like malaria and water hyacinth. Beside this fertile soil has been removed from annual production by flooding and erosion. If wise utilization and management strategies are not properly implemented; the future base of the existing and the coming generation, particularly the land and water resources, have been at risk alarmingly.

2.2. Overview of Irrigation Development in Ethiopia

Irrigated agriculture is the major consumer of freshwater worldwide, presently in the order of about 70%. However, water availability for agriculture continues to decline due to competing demands from other sectors such as municipal, industrial, recently environmental and recreational requirement (Abuzar et al., 2017).

Irrigation development in Ethiopia is classified based on the size of the command area, in three types: Small-scale irrigation systems (less than 200 ha), Medium-scale irrigation systems (200-3000 ha) and Large-scale irrigation systems (greater than 3000 ha). This classification system is the most common in Ethiopia (MOWR, 2002).

As Teshome (2006), modern small-scale irrigation development and management started in the 1970s introduced by the Ministry of Agriculture (MoA) in response to major droughts, which caused widespread crop failures and food insecurity.

Currently, the government is giving more attention to irrigation agriculture by means of improving the food security situation in the country. Efforts are being made to include farmers progressively in various aspects of management of small-scale irrigation systems, starting from planning, implementation and management aspects, mainly, in water distribution, operation and maintenance to improve the performance of irrigated agriculture (Makombe et al., 2011).

2.3. Types of irrigation schemes

Irrigation development is a key for sustainable and reliable agricultural development which leads to overall development in Ethiopia. At this time the Ethiopian government, under the growth and transformation plan, has given great attention to irrigation development projects, water center development, with priority given to small-scale irrigation schemes. The government believes that irrigation projects will help to better cope with climate variability and ensure food security. Irrigation schemes are classified as small, medium and large scale based on the area irrigated, scale of operation and type of control or management. But the criteria used for classification may vary from country to country (Makombe et al., 2011).

Irrigation schemes in Ethiopia are classified based on the size of the command area, technology used and management system. In the command area classification, they are classified as small-scale irrigation scheme (less than 200 ha), medium-scale irrigation scheme (200 to 3000 ha) and large-scale irrigation scheme (greater than 3000 ha)(MoWR, 2002).

2.4. Irrigation water control and management

According to (Shiberu and Hailu, 2011), water control denotes the ability of the system to distribute, apply or remove water at the right time, in the right quantity and the right place.

Water management is the integrated process of intake, conveyance, regulation, measurement, distribution, application and use of irrigation water at the farmer′s field and drainage of excess water from farmer′s field with proper amounts and at the right time for the purpose of increasing crop production and water economy in coincidence with other improved agricultural practices. It also includes numerous steps of investigations, planning, designing, construction, operation, maintenance and rehabilitation of irrigation and drainage facilities (Shiberu and Hailu, 2011).

2.4.1 Regulation of flow discharge and water levels

According to (Shiberu and Hailu, 2011), irrigation water flows are controlled with the help of hydraulic structures and spreads the fields at the appropriate time and in the quantities needed. To transport water from the source (often at some distance from the cultivated fields) to the fields, an infrastructure consisting of canals and regulation structures is necessary. An organizational structure is required to execute the necessary tasks to manage and control the infrastructures.

The water level and velocity control structures encompass a group of engineering works installed in open canal irrigation networks designed to regulate the water level in a canal, to control the quantity of water passing through it, to dissipate energy and allow water to be delivered accurately and safely to the fields without causing erosion. Such structures contain checks, or cross-regulators, drops or falls and chutes (Kraatz & Mahajan, 1975)

According to Lowdermilk (1981), water control refers to the ability of the system to distribute, apply, or remove water at the right time, in the right quantity and at the right place. The main purposes of water control in an irrigation project are to convey reliability (temporal), adequacy (volume balance, including seepage, operational and application losses) and equitable to irrigation fields (spatial parameters).

Depeweg (1999) described that, in view of its aim, an irrigation system has to be planned, constructed, operated and managed in such a way that all of the farm fields in the command area will get and discharge water in an appropriate, suitably arranged and adjustable manner.

The measurement of irrigation water is a vital element for its fair distribution and economical use. Measurement helps to ensure the maintenance of proper delivery schedules, to determine the amount of water delivered and to single out variances in distribution. As stated by Shiberu and Hailu (2011), by means of weirs, dams, canals and other constructions, the spatial and temporal distribution of water is regulated. An essential aspect of water control relates to the temporal and spatial distribution of water or in other words the modification of an agriculturally unfavorable timing of watering in the annual cultivation cycle. Unfavorable cycle includes both the transmission of water to overcome shortages (irrigation) and to remove excess water (drainage). The collection, control, allocation and distribution of water to groups of fields and producers are the main processes of an irrigation system. Irrigation systems collect, transport and distribute water for agricultural production with the objective to supply the root zones of the cultivated crops with the necessary amount of water.

2.4.2 Irrigation water management

As stated by Creighton (2005), "Irrigation Water Management" means management of irrigation water on the farm through the act of timing and regulating irrigation water application in a manner that will satisfy the water requirement of the crop without wasting water, soil, and nutrients and degrading the soil resource. The goals of any irrigation system are to provide irrigation water in the right amount (size, frequency and duration) at the right place and at the right moment. Almost all of the irrigation schemes started in the past in Ethiopia have been functioning below expected targets. In spite of the extensive investment irrigation development of both government and NGOs constructed and community managed irrigation schemes, the overall performance has continued far below expectations (Shiberu & Hailu, 2011)

According to (Shiberu and Hailu,2011), generally management levels can be categorized in to three:

- ✓ Conveyance or main level by the government or an irrigation authority
- ✓ Off-farm distribution or tertiary level, by a group of formally or informally organized farmers or water users
- ✓ Field level or on-farm distribution and application system managed by the individual farmer

2.5. Performance Evaluation of Irrigation Practices

2.5.1. Importance of performance evaluation

Many scholars stressed the importance of performance evaluation for an irrigation system. Much of the efforts to date in irrigation performance assessment has been focused on both external and internal processes of irrigation systems. These process indicators relay performance to management targets such as timing, duration, flow rate of water, area irrigated and cropping patterns. Effective irrigation management needs reliable performance assessment. Good farm irrigation management guarantees correct frequency of irrigations, correct application depth, uniform irrigation, minimum runoff and minimum deep percolation except for that necessary for salt management, minimum erosion and optimal return on irrigation investment. With progressively increasing physical infrastructures of irrigation projects, special consideration should be given to the performance of the systems (Kloezen et al.,1998).

The principal objective of evaluating surface irrigation systems is to classify management practices and system configurations that can be viably and effectively implemented to improve the irrigation efficiency. An evaluation may show that higher efficiencies are possible by reducing the duration of the inflow to an interval essential to apply the depth that would refill the root zone soil moisture deficit. Evaluation may also show opportunities for improving performance through changes in the field size and topography. Evaluation data can be collected periodically from the system to improve management practices and recognize the changes in the field that occur over the irrigation season or from year to year. Surface irrigation system is a complex and dynamic hydrologic system and hence, the evaluation processes are essential to optimize the use of water resources in this system (Walker, 1989).

As many farmers who are accomplished irrigation schemes do not perform as well as they should, there is a need to identify the areas in which they lack their potential. It is therefore essential to measure and evaluate their success or failure objectively and identify specific areas in need of improvement (Manor and Chambouleyron ,1993).

To achieve sustainable production from irrigated agriculture it is clear that the utilization of essential resources in irrigated agriculture (water and land) must be improved. Thus on-farm and conveyance irrigation systems and operations want to be evaluated against the potential efficiency of the systems. Performance assessment has been an integral part of irrigation since man first started connecting water to improve crop production. Evaluation includes measuring conditions at one or more points in a field selected to be typical or representative for the projects (Pereira, 2002).

As stated by (Awulachew et al., 2011), irrigation performance assessment is rarely conducted in Ethiopia because of lack of field level data. Some attempts have already been made to assess the scheme level performance of some irrigation schemes. There is a need to develop aggregate indicators that offer an indication for the performance of irrigation development under limited data availability.

Therefore, improving the performance of the irrigation scheme is one of the issues of development of irrigation in developing countries and also essential due to relatively low performances (Awulachew et al., 2011).

2.5.2. Factors affecting the performance of irrigation schemes

As stated by Turral (1995), the factors that account for under performance of irrigation schemes include, among others:

- ✓ Poor system management and service provision
- ✓ Lack of clear and sustainable water rights to users, at individual or group level
- ✓ Poor understanding of farmer priorities and inadequate markets for products
- ✓ Lack of transparent accountability and supporting incentives for the managing entities
- ✓ Lack of clear and recognized responsibilities and authority vested in the managing organizations

2.5.3. Irrigation performance indicators

According to (Murray-Rust and Snellen, 1993), performance indicators measure the value of a particular item such as yield or canal discharge and must include a measure of quality as well as of quantity, and be accompanied by appropriate standards or acceptable tolerances. In connection with main system performance, the authors concluded that the services delivered by the system and the appropriate performance standards are greatly influenced by the design of that system. The development of irrigation practice needs knowledge of crop water requirement and yield responses to water, the constraints that are specific to each irrigation method and irrigation equipment, the limitations to the water supply system and the financial and economic implication of irrigation practice. Improvement of irrigation method needs the considerations of the factors influencing the hydraulic process, the water infiltration and uniformity of water application to the entire field (Hlavek, 1992).

Performance evaluation exercises are meaningful if connected with certain management objectives that are defined for certain given situations. Some key indices or terms are developed to define the achievement of these objectives, followed by the identification of variables that are controllable and measurable and can be regulated to achieve the established indicators. The indices are used to evaluate the farm irrigation system that could be categorized into delivery subsystem (the system extending from head-works to field canals) and water use subsystem (part of the system extending from field canals to water application system). The indices should be subjected to management control so that they can be manipulated to improve system performance (Walker & Skogerboe, 1987).

According to (Walker and Skogerboe,1987), efforts have been made over the years to develop appropriate evaluation models that could use the irrigation parameters and evaluate irrigation performance. Among these, the volume balance model is the basis for most design and field evaluation procedures. This has been verified with field and laboratory data. It allows quick and reliable definition of infiltration rates over the length of the field and it is easily extended to indications of uniformity and efficiency parameters.

In response to the insufficient performance of the existing irrigation system, focus was on the performance evaluation of the schemes. This led to the establishment of performance criteria such as productivity, adequacy, equity, etc. However, in conducting performance of irrigation, more than one viewpoint happens. In addition, few of these criteria reflect the view of the farmers (Gowing et al., 1996). It is therefore important that evaluation of the performance of surface irrigation systems be continued with a view of the stakeholders, i.e., the farmers in particular.

According to (Marinus G. Bos, 1997), different indices have been developed for evaluating the performances of individual irrigation systems and for comparing the performances of different irrigation systems as well as farms. The type and number of indices (indicators) used for a particular situation depend on the level of details required for quantification and on the number of disciplines selected for assessment. These may include: agricultural, water use, economics, environment, management, physical, etc. which are regarded as external indicators.

Most authors propose to use different indicators and different methodologies or tools to measure the same indicators. But this causes much confusion in evaluation. To avoid this, studies recently categorized indicators into two groups to evaluate irrigation systems; process or internal performance and comparative or external performance assessment methods (Marinus G Bos et al., 1993)

The common efficiency terms used for on-farm irrigation system evaluation (internal performance indicators) include application, uniformity, storage efficiency and adequacy, and recently complementary terms such as runoff, deep percolation ratio are being applied (Jurriëns et al., 2001). The principal terms and their uses are described as follows:

2.5.3.1. Internal indicators

These indicators study technical or field performance of a project how close an irrigation event is to an ideal one. An ideal or reference irrigation is one that can apply the right amount of water over the total region of interest (i.e. depth of root zone) uniformly and without losses. Analysis of the field data permits quantitative definition of the irrigation system performance. The performance of irrigation practice is determined by the efficiency with which water is transported through the canal, how irrigation is applied to the field, how adequate the amount is and how the application is uniformly applied to the field (Feyen & Zerihun, 1999).

2.5.3.1.1. Conveyance efficiency

As water becomes scarcer and the need becomes more persistent for maximum economic returns, new and more complete methods of measuring and evaluating techniques of handling irrigation water are necessary. The earliest irrigation efficiency concept of evaluating water losses was water conveyance efficiency. Most of the irrigation water came from diversions, from streams or reservoirs. Losses which occurred while conveying water were often excessive(Hassen, 2004).

Conveyance efficiency is defined as the ratio of the amount of water delivered at the turnouts of the main irrigation conveyance network to the total amount of water diverted into the irrigation system(Marinus G. Bos, 1997). It is one of the several related and commonly used output measures of performance that focus on the physical efficiency of water conveyance by the irrigation system.

Irrigation water is normally conveyed from a water source to the farm or field through natural drainage ways, constructed earthen or lined canals or pipe lines. Many conveyance systems have transmission losses, meaning that water delivered to the farm or field is usually less than the water diverted from the source. Water losses in the conveyance system include canal seepage, canal spills (operational or accidental), evaporation losses from canals and leaks in pipelines. Water conveyance efficiency also can be applied to evaluate individual segments of canals or pipelines. Typically, conveyance losses are much lower for pipe lines due to reduced evaporation and seepage losses (Irmak et al., 2011). In Tanzania, typical conveyance efficiency values generally reported are 70 and 50% for unlined poorly managed main and field canals respectively, while for the well managed canals the figures were 85 and 80% respectively (MoAFS, 2002).

According to (Mazumder 1983), losses of irrigation water occur during conveyance of water from the head of the canal to the farm plot. In open canals, such losses take place primarily due to evaporation and seepage. About 10 to 15% of the water admitted into a canal can get lost in this way.

2.5.3.1.2. Application efficiency

After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency. One very common measure of on farm irrigation efficiency is application efficiency. That asks how much of the water applied to the crop is actually used for crop growth or other beneficial uses?(Hassen, 2004).

Application efficiency is a common yardstick of relative irrigation losses and this definition is valid for all situations and all irrigation methods. Losses from the field occur as deep percolation and as field tail water or runoff and reduce the application efficiency. Water application efficiency (Ea) provides a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop. The objective is to apply water and store it in the crop root zone to meet the crop water requirement. Ea is a measure of the fraction of the total volume of water delivered to the farm or field to that which is stored in the root zone to meet the crop evapotranspiration (ET). Because of the losses during application, water application efficiency is always less than 100 percent. Water losses during irrigation include runoff, evaporation from water in the channels, evaporation from the soil surface and percolation below the root zone (Irmak et al., 2011).

Application of water to the field is the core activity of irrigation which is designed to disperse the incoming stream from higher level canals over the field thereby storing in the crop root zones (Awulachew & Ayana, 2011).

2.5.3.1.3. Storage efficiency

Application efficiency does not show if the crop has been under-irrigated. Small irrigations may lead to high application efficiencies, yet the irrigation practice may be poor, the concept of water storage efficiency is useful in evaluating this problem. The storage efficiency has little utility for sprinkler or micro irrigation because these irrigation methods seldom refill the root zone, while it is more often applied to surface irrigation methods(Hassen, 2004).

According to (Jurriëns et al.2001), the adequacy of irrigation turn is expressed in terms of storage efficiency, which is defined as the ratio between the storage depth and the required depth. The water storage efficiency refers to how completely the water needed prior to irrigation has been stored in the root zone during irrigation water application.

The requirement efficiency is an indicator of how well the irrigation meets its objective of refilling the root zone. This value is important when either the irrigations tend to leave major portions of the field under-irrigated or where under-irrigation is purposely practiced to use precipitation as it occurs. Storage efficiency is most directly related to the crop yield, since it will reflect the degree of soil moisture stress. Usually, under-irrigation in high probability rainfall areas is a good practice to conserve water but the degree of under-irrigation is a difficult question to answer at the farm level (Muleta & Quaraishi, 2013).

The growing scarcity of water and increasing realization of the value to be gained from irrigation have caused in high-priced water, discouraging the excessive use of water. Low financial returns from irrigation in the plains states today occur not because of excessive water application but because of insufficient application. This similar condition occurs in many other irrigated areas on a smaller scale. In many cases only a small fraction of the required water is being applied. The water application efficiencies under such practices are essentially 100 percent and yet the irrigation practice is poor. To assist in the evaluation of this problem, the concept of water storage efficiency (the ratio of stored water to required water) is essential(Hassen, 2004).

2.5.3.1.4. Overall scheme efficiency

The overall scheme efficiency (Eo) represents the efficiency of the entire physical system and operating decisions in conveying irrigation water from a water supply source to the target crop. It is calculated by multiplying the efficiencies of water conveyance and water application (Irmak et al., 2011)

According to Savva and Frenken (2002b), field application efficiency (Ea) is the one that contributes most to the overall irrigation efficiency and is quite specific to the irrigation method; any efforts that are made to improve on this efficiency will impact heavily on the overall efficiency.

2.5.3.2. External (comparative) performance indicators

Comparative performance indicators enable us to see how well irrigated agriculture is performing at different scales, i.e. at the scheme, basin, national or international scales (Dejen, 2015).

Comparative performance has a set of advantages for stakeholders in the irrigation and drainage sector, including policy makers, irrigation managers, researchers, farmers and donors. Land and water, the two main resources for irrigated agriculture are limited, and in some countries, critical. Irrigated agriculture production wants to improve the utilization of these increasingly scarce resources. Comparative (external) performance evaluation enables irrigation stakeholders to see how productively land and water resources are used for agriculture (Dejen, 2015).

External indicators evaluate inputs and outputs to and from irrigation schemes. They are generally meant to evaluate the efficiency of resource use (land, water, finance) in irrigated agriculture. External indicators can be best used as part of strategic performance assessment and benchmarking performance of schemes (Burt & Styles, 2004).

According to (Marinus G Bos et al., 1993),external performance indicators are grouped as follow:

2.5.3.2.1. Irrigated agriculture performance indicators

They are used for the evaluation of the project performance in terms of the production it results in. It expresses output of irrigated area in terms of gross or net value of production measured at local or world prices. 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 G Bos et al. 1993)

2.5.3.2.2. Water use performance indicators

This deals with the primary task of irrigation managers in the capture, allocation and conveyance of water from source to field by management of irrigation facilities. Indicators address several aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently and the service aspects of water delivery which include such concepts as predictability and equity (Marinus G Bos et al. 1993)

2.5.3.2.3. Physical performance indicators

Physical performance indicators are related with the 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).

3 .MATERIALS AND METHODOLOGIES

3.1. General Description of the Study Area

3.1.1. Shimburit irrigation scheme

Shimburit irrigation scheme is found in Amhara Regional state under East Gojjam zone , Deber Elias woreda, particular kebeles of Yegdad and Yekomit. It is far from 15km from Deber Elias (woreda town) and also 55 km From Debre markos Zonal town and located at the pocket of the main road from Debre markos to Baherdar at a geographical location of 1147435m N latitude and 324785m E longitiude Adindan UTM Zone-37and altitiude 2133.58m a.s.l. The scheme was planned to irrigate 94.5 ha of land.

The micro earth dam construction of this irrigation scheme was started in 2007 E.C. on Shimburit River by the Agriculture Growth program and finalized 2011 E.C and gave a service for five years operational period. The silt excluder, settling basin and spillways of the scheme are working properly.

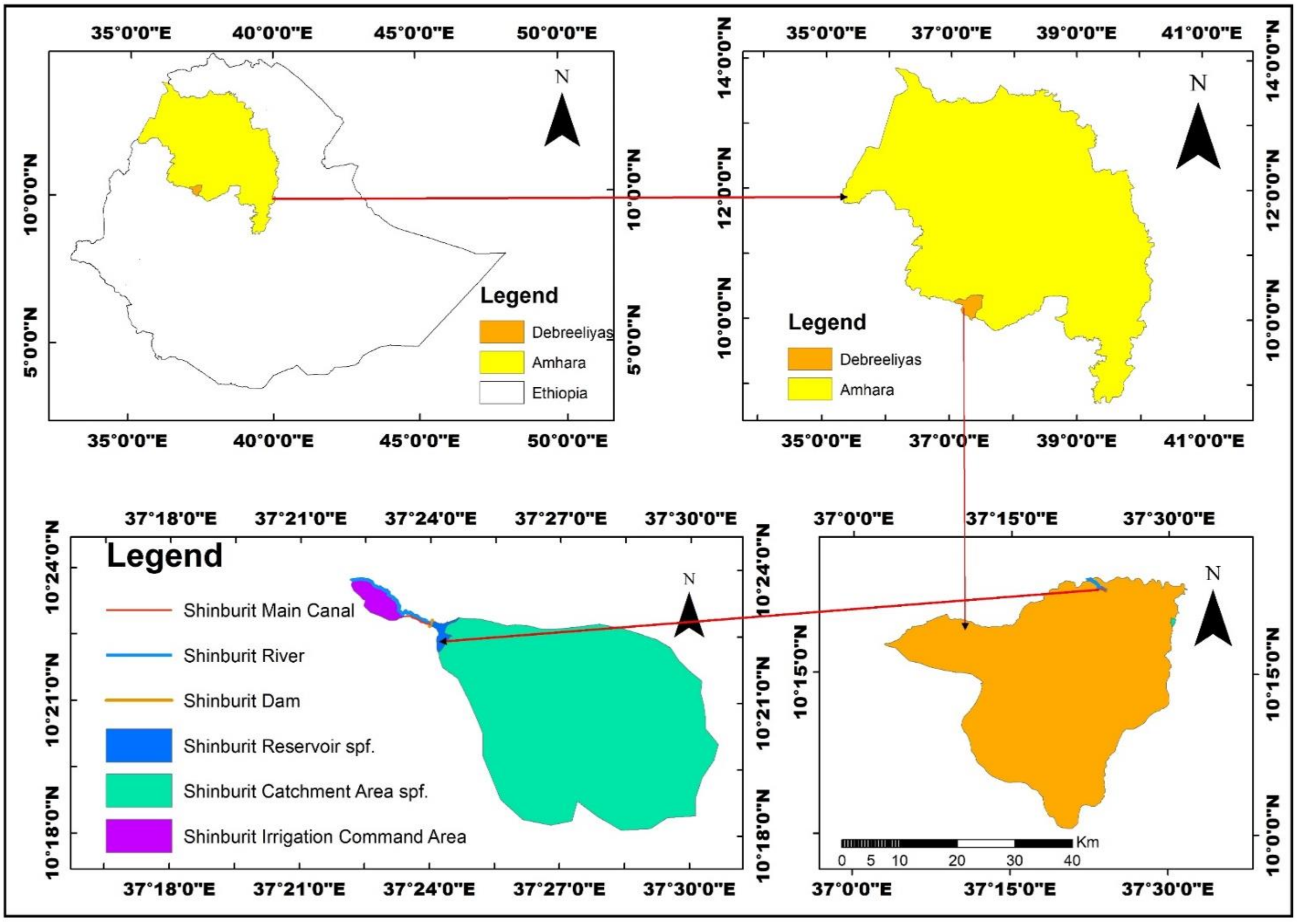
The length of masonry lined main canal of this scheme is 3.14 km & also the masonry lined secondary canal length 2.28 km, four earthen tertiary canals and Seven earthen field canals.

Flooding type of irrigation is widely practiced for the main crops, while at the initial stage of growing period farmers have tried to practice furrow irrigation method for maize, pepper, onion, potato and tomato. Rotational irrigation schedule has been practiced in the irrigation scheme and most of the time it takes five to seven days for seasonal crops and fifteen days for perennial crops for one cycle or rotation.

The main crops grown in Shimburit irrigation scheme are onion, tomato, maize, wheat, potato and pepper. Among the mentioned crops, onion was the dominant crop produced. These crops are grown during both rain and dry seasons. During the rainy season, even if the rain is sufficient for the crop, irrigation water is supplemented when vegetable crops are transplanted. The farmers themselves, including their family, do all the farming practices. And also, Cash crops like avocado, coffee & sugarcane have been produced.
However, during peak times like harvesting, farmers are forced to employ additional labor on a daily wage basis. In the irrigation project there is no rule or restriction on the farmers what type

of crop to produce. The farmers have the right to choose what type of crop to plant as long as the crop is profitable and the water allocation is adequate to produce the selected crops.

There is a loss of water at different points of Main canal, secondary canal and tertiary canals like at road cross point, at drop structure and around field canals because of illegal water diverting, overtopping and canal widening. There is one local union established for this irrigation scheme. Because of this the farmers are going to practice, how to manage the irrigation scheme and they are not forced to sell their product to the merchants at a low price.



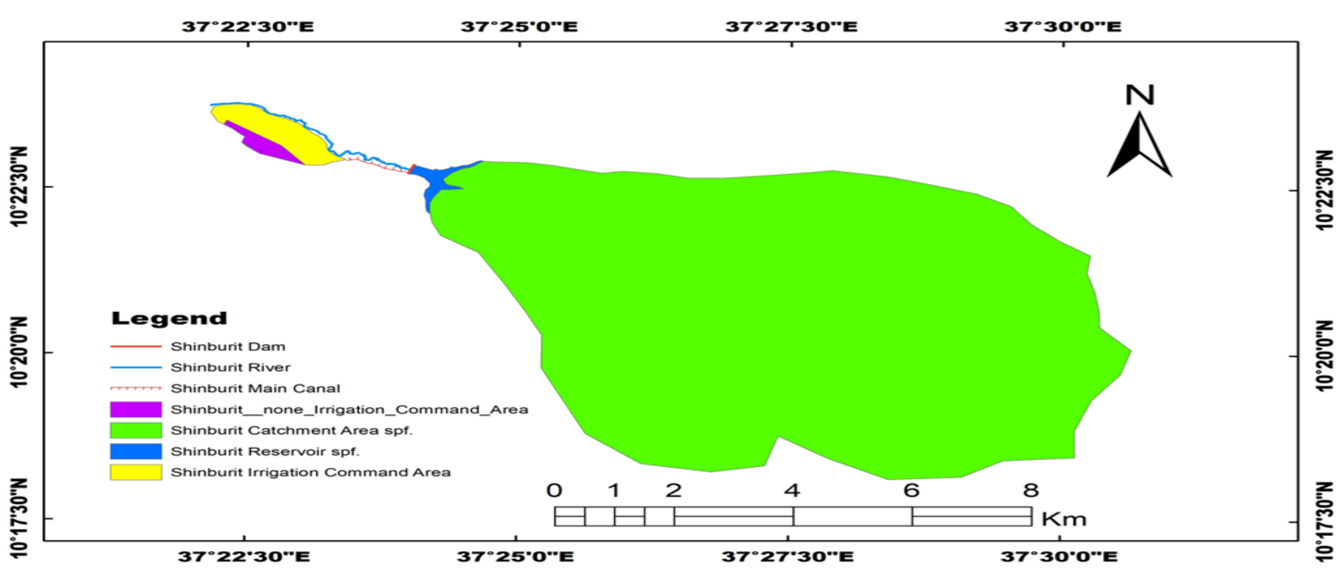


Figure 3. 1 Location maps of Shimburit small scale irrigation scheme

Climate

The meteorological data of Shimburit small scale irrigation scheme were collected from West Amhara meteorology agency Baher Dar. The nearest meteorological stations for shimburit small scale irrigation scheme were Debre Markos and Debre Elyas stations.

The average minimum and maximum temperature data was collected from Debre Elyas & Debre Markos station (1990-2021) and rainfall data was collected from Debre Elyas & Debre Markos station (1990-2021). Based on such temperature and rainfall data, reference evapotranspiration (ETo) using CROPWAT 8.0 by Penman-Monteith method and effective rainfall by USDA SCS method were determined. The details of meteorological data of the area were shown in figure 3.2 and appendix table 8.1.

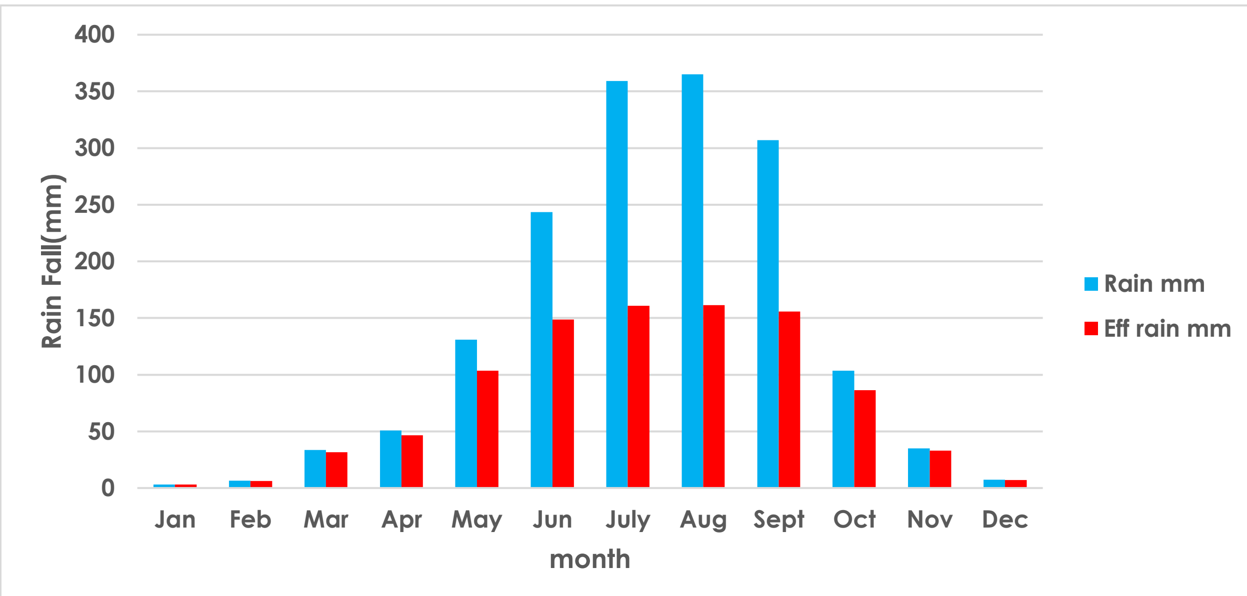


Figure 3. 2 Average monthly Rainfall data & Effective Rainfall for Shimburit SSI at Debrelyas station

3.2. Materials and Tools used for data collections

- ✓ Geographical positioning system (GPS)**:-** used to capture geo-referenced data (Easting, Northing and Elevation) of the study area. It also provides location of discharge measurement point at inlet points and at outlet points of main canal, secondary canal and field canals.

- ✓ Measuring tape: - used to measure length and width of canals and depth of water in the canals.
- ✓ Current meter: - used to measure velocity of diverted flow in the canals.
- ✓ Parshall flume: - used to measure the amount of diverted water to irrigated fields.
- ✓ Stop watch: - used to measure diverted water flow time taken to pass control points.
- ✓ Soil laboratory materials: - like weight balance used to measure weight of sample soil, soil auger used to dig soil sample, soil moisture measuring material and Oven used to dry moist soil sample with high temperature (reach to 105^0c).
- ✓ Arc-GIS: - used to prepare a command map of the study area.
- ✓ Google Earth: - used to collect and save the important point, area and other related things used as input to prepare the map of the study area by GIS.
- ✓ CROPWAT8.0: - used for the determination of reference evapotranspiration, crop water requirement and irrigation requirements.

3.2.1. Data collection

The data arrangements and processes for evaluation of performance of irrigation schemes were done using both primary and secondary data. The following data and method of data collection were used to evaluate the performance of the irrigation scheme.

3.2.1.1. Primary data collection

The primary data were collected through field observations, measurements and laboratory analyses. Frequent field observations were made to observe and investigate the method of water applications and practices related to water management techniques made by the farmers.

Measurements of water discharge at diversion points of this irrigation scheme were taken and also at the initial and final points of secondary, tertiary and field canals. To determine soil texture of each farmer's field, twenty-seven soil samples from nine locations from the scheme at three different depths were collected. And also using core sampler undisturbed soil samples were collected from different depths and the bulk densities at different depths were determined.

Additionally, GPS data were also recorded to locate the boundary of the command area, actual canals network and location of canal structures. This was done by walking around the boundary of the command area and along canals and taking point data. The recorded point data were transferred to map source then downloaded to GIS software and then digitized to locate the command area with irrigation canal network and layout within the boundary on ArcGIS.

3.2.1.1.1. Soil Sampling

Soil samples were taken from the onion fields where the maximum effective root zone is 60 cm (Allen et al., 1998b). Hence, composite soil samples at 0-20 cm, 20-40 cm and 40-60 cm depths have been collected for the determination of soil physical properties such as soil texture, Field capacity (FC) and permanent wilting point (PWP).

The analyses were carried out through pressure plate apparatus in the laboratory. The total available soil moisture (TAW) for the plant is between Field capacity and Permanent wilting point. The magnitude of the total available moisture is a function of soil texture and structure and indicates the capacity of the soil to have water to be extracted by the plant. Total available water (TAW) is the total amount of water a crop can extract from its root zone. Before the wilting point is reached, a plant is already suffering from water stress. Readily available water (RAW) uses the fraction (p) of the total available water (TAW) that can be safely removed before stress occurs. Based on soil parameters of textural class, FC, PWP, can specify the value of depletion fraction (p) from FAO recommendations.

For the determination of soil textural class, nine composite soil samples at the specified depths were taken at three different locations (head, middle and tail end of the scheme). Soil particle size composition of each sample was determined in the laboratory by using the hydrometric method. Then based on the percentage of composition, the soil textural class was determined by USDA soil textural triangle method as shown in appendix figure 8.3.

By using core sampler, undisturbed soil samples were collected at specified depths and the bulk densities at each depth were determined. Soil samples were also collected to determine the soil moisture content one day before and after irrigation by collecting fifty-four soil samples from the scheme with an interval of 20 cm to a depth of 60 cm. It was supposed that the effective root zone of the irrigated vegetable crop is not more than this depth. The moisture content of the collected soil samples was determined by using gravimetric method. The volumetric moisture content base was calculated by using equation 3.1 (Kamara & Haque, 1991) as:

$$W\theta = \frac{Ww - Wd}{Wd} * 100 * Bd \text{……………………………………………………….Eq.3.1}$$

Where, W_θ is volumetric soil moisture content (%), W_w is wet weight of the soil (g) and W_d is dry weight of the soil (g) and B_d is bulk density of soil (g/cm^3).

To calculate bulk density, the core soil samples were dried at 105 °C for 24 hours and it was then calculated using the following equation.

$$\rho b = \frac{Wd}{Vc} \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots .. Eq. 3.2$$

Where, ρ_b = soil bulk density (g/cm^3), W_d = weight of dry soil (g) and V_c = volume of core sampler (cm^3).

3.2.1.1.2. Flow rate measurement

Flow rate measurement is a relevant data for irrigation scheme performance evaluation activities, calculation of conveyance efficiency, application efficiency and losses. There are different methods to measure the flow of water in the canals. For this study current meter and Parshall flume were used. At the points where, current meter and Parshall flume were not possible, a floating method was used to measure the amount of water flowing in the canal.

Frequent flow measurements have been taken starting from intake to referenced point of main, secondary and tertiary canals using current meter and floating methods.

From the main canal five measuring points were taken to capture the amount of inflow before entering to secondary canals to calculate the lost amount of water relative to the diverted amount of it.

Since the canal cross section of the scheme is rectangular, the amount of water flowing through it would be equal to the product of the average velocity (Va) and the area of the cross section (A). The wetted width of the canal was divided into three cross sections (at left edge, center and right edge) and the flow depth was measured at each division. The average flow velocity was measured at a depth of (0.6*d) from the water surfaces at each vertical; where, d is the respective depths of each division. The discharge in each subsection of the canal was determined by multiplying the area of the sub section by the average flow velocity in that section. The total discharge would be the summation of individual discharges in the specified cross sections.

$$\left.\begin{array}{l} v = 0.0913 + 0.317 * n\ for\ 0.00 < n < 1.98 \\ v = 0.019 + 0.3205 * n\ for\ 1.98 < n < 10.27 \\ v = 0.149 + 0.344 * n\ for\ 10.7 < n < 15 \end{array}\right\} \text{..................................Eq.3.3a}$$

Where,

V=velocity (m/s)

n=number of propeller rotation per second.

$$q = b * d * \left(\frac{v1+v2}{2}\right) \text{..Eq.3.3b}$$

$$\text{Then, } Q = \Sigma q \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{Eq. } 3.3c$$

Where, d is flow depth at each cross section (m), b is width of the cross section (m), q is individual flow rate through each sub-section (m^3/s), v1 and v2 are velocity through each sub-section (m/s) and Q is total discharge in the canal (m^3/s).

To determine the amount of water applied by the farmers to their fields, Parshall flume was fixed at the entrance of each field and frequent readings were taken. During the determination of the amount of water applied to the field, the depth of irrigation water passing through the flume to the field and the respective time intervals were recorded with the sizes of the fields being irrigated. Then the discharges of applied water were taken from the Throat of the written graph for corresponding depths of a specific size of Parshall flume.

3.2.1.2. Secondary data collection

For the selected irrigation scheme, secondary data were collected from Deberelyas woreda Agricultural and Rural Development Office. These include annual production, irrigable area, total command area, area irrigated per crop per season/year, crop types and yields and Climatic data of the irrigation project were collected from the nearby weather stations.

3.3. Data Analysis

Different methods of data analysis were used to attain the goal of the study. In this session the evaluation of performance of conveyance and diversion systems of irrigation were undertaken by using different performance indicators. To analyze the data; Survey data were analyzed using descriptive statistics. For data analysis and manipulation activities, CROPWAT 8.0 and GIS soft ware were employed. Finally, the selected performance indicators were calculated.

3.3.1. Determination of crop water and irrigation water requirement

To estimate the crop water requirement (CWR) and irrigation water requirement (IWR) of the irrigated crops at field levels and the irrigation scheme as a whole, the CROPWAT 8.0 was used. Determination of the crop water requirement by this model depends on the determination of reference evapotranspiration by Penman-Monteith equation (Smith, 1992). To determine ETo value, the model requires climatic data such as mean monthly minimum and maximum temperature (^{o}c), relative humidity (%), wind speed (km/day) and sunshine hours (hr).

$$ETo = \frac{0.408\Delta(Rn-G)+\frac{\Upsilon 900U2(es-ea)}{T+273}}{\Upsilon+(1+0.34U2)} \quad \text{.......................................Eq-3.4}$$

Where, ETo is reference evapotranspiration (mm/day), R_n is net radiation at the crop surface (MJ/m^2/day), G is soil heat flux density (MJ/m^2/day), T is air temperature at 2m height (^{o}C), U_2 is wind speed at 2m height (m/s), es is saturation vapor pressure (kpa), e_a is actual vapor pressure (kpa), e_s-e_a is saturation vapor pressure deficit (kpa), Δ is slope of vapor pressure curve (kpa/^{o}C) and $\boldsymbol{\Upsilon}$ is psychrometric constant (kpa/o_c).

The amount of water required to compensate for the evapotranspiration loss from the cropped field is defined as crop water requirement. According to Wondatir (2016), although the values for crop evapotranspiration under standard conditions (ETc) and crop water requirement are identical, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration. The program estimates (ETc) based on the equation:

$$ETc = ETo * Kc \quad \text{..Eq-3.5}$$

Where, Kc is crop coefficient, varies with crop growing stage.

The values of Kc of each major crop were taken from (Allen et al., 1998a). The determination of irrigation requirement was made after estimation of effective rainfall by USDA soil Conservation Serviced Method (Clarke et al, 2001). Irrigation is required when rainfall is insufficient to compensate for the lost by evapotranspiration. By calculating the soil water/budget of the root zone on a daily basis, the timing and the depth of future irrigations can be planned. In order to calculate the irrigation water requirement, CROPWAT 8.0 computes a daily water balance of the root zone. It is computed as:

$$IWR = ETc - Peff \qquad \text{Eq.3.6}$$

Where, ETc is crop evapotranspiration (mm/day) and P_{eff} is effective rainfall (mm/day).

And to estimate the total crop water requirement at scheme level, input data of actual irrigated area by crop type was included. The total net crop water requirement of the scheme was determined by the formula:

$$TCWR = \sum_{n=i}^{n} \left(\text{CWRi} * \frac{Ai}{Atotal}\right) \qquad \text{Eq.3.7}$$

Where, TCWR is total crop water requirement, A_i is area under crop i (ha), A_{total} is the total irrigation area (ha) and n is total number of crops.

3.3.2. Methods used to measure Performance indicators

Performance of the scheme was evaluated using both internal and external indicators. The internal performance indicators calculated were conveyance efficiency, application efficiency, storage efficiency and overall scheme efficiency. For computation of performance efficiencies, irrigation fields with onion crop were purposely selected. For this purpose, a total of nine farmers' fields were selected from the scheme, i.e. three from the head (H_1, H_2 and H_3); three from the middle (M_1, M_2 and M_3) and three from the tail (T_1, T_2 and T_3) and water users of Shimburit irrigation scheme.

The standardized performance indicators established by International Water Management Institute (IWMI) were taken to measure external indicators (Molden et al., 1998). The external indicators encompassed in this study were irrigated agriculture, water use and physical performance.

There are enormous numbers of indicators proposed by different researchers to evaluate the performance of irrigation systems (Burton et al., 2005). According to (Wahaj et al., 2007) all performance indicators can however be broadly classified into internal or process indicators and external or comparative indicators. The purpose of external indicators is to evaluate outputs and impacts of activities related to irrigation management and interferences across different systems or within the same system over time, while internal indicators are used to assess the actual irrigation performance in relation to system specific management goals.

3.3.2.1. Internal performance indicators

To determine numerical values of performance measures, certain parameters were measured or perceived before, during and after an irrigation event while farmers perform their normal irrigation practices.

The internal performance indicators for the scheme were calculated based on field measured data. The following on-farm irrigation performance and water loss measures or indicators were employed to characterize the performance of the on-farm irrigation systems for the scheme.

3.3.2.1.1. Conveyance efficiency

To determine the conveyance efficiency, discharge measurements were done on different points on the main and secondary canals. For this study current meter measurements were taken at ten points on head, middle and tail parts of the main canal and twelve points on secondary canals. The current meter measurements were done three times, and the average conveyance efficiency was calculated using the equation:

$$\text{Ec} = \frac{Wd}{Wf} * 100 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. \text{Eq3.8}$$

Where, E_c is conveyance efficiency (percent) between two points, W_d is water delivered to the irrigated plot (at the field supply channel) (m3/sec), W_f is water diverted from the source (m3/sec).

The average conveyance efficiency was determined as follows:

$$Ecave = \sum_{n=1}^{\infty} \frac{Ec}{n} \ldots\ldots\ldots\ldots \text{Eq. 3.9}$$

Where, Ecave. is average conveyance efficiency of main canal, Ec is conveyance efficiency between any two points on the main canal and n is the number of points on the main canal at which conveyance efficiency is determined.

3.3.2.1.2. Application efficiency

After the water reaches the field supply channel, it is important to apply the water as efficiently as possible. A measure of how efficiently this is done is the application efficiency. One very common measure of on farm irrigation efficiency is application efficiency. That asks how much of the water applied to the crop is actually used for crop growth or other beneficial uses? (Hassen, 2004)

The application efficiency measures the ratio between the volumes (depth) of water stored in the root zone for use by the plant to the volume (depth) of water applied to the field. The term has been stated in different ways over the years to include different parameters by different authorities. Field irrigation efficiencies are influenced by different factors such as soil type, field application methods, depth of application and climate. Very high values are attained in arid climates and where water shortages prevail, it indicates that the water available for use by the crop is higher than the water delivered to the field. However, in the area where the water applied exceeds water required, indicating an over irrigation, stresses should be given to reduce the amount of irrigation water (Shiberu & Hailu, 2011).

The water application efficiency is computed as:

$$Ea = \frac{Wc}{Wf} * 100 \ldots\ldots\ldots\ldots Eq. 3.10$$

Where, Wf is water delivered to the field (mm) and Wc is water available for use by the crop (mm).

3.3.2.1.3. Storage efficiency

According to (Zerihun et al., 1996) adequacy or storage efficiency is the measure of how close the applied amount is to the apparent requirement (the right amount) over the entire subject region and defined as the ratio between the amounts actually stored in the subject region to the required amount.

The adequacy of an irrigation turn expressed in terms of storage efficiency, which is defined as the ratio between the storage depth and the required depth (Jurriëns et al., 2001). Based on the moisture content at field capacity, permanent wilting point and bulk density of the soils of the selected irrigation fields and the root depth of the crop irrigated, the depth of irrigation water required by the onion crop was calculated at the 25% moisture depletion level. i.e. MAD of 0.25 (R. Allen, 1998)After determining the storage and the required depths, the storage efficiency was computed as follows(Hassen, 2004)

$$\text{Es} = \frac{Ws}{Wn} * 100 \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. \text{Eq.} 3.11$$

Where, Es is storage efficiency (%), Ws is depth of water stored in the root zone and Wn is depth of water required to be stored in the root zone and it is 75% of TAW. Total available water (TAW) which is an estimate of the amount of water a crop can use from the soil for the selected fields was calculated from the moisture content in volume percent at field capacity and permanent wilting point (R. Allen, 1998).

$$TAW(mm) = 1000 * (FC - PWP) * Zr \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots. Eq. 3.12$$

Where, TAW is the total available water in the root zone (mm), Fc is moisture content at field capacity (m^3/m^3), PWP is the moisture content at permanent wilting point (m^3/m^3) and Zr is the root depth (m). Finally, the overall scheme efficiency was computed as the product of conveyance efficiency and application efficiency.

It was calculated by using the following formula (Ramulu, 2005).

$$Eo = Ea * Ec \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 3.13$$

Where, Eo is overall scheme efficiency (%), Ec is conveyance efficiency (%) and Ea is application efficiency (%).

3.3.2.2. External performance indicators

External performance indicators evaluate irrigation systems based on relative comparison of absolute values rather than being referenced to standards or targets. Many indicators used for external performance evaluation can be computed from secondary data rather than primary data. These sets of indicators are considered to show gross relationship and trends are useful in indicating where more detailed study should take place, where a project has done extremely well; or where dramatic changes take place. According to (Marinus G Bos et al.,1993),external performance indicators are grouped as:

3.3.2.2.1. Agriculture performance indicators

A number of indicators were developed with regard to irrigated agricultural systems. They are used for the evaluation of the project performance in terms of the production it results in. It states output of irrigated area in terms of gross or net value of production measured at local or world prices. This discourses 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. Four indicators related to the output of different units were used for the evaluation of agricultural performance.

According to Molden et al. (1998),these indicators were formulated as follows:

$$\text{Output per croped area} = \frac{Value\ of\ production(\$)}{Irrigated\ cropped\ area(ha)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. Eq. 3.14$$

$$\text{Output per unit command area} = \frac{Value\ of\ production(\$)}{Command\ area(ha)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. Eq. 3.15$$

$$\text{Output per unit irrigated supply} = \frac{Value\ of\ production\ (\$)}{diverted\ irrigation\ supply(m3)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots.. Eq. 3.16$$

$$\text{Output per unit water consumed} = \frac{Value\ of\ production}{Volume\ of\ water\ consumed\ by\ ET(m3)} \ldots\ldots\ldots.. Eq. 3.17$$

Value of production: is the output of the irrigated area (US$) in terms of gross or net value of production measured at local or world prices. Irrigated cropped area (ha) is the sum of areas under crops during the time period of analysis. Command area (ha) is the nominal or design area to be irrigated. Diverted irrigation supply (m^3) is the volume of surface irrigation water diverted to the command area. In this study production from irrigated agriculture is the main issue to compare systems. However, there are difficulties when comparing different crops across a system, say onion and tomato, as one kg of onion is not readily comparable with one kg of tomato. When only one irrigation system is considered or irrigation systems in a region where prices are similar, production can be measured as net value of production and gross value of production using local values. As a result, agricultural output production values were determined through local price and finally they were converted to US$; to standardize and to compare the results relative to other research findings in the world.

3.3.2.2.2. Water supply indicators

According to (Molden et al., 1998) the water supply indicators (relative water supply and relative irrigation supply) are better matched to place the irrigation system in its physical and management context. Higher values of these indicators indicate a more generous supply of water. In this case, productivity to land may be more important. Where the water supply indicators show a lower value, it indicates a condition of a more constrained water supply and values of productivity per unit of water are more important.

As (Marinus G Bos et al., 1993), states that these indicators deal with the main task of irrigation managers in the capture, allocation and conveyance of water from source to field by the management of irrigation facilities. Indicators address numerous aspects of this task: efficiency of conveying water from one location to another, the extent to which agencies maintain irrigation infrastructure to keep the system running efficiently and the service aspects of water delivery which include such concepts as predictability and equity.

3.3.2.2.2.1. Relative water supply (RWS)

As stated by Levine (1982), relative water supply indicates the adequacy of water applied to the amount of water demanded by the crop. It is the ratio of total water supplied by irrigation plus rainfall to total water demanded by crop i.e. actual crop evapotranspiration (ETc).

$$\text{Relative water supply} = \frac{Total\ water\ supply}{Crop\ water\ demand} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots 3.18$$

Where, Total water supply = diverted water for irrigation plus rainfall (m3), Crop water demand =potential evapotranspiration or the real evapotranspiration (ETc) when full crop water requirement is satisfied (m3).

3.3.2.2.2.2. Relative irrigation supply (RIS)

According to (Molden et al., 1998) and (Perry ,1996),it is the ratio of irrigation supply to irrigation demand. This indicator is convenient to assess the degree of irrigation water stress or abundance in relation to irrigation demand.

$$Relative\ irrigation\ supply = \frac{Irrigation\ supply}{Irrigation\ demand} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 3.19$$

Where, Irrigation supply is only the surface diversion of irrigation (m^3)

Irrigation demand is the crop ET minus effective rainfall (m^3).

RIS relates irrigation supply to irrigation demand of the irrigation schemes in the production season. The calculated value shows some indication as to the condition of water abundance or scarcity and how tightly supply and demand are coordinated. If the value is greater than one, it indicates irrigation supply was beyond the irrigation demand, if it is less than one, the supplied amount of irrigation was sufficient to demand, i.e. neither surplus nor deficit. Most of the time it is better to save a RIS near one than a higher value. However, the indicator did not show the monthly relation between irrigation supply and irrigation demand (Wondatir, 2016).

3.3.2.2.3. Physical performance indicators

Physical performance indicators are interrelated with the 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 command areas are not fully under irrigation in a particular season (Shiberu & Hailu, 2011). The selected indicator used for evaluation of physical performance was irrigation ratio. This can be stated as the follows (Molden et al., 1998).

$$\text{Irrigation ratio} = \frac{Irrigated\ Area(ha)}{Command\ Area(ha)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots Eq. 3.20$$

Irrigation ratio is the ratio of currently irrigated area to irrigable command or nominal area. It expresses the degree of utilization of the available command area for irrigated agriculture at a particular time. Shortage of irrigation water, lack of irrigation infrastructure, lack of interest on irrigation due to less return, reduced productivity due to problems such as salinization or water logging, etc. could result in underutilization of land. On the other hand, cropping intensity, a ratio of annual cropped area to command area, is indicative of annual land utilization (Dejen, 2015).

4. RESULTS AND DISCUSSION

4.1. Physical properties of Soil

To investigate some of the physical properties of soil in the sites moisture content at field capacity (FC) and permanent wilting point (PWP), moisture content before and after irrigation, texture, and bulk density, for the purpose of understanding the general feature of the irrigated soil type, different field observations were taken and analyzed.

Based on soil samples taken at three depth intervals as, (0-20, 20-40, and 40-60 cm) for the scheme, the soil textural class of the irrigation scheme was determined based on the particle size distribution through using USDA SCS Soil Textural Triangle (Appendix figure 8.3). The soil textural class in the project area was clay for the selected farms at the irrigation scheme. The bulk density values ranged from 1.06 to 1.28 g /cm3 and an average value 1.17 g /cm3 at the irrigation scheme. Generally the top surface soil has lower bulk density than the subsurface soil. (Miller & Donahue, 1995) recommended soil bulk density below 1.4 gm/cm3 for clays and 1.6 gm/cm3 for sands in order to get better plant growth. Then the bulk density value of the soils at the Shimburit irrigation scheme indicates that there was no compaction that could limit infiltration of water into and through the soil and root penetration.

The volumetric soil moisture content at field capacity and at permanent wilting point for the scheme varies from 30.01to 39.74% an average value 34.44% and 16.19 to 23.61% an average value 19.66% respectively.

The total available water (TAW) for the scheme varies from 137.2mm/m to 168.8mm/m and an average value 153.00 mm/m. In general soils of the Shimburit irrigation scheme are medium as per available water holding rating (McIntyre, 1974).The result describe that the relevant soil physical properties measured are not different to a great deal from each other with depth and across the different sampling points indicate that the soils of the study area are more or less homogeneous. The details of soil textural class, bulk density, volumetric moisture content at field capacity and permanent wilting point for Shimburit irrigation scheme are presented in appendix table (8.4).

4.2. Internal performance indicators

4.2.1 Application efficiency

Water application efficiency delivers a general indication of how well an irrigation system performs its primary task of delivering water from the conveyance system to the crop (Muleta & Quaraishi, 2013).

The application efficiency is an indication of how the applied water is stored in the root zone and how much of it is lost by runoff, evaporation and percolation.

The finding indicates that the upstream irrigators of Shimburit small irrigation scheme were inefficient by applying excess water to their fields. As seen from figure 4.1, water was applied to the field by flooding type irrigation and water was lost by surface runoff.

The results of the application efficiency for the selected fields in the scheme were found to be 61.3%, 79.59% and 65.74% for upper users, middle users and lower users respectively with an average value of 68.9%.

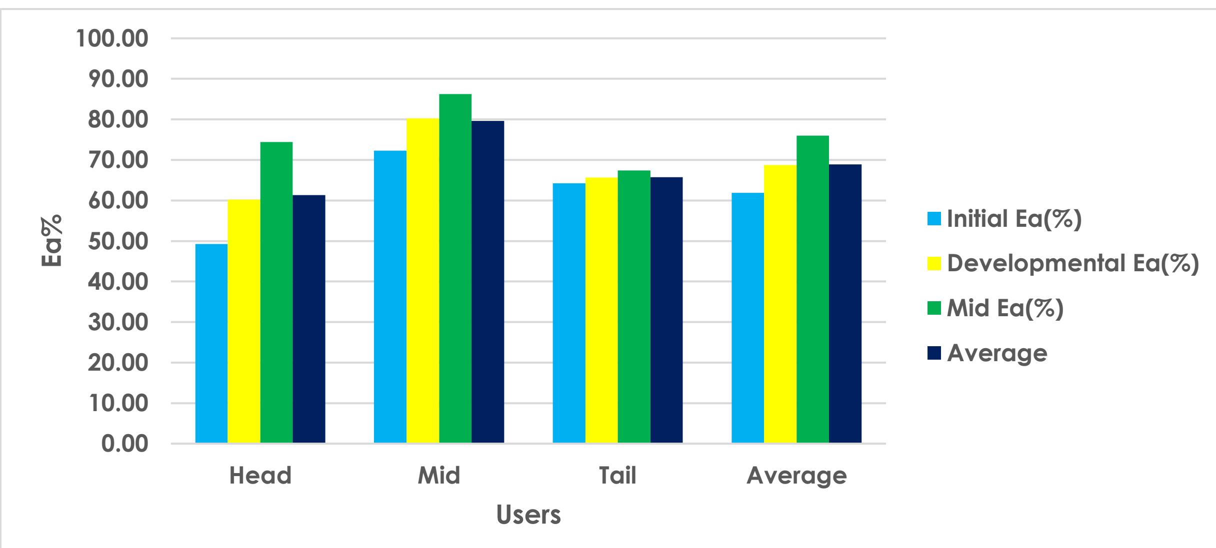


Figure 4. 1. Application efficiency for Shimburit irrigation scheme

The result shows that the application efficiency is higher at the middle than at the head and tail parts, because at the middle there is less surface runoff (those irrigators at the middle part use irrigation water efficiently as compared to the head and tail users and the irrigated land has not that much undulating slope as head and tail parts).

The detail of the application efficiency for the selected fields in the scheme is shown in Appendix table 7 and the average value of application efficiency are presented in Figure 4.1.

The application efficiency at the initial stage is lower than that of developmental and mid stages for Shimburit irrigation scheme. This is due to the crop at the initial stage being unable to absorb water from deeper depth and then much of the applied water would be lost. (Howell, 2003) proposed that it could be in the range of 50-80% for graded furrow irrigation and the result is between this limit.

4 .2.2. Conveyance efficiency

The conveyance efficiency of the scheme on the main canal varies from 75.75 to 83.58% with average value of 79.14% and the maximum value is at head and minimum value is at tail part of the main canal. The conveyance efficiency of the scheme on secondary canal one varies from 58.09 to 80.31% with the average value of 72.83% and secondary canal two varies from 75.56 to 78.86% with an average value of 76.28%.

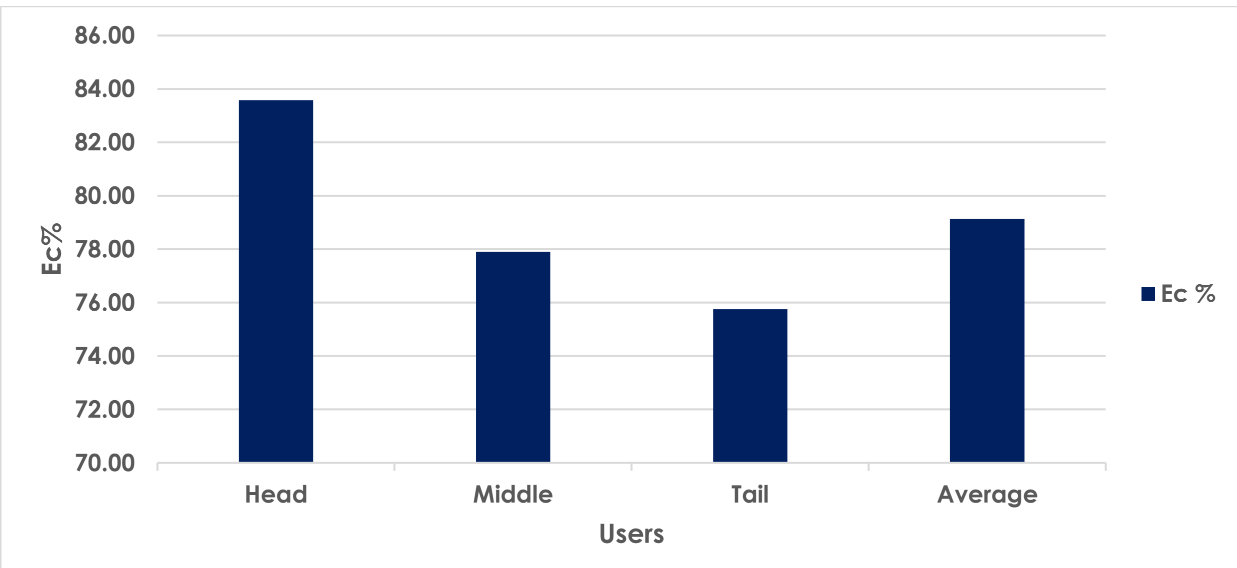


Figure 4. 2. Conveyance efficiency of Shimburit main canal

The result shows that the conveyance efficiency is higher at the head and middle parts than at the tail part, because most parts of the main canal at the head and middle parts are lined (less seepage losses), the unlined parts are cleaned regularly and there is a less broken irrigation infrastructure at those parts.

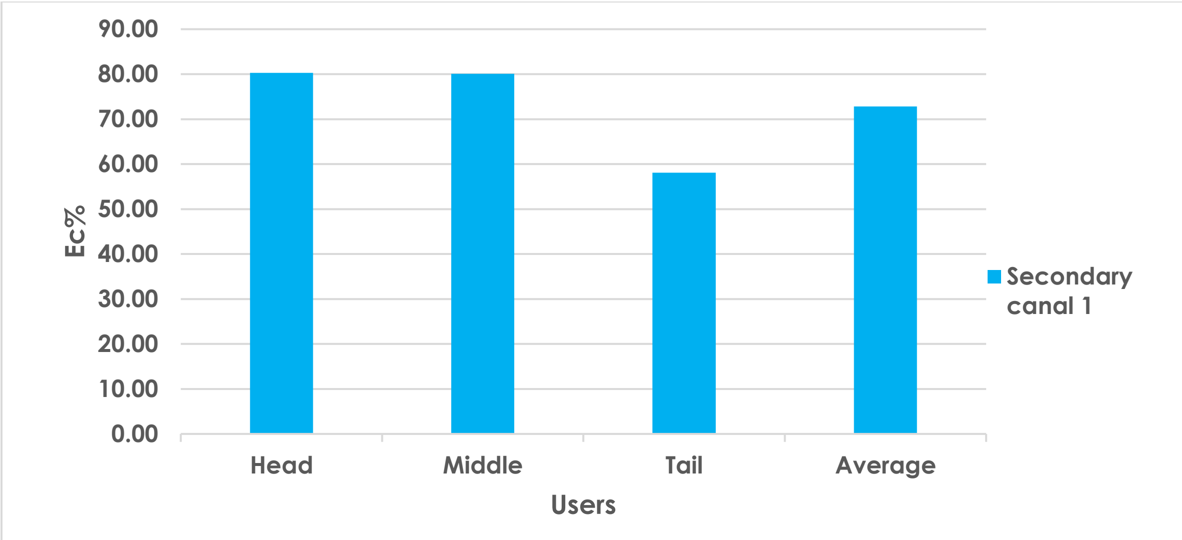


Figure 4. 3. Conveyance efficiency of Shimburit secondary canal 1

The result shows that the conveyance efficiency value of secondary canal 1 at the head and middle part is higher than at the tail part because most of the canal at these parts are lined (less seepage loss) and less broken irrigation infrastructures.

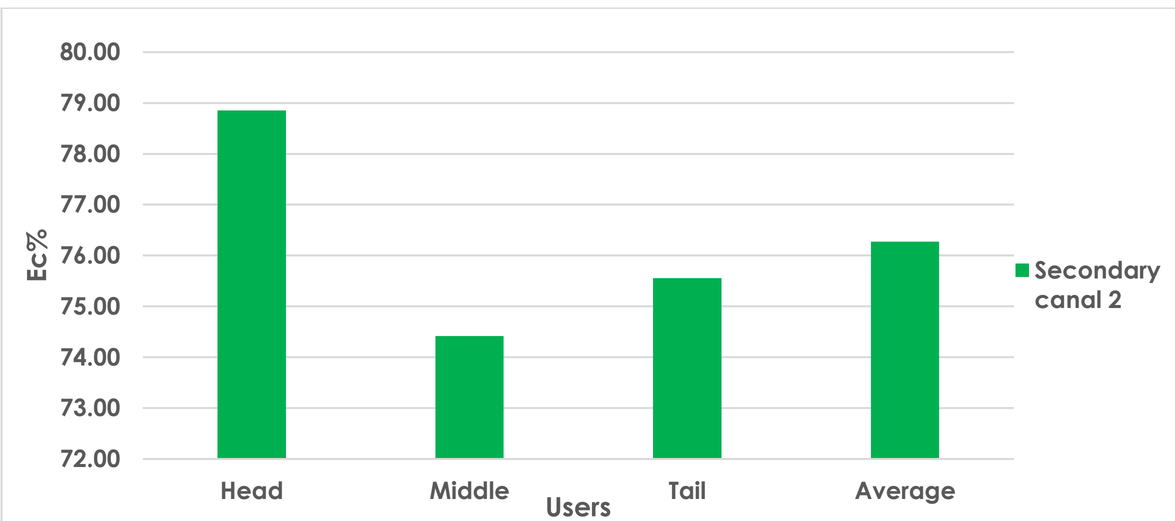


Figure 4.4. Conveyance efficiency of Shimburit secondary canal 2

The result shows that the conveyance efficiency at the head and tail parts of the canal are higher than at the middle part, because most of the canals at those parts are lined and there is less seepage losses.

4.2.3. Storage efficiency

Storage efficiency of the scheme was computed using equation (3.11). Since storage efficiency is the ratio of average depth of water stored to that of required depth .

According to (Allen et al., 1998a), the required depth was calculated from total available water (TAW) considering 25% moisture depletion level.

The results of storage efficiency of selected fields from the Shimburit irrigation scheme were 30.92%, 34.71% and 33.39 % at upper, middle and lower users respectively with an average storage efficiency of 33.01%.

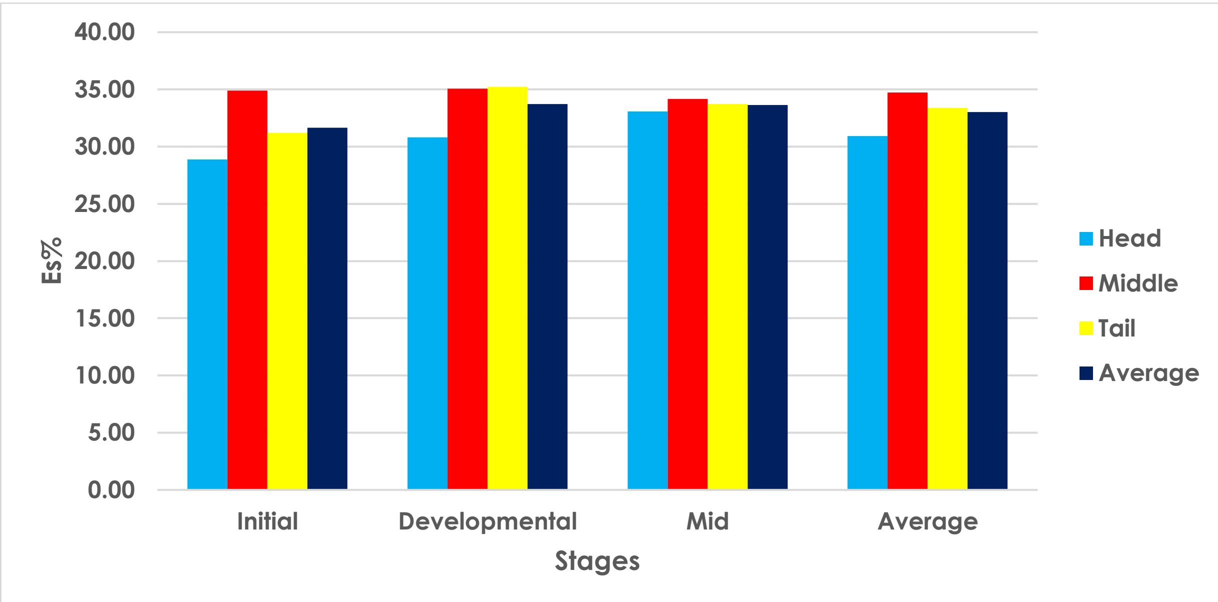


Figure 4. 5. Storage efficiency of Shimburit irrigation scheme

The Figure shows that storage efficiency of the scheme in all stages is very poor. The average values of storage, application and conveyance efficiencies for the scheme are shown in Figure 4.6 and the details of storage efficiency for selected fields are shown in Appendix table 8.

Even if the application efficiency value alone was not an indication of adequate irrigation water or better method of application, the combination of it with storage efficiency shows how farmers are managing irrigation water in the scheme. In general the storage efficiency of the scheme was very poor as compared to 63% storage efficiency usually found in typical furrow irrigation systems (Raghuwanshi & Wallender, 1998). The lower value of storage efficiency in the scheme is due to undulating slope of the command area and then there is surface runoff.

4.2.4. Overall scheme efficiency

According to (Shiberu and Hailu ,2011) the overall efficiency of the scheme is the ratio of water made available to the crop to the amount released at the headwork. In other words, it is the product of conveyance efficiency and application efficiency. The overall efficiency of the scheme is 54.5%

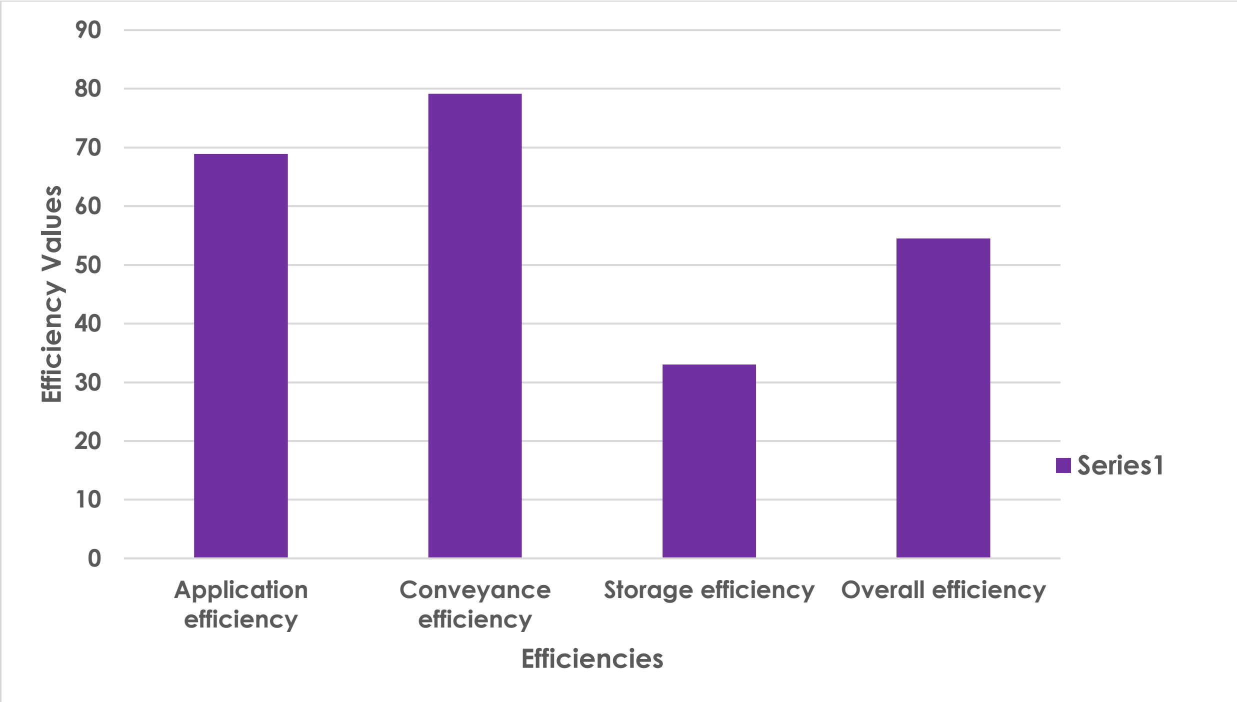


Figure 4. 6. Average values of internal performance indicators

The result of overall efficiency of the scheme was almost within the range of values (40-50%) commonly observed in other similar African irrigation schemes (Savva & Frenken, 2002b).

Generally the field application efficiency (Ea) is the one that contributes most to the overall irrigation efficiency and is quite specific to the irrigation method; any efforts that are made to advance on this efficiency will impact heavily on the overall efficiency (Savva & Frenken, 2002b).

4.3. External Performance Indicators

According to (Molden et al., 1998), external performance indicators are those indicators based on outputs and inputs from and to an irrigated agricultural system. However, they practically deliver little or no detail as internal processes that lead to the output.

4.3.1. Water supply performance indicators

Relative water supply (RWS) and relative irrigation supply (RIS) were calculated using equation 3.18 and 3.19 respectively, as described in section 3.3.2.2.2. From the computation of the mean irrigation water discharge at the main canal inlet, total precipitation and crop water requirement during irrigation season, the relative water supply and relative irrigation supply results are attained.

The crop water requirement (CWR) and the irrigation requirement (IR) were calculated for the irrigated crop (onion) for the 2022 cropping season.

Table 4.1. Results of CWR and IR for Shimburit irrigation scheme

Scheme	Crop	Area (Ha)	Total RF mm/season	Effective RF mm/season	Crop water requirement mm/season	Irrigation requirement mm/season	Crop season
Shimburit	Onion	40.5	199.3	164.9	447.2	282.3	Feb-May
	Potato	14	203.3	135.7	505.4	369.7	Jan-May

Since a single crop (onion) was selected, the crop water requirement and irrigation requirement of onion represents the irrigation area in the scheme. The result of total rainfall for the irrigation season was gained from climatic data.

The results of crop water requirement (CWR) from Table 4.1 were changed into depth and multiplying it by irrigated area and the amount of crop water requirement (CWR) in volume for this irrigation scheme is 251,872 m^3/season. The total irrigation requirement is computed in the same way and the result is 166,089.5 m^3/season. The result indicates that there was less rainfall during the irrigation season.

The amount of irrigation water diverted during the whole season for the scheme was measured at the canal intake (Table 4.2) and the average value is 590,717.91m^3/season and the depth is computed as; volume of water diverted by total irrigated area. The result is 1084 mm and from appendix Table (1) the total rainfall for onion in cropping season (Feb-May) was 199.3mm and crop water requirement (CWR) was 447.2mm. For potato crop in cropping season (Jan-May) the total rainfall and crop water requirement (CWR) values are 203.3mm and 464.7 mm respectively.

Table 4. 2. Average flow measured at canal intake in Shimburit irrigation scheme.

Date	Width(cm)	Depth(cm)	Flow Area (m2)	Surface flow velocity (m/s)	Flow discharge (m3/s)	Flow discharge (l/s)
18/02/2022	60	52	0.31	0.22	0.0676	67.61
20/03/2022	60	50	0.30	0.23	0.0681	68.13
22/04/2022	60	49	0.29	0.23	0.0688	68.80
22/04/2022	60	48	0.29	0.24	0.0691	69.12
14/05/2022	60	44	0.26	0.26	0.0682	68.18
				Average	0.0684	68.37
				IWS	590,717.91 (m3/season)	590,717,905.92 mm/season

Table 4. 3. Results of some parameters for Shimburit irrigation scheme in 2021/2022 cropping season.

Scheme	Command area(ha)	Irrigated Area (ha)	Irrigation supply		CWR(mm)	IR(mm)	Total RF(mm)
			m^3	mm			
Shimburit	94.5	54.5	590717.91	1083.89	462.15	304.75	203.3

Based on the results in table 4.3 RWS and RIS for the scheme was determined using equation 3.18 and 3.19 respectively and the results are presented in Table 4.4.

As shown from the result (Figure 4.4), the value of both relative water supply (RWS) and relative irrigation supply (RIS) values for the scheme are greater than one. Relative irrigation supply (RIS) emphases on supply of irrigation water alone, in contrast to relative water supply (RWS) which also includes rainfall. The calculated relative irrigation supply (RIS) and relative water (RWS) results during the irrigation period were 3.56 and 2.79 respectively.

The values obtained indicate that a system is not constrained by water supply for crop production; it is possible to irrigate additional areas with the current amount of irrigation water and rainfall.

(Perry, 1996), also categorized relative water supply (RWS) values ranging from 0.9 to 1.2 as adequate, from 1.2 to 1.8 as excessive and values from 1.8 to 2.5 as very excessive. According to him, the result of relative water supply (RWS) at Shimburit irrigation scheme is very excessive.

The result of relative water supply (RWS) shows that it could irrigate additional farm land with this delivery amount and available effective rainfall in the area. The result was helpful for planning to construct a canal branched from the existing main canal to increase the command area.

The reason why the entire command area was not under irrigation is not due to shortage of water rather it could be that farmers low economical capacity to afford high inputs (Fertilizers, crop protection chemicals and improved seeds) required for cash crop production. And also, the communal grathing land, local villages, trees, shrubs, unlevel land scape and stony areas are available on the Command area.

According to (Wondatir, 2016), the value for relative irrigation requirement (RIS) greater than one shows that irrigation supply was beyond the irrigation demand, if it is less than one, the irrigation supply was below the irrigation demand. Based on the result at Shimburit irrigation scheme, farmers were applying more water than the required amount. In order to maximize water use efficiency of the scheme, it is essential that the amount of water supplied to the scheme must be reduced.

As stated by (Savva and Frenken, 2002), if irrigation is the only source of water supply for the plant, the irrigation requirement will always be greater than the crop water requirement to avoid inadequacies in the irrigation system. If the crop obtains some of its water from other sources (rainfall, water stored in the ground, underground seepage etc.), then the irrigation requirement can be considerably less than the crop water requirement.

Generally, irrigation water should be delivered to fill the gap between crop water requirement and rainfall. If this objective is attained, the value of relative irrigation supply (RIS) could be near to one. But the result of relative irrigation supply (RIS) at Shimburit irrigation scheme is greater than relative water supply (RWS) which indicates the farmers are applying irrigation water without considering rainfall in the area.

Generally it is better to have relative irrigation supply (RIS) close to one than a higher or lower value (Molden et al., 1998).

4.3.2. Agricultural output performance indicators (water and land productivity)

The productivity is related to output from the system in response to the input added to the system and there are numerous indicators of productivity. It is essential to consider the performance of the irrigation scheme over space. This includes performance indicators, which are associated with production. To know the productivity of the selected irrigation project in terms of their output per area and water supply, four comparative indicators (output per cropped area, output per unit command area, output per unit irrigation supply and output per unit water consumed) were used in the study.

Output per cropped area and output per command area in a single irrigation scheme shows about land productivity and also the relation between the two is an indication of how the nominal or intended command area is irrigated or not. i.e. if the values of two indicators are much similar, the intended command area is irrigated and if output per command area is much higher than output per irrigated area, less area is irrigated than intended or designed area. Whereas, output per irrigation water supplied and output per water consumed are indications of water productivity.

Table 4. 4 Command cropped area, irrigation supplied and yield for Shimburit irrigation scheme.

Scheme	Cropped Area (ha)	Command Area(ha)	Water consumed (m3/season)	Irrigation supplied (m^3/season)	Production (Quntals /ha)	Price (birr/kg)	Income (birr/ha)
Shimburit	54.5	94.5	251,872.0	590717.91	180	30	540000

The values of selected agricultural performance indicators for the scheme are determined based on the results in Table 4.4 and using their respective equations defined in the methodology (section 3.3.2.2.1) and the results are described in Table 4.5.

Table 4. 5 Agricultural performance indicators for Shimburit irrigation scheme.

Scheme	Output /cropped area		Output /command area		Output/irrigation supplied		Output/water consumed	
	Quintals/ ha	Birr/ha	Quintals/ha	Birr/ha	Quintals /m3	Birr/m3	Quintal s/m3	Birr/m3
Shimburit	180	540000	103.81	311428.6	0.017	49.82	0.039	116.85

The farmers in Shimburit irrigation scheme are less stressed in water and they are not expected to pay for irrigation water, their management would be poor. The output per unit irrigation water supplied was 0.017 quintals/$m^{3.}$

When land is a limiting factor relative to water, output per unit land may be more important, when water is a limiting factor for production, output per unit water may be more important (Molden et al., 1998). Since water is a limiting factor relative to land in the Shimburit irrigation scheme, the value of water has to be given more emphasis.

4.4. Physical performance indicators

Physical performance indicators are associated with the changing or losing irrigated land in the command area for different reasons. Sustainability of irrigated area and irrigation ratio are the indicators of physical performance. But sustainability of irrigated area needs the data of the initial irrigated area which is not available for the selected scheme. Then the physical performance indicator encompassed in this study is irrigation ratio only. Irrigation ratio, being an indicator for the degree of utilization of the existing land for irrigation, is a convenient indicator for whether there are factors contributing for under irrigation of the command area.

Table 4.6. Results of irrigation ratio (IR)

Scheme	Command area (ha)	Irrigated area (ha)	IR
Shimburit	94.5	54.5	0.6

The result shows that from the total command area of 94.5 hectare, 54.5 hectare of the area was under irrigation at the scheme. The reason for lower value is that farmers low economical capacity to afford high inputs (Fertilizers, crop protection chemicals and improved seeds) required for cash crop production. And also, the communal grathing land, local villages, trees, shrubs, unlevel land scape and stony areas are available on the Command area.

5. Conclusion

In this study, an attempt was made to evaluate the performance of Shimburit small scale irrigation scheme in Amhara Regional state under East Gojjam administrative zone, Debere Elyas district by using internal or process and external or comparative performance indicators.

Internal performance indicators computed in this study were conveyance efficiency, application efficiency, storage efficiency and overall efficiency. External performance indicators encompassed in this study were agricultural output, water use and physical performance.

Even if the conveyance efficiency of Shimburit irrigation scheme was more than the recommended value (i.e. 70 percent for unlined poorly managed canals observed in other African countries) there are unlined parts of the canals, no regular cleaning and maintenance of broken parts. The application efficiency of the scheme was found to be good as compared to in the range of 50-80% for graded furrow irrigation and the result is almost in this limit.

In general, the storage efficiency of the scheme was very poor as compared to 63 percent storage efficiency usually found in typical furrow irrigation systems.

The relative irrigation supply for Shimburit small irrigation scheme shows that there is a high ratio, which implies that the amount of water applied during irrigation events was much higher than that required by crops. The output per command area was observed to be relatively low in the scheme. This indicates that a large amount of the command area was not under irrigation during the study season in the scheme due to farmers low economical capacity to afford high inputs (Fertilizers, crop protection chemicals and improved seeds) required for cash crop production. And also, the communal grathing land, local villages, trees, shrubs, unlevel land scape and stony areas are available on the Command area.

In general, based on the assessment carried out, it can be concluded that Shimburit irrigation scheme needs improvement, so measures should be taken to advance the performance of the scheme

6. Recommendations

- ✓ In Shimburit small scale irrigation scheme some parts of main and secondary canals necessitate lining to increase water delivery efficiency in the scheme.
- ✓ Water conveyance efficiency of the scheme is low. Hence, the conveyance systems should be enhanced through regular canal cleaning and maintenance of broken irrigation infrastructures.
- ✓ Supplying high quality inputs with moderate price and enough quantity and familiarizing high value crops are very important to increase the output value of production per unit irrigated area and per unit command area in the scheme.
- ✓ The storage efficiency is lower than the recommended value; the loss should be minimized through soil preparation to conserve water (by adding organic fertilizer like compost, by using biological soil conservation methods).
- ✓ According to the results gained, water management practice of the scheme was generally poor. Therefore, farmers, development agents and concerned bodies of the scheme should follow and organize visits to the site for sharing their experience with one another.
- ✓ It is better to strengthen water user associations for better water management in the scheme.
- ✓ Therefore, for the advance of the irrigation system management and the irrigation practice of the scheme regular performance evaluation is very important.

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8. APPENDICES

8.1. Appendix Tables

Table 8. 1. Climatic data from Debermarkos and Debre Elyas stations (1990-2021) and CROPWAT output of ETo and Reff for Shimburit irrigation scheme

Month	Min Temp °C	Max Temp °C	Humidity %	Wind km/day	Sun hours	Rad MJ/m²/day	ETo mm/day	Rain mm	Eff rain mm
January	12.6	26.6	40	102	8.8	20.2	4.08	3.2	3.2
February	14.1	29	35	120	9.2	22.1	4.85	6.4	6.3
March	13.5	29.6	40	122	7.9	21.4	4.96	33.5	31.7
April	13.2	29.1	46	127	7.3	20.8	4.88	50.7	46.6
May	12.3	28.3	56	118	7	19.9	4.51	131	103.5
June	12	23.8	75	107	5.4	17.2	3.48	243.6	148.7
July	11.4	21.7	83	102	3.4	14.3	2.81	359.3	160.9
August	11.3	21.1	84	95	3.7	15	2.82	365.2	161.5
September	11.8	21.7	76	91	5.8	18.1	3.32	306.9	155.7
October	11.9	24.2	58	103	8.2	20.9	3.97	103.5	86.4
November	12.8	26.1	50	99	8.7	20.3	3.95	34.9	33
December	13.6	27.6	44	100	9.1	20.1	4.06	7.3	7.2
Average	**12.5**	**25.7**	**57**	**107**	**7**	**19.2**	**3.97**		
Total								**1646**	**944.7**

Where, ETo and Reff are reference evapotranspiration and effective rainfall respectively

Table 8. 2. CROPWAT output for Onion water requirement

Month	**Decade**	**Stage**	**Kc coeff**	**ETc mm/day**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**
Feb	2	Init	0.7	3.4	20.4	0.7	19.8
Feb	3	Init	0.7	3.42	27.4	4.3	23.1
Mar	1	Deve	0.77	3.82	38.2	8	30.1
Mar	2	Deve	0.91	4.52	45.2	11	34.2
Mar	3	Mid	1.04	5.11	56.2	12.5	43.7
Apr	1	Mid	1.05	5.17	51.7	12.6	39.2
Apr	2	Mid	1.05	5.14	51.4	13.6	37.9
Apr	3	Mid	1.05	5.01	50.1	20.6	29.6
May	1	Late	1.05	4.86	48.6	28.5	20.1
May	2	Late	0.92	4.16	41.6	35	6.5
May	3	Late	0.79	3.29	16.4	18.1	0
Total					**447.2**	**164.9**	**284.1**

Where, Kc is crop coefficient, ETc is crop evapotranspiration and IR is irrigation requirement

Table 8. 3. CROPWAT output for Potato water requirement

Month	**Decade**	**Stage**	**Kc coeff**	**ETc mm/day**	**ETc mm/dec**	**Eff rain mm/dec**	**Irr. Req. mm/dec**
Jan	2	Init	0.45	1.84	5.5	0.2	5.5
Jan	3	Init	0.45	1.96	21.5	1.2	20.3
Feb	1	Deve	0.56	2.58	25.8	1.1	24.7
Feb	2	Deve	0.76	3.69	36.9	1.1	35.8
Feb	3	Deve	0.94	4.6	36.8	4.3	32.6
Mar	1	Mid	1.05	5.17	51.7	8	43.6
Mar	2	Mid	1.05	5.21	52.1	11	41.1
Mar	3	Mid	1.05	5.18	57	12.5	44.5
Apr	1	Mid	1.05	5.15	51.5	12.6	39
Apr	2	Mid	1.05	5.12	51.2	13.6	37.6
Apr	3	Mid	1.05	4.99	49.9	20.6	29.4
May	1	Late	0.95	4.42	44.2	28.5	15.6
May	2	Late	0.78	3.53	21.2	21	3.7
Total					**505.4**	**135.7**	**373.4**

Where, Kc is crop coefficient, ETc is crop evapotranspiration and IR is irrigation requirement

Table 8. 4. Selected soil physical characteristics of Shimburit irrigation scheme

Code	Soil depth (cm)	Particle size			Textural class	Fc(vol%)	PWP(vol%)	TAW(%)	TAW(mm/m)	Bd(g/cm^3)
		Sand	Silt	Clay						
H1	0-20	19	42	39	Clay Loam	31.75	17.01	14.74	147.4	1.06
	20-40	22	43	35	Clay Loam	32.14	16.24	15.9	159	1.13
	40-60	23	39	38	Clay Loam	32.39	16.76	15.63	156.3	1.19
H2	0-20	18	35	47	Clay	31.09	16.61	14.48	144.8	1.10
	20-40	20	37	43	Clay	31.3	17.25	14.05	140.5	1.15
	40-60	21	34	45	Clay	31.49	17.38	14.11	141.1	1.22
H3	0-20	25	38	37	Clay Loam	30.39	16.31	14.08	140.8	1.09
	20-40	24	39	37	Clay Loam	30.01	16.19	13.82	138.2	1.15
	40-60	26	38	36	Clay Loam	30.19	16.34	13.85	138.5	1.25
M1	0-20	23	39	38	Clay Loam	35.14	19.21	15.93	159.3	1.06
	20-40	22	39	39	Clay Loam	35.08	19.28	15.8	158	1.10
	40-60	24	38	38	Clay Loam	34.97	19.31	15.66	156.6	1.17
M2	0-20	15	35	52	Clay	34.39	20.41	13.98	139.8	1.07
	20-40	12	37	51	Clay	34.37	20.17	14.2	142	1.14
	40-60	13	33	54	Clay	34.24	20.26	13.98	139.8	1.22
M3	0-20	21	42	37	Clay Loam	33.03	19.31	13.72	137.2	1.14
	20-40	22	43	35	Clay Loam	33.05	19.26	13.79	137.9	1.23
	40-60	23	41	36	Clay Loam	33.12	19.29	13.83	138.3	1.23
T1	0-20	12	34	54	Clay	39.49	22.61	16.88	168.8	1.09
	20-40	10	37	53	Clay	39.33	22.67	16.66	166.6	1.16
	40-60	13	38	49	Clay	39.74	22.86	16.88	168.8	1.23
T2	0-20	11	36	53	Clay	38.12	23.31	14.81	148.1	1.09
	20-40	12	35	53	Clay	38.03	23.29	14.74	147.4	1.12
	40-60	14	34	52	Clay	38.07	23.61	14.46	144.6	1.16
T3	0-20	10	38	52	Clay	36.19	22.31	13.88	138.8	1.21
	20-40	8	37	55	Clay	36.07	21.95	14.12	141.2	1.24
	40-60	11	5	84	Clay	36.69	21.71	14.98	149.8	1.28
min						**30.01**	**16.19**	**13.7**	**137.2**	**1.06**
max						**39.74**	**23.61**	**16.9**	**168.8**	**1.28**
ave						**34.88**	**19.90**	**15.30**	**153.00**	**1.17**

H1, H2 and H3 are code of fields selected from head, M1, M2 and M3 are code of fields selected from middle and T1, T2 and T3 are code of fields selected from tail sections and BD is bulk density, TAW is total available water, PWP and Fc are moisture contents at permanent wilting point and field capacity respectively.

Table 8. 5. Soil moisture contents one day before and after irrigation

Stage	Field code	Soil depth(cm)	BD (gm/cm3)	moisture before irrigation (%)	moisture after irrigation (%)	Moisture stored in depth (%)	Moisture stored in depth (mm)
Initial	H11	0-20cm	1.06	26.82	29.97	3.15	6.72
	H12	20-40	1.13	30.09	33.29	3.19	7.24
	H13	40-60	1.19	28.07	31.36	3.29	7.82
	H21	0-20	1.10	31.26	35.25	4.00	8.78
	H22	20-40	1.15	28.23	31.65	3.42	7.90
	H23	40-60	1.22	24.96	27.15	2.19	5.32
	H31	0-20	1.09	31.33	35.46	4.13	8.98
	H32	20-40	1.15	31.16	34.12	2.96	6.79
	H33	40-60	1.25	30.54	32.80	2.26	5.64
	M11	0-20	1.06	30.50	35.58	5.08	10.76
	M12	20-40	1.10	28.06	31.97	3.90	8.59
	M13	40-60	1.17	30.51	33.26	2.74	6.44
	M21	0-20	1.07	27.66	32.41	4.75	10.14
	M22	20-40	1.14	27.92	32.07	4.15	9.42
	M23	40-60	1.22	26.21	29.44	3.23	7.86
	M31	0-20	1.14	33.14	38.04	4.90	11.17
	M32	20-40	1.23	29.18	33.20	4.02	9.86
	M33	40-60	1.23	30.14	31.97	1.83	4.49
	T11	0-20	1.09	34.73	36.78	2.05	4.46
	T12	20-40	1.16	29.13	33.62	4.49	10.39
	T13	40-60	1.23	29.41	32.34	2.93	7.21
	T21	0-20	1.09	32.20	36.52	4.32	9.40
	T22	20-40	1.12	30.86	34.43	3.57	7.96
	T23	40-60	1.16	34.27	37.87	3.59	8.37
	T31	0-20	1.21	32.38	36.71	4.33	10.45
	T32	20-40	1.24	28.68	32.79	4.10	10.19
	T33	40-60	1.28	27.53	29.35	1.82	4.66
Developmental	H11	0-20	1.06	28.83	31.60	2.77	5.91
	H12	20-40	1.13	30.03	32.33	2.29	5.20
	H13	40-60	1.19	27.63	31.37	3.75	8.90
	H21	0-20	1.10	25.77	30.26	4.49	9.87
	H22	20-40	1.15	28.29	30.87	2.58	5.95
	H23	40-60	1.22	27.87	31.48	3.61	8.77
	H31	0-20	1.09	26.59	29.86	3.27	7.09
	H32	20-40	1.15	25.11	29.20	4.08	9.38
	H33	40-60	1.25	28.80	32.10	3.30	8.23
	M11	0-20	1.06	28.87	33.46	4.59	9.73
	M12	20-40	1.10	28.84	33.05	4.22	9.28
	M13	40-60	1.17	27.48	30.95	3.47	8.13

Developmental	M21	0-20	1.07	24.56	29.29	4.73	10.10
	M22	20-40	1.14	30.28	33.42	3.15	7.14
	M23	40-60	1.22	30.11	33.97	3.86	9.39
	M31	0-20	1.14	27.96	32.54	4.58	10.44
	M32	20-40	1.23	28.73	31.76	3.03	7.42
	M33	40-60	1.23	28.80	31.91	3.10	7.62
	T11	0-20	1.09	33.01	37.06	4.04	8.81
	T12	20-40	1.16	33.80	36.32	2.52	5.83
	T13	40-60	1.23	27.93	33.35	5.41	13.31
	T21	0-20	1.09	29.69	35.95	6.27	13.63
	T22	20-40	1.12	30.15	34.55	4.41	9.83
	T23	40-60	1.16	28.45	31.05	2.60	6.06
	T31	0-20	1.21	25.80	30.48	4.68	11.29
	T32	20-40	1.25	28.37	31.56	3.19	7.98
	T33	40-60	1.28	25.44	27.86	2.42	6.22
Mid	H11	0-20	1.06	29.31	31.65	2.33	4.97
	H12	20-40	1.13	27.57	32.43	4.86	11.00
	H13	40-60	1.19	28.36	31.43	3.07	7.30
	H21	0-20	1.10	26.13	29.89	3.75	8.24
	H22	20-40	1.15	26.90	31.25	4.35	10.06
	H23	40-60	1.22	29.41	31.92	2.51	6.10
	H31	0-20	1.09	26.02	31.05	5.03	10.91
	H32	20-40	1.15	26.93	30.05	3.11	7.15
	H33	40-60	1.25	26.39	29.90	3.50	8.73
	M11	0-20	1.06	28.31	32.37	4.06	8.60
	M12	20-40	1.10	26.59	29.82	3.22	7.09
	M13	40-60	1.17	29.45	34.07	4.62	10.84
	M21	0-20	1.07	28.23	32.14	3.90	8.33
	M22	20-40	1.14	28.83	32.42	3.59	8.16
	M23	40-60	1.22	30.72	33.85	3.13	7.61
	M31	0-20	1.14	30.47	33.78	3.31	7.54
	M32	20-40	1.23	26.39	30.42	4.03	9.88
	M33	40-60	1.23	28.72	32.43	3.71	9.11
	T11	0-20	1.09	34.21	37.34	3.13	6.83
	T12	20-40	1.16	35.03	38.21	3.18	7.36
	T13	40-60	1.23	32.25	36.80	4.55	11.19
	T21	0-20	1.09	33.76	37.86	4.10	8.92
	T22	20-40	1.12	30.64	34.58	3.94	8.79
	T23	40-60	1.16	32.38	37.03	4.65	10.82
	T31	0-20	1.21	32.21	35.59	3.38	8.16
	T32	20-40	1.24	33.16	36.71	3.55	8.81
	T33	40-60	1.28	31.87	35.11	3.25	8.32

Table 8. 6. Conveyance efficiency and loss rate

Cana section	Segment no.	Distance b/n points(m)	Inflow(l/s)(Initial)	Out flow(l/s) (final)	Conveyance loss		EC(%)	Remark
					l/s	l/s/m		
Lined main canal	1	160	94	76	18	0.113	80.85	b/n intake & canal point
	2	120	40	32	8	0.0667	80.00	Middle
	3	120	24	21	3	0.025	87.50	Lower
Average						**0.068**	**82.784**	
Unlined main canal	4	30	60	54	20	0.667	90.00	Upper
	5	40	28	20	8	0.20	71.43	Lower
Average						**0.433**	**80.714**	
Secondary canal 1	1	26	25.9	20.8	5.1	0.196	80.31	Middle
	2	30	20.6	16.5	4.1	0.137	80.10	Users
	3	18	13.6	7.9	5.7	0.317	58.09	
Average						**0.216**	**72.831**	
Secondary canal 2	1	90	17.12	13.5	3.62	0.040	78.86	Lower
	2	62	12.43	9.25	3.18	0.051	74.42	Users
	3	92	7.65	5.78	1.87	0.0203	75.56	
Average						**0.037**	**76.276**	

Table 8. 7. Application efficiency and total discharge applied at selected fields of Shimburit irrigation scheme**.**

Stage	Field	Field code	Q (l/s)	Elapsed time(s)	Field Area(m2)	Total Volume(m3)	Applied depth (mm)	Stored depth (mm)	Water depth (mm)	Ea(%)
Initial	Head	H1	2.35	18000	725	42.3	58.34	22.07	79	37.83
		H2	2.2	18000	896	39.6	44.20	21.93	76	49.62
		H3	2.1	21600	1260	45.36	36.00	21.69	78	60.25
	Middle	M1	2.03	18000	1036	36.54	35.27	25.72	77	72.92
		M2	1.8	15000	726	27	37.20	27.48	68	73.87
		M3	1.65	18000	816	29.7	36.4	25.5	72	70.1
	Tail	T1	1.86	21600	858	40.18	46.83	22.1	75	47.20
		T2	1.73	16200	750	28.03	37.37	25.61	68	68.53
		T3	1.69	18500	924	31.27	33.84	26.03	72	76.92
Develop mntal	Head	H1	2.05	19800	725	40.59	55.99	22.14	77	39.55
		H2	1.87	18000	896	33.66	37.57	24.56	78	65.38
		H3	1.9	21600	1260	41.04	32.57	24.7	72	75.83
	Middle	M1	1.85	16200	1036	29.97	28.93	26.79	68	92.61
		M2	1.78	12600	726	22.43	30.89	26.66	74	86.30
		M3	1.5	22320	816	33.48	41.03	25.35	79	61.78
	Tail	T1	1.53	19800	858	30.29	35.31	27.89	73	78.99
		T2	1.75	23400	750	40.95	54.60	29.48	65	53.99
		T3	1.8	21600	924	38.88	42.1	26.91	70	63.95
Mid Stage	Head	H1	2	18000	725	36	49.66	25.26	74	50.87
		H2	1.45	16200	896	23.49	26.22	24.44	69	93.22
		H3	1.82	23400	1260	42.6	33.8	26.75	72	79.14
	Middle	M1	1.6	18000	1036	28.8	27.80	26.3	64	94.61
		M2	1.66	20880	726	34.66	47.74	24.17	71	50.63
		M3	1.5	12600	816	18.9	23.16	26.29	75	113.51
	Tail	T1	1.6	18000	858	28.8	33.57	25.38	67	75.61
		T2	1.7	21600	750	36.72	48.96	28.5	62	58.21
		T3	1.75	20160	924	35.28	38.18	26.07	66	68.28

Table 8. 8. Measured water depths applied to the field and storage efficiency of Shimburit irrigation scheme

Stage	Field	Water depth (mm)	Q (l/s)	Elapsed time(s)	Field Area(m2)	TAW(mm/m)	Applied depth (mm)	Stored depth (mm)	Wn(mm)	Es(%)
Initial	Head	79	2.35	18000	725	176.43	58.34	21.78	79.39	27.43
		76	2.2	18000	896	164.33	44.20	22.00	73.95	29.75
		78	2.1	21600	1260	161.37	36.00	21.40	72.62	29.47
	Middle	77	2.03	18000	1036	180.17	35.27	25.79	81.08	31.81
		68	1.8	15000	726	162.73	37.20	27.42	73.23	37.44
		72	1.65	18000	816	160	36.4	25.52	72.00	35.45
	Tail	75	1.86	21600	858	190.27	46.83	22.06	85.62	25.77
		68	1.73	16200	750	168.90	37.37	25.73	76.01	33.85
		72	1.69	18500	924	165.47	33.84	25.31	74.46	33.99
Develop mntal	Head	77	2.05	19800	725	176.43	55.99	20.01	79.39	25.20
		78	1.87	18000	896	164.33	37.57	24.59	73.95	33.26
		72	1.9	21600	1260	161.37	32.57	24.70	72.62	34.01
	Middle	68	1.85	16200	1036	180.17	28.93	27.14	81.08	33.47
		74	1.78	12600	726	162.73	30.89	26.63	73.23	36.37
		79	1.5	22320	816	160	41.03	25.48	72.00	35.39
	Tail	73	1.53	19800	858	190.27	35.31	27.94	85.62	32.64
		65	1.75	23400	750	168.9	54.60	29.53	76.01	38.85
		70	1.8	21600	924	165.47	42.1	25.49	74.46	34.23
Mid Stage	Head	74	2	18000	725	176.43	49.66	23.27	79.39	29.31
		69	1.45	16200	896	164.33	26.22	24.40	73.95	32.99
		72	1.82	23400	1260	161.4	33.8	26.80	72.62	36.90
	Middle	64	1.6	18000	1036	180.17	27.80	26.54	81.08	32.73
		71	1.66	20880	726	162.73	47.74	24.10	73.23	32.91
		75	1.5	12600	816	160	23.16	26.54	72.00	36.86
	Tail	67	1.6	18000	858	190.27	33.57	25.37	85.62	29.63
		62	1.7	21600	750	168.9	48.96	28.54	76.01	37.54
		66	1.75	20160	924	165.47	38.18	25.30	74.46	33.97

Table 8. 9. Crop parameters for irrigated crops in Shimburit irrigation scheme

Crop	Crop parameter	Initial	Developmental	Mid	Late	Total
Onion	Stage length(days)	15	25	45	15	100
	Crop coefficient(Kc)	0.7		1.05	0.75	
	Rooting depth(m)	0.25		0.6	0.6	
	Critical depletion(p)	0.3		0.3	0.3	
	Yield response (ky)	0.45	0.6	0.8	0.3	1.1

8.2. Appendix Figures

Figure 8. 1. Bulk density determination

Figure 8. 2. Parshall flume withe written graph

Figure 8. 3. USDASC soil texture classification triangle